CIB-W096

ARCHITECTURAL MANAGEMENT

Vienna University of Technology
Austria, 13 - 14 October 2011

Architectural Management in the Digital Arena

Editors: Ad den Otter, Stephen Emmitt & Christoph Achammer

Proceedings
The CIB-W096 conference 2011, Vienna 13-14 October 2011
is sponsored by the international journal Architectural Engineering and Design Management (AEDM)
with a Best paper award
and 1 month free access to the electronic version of the Journal for all authors.
Proceedings of the CIB-W096 conference Vienna 2011

Architectural Management in the Digital Arena

ISBN nr.: 978-90-386-2810-3
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**Architectural Management in the Digital Arena**

Leading research into architectural design management is the CIB’s working committee W096 Architectural Management. CIB-W096 was officially established in 1993, following a conference on ‘Architectural Management’ at the University of Nottingham in the UK. Since this time the commission has been active in the area, with regular international conferences, meetings, published conference proceedings and other publications.

CIB-W096 brings together researchers and practitioners concerned with the whole life cycle of building and construction projects. Recently the members of the working group have concentrated on achieving value for stakeholders and this work led to a focus on integrated design teams and improved communications. Active working areas are; revaluing design, communicating design, inclusive design, design management, design integration, design management education and revaluing architectural practice - all with an underlying sustainable agenda. In addition to the publication of peer reviewed conference proceedings the commission has produced the book *Architectural Management: international research & practice* (Eds. Emmitt, Prins, Otter, 2009, Wiley-Blackwell, Oxford), which provides a state of the art report into the rapidly evolving field of architectural management.

One of the most topical issues to be dealt with by CIBW096 concerns information technologies and building information modeling, the theme of this, the commission’s 24th, conference. Architectural design processes are iterative processes in which designing and decision making are interwoven. Demands, wishes and concerns of clients and stakeholders for a beautiful, well functioning and sustainable building need to be fully understood and effectively communicated within the temporary project team. The focus of architects, managers, advisors and engineers has evolved from the project to responsibilities for the entire life cycle of the building. This is set in an age of rapid advances in digital technologies and changing responsibilities.

This conference explores applications of architectural management using all types of electronic media for creating, communicating and realizing design in a variety of different contexts; as well as addressing long running themes within the architectural management knowledge domain.

This proceedings contain 27 peer reviewed papers within the conference topics:

- Smart, lean and intelligent architectural design management;
- Application of collaborative technologies, such as building information modeling (BIM);
- Integrated (sustainable) design solutions and integrated working practices;
- Managing roles and legal responsibilities for design in a digital age;
- Global versus local challenges for architecture

For further information about CIB W096 visit: [http://qa.cib-w096.nl/index.html](http://qa.cib-w096.nl/index.html)
Keynote Speakers

Prof. Dipl.ing. Christoph M. Achammer
Keynote speech 1: October 13th 2011 at Kupel Saal TU-Wien, 9.00 – 9.45 hours.

Christoph M. Achammer is Professor at the Technical University, Vienna since 2001 and is head of the “Institute for Industrial Building and Interdisciplinary Construction Planning”. He is also the CEO of ATP (Achammer, Tritt und Partners) an International performing Architectural and Engineering firm with 450 employees and offices in Vienna, Innsbruck, Munich, Frankfurt, Budapest, Zagreb and Zurich. The firm slogan is: Architects and engineers for excellent buildings.

Prof.dr.ir. Bauke de Vries
Keynote speech 2: October 14th 2011 at Kupel Saal TU-Wien, 9.00 – 9.45 hours.

Bauke de Vries is Professor at the University of Technology (TU/e), Eindhoven since 2004, and head of the group Design Systems. Design Systems (DS) develops and researches novel tools, interfaces, and decision support systems for architects. The DS curriculum not only deals with traditional CAAD education, but also educates students to become Building Information Technologists between the Building & Construction Industry and IT companies. The group’s focus is on research and development on integrating methods, models and techniques in design and decision support systems (DDSS) for end users. The research is part of the DDSS research program. Topics are: a) Simulation of Human Behavior in the Built Environment; b) Multi-agent systems for design and planning; c) Concept modeling for the support of collaborative design.

From the organizers of CIB-W096

We would like to thank the members of the scientific committee, our review assistant Jasper Kock, the secretary of ADMS, Mrs. Elle Abzach, and our host Christoph Achammer and his staff: Mrs. Iva Kovacic and Mrs. Isolde Tastel for their help in ensuring a successful conference.

Ad den Otter, Stephen Emmitt and Matthijs Prins
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Abstract: At a point in time when technologies for remote and asynchronous forms of collaboration are pervasive, being able to justify the time, space and places for collocated working becomes increasingly important. This article provides an account of a way of working in a multidisciplinary design practice where the setting, the routine yet ordered practices and a series of design meeting events were seen to feature in the organisation of the design work. In this account, the notion of the design meeting as an event category is questioned, as different forms of design meeting staged for different purposes were observed. In various ways the inter-disciplinary inputs to the design of a project were coordinated and this was seen to happen in a series of workplace interactions and practices that were part of the ecology of a multidisciplinary design organisation. Collectively, these situated observations support multidisciplinarity as a location-based way of working in a real-time synchronous manner.

Keywords: Design, Multidisciplinarity, Meetings, Coordination, Interaction, Synchronous communication

1. INTRODUCTION

Design in the construction sector (architectural, engineering and construction industries, AEC) is a collaborative activity by necessity. It is because of project team configurations, divisions of labour, the numerous disciplines and fields of design expertise represented within a team that forms of collaborative working are necessary (Bresnen, Goussevskia et al. 2005). Collaborative design and forms of design coordination are needed to integrate inputs across knowledge domains and this occurs in various ways and in a variety of settings throughout a construction project.

This article focuses on what is initially framed as a type of event, design meetings, to examine some of the ways that these interactions feature in the coordination of the design of a project between the participants. The preliminary focus is on what happens in design meetings in practice, initially as an unmotivated study, observing how the participants interact in meetings. This article draws attention to some routine practices within a multidisciplinary design team that feature in the coordination of design. The ways of working observed provide a foundation for reflection on what are the current motives for face-to-face interaction and location-based working, now that technologically-mediated collaborative environments are available.

This argument is structured first, presenting an overview of some previous research on meetings in design and construction settings to provide a framing for what is meant by design meetings for this
study. Next the analytic orientation for the research is introduced, followed by the substantive part of the article, where accounts of what was seen to happen in design meeting settings are presented. The accounts are presented as a slice through routine life as it happens in a multidisciplinary design organisation, examining what is being accomplished by a cross-disciplinary design team. Lastly, reflections on contingencies between face-to-face and technologically supported collaboration are discussed.

2. WHAT’S SPECIAL ABOUT DESIGN MEETINGS?

Selected studies of interaction in design meetings provide a foundation from which to probe what we mean by design team meetings for the purposes of this research, to then examine what makes them special.

2.1 Routine practice, routine events

Design meetings are remarkable in construction project environments for several reasons. They are part of a way of working and the everyday life of a project and as such feature in the routine organisation of a project. Design team meetings are the locus for conversations between designers with different knowledge backgrounds to discuss the current status of the design, information that is missing and where possible, to negotiate design solutions (Cross and Clayburn Cross 1995). Analysis of design team interaction is reported as an aspect of communication and in meeting settings specifically (Emmitt and Gorse 2007; Kleinsmann, Valkenburg et al. 2007; Maier, Eckert et al. 2009; McDonnell, Lloyd et al. 2009). Seldom examine are the characteristics of design meetings. Two characteristics of design meetings are noteworthy: as events, that is, as a marker in time, and as a location, in providing a space and place for interaction. Meetings are milestone events in the life of a project and can mark memorable moments in time when significant decisions were made and shifts in understanding of the design happen and become shared, for example, stories about a project (Lloyd 2000; McDonnell, Lloyd et al. 2009). In this respect design meetings, as events, can act as a form of temporal marker for the design of a project as it evolves and progresses through stages in a project’s life cycle. Design meetings often provide a setting for the members of a design team to meet in person, in face-to-face interaction (den Otter and Emmitt 2007; Emmitt and Gorse 2007; Gorse and Emmitt 2007; Emmitt 2010) where patterns of interaction are revealing of more dominant parties in meetings (Austin, Steele et al. 2001; Hugill 2004; Foley and Macmillan 2005).

Meeting in face-to-face configurations is not always the case now forms of video-conferencing and conversations augmented by video become ubiquitous (and at its most elemental includes using skype and face-time). We are designing buildings at a time when there is choice in the collaboration media
used. We have technologically-mediated support for synchronous collaboration in remote situations (e.g. shared BIM model), as well as asynchronous modes for information sharing (den Otter and Emmitt 2007). While the richness of communication in face-to-face interaction is well documented (Dixon and Panteli 2010), as well as discussion of what is lost in non-proximal interaction (Luck under review), a question that persists is, what happens in and around design meetings to substantiate meeting in person now that remote collaboration is viable?

2.1.1 Framing the research

This study of interaction in design meetings takes an ethnographic form, observing and video-recording activities that take place in the workplace of one of the largest multidisciplinary practices that provides consultancy services to the construction and major infrastructure sectors on prestigious projects internationally. There has been over 150 hours contact time to date with the research partner organisation, spent at their offices gathering approximately 100 hours of video footage. The research team have a rich body of data and experiences to draw from, including conversations with many people in various workplace settings, as well as the more substantive and enduring video records of interactions that are available for repeated viewing in fine-grained detail. Given this open access and engagement with the project the researchers had ample opportunity to become familiar with ways of working for this multidisciplinary design team as they undertook their work activities in real-time, as well as a broader sense of how this activity fits within the wider organisation.

The analytic orientation is informed by ethnomethodological conversation analysis where emphasis within an account is placed on ‘what gets done’, that is, what is accomplished in interaction rather than ‘who does what’, to attribute actions to a person because of their job title or the design discipline they belong to. This position is not in denial of imbalances in speaker privileges between the people present but because the negotiation of interactional ‘power’ is an already highly reported and known phenomena (Hugill 2004) comment on speaker frequency becomes less remarkable than what is accomplished between the participants.

The focus of the research is on coordination as it happens in design meetings, following the life of one construction project longitudinally from the early design stages through to detailed design. Significantly, all the design disciplines appointed for the project observed are employed by the same multidisciplinary organisation. Studying a multidisciplinary practice is an auspicious setting to focus on the coordination of design expertise in everyday workplace settings. In this respect what is being observed is the coordination of design activities across (design) disciplinary boundaries within an organisation, a management concern that can be traced back to Lawrence and Lorsch (1967). In the later twentieth century it was acknowledged that activities in the AEC sector are undertaken as project-based work in temporary-multi organisations, TMO (Hobday 1998) which bring together
organisations with different expertise for the duration of a project. The conditions of this data provide access to situated inter-disciplinary design activity and its coordination within a multidisciplinary design organisation.

For this organisation design meetings took several forms and brings into question what we mean by ‘design meetings’ and whether previous research is necessarily reporting on the same type of event or phenomena. In short, is it solely the presence of designers at a meeting that constitutes some form of interaction as a design team meeting? To address these methodological concerns the forms of interaction that characterise ‘a design meeting’ for this research are next outlined.

3. MULTIDISCIPLINARY WORKPLACE AND SPACE PRACTICES

Designers with different disciplinary expertise meet in person regularly in a range of design meeting settings. The forms of meetings studied include: i. design co-ordination meetings ii. impromptu meetings after a design co-ordination meeting, iii. design workshops and iv. ad-hoc interaction of designers at work in the studio. It is acknowledged that there are other types of meeting that feature in the routine working of this organisation, which were not part of this research, although they are important for day-to-day functions and the smooth running of the organisation. A sketch characterisation for each of the design meetings follows.

3.1 Design coordination meetings

The principal design meetings held on a routine basis were called the ‘design coordination meetings’. The design of the project was progressing at a fast pace and design coordination meetings were usually held at weekly intervals (although the frequency of the meetings did vary dependent on project progress). Design coordination meetings were a planned event, held in a meeting room within the organisation’s office building that was booked in advance. The date for a next meeting was set at the end of the preceding meeting and an agenda for each meeting was circulated by e-mail beforehand. Minutes for a meeting were taken, either by the design manager or the project administrator.

The meetings were chaired by the project’s in-house design manager with usually one representative from each of the design disciplines in attendance: the project architect, structural engineer, M&E building services, landscape and BREEAM consultant. A routine pattern at these meetings was for each discipline to present an update on their progress, starting with the project architects account. Each meeting’s content involved the interplay between accounting for activities that have happened during the week, and task-coordination actions, planning ahead for future actions e.g. discussing which information was outstanding and allocating responsibilities for providing this.
Noticeably at these meetings there was limited visible reference to a design programme, although the design manager was monitoring progress against a programme and commenting on progress against project stage deadlines and shorter-term task deadlines within the design team. Other than referring to the agenda and the person taking minutes the use of artefacts at these meetings was rare and limited to the participants’ occasional note taking.

### 3.2 Impromptu design meetings

Impromptu design meetings were events that took place directly following a design co-ordination meeting (usually 5-10 minutes after) to discuss an issue raised in the previous meeting that was not resolved at that moment in time, with the materials (include people/expertise) at hand. The people present at the impromptu meetings varied, dependent on the topic being discussed and in the selection of people present there was determination of the design expertise considered relevant for decision-making on this issue. At one of these meetings an architect from another project was asked to join, so expertise and lessons learnt from experience could inform the discussion of a similar issue on another project, and was an example of the inter-organisational ‘learning’ that was going on within the multidisciplinary practice. The project architect led these meetings and there was no agenda or minutes, as was routine for more formally organised meetings. Indeed the tone of the meetings was more conversational than the coordination meetings, however the topics discussed were also highly work-task oriented. The term impromptu acknowledges that these events were improvised, creatively making use of the people available just after a meeting, finding an unoccupied meeting room and as the conversation was not steered by an agenda.

### 3.3 Design workshops

Design workshops were organised at intermittent intervals dependent on the project’s progress specifically to report to the whole design team on the progress and development of the design, and involved more than 15 people. In several respects the design workshops shared similarities with design crits in architectural education, as materials were displayed on pin-boards, then one person presented their work to the audience and this aspect of the design was then discussed by those present.
The workshops took place in the design studio, which added to the sense that a project milestone-event was taking place. The event engendered a sense of occasion in the design studio and shared awareness of the project and its achievements across the workplace. A design workshop was an opportunity to showcase the project and to profile the design progress that was being made.

Noticeably at these events questions were asked that crossed design disciplines, seniority, and levels of design expertise. The presentations were listened to then robustly but fairly critiqued by those around the presentation area, as much to highlight areas for further attention rather than to problem-solve at that moment in time. Some points were raised and questions asked by people who weren’t directly affiliated with the project. Design workshops provided a setting for inter-project information sharing and learning from others’ experiences, for example, discussion of on-site difficulties with courtyard configurations, foundation design and ways in which situations had been resolved on other projects. Occasionally a succinct account, verbalising a lesson learnt was presented, and arguably this illustrates a more embedded and targeted way to share organisational knowledge than retrospective project case studies. Seemingly this event ‘type’ served many design coordination functions, yet it was only possible because the design team was multidisciplinary and based at the same location: it provided a deadline for the completion of a design stage, an event and sense of collective project-team achievement, and significantly it engendered intra-project/organisational learning and the cross-fertilisation of design ideas. This is an aim within learning organisations, yet seldom is situated learning and knowledge transfer between projects manifest in as pronounced a way as the design workshop events.

3.4 Life in the design studio

Characterising ad-hoc interaction in the workplace as a form of ‘meeting’ is unusual, but is used here as a means to describe the face-to-face interactions and communication between designers that took place in the design studio, in their ‘office’ workplace setting. The term ad-hoc acknowledges that these interactions were in response to something that was happening at that moment in time and also
to associate what was happening in the studio with ad-hocing, that is, the work-a-rounds, which are routinely part of how people get things done with the resources currently available to them (including the expertise and information from work colleagues). Deliberately this term avoids the over simplification and categorisation of some kinds of interaction as ‘formal’ or ‘in-formal’ as much of what goes on within a design practice was seen to be contingent and interdependent, and eludes these limiting categories. The significance of local, random actions that are seemingly unrelated to project tasks sometimes understood as relevant with only hindsight, and when the design of the project is viewed holistically. Indeed, it can be difficult to recognise the design significance of individual actions at the moment in time they occur, for example, a brief conversation, fleeting interactions in the studio.

Deliberately the design studio was organised to bring different design specialisms into close proximity, both in the sense of how it was conceived as a workplace as well as its physical configuration, in effect how it was ‘laid out’. Disciplines including architecture, structural and various forms of services engineering, design/project management, BREEAM consultants work on the same floor of an open plan office space. The ad-hoc conversations that were more ‘design-focused’ in this setting included, discussion at computer terminals, with reference to images on the screen, printed drawings and sketching on overlay paper, using the routine artefacts and ephemera associated with design in a studio setting that have been described extensively (Henderson 1999; Wagner 2004). To illustrate, the architect leading the project discussed with an architect colleague (also part of the project-team) what was likely to happen in the afternoon and what to do while they were away from the office. This in effect was a form of coordination, to steer events that were likely to happen in their absence towards the task at hand (the super-ordinate task of completing the design of the project). Unsurprisingly there were other, even more spontaneous interactions between people in the workplace that happen across design disciplines, projects, seniority/expertise etc. for example, at the print area, using the kettle and dishwasher in the kitchen spaces within the studio. These conversations were not always work-related but are indicative of ways in which the physical configuration of the workspace provided opportunities for interaction and influenced the ease with which unplanned and unanticipated workplace conversations took place between people, in person. Indeed, relationships between spatial configurations and the potential for interactions between people are well-known in man-environment studies and these also feature in the workplace settings in which people design environments for others.

An open-plan office workspace (designed to a BCO spec.) had the feeling of a creative design studio, in many ways akin to design studios in schools of architecture. Everyone had a dedicated workspace with a computer and layout space and some near-proximal territorial space. The use of shared facilities, dishwasher, printing area meant that wandering around the open-plan space was not always for project-based reasons. The design studio in several respects became a physical
manifestation for a matrix organisation, where project-based working took place but significantly this involved both cross-disciplinary (that is, inter-disciplinary, within (intra) project coordination) and between inter-project collaboration. By organising the workplace around project-based groupings rather than disciplinary expertise serendipitous, inter-disciplinary interactions were more likely to take place. In other words, the physical configuration of the workplace working provided opportunities for the mundane, everyday cross-disciplinary interactions to occur that increase awareness of ongoing, near proximal and background activities. Engendering friendship bonds, associations and awareness of other colleague’s activities as well as what was happening in the studio became ingrained in the workplace ecology.

Indeed, providing a workplace environment for increased **multidisciplinarity** was a motivation for the relocation to this building. Prior to occupying this building the multidisciplinary firm’s workplaces were organised by design discipline, a workplace configuration that impaired impromptu cross-disciplinary interactions and reinforces silo-working within an organisation (where information generated by one expertise is ‘passed over the wall’ to another). While the coordination of design and the integration of information generated by one discipline for use by another is not solely resolved in face-to-face interaction, as will be considered, from these brief accounts of life in a multidisciplinary design studio we begin to get a sense of the coordination work that is being done in range of direct, real-time design team settings.

### 3.5 Hardwired collaboration

The focus so far has been on face-to-face interaction and unacknowledged is the technological infrastructure underpinning the activities of the designers. While the organisation of the physical workplace is one means to encourage interaction between people across disciplines and between projects, the information architecture and the organisation of the computer-based infrastructure provides hardwired support for design collaboration. In their use of information systems, the design team were using various collaboration media in a digital environment accessed through a network from a computer terminal at their workplace. Much of the work-time of the designers, irrespective of their discipline, was spent using a computer generating design content using Revit drafting and 3D modelling tools. This activity was augmented by routine ways of working, e-mail communication and access to the organisation’s intranet and a file storage repository structured for designers to post drawings along project protocols. The transition from using drawings and 3D drafting tools to a Revit building model was happening as this project progressed. The coordination of a building’s design to some degree happens using a design tool with a clash detection function, as the spatial location of objects within the building model are known. However, planning the design activity and the timing of information so not to delay the design of the project was often resolved in conversation at a
coordination meeting. Some very pragmatic prompting for dimensional information occurred: how much space will the plant room occupy? what’s the size of the eco centre, the boundaries of the site, position of the railway lines and the accuracy of this information when modelling and predicting behaviours of a the flood plane over a 100-year timescale? Drawing attention to the ‘known unknowns’ in information terms was a task-coordination characteristic at design coordination meetings.

The imprecision of the building object as it is being designed remains a characteristic of design work and at it was apparent that changing the design tool did not resolve all the design coordination issues. Collaborative design work was seen to be underpinned by technologies of various forms, paper-based notes and printed drawings, the routine artefacts and ephemera associated with the representation of configurations of the design as they evolved, as well as the introduction of modelling design tools. The combination of analog technologies with digital tools was a way of working involving hybrid practices, where the integration and embedding of newer tools into routine practice was ongoing within this project. Indeed, the use of Revit, learning experiences and cross-disciplinary integration were sometimes the topic of conversation.

4. A MULTIDISCIPLINARY DESIGN ECOLOGY

Observing the routine activities of a design team this research has been able to outline some of the day-to-day ways of working that order the activities of designers and the coordination of design inputs within a multidisciplinary team.

4.1 Design meetings as an interaction event ‘type’

Instead of viewing design team meetings as a type of event and examining similarities and differences between interaction in meetings, say at the early stages of design in comparison with later stage construction meetings, a range of design meeting interaction types were observed that happened at patterned intervals at the same stage of a project. In other words, the differences between the events observed were not due to temporal phases of a construction project, changes of participants within the design team or a contractor’s appointment (differences that have previously been noted).

While the presence of designers is a condition for a design meeting, different forms of design meeting had different characteristics; people present, location for the event and the content of the meeting, for example the detail in which aspects of the project’s design were discussed. These differences were noticeable and provide a basis to challenge the view of a ‘design meeting’ as a generic event type, as design meetings were more nuanced.
4.2 Nested contexts for interaction

Observing design project work in a multidisciplinary practice it was seen that there were a range of design interactions and a series of settings for face-to-face interaction with different characteristics. These events provided a series of nested contexts, that is, a suite of design meeting settings to discuss the design of the project, patterned at different timescales and with degrees of formality in their planning and self-organisation. The characterisation of design meeting by ‘type’ was not investigated in detail here and warrants further examination, for example, what are content boundaries for design coordination meetings and when is the discussion of an issue deferred to an ad-hoc meeting after the coordination event? Noticeably much was happening around the routine design meetings to warrant meeting in person even when alternative form of collaboration for distributed asynchronous and remote synchronous collaboration were available.

4.2.1 Patterned events with a loose-fit

The organisation of design coordination meetings and design workshops was at patterned intervals, aligned with the progression of the scheme’s design. The coordination meetings were planned events that provided a routine backdrop for the cross-disciplinary discussion of the project. The designers knew in advance the date of a next planned event, and this as an opportunity to raise information and coordination issues. This pattern provided a framework for planning ahead, knowing that others in the team would be present to answer queries.

The organisation of a next meeting was itself a form of coordination, which followed an indicative pattern defined by the project programme, yet with a loose-fit relationship that was contingent on design progress. The frequency of the events was structured but attentive, for example, to periods when more client decisions were being made, when there was increased design coordination activity and the integration of inputs. There was also loose-fit within an event. There was variation in the length of a meeting, the sequence in which design disciplines spoke and between the content and topics discussed at a ‘type’ of meeting. The coordination of design over spilled the design coordination meetings. Self-organised practices and interactions in the workplace were seen to feature in the coordination of the design, as well as the interplay between face-to-face and technologically-mediated collaboration.

4.3 Workspace, workplace and work activity

Face-to-face interaction is often assumed to be the optimal communication mode and one used to inform the design of communication systems and groupware in other settings. However, meeting in person did not necessarily result in the resolution of all the project issues at that moment in time.
Indeed meeting in person was seen to be as much about task-coordination and reaching agreement on next actions and responsibilities to produce information as in-situ design coordination. Face-to-face interaction was ongoing in parallel with interaction on digital platforms and distributed forums for sharing design information. Collaboration configurations were contingent on project characteristics and video conferencing and other tools were available for remote collaboration and distributed working on international projects within a global organisation.

This account has highlighted merits of location-based working for a multidisciplinary design practice. A range of nested contexts provided a pattern and to some degree ordered routine for cross-disciplinary design interactions. The ordered, yet loose-fit configuration of events accommodated the spoken interactional self-organisation of relevant content by the participants present at a meeting.

Decisions concerning the organisation of the workplace, the layout of an office and more local configurations of workplace settings were seen to feature in accommodating serendipitous interactions between people. The workplace was not understood as a benign environment or background ‘context’ against which activities happen, but as a configurational space for interactions. In the studio’s ambience a glance across the office can attract someone’s attention, while orienting to a monitor was indicative or more focused activities.

This research has illustrated that the workplace ecology acts as more than a setting or container for work-related interactions, but provides a patterned way of working for this multidisciplinary design practice. A range of design meetings and interaction situations were seen to be part of the project and workplace routine that were planned, situated, ad-hoc and at times serendipitous. The workplace ecology is more than a metaphor for a way of working. Prominent human ecological concepts including interaction, levels of integration and interdisciplinary relationships were characteristics seen to be import to multidisciplinary working in this workplace setting.

5. CONCLUSIONS

Much is already known about design meetings and patterns of communicative practice amongst design teams. This research complements and develops understanding of design team communication by examining an underexplored aspect of designers’ communication, the characteristics of the meetings in which design is discussed. Provided is an account of design team meetings as types of event, with different characteristics that were observed during the early stages of a building project. A characterisation for each meeting interaction ‘type’ was presented. The notion of a ‘design meeting’ as a universally comparable category of event was challenged as the design team interactions observed were nuanced, with variation and permutations in both the form and structure of each meeting ‘type’. The participants at the meeting did not change, but the ways that the design was presented and
discussed in conversation did. The characterisations of meeting types described are acknowledged as situated, and specific to the organisation of design work in this organisation. Provided is a formative framing which will be relevant to be ‘event type’ specific when analysing design meetings in the future. It is acknowledged that the of design meeting types and the patterns of organisation observed may not reflect ways of working in the AEC sector generally. Through the application of this design meeting framing in other settings this will be tested. What this account articulates is a way of working where there were nested contexts for direct contact between members of a design team, with a pattern of organised events that helped to structure interactions across disciplinary design expertise. A loose-fit relationship between the content of a meeting and the event ‘type’ was observed and the interplay between the self-organised and more planned events warrants more detailed examination. This patterned, yet flexible way of ordering inter-disciplinary interactions seemingly worked well for this organisation, particularly as the configuration of the workplace supported design as a location-based activity and multidisciplinary as a way of working. The design tools used were observed to support cross-disciplinary collaboration and to augment rather than replace face-to-face interaction.

6. ACKNOWLEDGEMENTS

This research would not have been possible without support from the EPSRC and open access and collaboration with the industrial partner organisation, as well as the people working on the construction project who individually gave their consent to record their design meetings.

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Integration along the Value Chain in Construction through Robot Oriented Management

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Abstract: Construction industry has a low productivity rate concerning the raw material input and about 40% - 50% of global raw materials are used for the construction of our environment. Construction waste states the largest waste fraction even in highly industrialized countries and buildings are among the most expensive goods that we produce. Although we have achieved that complex high-tech products as cars and computers are produced with high efficiency, we have not brought the production of simple low-tech products as buildings to a comparable level. An alternative method to conventional construction is the large scale deployment of industrialization, enabled by applying automation and robotics based processes and technologies throughout all phases of the life cycle of built environments. Therefore, complementary robot oriented management has to address all value-added steps from off-site fabrication, ERP Logistics, on/off-site combined management, automated on-site assembly, construction robotics to service robotics, automated deconstruction and remanufacturing. The present paper first analyzes best-practice industrialization/automation and Mass Customization projects, which have been tested or applied successfully in larger scales during the last decades. The projects are organized and presented in accordance with the value-added steps in order to show that all projects, processes and technologies in combination would represent the whole value chain or value system. Through industrialization and complementary Robot Oriented Management, construction industry would be able to simultaneously address multiple parameters relevant for sustainable economic, environmental and social development. The paper shows, that integrating and managing the advantages of the analyzed best practice examples allows for closed and controlled chains concerning technology, processes, resources and information flow and value creation. Further, Robot Oriented Management would not only be limited to building fabrication but also link systems of controlled deconstruction, component reuse and re-customization to a network for continuous and industrially organized resource circulation.

Key words: Robotics, Value Chain, Construction Management, Closed Loop

1. INTRODUCTION

As in any other industry value creation in construction is a complex process. It starts long before the “design” or “architecture” is fixed and generally ends 60-80 years after the “product” building has been set up and brought into operation. Buildings have an extremely long life cycle and the value which is captured through this long cycle is the reason why development is done, architecture can be set up and finally the building can be constructed. Even the building’s deconstruction plays a role in this process as deconstruction itself states a cost factor which has to be taken over by somebody involved in the value chain – or at least this cost factor is handed over as part of the declining value to the next development after a particular building or ground has been disused.
1.1 Factors leading to Disintegration in Construction

Despite obvious interdependencies, the integration along the value chain in construction is problematic. In general following aspects have a negative impact on integrated thinking:

- Each step (project development, planning, construction, facility management, and deconstruction) is traditionally performed by different players with different backgrounds. Only a few firms have the ability to over span more than two of the mentioned steps.
- More and more the architectural part is split in two sections: architecture in terms of design and architecture in terms of detailing the design for construction are each done by specialized architects.
- Architects often overemphasize design aspects with a negative impact on the “producability” of the building and thus on the overall value system.
- Developers are often from financial and civil engineering backgrounds and cannot fully consider necessary architecture and design aspects in their calculations.
- Especially during the construction phase a huge number of sub-contractors are involved and the overall construction task has to be split up in a multitude of sub tasks which are complicated to coordinate.
- Most of the sub-contractors are small to medium sized enterprise with low management capability. They use low-quality or no computer programs that are able to support scheduling and organization.
- New tools as Building Information Modeling cannot unfold their full potential as especially construction is mainly based on conventional, crafts based construction making it necessary to re-translate the digital information into “analog” commands.
- The biggest gap in the value chain exists between planning/construction and building operation. Most architects, planners and sub-contractors hand over their products and are not involved in the building’s life cycle.
- Although facility management is advancing and is using advanced tools for computer aided facility management (CAFM) little knowledge exists in using information set up during planning/construction for the building’s (value creating) operation.
- Deconstruction as a value creating parameter is completely neglected.

1.2 Value Creation and Management

Project management and controlling are professional tools which accompany planning and construction phase in order to assure that the parameters setup in the prior phase of project development (the origin of the value creation) are realized as precise as possible in later phases. Changes of cost, quality or the building’s organization and layout make the value calculation done
invalid and thus threaten (annual) return on investment and the value that can be captured through the building over time. The task of project management and controlling tools is exactly to avoid this through organizational planning, continuous set-actual performance assessment and other management tools. Thus, project management acts as an intermediate between investor/developer on the one side and implementing planning and construction entities on the other side.

1.3 The Answer: Industrialization and Robot Oriented Management

An alternative method to conventional construction is the large scale deployment of industrialization, enabled by applying automation and robotics based processes and technologies throughout all phases of the life cycle of built environments. Therefore, complementary robot oriented management has to address all value-added steps from off-site fabrication, ERP Logistics, on/off-site combined management, automated on-site assembly, construction robotics to service robotics, automated deconstruction and remanufacturing. The present paper first analyzes best-practice industrialization/automation projects, which have been tested or applied successfully in larger scales during the last decades (chapter 2). The projects are organized and presented in accordance with the value-added steps in order to show that all projects, processes and technologies in combination would represent the whole value chain or value system. Further, basic principles for integrating advanced production technology in construction along the value chain through robot oriented management are presented (chapter 3). Finally we summarize our findings (chapter 4).

2. BEST-PRACTICE INDUSTRIALIZATION PROJECTS

Throughout recent history in industrialized construction several large-scale industry projects have been conducted and various technologies and high-tech based methods have been applied. All of those projects, technologies and methods have addressed different issues relevant for efficient and sustainable construction and have therefore, focused on different and dedicated ecological, environmental, social or technological aspects. Moreover, each of those projects, technologies and methods exemplarily represents a certain step of the value chain reaching from customized prefabrication and “production pull” systems to on-site automation, on-site robotic cooperative systems, controlled deconstruction, reverse logistics and recycling. This chapter analyses deployed large scale projects, which efficiently addressed dedicated parameters relevant for sustainable high-performance industrialization and mass customization in construction.
2.1 Off-Site Fabrication in Japan

In Japan customized fabrication has a long history. After the second world war Toyota Motor Corporation searched for a way to improve its’ productivity by a factor of ten (Ohno, 1988). Already at that time, the Japanese market was changing fast and demanding for extremely small series of cars. Toyota Researchers at that time also visited the factories of Ford and GM and concluded that a fabrication strategy based on mass production strategies and “economies of scale” would not work in the Japanese socio-economic system. Additionally, they feared phases of economic recession, which lower production batches even more. Under those circumstances and derived from those needs the famous “TPS” (Toyota Production System) was born (Ohno, 1988). The system’s basic idea is to turn around the conventional one-directional information and production flow. In TPS, therefore, the information about the demanded product is directly sent to the final assembly station. From there (by means of Kanban), components are ordered and previous processes are controlled. The system orders only parts that are actually demanded for a certain individual car (“Production Pull System”). Thus Toyota could build up a production which is strongly connected to customers’ real needs. Finally, the system turned out to work better the lower production batches became (Ohno, 1988). Sekisui Heim, famous for its legendary “Unit-Method” introduced its’ HAPPS (Heim Automated Parts Pickup System, Fig. 2) (Furuse and Katano, 2006) in the 70s and started to deliver industrialized houses with individual floor plans.

Figure 2. Functionalities of Heim Automated Parts Pickup System (HAPPS) Sekisui Heim, Japan.

2.2 Modular and Flexible On-site Automation

Since 1990, about 20 automated high-rise Automation sites have been operated by various Japanese companies (Taisei, Takenaka, Kajima, Shimizu, Maeda, Kumagai, Ohbayashi). An automated high-rise construction site can be defined as a vertically moving factory (Fig. 4) combining semi- and fully automated storage systems with transport and assembly equipment (Fig. 5) and/or robots to erect a building almost completely automatically (Fig. 6, 7) (Linner and Bock, 2009). A further goal of those systems is to
improve the organization of construction processes and construction management by using real-time ICT and advanced control systems enabling a continuous flow of information from planning and designing to control the automated on-site systems (Bock, 2007). Fully automated and semi-automated on-site factories reduce labor requirements by around 30%, and in the future they are expected to achieve a labor saving of more than 50%. Today semi-automated high-rise construction systems are even capable of creating individual and non-rectangular buildings (Fig. 9) (Ikeda and Harada, 2006). The high rate of defined processes reduces material and resource consumption and construction waste is nearly completely avoided. Moreover, on-site factories provide an appropriate and safe working environment. Automated Building Construction Systems can be designed highly modular and flexible (Fig. 8). Today also European construction firms have adopted flexible site-automation systems (e.g. Skanskas, Fig. 10, 11).

![Figure 4. Super Construction Factory of Automated Building Construction System (ABCS, Obayashi) in operation.](image1)

![Figure 5. Z-Carry, Robotic Subsystem of Automated On-site Building Production with AMURAD System, Kajima, Japan.](image2)

![Figure 6. AMURAD System, Robotic Device for automated positioning of columns; floors are assembled in the ground floor and then pushed upwards subsequently.](image3)

![Figure 7. FACES Automated Construction System (Goyo) of the company Penta Ocean in operation, Japan.](image4)

![Figure 8. The SMART High-Rise Construction System is a modular, changeable and reconfigurable on-site factory kit.](image5)
Figures 9. Today semi-automated high-rise construction systems are capable of erecting individually designed and non-rectangular buildings, Tokyo, 2008.

Figure 10. Pilot Test of new automated construction method: An automated system assembles the floors in the ground floor level. Hydraulic presses raise floors and buildings step by step. Skanska, Sweden, 2009.


### 2.3 Flexible Site Robots

Early on-site construction robots were introduced in the civil engineering sector due to repetitive working tasks such as road construction tower and bridge building, dam construction, nuclear power plant construction and tunneling. Major Japanese construction companies were researching and developing robotizes construction processes since the beginnings of the 1980s. Initially, individual robots and remote controlled manipulators were developed for specific processes on building sites. This included robots for delivering concrete, handling concrete, applying fireproofing to steel constructions, handling and positioning large components and façade inspection or painting robots (Fig. 12–13). In Japan in total over 400 different robots were developed and used on building sites. In Germany since the 1990s various robots have been created for supporting interior finishing and refurbishing work in order to increase productivity of building stock modernization (Bock and Linner, 2009).
2.4 Systemized Deconstruction

Within 11 months, three high-rise buildings in the center of Tokyo recently were deconstructed by a semi-automated deconstruction system (Kajima). The process of deconstruction was reversed and re-engineered. It starts with the dismantling of the ground floor. Meanwhile dismantling the ground floor, the upper part of the building was held by IT-coordinated hydraulics. With this method, floor by floor was dropped down subsequently and disassembled at the ground floor level (Fig. 14). As the deconstruction thus was highly coordinated and could conveniently be conducted on the ground floor level, 93% of the building components could be recycled (recycling rate of conventional demolition: 55%) (Bock, 2009). This example shows that the consequent deployment of advanced on-site technologies could be crucial for sustainability in construction/de-construction in the future.
2.5 Building Re-Customization

All obsolete building modules of Sekisui Heim can be accepted as trade-in values for a new Sekisui Heim building. Therefore, the deconstruction process is a reversed and modified version of the construction process (Fig. 16) which is based on subsequent unit factory completion of modular units on the conveyor belt as described before. For deconstruction first joints between steel frame units are eased, and then the house is transported to a special dismantling factory unit by unit. There the outdated finishes are dismantled and fed into advanced reuse cycles established around factories. The bare steel frame units are further inspected and renovated and then equipped with new finishes desired by a customer who has chosen to buy a remanufactured house. On a Web-Platform for “Reuse System Houses” (Sekisui Heim, website), Sekisui organizes a matching of people who want to sell their modular house for reuse and people willing to buy a remanufactured home.

The newly outfitted units are then assembled on a new foundation in a new site (Fig. 15). Thus the system allows e.g. that a house once purchased by parents or grandparents could be relocated and reorganized to serve children or grandchildren. For remanufactured homes Sekisui Heim offers the same guarantees, supports and services as for newly built houses.

3. INTEGRATION ALONG THE VALUE CHAIN BY ROBOT ORIENTED MANAGEMENT

Future sustainable industrialization and robot oriented management in construction has to address all value-added steps from off-site fabrication, ERP Logistics, on/off-site combined management, automated on-site assembly, construction robotics to service robotics, deconstruction and remanufacturing. High-tech construction would then allow addressing economic, environmental, social and technological issues simultaneously. Here industrialization has particular advantages, as it allows gradual implementation of new technologies for reducing energy, material and waste consumption and for upgrading working conditions, health and low wages. Further, industrialized
processes, methods and technologies are crucial for developing affordable and thus sustainable housing. In this chapter, we present a framework for industrialization and robot oriented management, which was derived from the above analysed best-practice examples. The examples analysed showed that industrialization, flexible automation and construction robotics could be integrated with all value-added steps. Integrating and managing the advantages of those practices would allow for closed chains concerning technology, processes and information in the building construction process. From the analysis done in section 2 the following basic principles enabling an integration along the value chain could be derived:

### 3.1 Implementing Human-Robot-Cooperative Systems

The next generation of robots will work in the direct operating range of human workers in order to achieve a maximum of flexibility, which is a basic requirement for customization and flexible individual product fabrication by industrialized methods. Robotic systems of the next generation will rather be “assistants” (EUROP, 2009), helping human workers to perform complex tasks, than fully autonomous systems. New interaction concepts, interfaces, concepts for lightweight robots, integrated force-torque sensors and teaching systems are therefore, now developed by researchers around the world. Conventional construction robotic systems, guidance or remote-controlled system, have to solve complex problems in unstructured and complex construction sites. A solution to address these problems is the strategy of “human-robot cooperative manipulation”. Robots are capable of high speed motions and power assistance, whereas humans are slow and weak concerning heavy construction work. On the other hand, humans are much more flexible and adaptable concerning thinking, orientation and operational behaviour. The strategy of “Human-Robot-Cooperative-Manipulation” (Lee, Lee et. al., 2007) integrates the advantages of both robots and human beings and creates highly flexible cooperative systems that are predestinated for complex tasks in factories or on construction sites (Fig.17).

![Figure 17. Concept of human-robot cooperative manipulation able to create highly flexible cooperative systems for complex tasks in factories or on construction sites (Lee, Lee et. al., 2007).](image-url)
3.2 Reducing Complexity: Robot Oriented Design

In integrated industrialized construction, the product structure is the most crucial and most complex item of the whole process chain (Bock, 1988). It is impossible to successfully apply the building structure known from conventional buildings. Systemized and modularized building structures have to be developed in close cooperation with the needs of fabrication, logistics, customization and robotic and cooperative applications. Further greater agreements and standards on those systemized building structures should be deployed in the industry’s legal framework to foster the exchange and substitution of materials, sub-components and components among the industry’s players. Further the structural elements (e.g. steel structure) should be clearly separated from the infill (cables, electricity, appliances) and from the façade elements and interior finishing. Then facade elements and interior finishing could be designed more or less individually, whereas structure and infill could be standardized.

![Figure 18. Robotic Construction Automation System Technology. Model of the first Korean automated construction site. The orange frame is part of a vertically moving on-site factory. To the frame robotic devices, robotic transportation systems and assistance technologies are attached. The whole system is based on principles of Robot Oriented Design. Seoul, 2010.](image)

To the product structure all other processes, technologies, and business strategies are strongly related. An open building structure is fundamental to dynamically integrating and applying new and also modularized ecologies of technologies, microelectronic systems, devices and services.

Additionally, Body-in-White assembly simulations (Wang, Chen et. al., 2004), which are state-of-the-art in aviation industry, car manufacturing and ship building industry, could not only assist in developing industrialization and robot oriented design but could significantly reduce time and error cost in final construction operations. The principles of Robot Oriented Design are currently applied at the first Korean automated construction site (Fig. 18).
3.3 Towards Robot Oriented Management: “Production” Flow and Mass Customization

Conventional construction today is heavily relying on human power. It delivers individual products, yet at high costs and nearly without relying on high-tech solution. Robotics and advanced equipment are not in the focus of architecture and construction. Moreover, construction products are still inflexible, showing a highly interdependent component structure. Industrialization in architecture and construction for a long time has not been considered as being able to deliver individual buildings adjusted to locations and people’s need. Moreover, today, the demand for expressive and diverse buildings requires an even more advanced building typology. This perspective considers not that up to now architecture has only tried to achieve industrialization by changing construction to serialized prefabrication. However, today new approaches as mass customization allow an industrialized fabrication of individual construction products from infill elements up to whole units and houses. Customization is a strategic means for delivering user adapted or even personalized houses at same or even lower cost than standardized mass production (Piller, 2006). It aims at enhanced efficiency meanwhile creating user adapted products. Therefore, customization is not only based on the control of a single process or CNC machine but on creating new organizational structures over the whole value chain corresponding with information flows between enterprise, product, machinery, robots, customers and all complementary sub-processes. Moreover, Mass Customization allows fabricating houses to order by industrial means minimizing the input of resources, workforce and energy.

3.4 Addressing Eco Issues through Robot Oriented Management

Eco-factories are factories that produce at high efficiency and in accordance with environmental needs: carbon neutral, powered by renewable energy, zero-waste (Business and Economy Trends in Japan: Zero Waste Factories, Japan, website). An essential economic and ecologic factor in most industries today is the implementation of factories with low or even no environmental impact (Williams, Westkämper et. al., 2009). Additionally, with the implementation of industrialized and modularized structures, eco-processes once established could be improved gradually. Eco-factories are often established through applying Environmental Management Systems (EMS) (US Environmental Protection Agency, website) that are complementary with advanced resource control technologies. Therefore, factories are increasingly able to manage the closed-loop circulation of all resources and materials efficiently. Further, technologies for using renewable energy, solar modules and cogeneration systems are gradually deployed in industrial facilities to generate electricity and heat for the production, meanwhile waste and heat recovery systems allow a passive-house-like energy
circulation within the factory. The research aims here into the direction of more or less autarkic factories, which even could process their own waste to generate resources and energy. Moreover, the reduction of waste through continuously improved and demand oriented production “pull” processes and advanced production equipment is another aspect, which shows the advantages of switching material-intensive processes from the construction site into the controlled environment of an off-site or on-site factory. Further, systems for reverse logistics, remanufacturing and recycling as discussed before could be closely linked to eco-factories creating closed-loop manufacturing structures for sustainable resource, material and component circulation (Fig. 19).

Figure 19. Towards closed-loop component circulation in construction through automation and robotics: Reverse logistics, remanufacturing and recycling could be closely linked to eco-factories creating closed-loop manufacturing structures for sustainable resource, material and component circulation throughout the whole building lifecycle.

4. CONCLUSION

New organizational structures, new processes and technologies, microelectronic systems, ICT, flexible automation, robotics, human-machine-cooperative systems, tagged equipment, modular building components and knowledge based logistics are enablers of a shift towards sustainable economic construction when they are designed as complementary parts of a total system. Industrialized structures provide the basic foundation for a gradual development towards a more sustainable construction industry. Therefore, in this paper, examples have been given which outline
best-practices in sustainable industrialized construction. Further, basic principles for integrating advanced production technology in construction along the value chain through robot oriented management have been present. Through industrialization and complementary Robot Oriented Management, construction industry would be able to simultaneously address multiple parameters relevant for sustainable economic, environmental and social development. The paper shows that integrating and managing the advantages of the analyzed best practice examples allows for closed and controlled chains concerning technology, processes, resources and information flow and value creation. Further, Robot Oriented Management would not only be limited to building fabrication but also link systems of controlled deconstruction, component reuse and re-customization to a network for continuous and industrially organized resource circulation.

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5.1 Websites

Federal Statistical Office [www.destatis.de](http://www.destatis.de)
An innovative signage design software to assist wayfinding in complex environments

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Abstract:
Wayfinding is a critical process for navigating through an environment. The process has three stages; “Plan, Orientate, and Proceed”. Signs and other visual aids play a key part in the wayfinding process, affecting the efficiency of the wayfinding operations. This makes both the architectural and the signage design very important. Signage design involves a variety of practitioners who collaborate to provide a signage layout which is safe and efficient, and assists in the provision of a good wayfinding environment. This paper highlights the advantages of using an innovative software-tool that can assist and speed up the signage design process. The software plugs into AutoCAD, and can significantly reduce the time taken to create signage layout for a building, and its subsequent assessment of suitability and efficiency. Loughborough University, in collaboration with the University of Zaragoza, Spain, are developing the software so that it may be used on major construction projects. The group are currently in the process of applying and verifying the benefits of the software tool on an existing large UK construction project. The client has a particular interest in wayfinding issues, not only because of the type of building, but also due to the large, phased nature of the regeneration works proposed. Using the widely used AutoCAD architectural design software package as a platform, the signage design software can be easily incorporated into existing drafting procedures, and make the signage design of buildings more collaborative overall.

Key words: Usability, CAD drawing, Wayfinding

1. INTRODUCTION

Since the advances in desktop computers in the 1980s an increasing number of architects’ offices have used computer-aided design (CAD) systems to develop the drawings that define the plans and details of a building or structure. Today CAD drawing files are shared between project members, on large projects, using file sharing management systems which operate over the Internet allowing the different disciplines (architecture, structure, mechanical and electrical engineers) in different geographical locations to work together simultaneously. These relatively rapid changes in the management of architectural drawings have left some gaps where certain processes continue to be carried out in a more traditional way. The positioning of safety signage within buildings and the repositioning of signs during phased refurbishment of complex structures where public access has to be maintained are an example of such processes and this paper describes the development of a
software tool by Zaragoza University in Spain and the assisted redevelopment at Loughborough University in the UK to help architects fill these gaps.

2. **USEABLE BUILDINGS**

Good buildings are generally classed as those that are comfortable (keep out rain and cold and provide thermal comfort), stable (have good foundations and made with sound materials) and appeal to the senses (are visually appealing and feel nice to be in). These qualities usually refer to a shelter or a building fit for human habitation (Wooten, 1624). Even when looking at structures’ performance requirements (appearance, durability, dimensional suitability, strength and stability, whether exclusion, sound control, thermal comfort, fire protection, lighting and ventilation, sanitation, security, and cost) there is no mention of the ability to navigate through the building but escape in the event of fire is covered under fire protection. This is mainly concerned with providing fireproof materials to align time for persons to escape the building but starts to raise concerns about multi-storey buildings and access routes (Osborne, 1989).

Usability is a common theme in modern engineering journals, but how is it measured in an architectural design context? (Afacan and Erbug, 2009). While guidelines and standards exist designers have difficulty deciphering the academic source of information (Gregor et al, 2005). Usability and human factors are, in effect, complex disciplines with a need for specialist subject knowledge. However, designers are expected to consider usability in their designs. For large construction projects human factors needs are now often mediated by expert consultancies. For smaller projects this important detail is often an afterthought left in the hands of a novice designer towards the end of the design stage. However, there appears to be a communication gap between designers and other professionals (Afacan and Erbug, 2009) and on smaller projects a lack of holistic design knowledge may cause problems in highlighting far reaching design and usability issues. Another problem is the type of human factors information that is supplied to designers. Information is often in pictorial, textual and numerical form so that it needs to be interpreted to be incorporated into the design (Carmicheal et al, 2007). In construction there is a lot of time pressure so if information is not given in a useable format then it is often ignored (Nicolle et al, 2003). However, ignoring these issues at the design stage can have serious and costly implications for the final design such as cost overruns, customer aggravation, end user accidents and loss of reputation for the designers. Designers are aware of the guidelines, theories and regulation but problems arise where it is necessary to implement these issues into practice. If this information is missing then how are these user needs translated into reality? How are they expressed at the final design stage? Designers will generally not be users of the final building, they therefore may find it difficult to empathise with the diverse array of end users (Preiser,
If the designer is unable to empathise with the end user and through the nature of the job does not have time to empathise with their needs then there is a need for a better means of communication media that is easily understood by all parties and transferable into the design.

3. WAYFINDING

Early in the last century, psychological research investigating rats navigating a maze (Tolman and Honzik, 1930) eventually led to the theory of cognitive maps in rats and men (Tolman and Honzik, 1948). The findings suggested that people learn about ‘what leads to what’ and have expectations (cognitive maps) about how to navigate through a maze (complex building layout). As early as 1958 architects and psychologists were working together on the construction of buildings and carrying out post-occupancy evaluation studies (Bonnes and Secchiaroli, 1995). In order to understand how people mentally form cognitive maps, the ‘travel plans’ they propose and carry out in their environments must be considered (Garling and Golledge, 1989).

To be able to move and act in a specific environment it is necessary to possess a type of knowledge which, besides carrying out the function of atlas, also carries out the function of mental encyclopaedia (Russell and Ward, 1982). This is to say that when people interact with an environment the knowledge of that environment is built up of static mental representations of ‘where’ things are located in physical space and specification about ‘what’ those entity are.

The results of experiments using virtual reality simulations to examine emergency evacuation of buildings (Tang et al, 2009) showed that the time to evacuate the building when no signs were available was three times the minimum time needed for emergency escape without error. The researchers repeated the experiment introducing signs and found an improvement in evacuation time. The results highlighted the importance of safety signage in evacuation situations. The study also investigated interpersonal differences and tendencies. Individual characteristics were recorded, it was found that men found the exit stairwell faster than women and that construction workers and fire safety personnel were not appreciably better at finding their way. The importance of signs was emphasised to overcome people's tendency to turn left even when signs indicate turning right. People are drawn towards a particular direction even when it is not their way out.

When a specific symbol has a poor association with its referent, there can be a problem in selecting or designing a better symbol. One approach is to create alternative designs for the same referent and to test them (Sanders and McCormack). In an examination of exit signs (Collins and Lerner, 1983), 18 alternative signs were tested under simulated emergency conditions with a very brief exposure time. The results showed that certain symbols for "No Exit" were confused with those for "Exit" and that the
best signs with those with "filled" figures, square or rectangular backgrounds and simplified (reduced number of simple elements) figures. Some of the designs are shown in figure 1 below.

![Figure 1: Examples of a very few of the 18 exits signs used in a simulated emergency experiment, with percentages of errors in identifying them as exit signs. (Source: adapted from Collins and Lerner, 1983)](image)

Owing to the complex nature of modern building wayfinding or the way in which we find our way in a geographical or built environment falls under the guise of cognitive ergonomics. In order to wayfind we build a cognitive map based on external stimuli to help us find our way (Finneran et al, 2011). From a designer’s point of view, in order for wayfinding to be effectively designed into an environment it needs to be seamless, done without the user’s conscious awareness. In fact the user should easily find their final destination without realising how they got there and signs and signage should enhance the user journey (Hawksworth, 2000). But if budgets are tight and human factors information is difficult to understand in its current format, how do you then design this seamless environment? The systematic anticipation of the user’s situation immersed in a complex environment is a demanding task for the designing architect (Brosamble and Holscher, 2008). EdelStein et al (2008) noted that building simulations in a CAD based environment is representative of a real life environment. Moreover, CAD-based representations are more easily understood by designers and other professionals. It appears that there is a need for a CAD-based tool for wayfinding design. The tool should integrate common standards regulations as regards current demands for signage so that design ideas and alterations may be easily communicated between the various stakeholders. The following section includes a description of a CAD based application which meets these criteria.
4. POSITIONING OF SIGNAGE

Research looking at architects’ understanding of human navigation (Brosamle and Holscher, 2008) used a series of semi-structured interviews to discuss concepts and techniques in architectural design in relation to navigation and orientation with 12 architectural designers and planners all of which had been working in architectural companies were several years. They found that architects concentrated on the visibility available to users in key locations rather than usability of the buildings and that locations were seldom considered in a systematic fashion. It was also noted that the tools and techniques in architectural design focus on the building, in particular its structure and form and that software supporting the architect working on complex buildings would improve the situation.

Although guidance is available for architects to provide adequate fire protection measures for new buildings these tend to concentrate on ensuring that escape routes are clearly indicated by proper signs (The Health and Safety (Safety Signs and Signals) Regulations 1996 set the standards for these signs). Moreover, specific guidance is given for both the colour (BS5378-2:1980) and layout (BS5499), which would be facilitated by ease of access to signage libraries. However, the standards offer little indication as to how or where the signs are to be positioned. This may lead to the non-standardised positioning of signage across projects. The positioning of signs in buildings is carried out in many different ways depending upon the individuals given the responsibility for this task, the environment in which the signs are to be placed and the type of signs required.

The Construction (Health, Safety and Welfare) Regulations 1996 require measures both to prevent fires happening and to make sure all people on construction sites (including visitors) are protected if they do occur. The Construction (Design and Management) Regulations 1994 (CDM) also require those designing, planning and carrying out projects to take construction fire safety into account. European guidelines state that clear signs must be provided and maintained in prominent positions indicating the locations of Fire Brigade access routes, escape routes, position of dry riser inlets and the fire extinguishers provided for use by trained staff. Signs should be reviewed regularly and replaced or repositioned as necessary (CFPA, 2009).

For construction phase wayfinding the person responsible for fire safety has to consider regulations and provide a means of escape for all workers and visitors; the fact that escape routes will tend to change during the course of construction; new escape routes to be added need to work with any existing escape routes on refurbishment projects; providing two escape routes offering escape in different directions wherever possible and consider workers in vulnerable or difficult areas such as crane operators. Escape route distances need to be determined depending upon the structure and layout of the building. Guidance provided by the UK’s Health and Safety Executive (HSE, 2010) shows maximum travel distances from any point in a room to an exit for different situations as shown in table 1.
The positioning of signs on construction projects is further complicated when dealing with large complicated projects, such as shopping centres and transport hubs where the construction work phases affect pedestrian traffic flow. Designers also need to consider that migrant workers of many different nationality may be present on a construction site. In this case appropriate signage and wayfinding facilities should be provided at the construction phase (Bust et al, 2008). With every phase of the construction work the pedestrian flow will have to be considered. In addition there is the potential of emergencies in either the existing complex or the construction work leading to evacuation from one into the other. The most complex of buildings will for the most part be service providers such as hospitals or shopping centres. This further complicates the issue, the equality act (2010) states that where goods and services are provided it is unlawful for the service provider to make it unreasonable for a disabled person to use a service. Way finding is a service. In these circumstances, with many factors having to be considered, those responsible for the positioning of the signs will obviously benefit from some form of computer aided design.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Maximum travel distances</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Fire hazard</td>
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<tr>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td><strong>Enclosed structures:</strong></td>
<td></td>
</tr>
<tr>
<td>Alternative</td>
<td>60 m</td>
</tr>
<tr>
<td>Dead-end</td>
<td>18 m</td>
</tr>
<tr>
<td><strong>Semi-open structures:</strong></td>
<td></td>
</tr>
<tr>
<td>Alternative</td>
<td>200 m</td>
</tr>
<tr>
<td>Dead-end</td>
<td>25 m</td>
</tr>
</tbody>
</table>

Source: Fire Safety in Construction – HSG168

Methods for positioning signs can vary considerably. For example, physical scale models are commonly used by architects to create the intended building and place wayfinding elements in the design. This method provides a useful visual aid, but there are serious concerns, at this scale important wayfinding elements may be considered too small or even insignificant which will lead to serious issues for the final building design.

Several other positioning methods are also available. Photographic and video walkthroughs allow each stage of the journey to be considered and documented, however this method can prove time consuming and monotonous. Questionnaire feedback may be used to probe information from environment end users, however this type of data collection is subjective and may be subject to end
user bias. Linear programming a mathematical modelling method has also been used to investigate wayfinding design and layout. While comprehensive results of this method are not easily communicated to the various relevant professionals.

4.1 ImplaCAD and SignCirCAD

On the basis of a review of current signage layout design system used by architects in Spain it was noted that the methods were generally paper based and not easily integrated with 2D and 3D software tools commonly used for other design processes. Signage layout design is highly unregulated which means there may be major variations from one project to the next. If signage design systems could be more easily integrated it would essentially improve time use, costs and end user satisfaction. It was decided that there was a need for a method to facilitate wayfinding design for architects that could be implemented at the design stage using available sign libraries to ensure compliance.

ImplaCAD is a 2D plug in for design software AutoCAD and has been developed in conjunction with Spanish design company Implaser and launched in 2008 for use with contemporary Spanish sign design. The software is in line with several standards and directives in its signage libraries. The European Council directive 92/58/EED and the Spanish Royal Decree 485/1997 were taken into account as were other standards such as the American National standard Z535 series or UNE 23034:1988 were also consulted during the first phase of the design project. The software works by allowing the designer to place signage within the drawing plans. Rays emanate from the placed signs which allow the designer to verify covered areas and eliminate congestion and blind spots (figure 2). Integrating the recommendations on viewing distance, line of sight and sign size the software highlights several key features. The software:

- Aids the placement of graphical symbols on architectural plans.
- Integrates with a commonly used design tool AutoCAD to allow design communication of design changes to the client as well as an interdisciplinary design team.
- Facilitates the placement of several sign types, flat, perpendicular to the wall and panoramic.
- Integrates a library of signage designs which meet the specifications of current standards.
- Analyses the signs areas of influence taking into consideration the size and physical shape of each placed sign. The designer may graphically visualise the specific area of coverage for each sign placed. This also allows the designer to verify that current regulations are adhered to, blind spots are covered and sign congestion is eliminated.
- Counts the total number of signs present in a drawing.
- Allows the user to place boundary tape and calculate the total length.
- Integrates pathways thus eliminating confusion when the designer considers sign orientation.
- Allows the user to consider visual obstacles which would limit the line of sight for the end user.
• Works using blocks in AutoCAD which implies that several different iterations of sign placement and design are possible. This is particularly beneficial from a usability point of view where a client may demand several variations for numerous users.

![Diagram of sign placement](image)

*Figure 2 Sign placement*

However, the tool was developed for an indigenous market and due to the specificity of the regulations integrated into the system the researchers realised that integration into large scale international projects would prove difficult. Researchers at Loughborough University were invited to use the software, to test it and make recommendations to develop its international and industrial potential. The Loughborough team assessed the software over several months and made recommendations to the researchers at Zaragoza University. While it was felt that the software is beneficial and allows for easy integration of signage into existing designs there were several concerns which are highlighted below:

• The time taken to place signs and how alterations made to one single sign were not integrated across the whole drawing.
• The designer had to manually trim the lines around an obstacle.
• The researchers also highlighted that British Standards differ significantly from Spanish ones and that a more extensive signage library would allow for these variations.
• The existing interface would need to be altered as at this stage the tool was primarily for Spanish speakers.
The Spanish researchers implemented the suggested changes and have developed the software into its current form (SignCirCAD). While maintaining the benefits of ImplaCAD in its current form the software boasts the following improvements:

- The current version allows the user to preset boundaries using polylines and commands to identify visual obstacles so that the designer does not have to manually edit the drawing.
- If alterations are made to the drawing the designer can select all signs which allows the drawing and signage to update to current standards.
- A significant feature of this tool makes it possible to generate listings of the inserted safety signs.
- It is possible to obtain valuable dimensional data about surfaces and areas that signs are covering, so their quantity can be optimized from different points of view, such as geometric or economic.
- Association of exits with their respective signs so that the quickest escape route may be identified which is of particular importance in the design of evacuation routes and procedures.
- The tool may be adapted to facilitate the placement of CCTV, fire hydrants and other safety equipment.
- The tool is also facilitated by an on-line tutorial available to users.

Researchers at Loughborough University have established industrial links with a major rail refurbishment project in the United Kingdom. The researchers at Loughborough will work alongside the design and innovation team on the build to assess the benefits of the tool in its current form for a major construction build. The researchers plan to tutor the design team in the use of the tool, monitor assessment and provide feedback to the Spanish researchers.

5. BENEFITS OF THE TOOL TO ARCHITECTS AND CLIENTS

For those architects that are averse to using high-end computer design solutions and are still moving cut-outs of signs around a floor plan to position them the SignCirCAD is a viable and more effective method. Whilst the researchers do not claim an extensive knowledge of computer solutions for
architectural design management from discussions with various construction industry professionals they believe that SignCirCAD offers a novel solution to a ubiquitous problem.

6. RELATIONSHIP OF THE TOOL TO ARCHITECTURAL MANAGEMENT

Design is an individualist, innovative process that does not easily lend itself to the constraints of modern management. However, architectural management is a field which aims to manage the design process. Building projects in particular are extremely complex and require many experts from several backgrounds and diverse competencies to work together as an effective team so that a client’s goals can be realised (Emmitt, 1999). The system has three key themes: people, processes and product. The authors envisage way finding as an essential part of the design process which the tool can help manage. This process will add value to the final design which is important to the client as a key theme of value in architectural management is inclusive design. The tool allows the iterative design of several different scenarios and layouts. As previously stated the authors do not claim to be experts in the field of architectural design and management. However, it is felt that the SignCirCAD offers a solution for architects to include and improve way finding and evacuation design process to benefit the final built product.

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Lean design management: exploring perception and practice

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Abstract: Many construction projects suffer from delays and cost uncertainty with the result that, in many cases, the customer or client is not satisfied with the final product. The importance of managing the early design phases effectively and efficiently is well-established, although how best to do this is not so clear. The successful use of lean management in the construction stage (using the principles largely developed by Toyota) has opened up the possibility of using lean management in the early design stage, thus helping to establish a systematic approach to managing construction projects and the organisations that participate in them. This study, explores the interpretation and application of lean design management in architecture, engineering and construction (AEC). A survey questionnaire was used to obtain a deep understanding of the issues connected with the current processes and practices in design management. The findings from 125 survey responses provide evidence that inefficiencies in design management practices in the UK construction industry are related to ineffective design management processes (e.g. briefing, design planning, etc.) as well as problems with procurement. The main conclusion drawn is that lean design management appears valid for implementation in the construction industry but needs to be customised according to the project context to achieve the desired value.

Keywords: lean design management; client briefing; design process waste; design process value stream; architecture, engineering and construction (AEC).

1. INTRODUCTION

Many construction projects suffer from delays and uncertainty in terms of cost with the result that, in many cases, the customer or client is not satisfied with the final product. Research has highlighted the importance of the early design phases in helping to reduce such uncertainty and improve quality; thus, the importance of managing this stage effectively and efficiently has been made clear. Despite this, much research effort has been, and continues to be, expended on the construction phases, with initiatives such as lean construction trying to deal with challenges that many would argue should have been dealt with in the earlier design phases. Clearly there is a need for better design management and attention is turning towards this phase in order to address these deficiencies. The successful use of lean management in the construction stage (using the principles largely developed by Toyota) has opened up the possibility of using lean management in the early design stage, thus helping to establish a systematic approach to managing construction projects and business. Indeed, it could be argued that a lean culture must be embedded within an organisation before it can apply the principles to projects.
However, a clear definition of what is meant by lean design is still being debated (Brookfield et al., 2004; Jørgensen & Emmitt, 2009).

The focus of this research was to obtain an understanding of the issues connected with current processes and practices in design management, as well as interfaces between lean management principles and the design process. This aims to help in deciding whether or not lean design management can be implemented in design processes for construction projects. If so, at which of design stages organization can start applying lean thinking management without interruption. This investigation is carried out within the construction industry in the UK using a survey questionnaire.

2. LEAN DESIGN MANAGEMENT

Management deficiencies have been shown to have a negative impact on the efficiency of the construction process in terms of the waste generated and contract variations occurring during construction while the success of a project and the value realised are highly dependent on the decisions made during the very earliest stages of a project’s development (Emmitt et al., 2004; Thyssen et al., 2008). Poor control of the early (design) stages has been identified as a major factor in reducing the overall performance and efficiency of construction projects (Hansen and Vanegas, 2003). An overall project’s final outcome depends on firm control in the earliest phases in order to avoid the effect of mistakes and omissions. This control involves design briefs, avoiding poor design and ensuring good-quality documentation as failure to do this leads to higher costs, increased litigation, schedule delays and lower quality of the final constructed product.

Research has indicated that material and information flows, and the generation of good value for the customers and end users involved within the design process, as well as transformations of inputs to outputs, are achieved effectively using a lean design management approach (Tilley, 2005). However, the complexity of the relationship between the fundamental principles of project management and the transformation model/theory of production work as obstacles which hinder the process of finding effective solutions to failures to manage the design process; this can result in poor levels of performance (Tilley, 2005). There is need to consider the nature of design and whether or not design development can be considered as part of production when considering the concept of lean design management. Improving the integration of project processes, design and construction have been identified as a key to the successful outcome and performance of a project as design cannot be considered separately from the construction process (Jørgensen and Emmitt, 2009; Brookfield et al., 2004). Thus, in order to achieve more efficient and better quality outcomes, Lean Design Management (LDM), or more specifically the introduction of ‘lean production’ principles to the process of design, has been promoted as a new approach (Egan, 1998).
However, due to inadequate design management and poor quality control of an end-product, together with problems concerning quality and efficiency experienced during the design process, there is a need to apply lean principles through design process to improve the quality of outcomes for the customer while, at the same time, reducing costs and resources through waste reduction (McCarron, 2006; Tilley, 2005). Moreover, these principles can be used to manage the development and production of documents, which become more and more detailed, until they reach a stage where they are suitable for use in planning, budgeting, estimating and eventually constructing (Tilley, 2005; Koskela, 2004).

Generally, the keys in ‘thinking lean’ are defining waste and speculating exactly what is of value within the organisation: i.e. precisely what activities and resources are needed. It is important to consider only those that are needed for the owner, client or end-user because including others is considered as waste (Poppendieck, 2002). Out of seven types of waste identified, only six can be considered to be within the construction design management process (transportation is not relevant):

- Extra tasks, iteration (Overproduction)
- Extra resources (Inventory)
- Each design member has to report to a coordinator who reports again to other design participants (Extra Processing Steps)
- Tasks flow on time (Motion)
- Lack of briefing (Defects)
- Customer responding (Waiting)

The main approach of any lean design management strategy should be to maximise the overall value for clients and end-users from the project, while maintaining a high level of performance from the design process. Jørgensen & Emmitt (2009) found that the successful application of lean was highly dependent upon the individuals involved and their ability to apply lean to the various aspects of projects. Issues such as communication problems in terms of inadequate briefings, client complexity, design time being shared equally between the architect and the engineers, and design team value not being fully considered by architects, have indicated that most waste occurs because of the practices in early design stages, but this is an area largely overlooked by researchers in the lean construction community. More focus is needed on identifying waste in architectural design, together with reasons why it occurs.
3. METHOD

The literature review was useful in helping to establish a lack of knowledge and understanding of lean design management. To help address this shortfall it was felt that a questionnaire survey would be useful in gathering the opinions of a wide range of professionals. A questionnaire survey was designed to collect qualitative and quantitative data and piloted on a small number of volunteers, following which a small number of revisions were made to aid the clarity of the questions. Questions were organised under a number of themed headings, namely background information, highlighting the issue, evaluating communication techniques, design management process formation, the implementation of lean management, and further comments and information.

The questionnaire was sent to 908 construction industry practitioners working in design companies and construction organisations, comprising; architects, design managers, project managers, coordinators, engineers and quantity surveyors.

A total of 163 questionnaires were returned, although not all were fully completed and therefore a decision was taken to exclude the incomplete questionnaires. This resulted in a sample size of 125 fully completed questionnaires. Responses were from a variety of industry practitioners (17 architects, 15 design managers, 38 project managers, 5 coordinators, 28 engineers and 12 quantity surveyors). However, it must also be stated that 10 responses were considered reliable as their responses to the other survey questions suggested that they actually carried out a role in the construction industry. It was discovered that their roles were not included in the categories provided as some of them stated their position in the optional section, headed “Further information”, at the end of the survey questionnaire. These roles were key account director, marketing manager, managing director and director of architecture.

A mixture of qualitative and quantitative data were collected; these expressed a diversity of experience and views in terms of the inefficiencies in the current construction design management practices and the implementation of a lean management approach in design processes, processes that are intended to manage the design stages efficiently, therefore ensuring the delivery of optimal value (in terms of the product/building) to the customer or client. Although the intention was to collect data from clients only two responded, and only one of these questionnaires was complete. This made it impossible to draw valid judgments concerning differences or similarities between the responses of clients and those of the industry practitioners.

4. RESULTS

Generally, the analysis of the data collected from industry practitioners from the survey questionnaires demonstrated that there is inefficiency in the design management practices in the UK
construction industry because of the poor design management processes. As a result, many construction projects are delayed and go over budget; in some cases, clients are also not satisfied with the final building. However, the data analysis illustrated that procurement methods are also responsible for inefficiency in the early design stage. The results presented below relate to the use of lean design management.

4.1 Inefficiencies in the design process (waste)

This study found that inefficiencies exist in the design process because of the nature of the process itself and the ways the design process is managed. These inefficiencies generate waste that must be mitigated or preferably eliminated. This waste results from human activity and current applications of design management.

It was found that the waste experienced in design processes is generated through the late approval of decisions by clients, resulting in a creeping escalation of a project’s scope. One engineer stated that: “The adage ‘fail to prepare, prepare to fail’ is very true with most things, especially construction”. Clients are often accused of causing inefficiencies because of vagueness in the content of the client’s brief and difficulties associated with securing their approval. Clients have also been criticised for failing to appreciate that a change during the design stage can potentially result in a complete redesign. One project manager claimed that: “Clients generally have no understanding of the commissioning process. They leave everything to the last minute then expect consultants/project teams to pull a rabbit out of the hat”. Clients are blamed too in terms of their side commissioners as, in most cases, they have no background experience regarding what they are commissioning and do not listen to the consultants they are paying to give them advice. Broadening the distribution of value to different stakeholders may therefore be achieved by gaining a better understanding of a client’s complexity (Tilley, 2005; Emmitt et al., 2005; Koskela et al., 1997).

Further waste is generated through poor design management (e.g. a lack of an efficient flow of information and overly complex designs; the brief may be poorly interpreted, the construction strategy might not be communicated early enough, and too many design alternatives might be offered etc.). Furthermore, design teams often do not appreciate that many clients are inexperienced, as one architect reported: “Clients can be trapped by their own decisions. It is the responsibility of the design team to fully appraise the client on these factors and ensure deliverable decisions are made”.

Far more waste is generated through the briefing (the main communication tool) because of inadequate brief documents and brief freezing. The client in a construction project is an integral participant in the design process, unlike in product design or manufacturing. One project manager claimed: “Design in construction is a complex problem and is not amenable to a single correct solution. The design team and the client's understanding evolves with time, therefore it is impossible
to define all the requirements at the outset of a project (the fallacy of a 100% brief). The search for solutions is iterative over time and must embrace bounded cognition (on all sides), increasing but imperfect knowledge, and be focused upon achievement of a satisfactory outcome”. What is more, clients are asked to put forward all of their requirements early on; as a result, clients are directed to make assumptions and therefore, designs are worked out based on soft assumptions that are liable to change. One engineer stated: “It cannot be expected that the design team can have the final solution from early on in the design. If that was the case, innovation and accurate design will not develop”. However, two main objects were also stressed: first, having a clear initial design brief to give a project a strong start; and, secondly, organising briefings in phases, in line with the development of the design. It was felt that some information should be frozen at gateways to phases; changes in the frozen information should not be allowed beyond these points as making processes too flexible can cause problems. However, the key is to freeze information at the right time when the right information is there. The respondents also pointed out the need to freeze phases as a way of measuring and managing any changes.

On the other hand, some participants claimed that briefing must remain fixed as a successful design requires the solid foundation of clear client requirements. One engineer stated: “If the brief is vague then a range of options must be considered as acceptable”. What is more, this type of briefing acknowledges changes in terms of both the budget and time as it acts as a benchmark against which the design is judged. One project manager stated: “If the brief is continually changing, the client must accept that the costs will change to go over budget. A completed section of work is destructive to a design team’s morale because of brief changes”. Another view was that, having briefings as a continuous process, might lead to a failure to concentrate on some early key issues. However, there is definite emphasis on fixed briefings at Stage D of the RIBA. One architect stated: “After a certain point, ‘development’ of the brief becomes change as an architect should assist the client to develop and modify the brief in the early stages of the project, as their requirements become clearer, or as the developing design throws up issues”. However, it should be stated that necessitating changes results in a better product (i.e. building) in terms of more value to the client, but in less value for the construction or design companies.

Planning design activities and allocating appropriate time for each has been addressed by this research. Most organisations in the UK tend to plan design activities in a similar way to construction activities; this is by using the critical path method. Very few carry out procedures in line with the process, such as peer design review workshops, where the design team members work out all the interdependencies in order to ensure that all parties know what they are delivering, to whom, and when.
Generally, the respondents argued that the aim is always to complete the design as early as possible but design time is controlled by several parameters, such as the business case (the procurement method), the complexity of the project, the project’s value, legislation and planning permission, deadlines imposed by clients, and the ability of the client to participate in the process. Furthermore, design time is allocated for each activity and this is based on experience rather than being based on a standard scale: e.g. productivity. This approach, without doubt, contributes to inefficiency in the design management process as the time for design activities is guessed at instead of being accurately allocated.

Some respondents expressed the view that it is necessary to employ a combination approach as design is different from production. Design is iterative, not linear, and therefore requires flexibility by allowing the consideration of various options, together with development based on assumption. The design management process is a chain of activity but there is a need to allow ‘loops’ within the process to allow for the review and evaluation of different proposals and alternatives. The reality of project timeframes requires that a design should be developed through three key elements: imagining, presenting and testing (Koskela et al., 1997). However, it must be stated that design time can be estimated or guessed only within the concept design stage as this is a creative stage based on mental activity which cannot be measured. At this point, the design ideas can still be played with to develop alternatives, unlike in other design stages where the ideas are prepared for execution and the process depends on people’s ability and the resources available.

One of the major findings of this study was that inefficiency in design stages occurs through deficiencies in the procurement method. It was found that design and build procurement has encouraged some early design issues to be ignored. This is mainly due to the general belief that design and build will allow uncertainty to be addressed later in the construction phase; this lack of accuracy, with the hope that ambiguity will be addressed at a later point, also appears to hinder the application of lean construction management.

4.2 Value stream

Another major finding from the study was that the UK construction industry suffers from a lack of awareness of the diverse nature of value and the importance of managing a three-dimensional construction value (i.e. the value of different clients or stakeholders, end users and the project team). One design manager claimed: “No one defines ‘value’ or how it is measured. Value is different for different clients”. There is a need to understand each element of value, as minimising waste alone does not guarantee the overall success of a project (Emmitt et al., 2005). Value differs from client to client and from organisation to organisation. Value for a client could equate to cost, time, function, sustainability or aesthetics, while value for an organisation could be time, profit, repeat business or
being well known. Value also differs from project to project: e.g. value for a show-piece project is not the same as for service or trade projects.

The study demonstrated that work productivity, in comparison to efficiency, is generally the most important criterion for measuring a company’s performance in terms of value. Moreover, the value stream in most organisations is not identified. However, some organisations claimed to identify value by looking at the following: opportunities, value delivered to the client's business, monthly projected income, customer feedback, risk analysis and successful credits gained at project stages and a few make use of some techniques such as value stream mapping, and KPIs.

4.3 The implementation of lean management

Another major finding of this study is that almost three-quarters of the sample was not utilising any specific approach to improve organisational performance in terms of the value delivered to the client and for waste reduction; only 15% of the sample is currently utilising the lean approach. Those that were using a lean approach claimed that the lean management philosophy was integrated with design management process through systematic routes, such as:

Ensuring the early engagement of all critical parties, designers, contractors and suppliers.

Reviewing collaboratively to agree about critical stages, to generate an action plan and to monitor jointly buffer usage to achieve certainty of delivery.

Detailing improvements and lean applications. Open workshops are also used where each process is checked against other similar projects and new ideas and concepts are introduced.

Making services as efficient as possible through the use of innovative technologies and management techniques.

Educating the project team in lean philosophy and encouraging them to adopt it in their commissions. There was agreement within the sample that the time invested in the pre-construction stage would reduce waste generated in the later project stages (because of incomplete briefing documents), eliminate cost overruns, and allow both efficient construction and high-quality production. However, there were two different approaches to this. The first group of respondents noted, as stated by one project manager: “Better management towards a ‘right first time’ culture”. As the brief is part of an early stage of the design process, so the key is to make it as project deliverable; therefore, the brief should be a clear and concise document, delivered as early as possible. The respondents argued that a good brief can be achieved through achieving the early engagement of all the major players and allowing the client sufficient time to ensure all requirements are identified.

Conversely, the notion that, as stated by an architect: “The current culture demands everything now” was blamed for waste by the second group of respondents. They argued that briefing documents need to be aligned to design stage gateways, which are then signed off by the client. In addition,
briefing documents at each stage need to be relevant to the information required. This can be achieved via user input throughout the project to ensure the brief is kept up to date. Furthermore, reporting at the end of each stage and filling gaps with missing information; establishing ‘design cut-off dates’ when, up to a specific date no costs are incurred; and then making clear that, after the ‘client sign off’ date, the client can expect costs for changes; these will all reduce waste.

Both groups emphasised the necessity of improving the quality of the brief by educating both designers and clients on the preparation of a clear brief and what this will look like. One architect stated: “They may not know the question until you ask it” so, providing benchmark guidance to the client and informing them clearly of their duty and responsibility for the brief, should be clarified to facilitate the production of a complete brief. The client must understand that ambiguity will result in delay and/or waste. Clients have to appoint suitable representatives who have relevant experience; these representatives must be briefed and made aware of how important decisions are, together with what the consequences are of not making or changing decisions.

In general, the comment on applying lean management to the design management process stated that lean management does not automatically mean that the process takes less time. Applying lean management is a costly process and most people will not venture into it as there is no a clear-cut desire for “value for money”. Another comment suggested that each process has its own characteristics so lean management needs to be customised to the process to which it is being applied. For example, the traditional procurement methods used by most construction companies hinder the lean construction process.

5. DISCUSSION AND CONCLUSIONS

The research has revealed a number of shortcomings in the design management processes and practices in the UK construction industry, and, more specifically, in processes at the scheme design stage. This can be traced back to inefficiencies in managing the design process. This finding is in line with the results of previous studies that claim that delays in projects, budget overspends and, in many cases, less value being delivered to the client, are related to the early design stages (Bertelsen and Emmitt, 2005; Hansen and Vanegas, 2003; Tilley, 2005). However, analysis of the data illustrated that procurement methods are also responsible for inefficiencies in the early design stage of projects. Findings also reveal that inefficiencies in managing the design process may have hindered the advantages of employing lean concepts. Clearly there is a need to improve the integration of project processes (Jørgensen and Emmitt, 2009; Brookefield et al., 2004; Bogus et al., 2000) and client briefing (Hudson, 1999).
Achieving efficiency is complicated due to several factors associated with the nature of the design process. These factors include the fact that many disciplines participate in the process: and clients (customers) are external parties in relation to the company. Clients initiate the design process and play a role as an integral control element; being the business generators and primary decision-makers. This differs from mass manufacturing, where clients or customers are not actually involved in the product design because they are not yet, at this stage, truly clients or customers. Their needs (desired value) are considered in the design but they are not directly engaged in the design process, and hence are not decision-makers in the design process. Indeed, even in car manufacturing, where lean concepts have been applied successfully, when the client wants to customise his/her product, the design process will be affected and it must be accepted and appreciated that extra cost and time must be allocated in order to achieve the desired value.

Lean design management appears valid for implementation in construction projects, but only if the concept of customising each application is considered. This depends on the client’s requirements, whether something is needed urgently, or if the project is a showpiece with fewer limitations on time and budget. In other words, lean design management needs to be customised in terms of the value of the desired project. However, to develop clear-cut decisions, there is a need for each value track to set out a general plan of lean design management that can be tested through case studies and programme monitoring.

With the benefit of hindsight, one of shortcomings of this research was the failure to define fully a starting point where a design organisation might apply lean-thinking management without interruption. From the data, it was felt that lean thinking management could be implemented starting from the design development stage (i.e. the scheme design stage) but it is recognised that in order to develop a better understanding face-to-face interviews and monitoring of live projects would be necessary. From this is may be possible to develop a generic process plan for lean design management, which could then be tested on projects be tested through case studies and programme monitoring to explore whether lean design management is applicable for all types of projects in the AEC and what, if any, characteristics relate to certain project types. Further research is also required to explore the experience and views of clients and the early engagement of other professionals with lean thinking, such as structural and M&E consultants. Additional research is also required to establish to what extent current deficiencies in the management of the design process influences the value delivered to clients and building users.
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Abstract: The majority of investors in Taiwan engaging in residential construction come in the form of construction companies. When these construction investors estimate the profit of a residential construction project, they often follow their past accumulated experiences and personal subjective judgments which may fail to understand the important decision-making factors, and may often cause the companies to face with financial crisis due to misjudgement. To compensate the aforesaid subjective misjudgements during the decision-making process, this study has summed up 26 important decision-making factors that would affect the profit earnings in residential construction project after conducting a questionnaire survey on construction investors, and analyzing the assessment process statistically. The SPSS software was adopted by this study to perform a factor analysis on the questionnaire scales using the Common Factor Analysis, and good results were obtained after reducing part of factors, and checking on the validity and reliability of the scales. The decision-making factors proposed by this study were divided into 6 aspects, namely construction, economy, site, company, policy and project aspects according to the attributes of each factor. The results are expected to provide a reference for the real estate industry and academic research units.

Keywords: Integrated Planning, Sustainable Building, Whole Building Approach, Planning Process Analyses

1. POINT OF DEPARTURE

1.1 Introduction

Today numerous regulations and planning targets for new as well as for refurbishment of existing buildings are required in order to meet the sustainability goals such as energy efficiency, minimisation of carbon footprint and emissions, over to socio-cultural aspects of human health and wellbeing. As a consequence, the processes for design and the management of buildings are experiencing a significant increase of complexity.

The action space for the innovative, cost-saving building design has been increasingly limited through sharpening of institutional and normative regulations such as Eurocode, concerning safety such as earthquake and fire protection codes. At the same time, the new innovative solutions are increasingly required in order to achieve “energy-plus” buildings that are the part of smart grids providing not only themselves but the whole neighbourhoods with energy (Blome, 2010). The EU
targets 20-20-20 - reduction of EU greenhouse gas emissions and primary energy use by 20% at simultaneous increase of renewable energies by 20% (European Comission) is only a part of institutional actions towards low-carbon society. The future actions of the European Union for climate protection and energy supply will be based on “post-carbon society” concept, which again focuses on low energy (energy efficiency measurements), low carbon (renewable energies and withdrawal from fossil fuels) and low distance (short routes) guidelines (Vogel and Bieser, 2010). The concepts such as 2000W society as defined by ETH Zürich , (ESC 2008) and Smart City represent a step towards more holistic, integral approaches, that are not focused singularly on the optimization of performance of single building but are introducing a systemic approach, where system synergies for energy production, distribution and storage are being taken into account.

However, with the increasing level of integration, the complexity level is increasing – the number of involved experts and stakeholders is growing ever larger, together with the diversity of working methods and different professional languages and understanding. Gladstein Ancona and Caldwell (1992) demonstrated in a survey with 45 product teams in high-technology companies that negotiation and conflict resolution skills have a major impact on the process performance. Mieth (2007) survey shows that 68% of the construction managers’ work exists of tasks which are significantly influenced by social competences (32% leading, 18% communication, 18% organisation).

We argue, that the greatest potentials for optimisation of planning processes for sustainable buildings lie next to the development of tools for quantification and simulation of planning targets, even more in intangible factors such as human interaction and communication.

1.2 Problem Definition

Despite the almost revolutionary requirements on building performance, especially in terms of energy efficiency, the processes for design of “new” buildings are still following the traditional paths – this construct being also supported by the fee structure for engineers and architects.

Today’s practices are affected by the scientific approach, that tries to break a problem in possibly largest amount of smaller pieces, led by the idea that problem solution can only be achieved through understanding of separated single pieces. The same principle applies to the planning process, where large number of specialists works separately on differentiated problems, however are required to create a holistic solution such as a building. Overlapping of various disciplines is discouraged due to numerous reasons – sharpening of codes and standards and meanwhile law-dominated building practices, being some of them. Further on, specialisation is seen as competitive advantage in today’s markets.

Many scientific and practice oriented approaches understand the planning process as a complicate task, that can be solved by maximisation of the experts knowledge, with an aim to find and optimize
the direct relation between cause and effect. Management Methods are based on facts (Snowden and Boone, 2007). The output of a problem-solving process that focuses on a complicated context is an “ideal process”. The authors question this approach, and argue that the “ideal process” is different for every stakeholder (multiple perspectives).

2. PARADIGM CHANGE THROUGH INTEGRATED PLANNING

Sustainability requirements for buildings, based on balance of economic, ecologic and socio-cultural issues respond to the Vitruvian view of the building as the composition of form, function and construction. Both concepts are based on holistic and overall concepts of balance and composition, much more than on fragmentation of singular aspects.

Therefore, the holistic design and planning processes for sustainable buildings should focus on creation of interfaces between different disciplines, instead of development of singular expert knowledge. To use a metaphor, the picture of a planning process has to be changed from a mechanistic machine to a living organism (Wiener, 1965). Expert knowledge represents neural nodal points, integrated planning can be seen as the interconnecting network of synapses.

In transformation from sequential planning to more integrated practice, there are several issues to overcome. First, a detachment from the theoretical construct of “ideal process” by using as much expert’s knowledge as possible is necessary. Secondly, there is a necessity for a shift in the view on the planning process as a complicated to a complex problem definition. Through the various interactions and dependencies complex processes can adopt various different conditions. Malik argues that it is not possible to find a connection between cause and effect (Malik, 2011). This change in understanding of problems as complex tasks requires different methods and tools to work with. In this kind of approach the process is seen as changeable and open, knowledge gaps are accepted. The according management tools are based on interaction and communication (Snowden and Boone, 2007). One major task is still the clear definition of project goals, but the way to achieve these goals is flexible and open.

Finally, a key to the transformation of planning practice lies in education. Separated education of engineering and design disciplines, as still practiced, results with fragmentation of problem-solving, actually causing that future planners look upon the building as a sum of the parts, instead of creating the awareness that they are much more.

A significant amount of literature implies on importance of integrated planning as crucial factor for sustainable buildings especially in regard of energy efficiency issues. Guzin Müller (2002) recommends employment of traditional planning techniques combined with implementation of new
technologies for energy efficiency, strongly emphasizing social aspects of users’ involvement in planning and future use of the building through participatory planning method.

Further notion is life-cycle oriented “Whole-Building-Design”, based on two foci: the integrated design approach and integrated team process (Prowler, 2008). On the one side there are the design or planning requirements for building performance to be met on holistic level, identified in this particular model as: accessibility, aesthetics, cost-effectiveness, functionality, historic preservation, productivity enabling (well-being of occupants), safety, sustainability (environmental performance of building elements). On the other hand there is integrated team which includes every stakeholder of the planning process, united in so called design charrette – collaborative brainstorming session encouraging the exchange of ideas but also enabling full understanding of all the parties as well as of set aims at the project start.

This concept has also been largely adapted in HOK guideline for planning of green buildings, where a flow chart and check list for the integrated planning process is precisely outlined. (Mendler, S., Odell, W., Lazarus, M.A., 2006). Kohler introduces an Integrated Life Cycle Assessment (Kohler, 2007) which would integrate and evaluate the environmental impacts as well as initial and life-cycle cost related to gross floor area of different granulations for macro, micro elements or construction works according to relevant planning phase, already beginning from programming or project development. Such a tool would require a large amount of building related data of different granularity, in order to be applicable in every phase and by every planning stakeholder. Kohler and Lützkendorf (König et al, 2009) therefore employ a notion of IP as “performance based building”, with necessity for of interdisciplinary (horizontal – planning profession related) and life-cycle oriented (vertical – building oriented) integration. Early implementation of simulation and prediction tools for later building performance for enabling of optimization in the early planning phases such as integral simulation with related databases is necessary method but hardly established on the market yet due to the lack of commercial tools.

The building certificates such as DGNB/ÖGNI (DGNB), Leed and similar are considering the necessity of integrated planning method instead of traditional, sequential method as essential for achievement of sustainability aims, and include indicators for evaluation of implementation of integrated planning.

3. PROPOSAL FOR A HOLISTIC INTEGRATED PLANNING APPROACH

In field of design process research much has been explored on more time-, cost- and quality-effective design processes for complex projects (Yazdani, Holmes (1999), Aken (2003)).
The optimized planning models originate from the realm of automotive or aeronautical industry, with high levels of technology, automation and skilled manpower. The current Central European (CE) construction sector still works with relatively low levels of automation, and with low-educated workforce. Further on, the major bulk of research on design of design processes has been conducted in Western Europe, where architectural planning and construction practice is organised and executed differently than in the CE, partially due to the different building tradition. The Anglo-Saxon model is strongly involved in concept and design, however manages the latter phases mostly through specifications and contracting (Mendel et al, 2006). The CE planning practice is deeply involved in all planning and construction phases of a project (HOAI, 2009), which again adds to the complexity.

We argue that buildings and built environment as such are composition of both tangibles (quantities) and intangibles (qualities), where intangibles are often reflection of “irrational” realm of clients’ wishes and desires or designers dreams. The different mind maps of different planning process stakeholders bring to the difficulties in communication and definition of quantifiable and understandable planning aims.

Therefore, we propose a holistic integrated planning approach for design and construction of buildings, which, distinguished from already established design-models from the automotive or aeronautical industry, introduces the component of People. The model defines two main components of Building (Object) and People (Stakeholder of Planning Process), which reflect two main fields of interest of analysis. The Tools for integrated planning are seen as integrating element among People and Building – connecting the building (virtual or real), with ideas, knowledge and needs of People – creating the interfaces (Figure 1). The Tools can be seen as software tools, such as BIM (Building Information Model), Energy Simulation and Parametric Design Tools or as skills such as communication, mediation and moderation skills.

The next chapters will offer a closer outline of components Building and People and refer to relevant tools.

*Figure 2. Relation between People, Tools and Buildings*
3.1 Building (Object)

In order to achieve a transformation in planning practice from fragmented process into the more integral one, a change in perception of building as static object towards the one of dynamic system is necessary. The life-cycle oriented, mid- and long-term strategies instead of short-term oriented planning aims are required for the realisation of sustainability objectives.

The current life duration of commercial real estate has been predicted by real estate investment management companies to lay somewhere around 50 years (Schulte, 2002).

Buildings change their original use two to three times throughout their lifecycle. The consumption of energy and resources is constantly progressing through building’s lifecycle with its multiple changes and mutations. The basic hypothesis states, that building itself is not a stable, static object but rather a dynamical system.

To demonstrate the changes of building in time, the flow analysis concept developed by Kohler (Kohler, 1998) is used. A building is represented through superposition of different flows taking place throughout its life-cycle: materials, energy, capital and information (Kohler, 1999). Moreover, different layers of building can be identified, according to their life-duration; which again experience different temporal changes: rhythms, cycles and phases. Brand (1994) proposes a “6s” building model, consisting of slow and long-lasting layers like site (eternal) and primary structure (50 - 60 yrs.), and fast and changing elements of short life duration such as skin (20 yrs.), services (7-15 yrs.), space plan (3 yrs.) and stuff-mobilia (monthly).

The ambivalent nature of a building as composition of “tangible - quantities” and “intangible-qualities” aspects brings problems for development of both clearly defined planning aims as well as of performance evaluation strategy. As tangible data a building’s quantitative characteristics concerning the ecologic and economic issues can be defined. The intangible data is expressed through quantitative characteristics such as formal, cultural and functional aspects.

Parametric model for performance evaluation can be built upon a system of sustainability indicators (BNB, 2011), describing building performance in terms of:

- ecology: construction demand, land consumption, soil pollution, CO2 emissions, energy consumption, substitution of fossil energy sources through regenerative energy sources, innovative technologies in energy efficiency
- economy: construction costs, investments, yields, LCC (heating and cooling, ventilation, lightning, maintenance, inspection and service), flexibility for further use
- socio-cultural aspects: relationship to the landscape, barrier free building, creation of liveable urban identity, accessibility of workplace residence quality for all ages, consideration of balanced income structure regarding working places, integration foreign co-citizens.
### 3.1.1 Tools

Building Information Modelling software such as Revit (2011) offers high level of integration of differently granulated and structured information in a one single model, and offers the possibility for simultaneous work of different disciplines such as architecture, structural engineering, building services etc. Through additional modules energy simulation and life cycle assessment is possible.

The life cycle cost calculation tools are rarer – in Central European space LEGEP (2011) is certainly the most reliable one, even though often criticised for not being suitable for the cost estimation and variant-evaluation in the early planning phases.

Numerous emerging international (DGNB, Leed, Bream) and national (ÖGNI, TQB) building certificates, offer systems for evaluation of different aspects of sustainability, and try to promote a holistic view on the building performance. Thorough extensive catalogue of indicators they also offer a source for visualisation of quantifiable planning aim for clients in early planning phases.

### 3.2 People

As shown before, an integrated planning process is open, flexible and can react to the changes of complex process surroundings. In the past, the majority of scientific and practical knowledge-creation was achieved by monitoring the processes detached from the involved people. To understand complex process conditions, it is crucial to involve the people who are creating the processes. It is not possible to handle these conditions only by measurable data and hard facts. Qualitative soft facts are becoming increasingly relevant and have to be integrated in the working process with complex systems, in order to create a more adequate process picture (Vester, 2002). This approach calls for an understanding of a planning process as a part of a social system.

As in complex surroundings the consecutive incidents are open, the atmosphere of uncertainty for the people involved is the consequence. The sociologist Niklas Luhmann showed, that complexity of a social system can be reduced by trust (Luhmann, 1996). For example, a planning meeting where all participants have to think about the “hidden agendas” of the other meeting attendees has significantly more complexity, than a meeting that is based on trust, where declarations can be taken without additional cognitive activities. Luhmann also demonstrates that a difference between a collective of single individuals and a connected social system occurs through communication. Additionally, the demand of social interaction through communication increases with the complexity of the process (Pawlowsky and Mistele, 2008), which is also a major aspect due to the increasing planning process complexity shown before. Also Orpen showed in a sample of 135 managers from 21 different firms in a variety of industries, that the quality of communication has a major impact on the satisfaction and the motivation of managers (Orpen, 1997). It is obvious, that motivation and satisfaction of employees
has an impact on the quality of a planning process. As a conclusion, it can be stated that one major aspect for the performance of a planning process is the way how people interact in the process.

To enhance and develop the quality of the project participant’s interaction, insights from sociological and medical sciences can help to improve current planning processes. Contrary to the common belief, communicational skills are learnable. The knowledge gain of the relatively new sciences such as neurosciences, with its non-invasive examination methods, has gained a new and differentiated understanding of human behaviour. To improve communicational skills and implement this knowledge, new ways of education and continuing education should be implemented. It is important to consider the interaction of people in educational programs. A separation into subjects, where each student has to improve as a single individual cannot contribute to development of any social competences. Another major skill is the ability to reflect own behaviour, which builds a base for social learning and the development of social skills. Educational programs should provide the space for the participants to rethink their own assumptions and behaviour (Schön D.A., 1983).

An integral planning process can handle more complexity, but it needs much more coordination between the participants compared to a sequential process approach. This also has effects on the leadership of integral process leaders. In an integrated team the responsibilities are also decentralised, which leads to more self confidence for all process participants. The leadership-characteristic is based on sense. Hüther assumes that the search for sense is a necessity which is resulting out of the structure and operation mode of the human brain (Hüther, 2007). Strict hierarchical structures are counterproductive for a team-based and self-organising process. The role of the process leader is characterised by coordinating activities. These open and variable boundary conditions also have to be considered in the contracts. Today’s contracts often focus on the clear detachment of responsibilities which prevents the team-based problem-solving processes. To ensure a holistic approach, the overlapping parts between different stakeholders are the major issue of consideration.

3.2.1 Tools

The tools to advance interaction and communication qualities between people are various. The proposed holistic integrated process approach demands an attitude of togetherness. Disciplines like mediation or the implementation of mediative know-how is focusing on this attitudinal level. As the core business of mediation is the dealing with conflicts, its fundamentals can be learned and implemented in the daily communication. The main characteristic is the changing from positions to interests. For the optimization of the process-performance, an interest-based communication can be crucial for the prevention of escalating conflicts and protection of effective teamwork.

Another major team-creating effect can be initiated by well designed kick off events. These events can bring people closer together and create a common picture of the task the team is focusing.
Additionally, the level of trust can be increased through reduction of process complexity. Arranging this event the so called “forming” phase of a team development process can be initiated (Tuckman, 1965).

According to the size of the project and the number of process participants, it can be effective to introduce for the designing and guiding of the process-communication responsible person. This person can moderate relevant project meetings and is the confidant in case of conflicts. To be impartial, it is crucial that this person is only reliable for the process communication and has no other tasks otherwise the guiding of communication can be in conflict with her own process interests.

There are various other tools coming from different disciplines like moderations, group dynamics, and psychology or consulting. As the process is open and flexible, the application of social-interactive methods is diverse and the effectiveness depends on a specific situation. Concluding can be stated, that the social competence of the process-participants and the creation of interaction between the people involved, is one of the major realms for improvement for today’s planning processes.

4. METHODOLOGY

This paper presents preliminary results of an experiment for the comparison of integrated and traditional, sequential planning, carried out within the research project Co Be: Cost Benefits of Integrated planning. The aim of the project is qualitative and quantitative analysis and simulation of the life-cycle cost-benefits of Integrated Planning (IP). The final goal is the compilation of 3-module Integrated Planning Guidelines for planners, investors and policy makers. Middle-term goal is implementation of strategic steps for integration of climate protection and energy efficiency aims within planning processes through policy but also through growing awareness among stakeholders (investors, users).

The holistic, integrated planning approach as presented in previous chapter builds theoretical base for the research project. One part of the research is the practice oriented case-study, through which the planning-processes for best practice energy-efficient buildings are analysed and documented.

The second part of the research covers the evaluation of the effects of the integral design and planning (IP) methodology and compares them to those of a traditionally sequential planning process (SP), for which a laboratory experiment was conducted. This first exploratory study of the integral and sequential planning was carried out with students in order to obtain large amount of qualitative and quantitative data and due to the long duration of experiment. In order to verify the results, a workshop with practitioners will be held, as the next step.

For the experiment-evaluation both qualitative and quantitative empirical research methods from social studies will be employed. Through the pre- and post questionnaires and time-sheets the
quantitative data was collected. The qualitative data gathering was organised through experience-workshop in a post-experiment event. The informal observation throughout the experiment and the pilot-experiment the insights especially in the communication, stress-level and conflicts within the planning teams were gathered. The practice-oriented perspective was brought in through the student competition character of the experiment, where an independent jury evaluated the projects on the pre-defined categories of: design quality, structure quality and realisation, cost-efficiency, renewable energy.

5. EXPERIMENT

The role-playing experiment was organised as student competition within the course “Building Process Management” for students of fourth semester of civil engineering together with higher semester architecture students. Planning teams included four roles of an architect, civil engineer for structure and building services, client and business advisor. The planning task was a design of a temporary smoothie-bar, based on renewable energies (solar gains) and resources (wood) in exact given time amount of eight hours. In order to achieve comparability of results, it was crucial that all experiment-participants have the same information-level, therefore use of internet and electronic devices was prohibited. Handouts, product information sheets, tables for calculation of solar gains, energy consumption, investment and return of were given to all participants.

The teams were split into two treatments: traditional, sequential planners (SP) and integrated planners (IP). In IP treatment the design-team members were grouped together at the same table, and worked on the given assignment simultaneously. In the SP treatment the roles, instead of teams were grouped together, e.g. all the architects were situated in one room. The work on the assignment was organised consecutively - scripts for temporal scenarios were developed as follows: in first step the client briefs the architect, only after the pre-design is satisfactory the engineer may be contacted by the client. After completion of the engineering and structural concept, which has to be approved by architect, the business advisor may be contacted – it is likely that he will change the concept significantly since his knowledge on core-business is much higher than that of other team-members. Further rule is, that only two team-members (planners) may be in the same room simultaneously, in order to represent the reality of traditional planning practice.
5.1 Evaluation of the first qualitative results

At the award event additional information from the participants was obtained by means of a small feedback workshop, in order to obtain the qualitative information on advantages and disadvantages of sequential and integral planning processes. This was done to blend the results from the quantitative analyses with qualitative information. Students were assigned to groups consisting of two members of the IP and two members of the SP treatment in the experiment and asked to name the advantages and disadvantages of integrated and sequential planning and to identify the main differences they experienced (qualitative results of this workshop are summarized in Table 2).

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<th>IP</th>
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<td>Pros</td>
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<td>focus on the own task</td>
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<td></td>
<td>teamwork</td>
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<td>cooperation problems</td>
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<tr>
<td>Cons</td>
<td>higher conflict potential</td>
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The advantages of sequential planning are above all seen in the possibility to focus on the own tasks (“more concentration on own task”, “focusing”), self-determination (“independent working is possible”). The list of disadvantages experienced in sequential planning was longer including communication problems (“long communication distances”, “ambiguities in communication”, ”bad information flow”, “bad communication”), unequal distribution of the workload over roles or time (“stress”, “lot of work for the client”) and problems in cooperation in a sequential planning process (“no influence on design proposals of other disciplines”, “common solution finding is not possible”).

As advantages of integral planning students mentioned the time saving (“Time saving” and “takes longer” as a disadvantage of sequential planning”), teamwork (“you are not alone”, “team spirit”,...
“teamwork functioned well”) better communication (“good information flow”, “conflict solving possible”, “feedback”) and better outcomes (“melting of ideas”, “rounder result”). Students found the conflict level in the integral planning process to be a negative aspect (“less peace”, “differences in opinion”), furthermore too much integration may also be conceived negative (“difficult to find a common language”, “everybody is meddling in the discipline of the other”).

As both planning processes have their pros and cons there might not be immediate differences in the satisfaction with the process itself and its outcome. However, the communication and team functionality is better for integrated planning teams and the student feedback throws light on the causes of these differences.

Through the informal observation was noticed, that the SP teams had to cope with lot more stress, especially the role of the architect. The architect of the pilot-experiment points out:” ...I wished I had three students that would draw for me, as the time was running out!” Also, the general conflict potential was notably higher, and was culminating with the time progress and as the deadline was approaching.

In general IP is seen by the students as more time efficient and offering more time for discussion (which also might lead to conflicts). SP consumes more time for coordinating and managing the process and also for communication loops as direct feedback in not possible. This leads to the conclusion, that the resource time is more efficiently used in the integral planning process, so that more time can be used on solving the design problem as not so much time needs to be spent on organizing the planning process or compensating its deficiencies. We expect that the detailed analyses of the planning processes on the quantitative basis of the records on conflict level, workload and task duration and distribution, which are currently performed, provide further insights about the detailed differences of the sequential and integral building planning process.

6. CONCLUSION

Through a discourse on rising complexity of the design and planning process caused by the demand for sustainable, energy-efficient buildings, was shown that a transition from traditional, fragmented planning practice towards more integrated practice is necessary.

The transformation of the traditional design and planning process requires on the one hand a change in the perception of buildings themselves – a lifecycle oriented approach in opposition to the short-term investor thinking enables development of long term strategies, necessary for realisation of sustainability aims. On the other hand, the design and planning processes themselves due to the raising complexity and large number of stakeholders need development of new working methods.
We argue that the greatest optimisation potentials for planning processes of sustainable buildings are to be found in the intangible realm, such as human interaction. For the achievement of successful sustainable buildings, we propose a holistic integrated planning approach, based on a two component model of Building and People, and the interface of Tools for Integrated Planning which builds synapse between two components. Through such approach, the consideration of “irrational” aspects within a design process can be achieved, and decision-making process supported not only through quantifiable, objective tools but also through design of human communication and interaction.

In order to compare and evaluate the integrated with the sequential planning process a role-playing experiment was conducted. As the first qualitative results of the experiment the advantages of integrated planning as being time efficient and more satisfactory for the team, were confirmed. However, the issue of high possibility of arousal of direct conflicts and arguments, through interfering in the realm of other disciplines underlines the necessity for development of new skills which are necessary for successful functioning of integrated teams. As advantage of IP also a building of team spirit was identified, that resulted with an overall rounder result through melting of ideas – which again underlines the importance of interlinking instead of fragmentation.

Further research will focus on the interpretation of quantitative data, through analysis of time sheets and pre- and post questionnaires. The performance of each discipline within treatment will be evaluated as well as across treatments. In this way it will be possible to identify the time-consuming activities within planning process, evaluate the number of feedback loops, to measure the stress levels. Based on the pre-questionnaires, the personality structure (e.g. introverted-extroverted) will be linked to the satisfaction and work performance within the treatment. Based on these results a customised, personality-oriented team work can be designed, in order to increase the trust and reduce number of conflicts in the construction business, as is yet the case.

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A Study of Decision-making Factors on the Project Profit of Residential Construction

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Abstract: The majority of investors in Taiwan engaging in residential construction come in the form of construction companies. When these construction investors estimate the profit of a residential construction project, they often follow their past accumulated experiences and personal subjective judgments which may fail to understand the important decision-making factors, and may often cause the companies to face with financial crisis due to misjudgement. To compensate the aforesaid subjective misjudgements during the decision-making process, this study has summed up 26 important decision-making factors that would affect the profit earnings in residential construction project after conducting a questionnaire survey on construction investors, and analyzing the assessment process statistically. The SPSS software was adopted by this study to perform a factor analysis on the questionnaire scales using the Common Factor Analysis, and good results were obtained after reducing part of factors, and checking on the validity and reliability of the scales. The decision-making factors proposed by this study were divided into 6 aspects, namely construction, economy, site, company, policy and project aspects according to the attributes of each factor. The results are expected to provide a reference for the real estate industry and academic research units.

Keywords: Residence, Decision-making Factors, Common Factor Analysis, Likert Scale

1. PREFACE

The investors of residential construction mostly rely on advertisement firms to assess the profits and prices of the housing products by making a market survey on the neighboring areas with similar products. They initially decide the product prices, and then revert to review the project profits by taking a primary concern on clearing the inventory. Such decision-making model lacks the specific tools to assist in setting the profits. However, in the course of promoting and setting the prices of the project, the construction investors often follow their accumulated past experiences and personal subjective judgments with the absence of objective aiding tools. This would often lead to misjudgment and result in sluggish sales, capital tied-up or heavy interest burden, causing the companies to face with financial crisis, or even go into bankruptcy. For the current domestic construction companies involved in project promotion, their capitals vary a great deal. For those with adequate funds, they are
able to withstand the blow of economic crisis; but for those with weak financial structure, their companies would likely to go broke if encountered with one or two losses in project promotion. Therefore, whether or not the investment opportunities and investment targets are appropriate, and whether or not the investment interest and investment risk assessment are accurate are closely related to the survival and sustainable management of the companies.

The study has summed up the impact factors on the aforesaid periodical literature and interviewed with the decision-making level of construction investors, scholars of the Department of Civil Engineering and Architectural, government construction and management personnel, and industrial, government officer and academic experts, and 43 decision-making factors were finally sorted and conducted with a questionnaire survey. The questionnaire survey was based according to the member lists of the Real Estate Development Association in Taipei City, Taichung City and Kaohsiung City by randomly picking up 500 construction developers. After sending the questionnaires by mail, 147 copies were statistically collected and the recovery rate accounted for 29.4% of total questionnaires. After deleting 13 copies of invalid questionnaires, the 134 remaining copies had recorded an effective recovery rate of 26.8%. The questionnaire is aimed to explore the influential extent on various factors while the construction investors are deciding on “the project profit of residential construction.” The five-point Likert Scale was used by the study to design the questionnaire. The respondents were requested to check and evaluate the 43 factors listed in the questionnaire according to their importance (from 1–5; 1 represented least importance, and 5 represented most importance). SPSS statistical software was used to conduct the factor analysis and factor reduction for checking the validity and reliability of the questionnaire. Finally, the decision-making factors affecting the “project profit of residential construction” were summarized.

2. RELATIVE LITERATURES

The prosperity of real estate market is primarily related to housing prices, vacancy number, money supply and government policies. The real estate market downturn is actually caused by excessive high housing prices, leading to a lack of effective demand and rush construction by the builders to result in oversupply. Secondly, if the government policies are predominating the housing market, it would easily lead to speculation in the real estate market to result in uneven distribution of social wealth, widen the gap between the rich and poor, and worsen the housing quality that has already been poor (Chin-Oh Chang, Chien-Wen Peng, 1997). The housing policy should be inter-coordinated with land policy, social policy and economic policy to fit into the country’s overall development plan. The housing policy should also play a function to induce housing investment, create a favorable investment environment, encourage private enterprises and organizations to participate in solving the housing
issue with the government altogether (Da-Wen Chao, 1999). While researching on the impact factors on real estate prices, we think that the previous studies had stressed too heavily on Hedonic Price Function. We therefore established various impact factors through a regression analysis (such as household, land use and location factors, etc.) on the regression functions of real estate rent-seeking prices. However, such regression model offers limited strategic analysis on major transportation infrastructure such as mass rapid transit system or land use policy, and on the changing effects of real estate transaction prices (Yen-Jong Chen, Ching-Huan Yang, 1999).

On location conditions, Lung-Shih Yang and Tsung-Yi ng Lu (1997) had taken the condominiums higher than 12 floors in Taichung City as the research objects, and discovered that the ideal distribution site of future high-rise condominiums are likely to spread on the development areas with dense public facilities and along the major circumferential roads. While conducting product positioning, the builders usually take the local building’s law restraints and housing market characteristics into consideration and try their best to concentrate on intensive buildings. From the product’s fundamental element point of view, there should at least be three elements to serve as the starting points in product positioning planning: land price, total residential area, and residential area (Chung-Hsien Yang, 2003). Chi-Yuan Liang (1999) cited a calculation method on vacant houses that used less than 20 degrees of Taipower electricity per month and evaluated that the vacancy rate in Taiwan fell between 9.16~13.43% in the years 1993~1997. The highest vacancy rate went to Kaohsiung (11.30%), following by Taoyuan County (10.97%), and Taichung County/City (10.23%); and the vacancy rate in Taipei was between 1.97~2.50%. From the above vacancy rate data, we can see that the real estate market in Kaohsiung City, Taichung County/City and Taoyuan County is poor, and that it is relatively stable in Taipei due significantly to the relationship of vacancy rate.

With regard to the impact on pre-sale housing prices and supply/demand issues, Chien-Wen Peng and Chin-Oh Chang (2000) used the co-integration test and error correction model to inspect the overall economic changes affecting the real estate market at different regions, and the study concluded that: there are the existence of long-term equilibrium relationship on the pre-sale housing prices and money supply, vacancy number, building permit and other variables in Taipei County/City, but when structural changes are taken into account, the relationship of pre-sale housing prices and building permit would change. Secondly, the elasticity impact of vacancy number on pre-sale housing prices is relatively greater than the impact of money supply and building permit, indicating that in order to solve long-term recession in real estate market, there is a need to digest the vacant and surplus houses. The factors that affect the housing price variables can be divided into general environmental factors and individual environmental factors. The former include: (1) Political factor: international situation and cross-strait relations. (2) Economic factor: national incomes, economic boom, price index, and interest rates. (3) Policy factor: construction financing, and government policies. (4) Social factor:
population growth, social changes, and family structures. The latter include: (1) Household characteristics: area (ping), room number, floor number, building materials, layout, and site area. (2) Neighboring characteristics: public facilities, and living density. (3) Regional characteristics: transportation conveniences, administrative zone, and land use intensity. (4) Other factors: marketability, and builder’s characteristics (Ming-Hong Lai, 1997).

The factor analysis was adopted by the study to determine the construct validity, the step of which was generally divided into: Principal Composition Analysis by selecting the factors with eigenvalue greater than 1, and axis rotation. Principal Composition Analysis was created by Pearson and was later developed into a kind of statistics by Hotelling (Chin-Shan Lin, 2003). Principal Composition Analysis is suitable to use in simplifying large amounts of variables with fewer components, and serve as a preparatory process in factor analysis. It assumes that the variables analyzed are free of errors, and the correlation coefficient matrix represents the correlation coefficient of the population. After N-variables are analyzed by the Principle Component Analysis, they will generate N-components. Generally, the researchers will select several top important components with larger variances from the N-components and ignore the less important components with smaller variances (Gorsuch, 1988).

As the weight of regression coefficient in the factor loading regression analysis was able to reflect the associated strength of variable items on different common factors, therefore, the factor loading could be regarded as the explanatory extent of different common factors among the variable items. As how big would the factor loading value be in order to include the variable items in the common factor, scholar Hari et al. (1998) thinks that we should consider the sample size while conducting the factor analysis. If the sample size is small, then the factor loading selection standard should be higher; and if the sample size is big, then the factor loading selection standard could be lower. The selection standard between the sample size and factor loading is shown in Table 1 and the standard selection criterion for the factor loadings is shown in Table 2(Shun-Yu Chen, 2004).

<table>
<thead>
<tr>
<th>Sample size</th>
<th>Standard value selection of factor loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0.75</td>
</tr>
<tr>
<td>60</td>
<td>0.70</td>
</tr>
<tr>
<td>70</td>
<td>0.65</td>
</tr>
<tr>
<td>85</td>
<td>0.60</td>
</tr>
<tr>
<td>100</td>
<td>0.55</td>
</tr>
<tr>
<td>120</td>
<td>0.50</td>
</tr>
<tr>
<td>150</td>
<td>0.45</td>
</tr>
<tr>
<td>200</td>
<td>0.40</td>
</tr>
<tr>
<td>250</td>
<td>0.35</td>
</tr>
<tr>
<td>350</td>
<td>0.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factor loading</th>
<th>Explained variance (factor loading²)</th>
<th>Condition of variable item</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.71</td>
<td>50%</td>
<td>Excellent</td>
</tr>
<tr>
<td>0.63</td>
<td>40%</td>
<td>Very good</td>
</tr>
<tr>
<td>0.55</td>
<td>30%</td>
<td>Good</td>
</tr>
<tr>
<td>0.45</td>
<td>20%</td>
<td>Fair</td>
</tr>
<tr>
<td>0.32</td>
<td>10%</td>
<td>Poor</td>
</tr>
<tr>
<td>&lt;0.0</td>
<td>&lt;10%</td>
<td>Rejection</td>
</tr>
</tbody>
</table>
Scholars Tabachnick and Fidell (2007) proposed the indicator selection criterion from different explanatory extents of explained variable items in individual common factors. From the measurement model test of structural equation model point of view, the indicator variables should be able to reflect the latent factors effectively, and their reliability index values should at least be higher than 0.50. The larger the factor loading, the greater the common factor characteristics could be detected by the variables. If the factor loading was larger than 0.71, then the common factor was able to explain 50% of variances in the indicator variables (the square of factor loading), and such condition was deemed ideal. If the factor loading was larger than 0.63, then the common factor was able to explain 40% of variances in the indicator variables, and such condition was deemed good. If the factor loading was smaller than 0.32, then the common factor was able to explain less than 10% of variances in the indicator variables, and such condition was deemed poor, and so this item could be considered deleted.

After completion of factor analysis, and in order to further understand the reliability and validity of the questionnaire, a reliability test was conducted by the study. When the percentage accounted for by the measurement errors of test score had been reduced, the percentage took up by the actual nature part would relatively be higher; on the contrary, when the percentage accounted for by the measurement errors of test score had been increased, the percentage took up by the actual nature part would relatively be lower, and its reliability coefficient would fall (Ming-Ning Yu, 2002). Based on Henson’s (2001) viewpoint, if the purpose of the researchers is to develop a predicted questionnaire, predictor test or a pioneer research to measure a certain concept, a credibility of 0.50~0.60 would be sufficient. If the purpose is basic research, a credibility of higher than 0.80 would be better; and if the test score is used to play an important role such as packet filtering, then the credibility should be higher than 0.90. Scholar Nunnally (1978) thinks that in general exploratory study, the minimum reliability requirement standard should be higher than 0.50, or better still, 0.60. But in the application of confirmatory study, the reliability should be higher than 0.80, or better still, 0.90. Scholar DeVellis (1990) has also pointed the following viewpoint: if $\alpha$ coefficient falls between 0.60 and 0.65, it is better not to use it; if $\alpha$ coefficient lies in between 0.65 and 0.70, it is considered as least acceptable; if $\alpha$ coefficient falls between 0.70 and 0.80, it is considered as relatively good; and if $\alpha$ coefficient lies in between 0.80 and 0.90, it is regarded as very good. Cronbach’s alpha coefficient is regarded as a kind of internal consistency reliability coefficient which is commonly used in Likert Scale. Such method was created by Cronbach (1951) by using $\alpha$ coefficient to represent the internal consistency reliability coefficient. The higher the $\alpha$ coefficient, the better is the internal consistency of the scale. The equation is shown as follow:

$$\alpha = K \left( 1 - \frac{\sum S_i^2}{S^2} \right) / K - 1$$

Therein, $K$ refers to as the total items in the scale, $S_i^2$ as the aggregate variance, and $S^2$ as the aggregated variance of the scale items.

3. **AN ANALYSIS OF THE IMPACT ON THE PROJECT PROFIT IN RESIDENTIAL CONSTRUCTION**

Shown in Table 3 is the descriptive statistics of 43 factors affecting the project profit of residential construction based on data collected from the questionnaires, showing the results of the number of samples, maximum values, minimum values, average numbers and standard deviations. The questionnaire of the study aims to explore and analyze the decision-making factors that would impose a greater impact on “the project profit of residential construction” to provide the construction investors a more objective reference in the process of assessing the residential construction project. The 43 factors listed in the questionnaire were formulated after reviewing the relevant literatures, discussing with scholars and experts, and combining the experiences from construction investors.
Table 3: The descriptive statistics of 43 factors affecting “the project profit of residential construction”

<table>
<thead>
<tr>
<th>No.</th>
<th>Decision-making factors</th>
<th>N</th>
<th>Number</th>
<th>Min. value</th>
<th>Max. value</th>
<th>Ave. value</th>
<th>Stand. deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>Land costs</td>
<td>134</td>
<td>1 5</td>
<td>4.35</td>
<td>0.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Site marketability</td>
<td>134</td>
<td>2 5</td>
<td>4.29</td>
<td>0.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Transportation convenience</td>
<td>134</td>
<td>2 5</td>
<td>4.25</td>
<td>0.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Economic growth rate</td>
<td>134</td>
<td>2 5</td>
<td>4.18</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Price positioning</td>
<td>134</td>
<td>2 5</td>
<td>4.10</td>
<td>0.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Government policies</td>
<td>134</td>
<td>2 5</td>
<td>4.05</td>
<td>0.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Construction cost control</td>
<td>134</td>
<td>2 5</td>
<td>4.01</td>
<td>0.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Construction quality control</td>
<td>134</td>
<td>2 5</td>
<td>3.93</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Interest rates</td>
<td>134</td>
<td>1 5</td>
<td>3.90</td>
<td>1.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Floor plan and layout</td>
<td>134</td>
<td>2 5</td>
<td>3.84</td>
<td>0.79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Finishing conditions</td>
<td>134</td>
<td>1 5</td>
<td>3.82</td>
<td>1.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Appearance</td>
<td>134</td>
<td>1 5</td>
<td>3.82</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Sales targets</td>
<td>134</td>
<td>1 5</td>
<td>3.81</td>
<td>0.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Estimated sales rate</td>
<td>134</td>
<td>1 5</td>
<td>3.79</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Distance to downtown</td>
<td>134</td>
<td>1 5</td>
<td>3.75</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Company’s financial status</td>
<td>134</td>
<td>1 5</td>
<td>3.73</td>
<td>1.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Length of construction period</td>
<td>134</td>
<td>1 5</td>
<td>3.72</td>
<td>0.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Wage rates</td>
<td>134</td>
<td>1 5</td>
<td>3.72</td>
<td>1.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Quality level of building materials used</td>
<td>134</td>
<td>1 5</td>
<td>3.68</td>
<td>0.92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Vacancy rate</td>
<td>134</td>
<td>1 5</td>
<td>3.66</td>
<td>1.04</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4: The component matrix after the 1st rotation on 32 factors

<table>
<thead>
<tr>
<th>Component</th>
<th>No.</th>
<th>Decision-making factor</th>
<th>Factor loading</th>
<th>Component 1</th>
<th>Component 2</th>
<th>Component 3</th>
<th>Component 4</th>
<th>Component 5</th>
<th>Component 6</th>
<th>Component 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component 1</td>
<td>8</td>
<td>Construction cost control</td>
<td>.805</td>
<td>.017</td>
<td>.154</td>
<td>.040</td>
<td>.080</td>
<td>.160</td>
<td>-.120</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Construction quality control</td>
<td>.796</td>
<td>.277</td>
<td>-.005</td>
<td>.026</td>
<td>.157</td>
<td>.136</td>
<td>.029</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Difficulty level in construction</td>
<td>.702</td>
<td>.064</td>
<td>.197</td>
<td>.157</td>
<td>.120</td>
<td>.116</td>
<td>.184</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Length of construction period</td>
<td>.699</td>
<td>-.072</td>
<td>.171</td>
<td>.141</td>
<td>.050</td>
<td>.184</td>
<td>.253</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Wage rates</td>
<td>.663</td>
<td>.046</td>
<td>.292</td>
<td>.291</td>
<td>-.056</td>
<td>.004</td>
<td>.001</td>
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</tr>
<tr>
<td></td>
<td>9</td>
<td>Quality level of building materials used</td>
<td>.529</td>
<td>.235</td>
<td>.194</td>
<td>.137</td>
<td>.038</td>
<td>.320</td>
<td>.207</td>
<td></td>
</tr>
<tr>
<td>Component 2</td>
<td>3</td>
<td>Site surrounding environment</td>
<td>.014</td>
<td>.864</td>
<td>.057</td>
<td>-.005</td>
<td>.070</td>
<td>.101</td>
<td>.032</td>
<td></td>
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<tr>
<td></td>
<td>2</td>
<td>Transportation conveniences</td>
<td>.131</td>
<td>.829</td>
<td>.159</td>
<td>.137</td>
<td>.044</td>
<td>.209</td>
<td>.010</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Perfect extent of public facilities</td>
<td>.008</td>
<td>.820</td>
<td>.167</td>
<td>.152</td>
<td>.061</td>
<td>.041</td>
<td>.034</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Distance to downtown</td>
<td>.174</td>
<td>.561</td>
<td>.026</td>
<td>.191</td>
<td>.085</td>
<td>.055</td>
<td>.152</td>
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</tr>
<tr>
<td>Component 3</td>
<td>1</td>
<td>Difficulty level in fund transference</td>
<td>.389</td>
<td>.006</td>
<td>.731</td>
<td>.281</td>
<td>.027</td>
<td>-.034</td>
<td>-.005</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Number of competitors</td>
<td>-.006</td>
<td>.098</td>
<td>.720</td>
<td>.112</td>
<td>-.015</td>
<td>.230</td>
<td>.267</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Proportion of own funds</td>
<td>.386</td>
<td>.062</td>
<td>.713</td>
<td>.230</td>
<td>.047</td>
<td>.061</td>
<td>-.088</td>
<td></td>
</tr>
<tr>
<td>Component 4</td>
<td>1</td>
<td>Latent investment risks</td>
<td>.242</td>
<td>.203</td>
<td>.614</td>
<td>-.089</td>
<td>.090</td>
<td>.095</td>
<td>.216</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Company's financial status</td>
<td>.264</td>
<td>.289</td>
<td>.462</td>
<td>.221</td>
<td>.250</td>
<td>-.155</td>
<td>.251</td>
<td></td>
</tr>
<tr>
<td>Component 5</td>
<td>7</td>
<td>Economic growth rate</td>
<td>-.001</td>
<td>.093</td>
<td>.042</td>
<td>.771</td>
<td>.075</td>
<td>.080</td>
<td>.210</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Annual price index</td>
<td>.124</td>
<td>.053</td>
<td>-.020</td>
<td>.697</td>
<td>.371</td>
<td>.034</td>
<td>.051</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Stock market performance</td>
<td>.080</td>
<td>.216</td>
<td>.101</td>
<td>.606</td>
<td>.062</td>
<td>.130</td>
<td>.133</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Interest rates</td>
<td>.271</td>
<td>.058</td>
<td>.307</td>
<td>.600</td>
<td>.174</td>
<td>.023</td>
<td>-.016</td>
<td></td>
</tr>
<tr>
<td>Component 6</td>
<td>1</td>
<td>Financing conditions</td>
<td>.433</td>
<td>.137</td>
<td>.345</td>
<td>.587</td>
<td>.003</td>
<td>.100</td>
<td>.044</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Government policies</td>
<td>.139</td>
<td>.159</td>
<td>.118</td>
<td>.156</td>
<td>.832</td>
<td>.030</td>
<td>.119</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Political relations</td>
<td>.048</td>
<td>-.003</td>
<td>-.063</td>
<td>.121</td>
<td>.770</td>
<td>-.037</td>
<td>.116</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Control laws</td>
<td>-.003</td>
<td>.140</td>
<td>.248</td>
<td>.237</td>
<td>.732</td>
<td>.178</td>
<td>.006</td>
<td></td>
</tr>
<tr>
<td>Component 7</td>
<td>6</td>
<td>Sales targets</td>
<td>.245</td>
<td>.055</td>
<td>.128</td>
<td>.146</td>
<td>-.007</td>
<td>.770</td>
<td>.070</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Floor plan and layout</td>
<td>.095</td>
<td>.475</td>
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<td>.278</td>
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<td>.566</td>
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<td>.000</td>
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<td>.073</td>
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Extraction method: Principal Component Analysis. Rotation method: including the Varimax with Kaiser normalization.
The five-point Likert Scale was used in designing the questionnaire, and that all factors were graded according to the influential extent in 1–5, 1 of which referred to as the lowest degree of impact, and 5 as the highest degree of impact.

3.1 The validity analysis of decision-making factors on the project profit of residential construction

The first factor analysis on the scales generated 7 components as shown in Table 4. For the decision-making factors selected from 43 factors affecting the project profit of residential construction, the average number greater than 3.50 indicated that its importance was higher than 70%.

There were a total of 32 impact factors, including: political relations, government policies, control laws, annual price index, financial conditions, economic growth rate, taxes, vacancy rate, perfect extent of public facilities, transportation conveniences, site surrounding environment, distance to downtown, company’s financial conditions, quality level of building materials used, price positioning, latent investment risks, number of competitors, estimated sales rate, length of construction period, interest rates, stock market performance, wage rates, sales target positioning, floor plan and layout, appearance, difficulty level in construction, construction quality control, construction cost control, marketability, proportion of own funds, difficulty level in fund transference, and land costs. The SPSS (Statistical Package for the Social Science) 12.0 statistical software was used by the study to further analyze the aforesaid 32 decision-making factors.

PDA (principal component analysis) was used to pick up the factor with eigenvalue greater than 1, and the maximum variance rotation method was then used to rotate the axis to set absolute value 0.5 as the minimum significant factor loading, and serve as an analysis standard to construct the validity scales on 32 factors four times.

Table 5: The total explained variables of the 1st analysis on 32 factors (extraction method: Principal Component Analysis)
Table 6: The component matrix after the 2nd rotation on 29 factors

<table>
<thead>
<tr>
<th>Component No.</th>
<th>Decision-making factor</th>
<th>Component 1</th>
<th>Component 2</th>
<th>Component 3</th>
<th>Component 4</th>
<th>Component 5</th>
<th>Component 6</th>
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</thead>
<tbody>
<tr>
<td>M38</td>
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<td>.026</td>
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<td>Construction quality control</td>
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<td>.024</td>
<td>.285</td>
<td>.003</td>
<td>.156</td>
<td>.146</td>
</tr>
<tr>
<td>M24</td>
<td>Length of construction period</td>
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<td>.135</td>
<td>-.074</td>
<td>.221</td>
<td>.061</td>
<td>.224</td>
</tr>
<tr>
<td>M36</td>
<td>Difficulty level in construction</td>
<td>.701</td>
<td>.168</td>
<td>.062</td>
<td>.221</td>
<td>.126</td>
<td>.145</td>
</tr>
<tr>
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<td>Wage rates</td>
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<td>.051</td>
<td>.265</td>
<td>-.065</td>
<td>-.012</td>
</tr>
<tr>
<td>M19</td>
<td>Quality level of building materials used</td>
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<td>.156</td>
<td>.216</td>
<td>.238</td>
<td>.051</td>
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<td>Economic growth rate</td>
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<td>.762</td>
<td>.089</td>
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<td>.158</td>
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<td>.040</td>
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<tr>
<td>M12</td>
<td>Transportation conveniences</td>
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<td>.818</td>
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</tr>
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<td>Distance to downtown</td>
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<td>.100</td>
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<td>-.042</td>
</tr>
<tr>
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<td>.687</td>
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</tr>
<tr>
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<td>.123</td>
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<td>.052</td>
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<td>Political relations</td>
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<td>-.009</td>
<td>-.044</td>
<td>.779</td>
<td>-.001</td>
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<td>Control laws</td>
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<td>.152</td>
</tr>
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<td>Sales targets</td>
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<td>.240</td>
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<td>-.090</td>
<td>.362</td>
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</table>

Extraction method: Principal Component Analysis. Rotation method: including the Varimax with Kaiser normalization.

Therein, component 7 contained three factors, namely M9 (vacancy rate), M23 (estimated sales rate), and M32 (land costs). The initial eigenvalue of component 7 was 1.060 (please refer to Table 5 for the total explained variance on the first analysis of 32 factors) to approach the 1.0 lower limit value of extracted component. Therefore, the three factors of M9, M23 and M32 were deleted from the 1st validity scale construction. When the scales were conducted with a 2nd factor analysis on 29 factors, it generated 6 components. Therein, the factor loading of M39 factor from component 6 (marketability) was 0.476. As it was smaller than 0.5, it was invalid to reflect the indicator variables. Therefore, M39 factor was deleted from the 2nd validity scale construction and left 28 factors behind. They were sorted by the study and shown in Table 6.
When the scale was conducted with a 3rd factor analysis, they generated 6 components. Therein, the factor loading of M19 factor from component 1 (quality level of building materials used) was 0.485 and the factor loading of M15 factor from component 4 (Company’s financial status) was 0.485. As it was smaller than 0.5, it was invalid to reflect the indicator variables. Therefore, M19 factor from component 1 and M15 factor from component 4 were deleted from the 3rd validity scale construction and left 26 decision-making factors behind. Due to the page’s limited, the table of component matrix after the 3rd rotation on 28 factors was omitted. The 26 factors affecting the “project profit of residential construction” were conducted with a 4th factor analysis and arranged in order by the study and shown in Table 7.

<table>
<thead>
<tr>
<th>Component 1</th>
<th>Construction Aspect</th>
<th>No.</th>
<th>Decision-making factor</th>
<th>Explained variance %</th>
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<tr>
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<td>0.485</td>
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<th>Decision-making factor</th>
<th>Explained variance %</th>
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<td>.0</td>
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<td>54</td>
<td>38</td>
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<td>.6</td>
<td>.1</td>
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<td>.08</td>
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<td>41</td>
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<td>Stock market performance</td>
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<td>.1</td>
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<td>.09</td>
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<td>Financing conditions</td>
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<td>.1</td>
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<th>No.</th>
<th>Decision-making factor</th>
<th>Explained variance %</th>
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<td>23</td>
<td>60</td>
</tr>
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<td>Distance to downtown</td>
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<td>.2</td>
<td>.5</td>
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<td>.0</td>
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<td>.70</td>
<td>42</td>
<td>05</td>
<td>12</td>
</tr>
<tr>
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<td>Proportion of own funds</td>
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<td>.2</td>
<td>.0</td>
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<td>92</td>
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<th>No.</th>
<th>Decision-making factor</th>
<th>Explained variance %</th>
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<td>.1</td>
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<td>00</td>
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<tr>
<td>M</td>
<td>Political relations</td>
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<td>.0</td>
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<td>1</td>
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<td>M</td>
<td>Control laws</td>
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<td>.1</td>
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<td>.03</td>
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<table>
<thead>
<tr>
<th>Component 6</th>
<th>Project</th>
<th>No.</th>
<th>Decision-making factor</th>
<th>Explained variance %</th>
</tr>
</thead>
</table>

Table 7: The component matrix after the 4th rotation on 26 factors
According to Table 7, the 6 components had been named by the study according to their property of factors and affecting the “project profit of residential construction” from the component matrix generated from 4th axis rotation on 26 factors. The 5 factors from the 1st component were named as Construction Aspect (including: construction cost control, construction quality control, length of construction period, difficulty level in construction, and wage rates). The 6 factors from the 2nd component were named as Economic Aspect (including: economic growth rate, annual price index, taxes, interest rates, stock market performance, and financing conditions). The 4 factors from the 3rd component were named as Site Aspect (including: site surrounding environment, perfect extent of public facilities, transportation conveniences, and distance to downtown). The 4 factors from the 4th component were names as Company Aspect (including: number of competitors, difficulty level in fund transference, proportion of own funds, and latent investment risks). The 3 factors from the 5th component were named as Policy Aspect (including: government policies, political relations, and control laws). The 4 factors from the 6th component were named as Project Aspect (including: sales targets positioning, floor plan and layout, appearance, and price positioning).

Based on Kaiser’s (1974) viewpoint, we can use the appropriateness of measures of sampling, i.e. the size of KMO (Kaiser-Meyer-Olkin) values to judge their suitability to conduct factor analysis. The basic principle of KMO statistics can be obtained in the net relevant coefficient of the variables. If there is a correlation between the variables, its simple correlation will be very high; but its net correlation among the variables will be smaller. The greater the net correlation coefficient among the variables, the smaller will be the common factor in the variables, indicating that the variable data are unsuitable to perform factor analysis. In this study, 26 factors affecting the “project profit of residential construction” were taken for a KMO test, and discovered that the KMO index values fell in between 0 and 1. If the KMO value was greater than 0.9, it indicated an excellent relationship among the variable items; and if the KMO value was greater than 0.8, it indicated a good relationship among the variable items; if the KMO value was greater than 0.7, it indicated a moderate relationship among the variable items; and if the KMO value was smaller than 0.5, it indicated a poor relationship among the variable items and unsuitable to perform factor analysis.

The analysis on KMO value on 26 factors sorted by the study is shown in Table 8. As the KMO value was 0.828, it was greater than 0.8 to indicate that it reached a meritorious index of good relationship among the variable items and the scales were suitable to perform a factor analysis. Generally, if the communality value was lower than 0.20 (this time the factor loading was smaller than 0.45), it indicated that the relationship between this item and common factor was not close, and this item could be considered deleted.

<table>
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<th>31 Appearance</th>
<th>35 Price positioning</th>
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</thead>
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<td>31</td>
</tr>
</tbody>
</table>

Extraction method: Principal Component Analysis. Rotation method: including the Varimax with Kaiser normalization. The rotation axis was converged on the 6th iteration. (SPSS analytical results)
relationship between the detected common factors and items. Shown in Table 10 is the total explained variance summary table of 26 factors of “project profit of residential construction.” After the extracted factors were axis rotated by the study, the 6 components with eigenvalue greater than 1.0 were recorded as 3.709, 3.212, 3.049, 2.765, 2.315 and 2.174, respectively.

The effective sample size recovered by this study was 134 copies. When compared with Table 1, the selection standard of factor loading should therefore be greater than 0.5. From Table 2 of “project profit of residential construction,” the 6-component matrix generated from 26 factors after axis rotation indicated that the factor loading of different components fell in between 0.531~0.877, and that the total explained variance of 26 factors was 0.662 show as table 10. The status of these variable items reached a good level to approach as an ideal index.

### Table 9: Common extraction value of 26 factors (extraction method: Principal Component Analysis)

<table>
<thead>
<tr>
<th>No.</th>
<th>Decision-making factor</th>
<th>Initial value</th>
<th>Extracted value</th>
<th>No.</th>
<th>Decision-making factor</th>
<th>Initial value</th>
<th>Extracted value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>Political relations</td>
<td>1.00</td>
<td>.677</td>
<td>M2</td>
<td>Number of competitors</td>
<td>1.00</td>
<td>.636</td>
</tr>
<tr>
<td>M2</td>
<td>Government policies</td>
<td>1.00</td>
<td>.813</td>
<td>M2</td>
<td>Length of construction period</td>
<td>1.00</td>
<td>.638</td>
</tr>
<tr>
<td>M3</td>
<td>Control laws</td>
<td>1.00</td>
<td>.696</td>
<td>M2</td>
<td>Interest rates</td>
<td>1.00</td>
<td>.680</td>
</tr>
<tr>
<td>M4</td>
<td>Annual price index</td>
<td>1.00</td>
<td>.650</td>
<td>M2</td>
<td>Stock market</td>
<td>1.00</td>
<td>.436</td>
</tr>
<tr>
<td>M5</td>
<td>Financial conditions</td>
<td>1.00</td>
<td>.584</td>
<td>M3</td>
<td>Wage rates</td>
<td>1.00</td>
<td>.637</td>
</tr>
<tr>
<td>M6</td>
<td>Economic growth rate</td>
<td>1.00</td>
<td>.622</td>
<td>M3</td>
<td>Sales targets</td>
<td>1.00</td>
<td>.674</td>
</tr>
<tr>
<td>M7</td>
<td>Taxes</td>
<td>1.00</td>
<td>.554</td>
<td>M3</td>
<td>Floor plan and layout</td>
<td>1.00</td>
<td>.777</td>
</tr>
<tr>
<td>M8</td>
<td>Perfect extent of public facilities</td>
<td>1.00</td>
<td>.791</td>
<td>M3</td>
<td>Appearance</td>
<td>1.00</td>
<td>.578</td>
</tr>
<tr>
<td>M9</td>
<td>Transportation</td>
<td>1.00</td>
<td>.791</td>
<td>M3</td>
<td>Difficulty level in construction</td>
<td>1.00</td>
<td>.620</td>
</tr>
<tr>
<td>M10</td>
<td>Site surrounding conveniences</td>
<td>1.00</td>
<td>.796</td>
<td>M3</td>
<td>Construction quality</td>
<td>1.00</td>
<td>.779</td>
</tr>
<tr>
<td>M11</td>
<td>Distance to downtown</td>
<td>1.00</td>
<td>.383</td>
<td>M3</td>
<td>Construction cost control</td>
<td>1.00</td>
<td>.725</td>
</tr>
<tr>
<td>M12</td>
<td>Price positioning</td>
<td>1.00</td>
<td>.693</td>
<td>M4</td>
<td>Proportion of own funds</td>
<td>1.00</td>
<td>.695</td>
</tr>
<tr>
<td>M13</td>
<td>Latent investment risks</td>
<td>1.00</td>
<td>.574</td>
<td>M4</td>
<td>Difficulty level in fund transference</td>
<td>1.00</td>
<td>.767</td>
</tr>
</tbody>
</table>

### Table 10: Total explained variables of 26 factors (extraction method: Principal Component Analysis)

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial eigenvalue</th>
<th>Extraction sums of squared loading</th>
<th>Rotation sums of squared loading</th>
<th>Cumulative variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.13</td>
<td>31.276</td>
<td>1.03</td>
<td>14.266</td>
</tr>
<tr>
<td>2</td>
<td>3.27</td>
<td>10.673</td>
<td>2.77</td>
<td>12.155</td>
</tr>
<tr>
<td>3</td>
<td>2.28</td>
<td>8.769</td>
<td>2.28</td>
<td>11.726</td>
</tr>
<tr>
<td>4</td>
<td>1.73</td>
<td>6.672</td>
<td>1.73</td>
<td>10.635</td>
</tr>
<tr>
<td>5</td>
<td>1.24</td>
<td>4.774</td>
<td>1.24</td>
<td>8.903</td>
</tr>
<tr>
<td>6</td>
<td>1.06</td>
<td>4.084</td>
<td>1.06</td>
<td>8.363</td>
</tr>
</tbody>
</table>


### 3.2 The reliability analysis of impact factors on the project profit of residential construction

In the scale of “project profit of residential construction,” the Cronbach's Alpha reliability statistics on 26 factors in the scale was found to be 0.908. They were sorted and shown in Table 11. When compared with the reliability criterion shown in Table 12, the internal consistency $\alpha$ coefficient was regarded as excellent when it was higher than 0.900. We can thus see that the scale reliability done by the study in “project profit of residential construction” was indeed ideal.

#### Table 11: Reliability statistics on 26 factors

<table>
<thead>
<tr>
<th>Cronbach’s Alpha value</th>
<th>Cronbach’s value standardized item</th>
<th>Number of items</th>
</tr>
</thead>
<tbody>
<tr>
<td>.908</td>
<td>.909</td>
<td>26</td>
</tr>
</tbody>
</table>

#### Table 12: Scale reliability criterion

<table>
<thead>
<tr>
<th>Internal consistency of $\alpha$ coefficient</th>
<th>Scale reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>More than 0.900</td>
<td>Excellent</td>
</tr>
<tr>
<td>0.800 ~ 0.899</td>
<td>Very good</td>
</tr>
<tr>
<td>0.700 ~ 0.799</td>
<td>Good</td>
</tr>
<tr>
<td>0.600 ~ 0.699</td>
<td>Fair</td>
</tr>
<tr>
<td>0.500 ~ 0.599</td>
<td>Acceptable but low</td>
</tr>
<tr>
<td>Below 0.500</td>
<td>Poor, better to delete</td>
</tr>
</tbody>
</table>

### 4. CONCLUSION

Investment in construction industry for the case are worth investing in a building, decision-making process in which an important influence factor should give priority to and assessment, and when there are several investment options are available, they should be selected which satisfied the important impact factors and assessment analysis, in existing literature on the lack of this aspect of the study, therefore, the study by the construction investment in the industry of the survey, summarized the residential construction investment in the case of important factors, want to help the industry in the decision-making and evaluation process can have a clearer direction and objectives. This study finally found out 26 decision-making factors and 6 components that related to “the project’s profit of residential construction”. The 1st to 6th components were named according to their property of factors...
as Construction Aspect, Economic Aspect, Site Aspect, Company Aspect, Policy Aspect and Project Aspect, respectively. The study built a hierarchy structure that involves in six aspects and twenty-six decision-making factors, show as Figure 1.

The results of this research showed the investment decision were influenced really deep by some factors such as: site surrounding environment, transportation conveniences, price positioning, government policies, construction cost control, control laws, but other factors such as: per capital income, difficulty level in recruiting workers, area size per household, population growth rate, company’s unfinished project number, total number of floors and so on that belong to the group of smaller influence factors.

The decision-making factors explored and obtained by the study are expected to help construction investors to understand the influential extent of these important factors on investment earnings while making their project investment estimation to draw up appropriate strategies or avoid the risks of the subjective error in judgment in advance. Discovery of this research investigation may provide the following researcher to use to develop model of the auxiliary investment decision, it also aims to serve as a reference to provide the academic field to conduct analysis and research related to making residential investment decision. We also recommend for the further research that try to find out the value of real affections between the project’s profit and these decision-making factors.

![Hierarchy structure's figure](image)

5. REFERENCES

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A Study of BIM Performance at the Design Stage by Architecture Consulting Firms in Taiwan

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National Cheng Kung University, Taiwan
¹Loughborough University, UK

Abstract: BIM has been accepted as a new paradigm that improves productivity of the building industry through facilitating process change in the way projects are delivered. It is widely implemented in countries like Finland, Norway, Denmark, Singapore and the USA. In Taiwan, a number of leading architecture consulting firms have adopted BIM for design. In countries where BIM policies, technologies and processes are relatively developed, BIM is used throughout the full building lifecycle. In Taiwan, however, BIM is just emerging, and there is currently no record of projects completed with full adoption of BIM from design to construction. Taiwanese architecture consulting firms primarily utilise BIM to improve performance at the design stage. The study sets out to explore the overall BIM performance level of Taiwanese architecture consulting firms at the project design stage through a case-study approach, where four of the country’s leading firms were selected to determine their BIM capability and maturity levels. Data was collected through direct observation, interviews and study of relevant documents and archival records. A BIM performance assessment framework was developed through a study of literature and used to analyse the empirical data. Discussions of the findings are organised around two research questions developed at the beginning of the study. Findings reveal BIM to be adopted primarily to improve visualisation and design coordination. Collaboration at the project design stage remains largely intra-organisational. The utilisation of BIM for design analysis and supply chain integration to achieve transformational effects for the building industry is challenged by problems that are legal, technological and organisational. The study concludes with suggestions of ways to help facilitate a top-down approach to BIM implementation to reap true productivity benefits from BIM use.

Key words: BIM Capability and Maturity, BIM Performance, Design stage, Process standardisation, Taiwan

1. INTRODUCTION

Building Information Modelling (BIM) is a relatively new industry term referring to parametric three-dimensional computer-aided design technologies and processes in the architecture, engineering and construction industry (Taylor, 2007; Eastman et al, 2011). It has been accepted as a new paradigm that improves productivity of the building industry through facilitating process change in the way projects are delivered. BIM is classified as a “systemic” innovation that impacts multiple specialist organisations (Taylor and Levitt, 2004), requiring strong collaboration between building project stakeholders throughout a building’s lifecycle in order for firms to reap full benefit from its adoption. Striving to promote the implementation of BIM beyond the firm level to an industry level, in countries such as Finland, Norway, Denmark, Singapore and the USA, the public and private sector have been actively taking initiatives to involve BIM in projects and develop relevant BIM guidelines to support the adoption of new business processes (Wong et al, 2009).
A number of architecture consulting firms in Taiwan are taking the lead in implementing BIM to improve the architecture design process, during which the making of critical decisions that affect the success or failure of the ensuing phases of the whole lifecycle takes place. BIM is utilised to assist with project design, documentation, construction planning and virtual construction. The experimental adoption of BIM by the Taiwanese firms, along with ongoing BIM research by leading academic institutions, all strive toward the goal of facilitating industry-wide implementation of BIM.

According to the AIA (2007), Building Information Modelling requires the integration of people, systems, business structures and practices into a highly collaborative process. The research reported in this paper sought to investigate how the existing organisational business processes needed to change in order for firms to reap full benefit from the adoption of BIM. The research was conducted in two phases. First, a number of BIM assessment tools were studied and used to develop a BIM performance assessment framework. This was done by reviewing the literature. In the second phase four leading architecture consulting firms in Taiwan, who were using BIM in the design phase of projects, were assessed against the framework. Project data was reviewed and interviews were conducted to assess their overall level of BIM performance. Factors underlying the limited success of BIM implementation at the organisational and industry levels are discussed in the concluding section of the paper.

2. DEVELOPING A BIM PERFORMANCE ASSESSMENT FRAMEWORK

In the process of developing a BIM performance assessment framework, the author established that BIM was currently being utilised at the Firm level, where firms were working toward the end goal of achieving BIM utilisation industry-wide, across the entire supply chain. To achieve this, Kauffman and Tsai (2010) in their depiction of IT process standardisation draw attention to the need for a firm to work on developing organisational business processes in support of the IT innovation. Organisations with similar and mutually supportive business processes gradually form what Kauffman and Tsai term “coalitions” to achieve integrated project delivery, transforming the way the entire industry operates. This section provides a brief overview of the components making up the framework.

2.1 Business process re-engineering

The extent to which an organisation can generate value from investment in BIM innovation is determined by how much change an organisation is willing to make to its existing business practices, what the author refers to as business process re-engineering. As Clark and Stoddard (1996) put it, technological and process innovations are interdependent and have positive impacts when the two are combined to transform organisations, processes and relationships. Taylor and Bernstein (2009) identify four distinct BIM practice paradigms- visualisation, coordination, analysis and supply chain integration. When BIM is used for visualisation, no major business process change is involved as BIM is used by project network participants simply to understand and represent the 3D characteristics of a facility (Taylor and Bernstein, 2009). At the coordination level, BIM is used to evaluate the relationship of component building parts for interferences and connections, and to produce coordinated orthographic drawings of the project. Increased exchange of electronic files requires firms to address the issue of technological interoperability. Analysis involves using the BIM representation to evaluate the performance of the building. Business processes must be designed to enable active collaboration with other disciplinary players across the project network. Finally, evolving to supply chain integration requires the sharing of BIM data in the supply chain, and redesigning the collaboration process in response to a much more integrated modelling approach (Taylor and Bernstein, 2009).
Mooney et al (1996) explain that different approaches to the use of BIMs derive different effects that will determine the business value of such approaches. Three types of effects are derived-automational, informational and transformational. If organisational business processes, technologies and policies can be organised around facilitating supply chain integration to achieve transformational effects through Integrated Project Delivery (IPD), productivity of the building industry as a whole will be significantly improved. Integrated Project Delivery changes the traditional phases of projects. The integration of early input from constructors, fabricators, installers, suppliers and designers as well as the possibility to model and simulate the project using BIM tools enable the design to be brought to a much higher level of completion before the documentation phase starts. According to the AIA (2007) the purpose of Integrated Project Delivery is to optimise project results, increase value to the owner, reduce waste and thus maximise efficiency through all phases of design, fabrication and construction. Achievement of IPD is critical to the ability of the building industry to reach a higher level of productivity and efficiency.

2.2 BIM performance assessment tools

BIM is a potential medium for facilitating seamless collaboration among project teams to achieve IPD (Taylor and Bernstein, 2009). However, successful use of BIM has to be complemented by supportive business processes. To describe the extent to which an organisation supports its adoption of BIM with its business processes, BIM performance assessment tools including the scope of BIM use, BIM Capability and BIM Maturity are introduced.

2.2.1 Scope of BIM use

The scope of BIM use describes the environment within which BIM information is used for collaboration. It consists of two dimensions of study; the number of organisations and the number of domains. A BIM can be used within one organisation only (Fox and Hietanen, 2007), sharing BIM files at the firm level. These firms use the BIM strictly as an internal tool, and distribute resulting information as traditional drawings and specification to collaborators. Alternatively, a BIM can be shared by a number of organisations (Fox and Hietanen, 2007), sharing files at the project and supply chain levels. With project-level sharing, firms share BIM-based data amongst the project team. Using BIM through the building design-to-construct calls for supply chain-level sharing. Moreover, a BIM may encompass only one domain. Alternatively, a BIM may encompass a number of domains (nD). The inter-organisational use of nD BIMs can require much more advanced BIM knowledge than the use of a single domain BIM within a single organisation. Any BIM that supports analyses from the perspectives of a number of different domains, such as space management, cost management, construction management, can be described as a nD BIM (Aouad et al., 2005).

2.2.2 BIM Capability

BIM capability is a measure of a team or an organisation’s basic ability to perform a task or deliver a BIM service/product (Succar, 2009). The BIM Capability Stages define the minimum BIM requirements- the major milestones that need to be reached by a team or an organisation as it implements BIM technologies and concepts. Four stages of BIM capability have been proposed by Succar (2009), starting from the initial stage of using BIM for visualisation through coordination and analysis to supply chain integration where integrated project delivery may be achieved. A number of qualitative indicators are used to help determine the stage a firm is at. A portion of the indicators have been abstracted below to illustrate the characteristics specific to each BIM Capability Stage.
Table 1. Qualitative indicators of BIM Capability Stages

<table>
<thead>
<tr>
<th>BIM Capability Stages</th>
<th>Qualitative Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
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<td>1</td>
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</tbody>
</table>

2.2.3 BIM Maturity Index

The BIM maturity index (BIMMI) reflects the specifics of BIM technologies, processes and policies (Succar, 2009). It has been formed by investigating and then integrating various maturity models from different industries. BIMMI contains five exclusive Maturity Levels: initial/ad-hoc, defined, managed, integrated and optimised.

Table 2. Qualitative indicators of BIM Maturity Levels

<table>
<thead>
<tr>
<th>BIM Maturity Levels</th>
<th>Qualitative Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
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<td>2</td>
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</tbody>
</table>
2.3 BIM performance assessment framework

The BIM performance assessment framework, shown in Figure 1, was developed to illustrate the progression of BIM from adoption at a firm level to an industry level. The flowchart describes significant aspects that need to be considered and indicates the performance tools that are used to generate specific effects from BIM. Business processes are marked as ‘forces’ that drive successful implementation of BIM. In the study of business processes, the interaction between policies, processes and technology is to be considered. The scope of BIM use, BIM capability and maturity are evaluated to assess whether BIM has achieved an automational, informational or transformational change to a firm. The framework is important in helping the researcher plot the capacity of a firm for Integrated Project Delivery. It will be used to guide data collection in the field investigation stage.

![Figure 1. BIM Performance Assessment Framework](image_url)
3. INVESTIGATING PRACTICE IN TAIWAN

The aim was to gain insight into the use of BIM by leading architecture consulting firms in Taiwan using qualitative data. Four leading architecture firms were selected; chosen because each firm had completed at least three projects using BIM at the design stage. This gave a total of twelve projects that could be evaluated to understand the firm’s business processes; and determine the scope of BIM use, BIM Capability and BIM Maturity. Two primary questions were addressed:

RQ 1: What is the overall BIM performance among architecture consulting firms in Taiwan that have incorporated BIM into their architectural design process?

RQ 2: How can critical obstacles embedded in the current system of BIM use in Taiwan be addressed?

3.1 Research method

The explorative nature of this preliminary study of BIM and associated organisational business processes required a research strategy that was able to provide descriptive accounts of cases through gathering qualitative information. According to Schell (1992), case studies are the most flexible of all research designs, allowing the researcher to retain the holistic characteristics of real-life events while investigating empirical events. Case studies are most suitably used to answer 'What' and 'how' questions, and were ideally suited to this inquiry. The case study's strength lies in its ability to deal with a full range of evidence - documentation, artifacts, interviews and observations. The BIM performance assessment framework was used to guide the data collection and also to formalize the case study findings.

3.2 The research process

The research process was undertaken into two phases. In the first phase a ‘digging broadly’ strategy (Moum, 2008) was used in order to locate BIM players and understand the relationships between BIM stakeholders. Active liaison with the National Taiwan University Centre for BIM Research enabled access to forums and symposiums in which major players gathered to discuss BIM roadmaps and obstacles. Through participation in events, preliminary insights into BIM from the perspectives of the client, construction project team and software producer was acquired. This interaction also allowed major BIM players to be identified and selected as potential case studies. Preliminary informal interviews were then conducted with these major players to enable a more sound technical understanding of BIM by the researcher.

In the second phase, an elaborative and ‘digging deep’ strategy was used to achieve a more detailed understanding of the information gathered in phase one. Projects that had employed BIM in the design phase were studied and interviews are conducted to clarify and extend the understanding of the printed material. The interviews helped gain insights into how business policies and processes interacted with the BIM technology. Empirical data from interviews and printed sources were analysed with a focus on the scope of BIM use. The aim was to deduce their respective BIM capability and maturity levels, and determine the business value derived from BIM use, in terms of effects of BIM adoption; which were automational, informational or transformational.

Most interview material was recorded via a digital recording device. Where it was inconvenient to do so, key points were jotted down during the interview and later analysed. The recorded information was analysed against BIM Capability and Maturity Indicators to determine BIM Performance. The research process is summarised in Figure 2 below.
4. CASE STUDY FINDINGS AND DISCUSSION

Case study findings revealed BIM to be adopted primarily to improve visualisation and design coordination. Collaboration at the project design stage remains largely intra-organisational. The utilisation of BIM for design analysis and supply chain integration to achieve transformational effects for the AEC industry is hampered by problems that are legal, technological and organisational. The study concludes with suggestions of ways to help facilitate a top-down approach to BIM implementation to reap true productivity benefits from BIM use.

With increasing industry awareness of BIM as a new paradigm in project delivery, the firms using BIM in their projects prefered marketing their ability, in the hope of regaining a competitive footing against their rivals. The firms have chosen to adopt BIM, not due to pressure from clients, but because of the advantage of better design coordination (through clash detection and scheduling). Architecture consulting firms in Taiwan have shown a reluctance to share BIM at the inter-organisational level.
They do not use others’ BIM drawings, and do not require BIM from partners. The following details the context of BIM adoption within each case study firm.

Firm A: client holds separate contracts with the architect and the engineering consultants. BIM is used strictly within the firm. BIM is used to perform clash detection, quantity take-off, for construction drawings, external wall partitioning and scheduling—hence for coordination purposes. BIM is used within a single organisation for architectural design coordination. Value is seen to be derived from BIM being substituted for labour. Productivity improvements, labour savings and cost reductions were reported benefits of using BIM.

Firm B: The interviewee revealed that the use of BIM in the firm has not been made known to the client. Architecture design firms that have adopted BIM may not want to share electronic files with their customer and partner firms, or even let those firms know they are using BIM. In this way, they could continue to charge similar rates for the same work that is taking them substantially less time to complete. In this case, the productivity improvements, labour savings and cost reductions brought about by the use of BIM was being used to boost the profitability of the architectural business and were not being passed on to the client.

Firm C: the firm has established a close relationship with its main client. Some instances of inter-organisational BIM sharing were evident in the projects analysed. Data indicated a breakthrough where BIM is used for energy analysis for one of the projects. BIM has been used to achieve informational effects, where exchange and sharing of BIM enabled comparative analyses of factors, such as construction cost and energy consumption, has reportedly led to improved decision quality, decreased use of resources and enhanced organisational effectiveness and quality.

Firm D: projects were selected to demonstrate the use of BIM at three different stages of design: schematic design, design development and construction documentation, each with increasing levels of detail. BIM was reportedly used for solar analysis, coordination of drawings, visualisation and structural/ MEP. There was no evidence of inter-organisational exchange of BIM. An informational effect is achieved by the firm using BIM to perform various analyses, even though BIM is not shared at the inter-organisational level. Results from the interview with the firm representative suggest that BIM maturity is at the level where it is defined and managed.

4.1 BIM implementation within the building industry in Taiwan

The adoption of BIM by Taiwanese AEC firms has been slow, and is seen to be localised in the capital city of Taipei. The majority of architecture design firms still rely on traditional methods to perform architecture design. From field investigation, it was found that some major public clients have realised the immense potential of BIM to reduce project costs and errors, and are beginning to request the adoption of BIM by their project teams. The Department of Rapid Transit Systems (DORTS) is one example of such public clients. Its architecture design consultants, as a result, are encouraging employees to learn Autodesk Revit by offering professional training. Firms that are already implementing BIM currently constitute the minority of consulting firms in Taiwan. Indeed, it was found that firms are not very enthusiastic about facilitating inter-organisational use of BIM.

4.2 Addressing the research questions

The answer to research question 1 is structured upon the logic of the BIM performance assessment framework, and determined through mapping the scope of BIM use, BIM capability and maturity within each firm. Research question 2 is addressed in two stages. Stage 1 involves identification of obstacles inhibiting the proliferation of BIM adoption within the building industry. At stage 2, solutions to the problems are proposed by reference to the extant literature.
4.2.1 RQ 1: What is the overall BIM performance among architecture consulting firms in Taiwan that have incorporated BIM into their architectural design process?

Overall BIM performance among architecture consulting firms in Taiwan is illustrated in Figure 3. The BIM Capability, Maturity and Scope of BIM use are derived from taking the average of results obtained from each of the four case studies. Architectural design BIM is mostly used within the firm for architectural design or for several different types of analyses. BIM is used not only to advance communication through better visualisation, but is further utilised for collaboration among members of the project team within the firm. BIM Maturity hovers between the Ad-hoc and Defined Level, with BIM being driven by the overall vision of senior managers, but processes and policies and contractual aspects have not yet been clearly defined. Automational and information effects have resulted from the adoption of BIM. These indicate that value is accrued from improved decision quality, employee empowerment, decreased use of resources, enhanced organisational effectiveness, and quality. Firms have moved from adopting operational thinking to increase productivity, to undertaking functional thinking, where functionality of the firm is increased.

BIM is a new industry practice paradigm that is heavily reliant upon mutual collaboration and interoperable business processes. The inability to perform inter-organisational BIM collaboration has severely hampered organisations’ BIM performance. As Kiviniemi (2008) points out, a lack of inter-organisational BIM exchange would make building design analyses difficult to carry out, thus restricting BIM capability to move beyond the stage of collaboration. The sharing of building information models is observed to have remained largely intra-organisational and, as a result, the use of BIM to perform more complex functions such as energy analysis (which usually requires different disciplines to collaborate and exchange data) becomes difficult. At present, the use of BIM in Taiwan for purposes beyond that of Coordination is rare.

![Figure 3. Overall BIM Performance of architecture consulting firms in Taiwan](image-url)
4.2.2 RQ 2: How can critical obstacles embedded in the current system of BIM use in Taiwan be addressed?

Three problems have been observed in the current system of BIM implementation in Taiwan. These problems are general to the diffusion of BIM practice at the industry level, and specific to the facilitation of inter-organisational collaborative processes.

- Legal issues concerning Intellectual Property Rights of use of BIM object library.
  Issues of BIM Intellectual Property Rights are a major area of concern for all of the firms in Taiwan. Recognizing the urgent need to resolve, or at least address uncertainty in the area, considerable effort has been invested by the National Taiwan University’s Centre for Building and Infrastructure Information Modeling and Management in conducting relevant research.

- Project partners may not be BIM users
  The fact that project partners may not be BIM users alludes to the problem of insufficient proliferation of BIM in the AEC industry. The slowness of BIM adoption in Taiwan may have resulted from the market-driven nature of BIM implementation. In countries like Singapore and Norway where the regulatory authorities have taken a lead, BIM adoption is well on track. Therefore, a top-down approach to BIM implementation, where a government body is the main driver, should be adopted. The CORENET initiative in Singapore has been recognised to be an effective form of the top-down approach. The CORENET initiative was launched in 1995 and its aim is ‘to reengineer and streamline the fragmented work processes in the construction industry, so as to achieve quantum improvements in turnaround time, quality and productivity’ (Teo and Cheng, 2006).

- Different organisational agendas.
  Resolving organisational differences is the basic requirement for facilitating IPD. This may be achieved through the concept of project alliancing, which involves the collaboration of owner and non-owner participants to deliver the capital phase of a project, with all participants sharing the responsibility for project risks and for achieving project objectives. The project alliance model creates a commercial framework where all participants win or all lose, depending on their collective performance against project objectives. This creates both an incentive to achieve project objectives and a ‘best for project’ focus among participants. In comparison with traditional forms of procurement, project alliances rely more on developing trust and strong relationships to drive performance than on the legal and contractual relationship between participants. Project alliances are based on clearly understood principles to which all participants are fully committed.

4.3 Conclusion

Implementation of BIM requires active public and private support, as well as continuous research in BIM policies, technologies and processes and refinement of BIM guidelines. In Singapore and the Scandinavian countries (Finland, Norway and Denmark), on top of private sector support and various research efforts, there is strong government devotion in developing and promoting BIM. Policies are well developed and strictly adhered to by industry players. By contrast, Taiwan illustrates an AEC industry where BIM is market-driven and where large private companies are the major drivers. No guideline has been published to date, and the NTU Centre for BIM Research is one of only a very few known organisations conducting BIM research and education in Taiwan.

Findings from the study of literature suggest that in countries like Singapore, processes and policies have already reached a certain level of maturity. The major problems associated with BIM implementation surround issues of technological interoperability since collaboration among project participants using BIM is intense. In Taiwan, on the other hand, the AEC industry is still awaiting
national BIM policies to be developed. Issues such as Intellectual Property (IP) Rights must be addressed before further progress may be made.

The research reported in this paper gives a snapshot of BIM use in Taiwan by four leading architectural practices. The research has helped to identify some of the barriers to further implementation and suggests that a purely market driven approach to BIM adoption is not necessarily the best approach for Taiwan’s AEC industry. Clearly, as BIM becomes more widespread and clients become more demanding, the adoption of BIM will increase as architectural firms respond to market pressures. However, there does seem to be a need for a top down approach as well, and it is hoped that there will be developments along these lines in the near future. Future research will continue to monitor the uptake of BIM by architectural firms and other members of the AEC sector in Taiwan in an attempt to better understand and benefits and challenges associated with the technology.

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CIB-W096 2011 Vienna
A Design Control Structure for Architectural Firms in a highly Complex and Uncertain Situation

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Abstract: A large architectural firm in a highly complex and uncertain production situation asked to improve its existing “production control” system for design projects. To that account a research and design project of nine months at the spot was defined. The production control in the organization was based on a mix of project management tools, resource allocation to whole projects, and regular updating of the project portfolio. The results of the research analyses showed that the situation of the firm’s design projects cannot be controlled with only such tools, due to lack of coherence between the “production control” and the design situation. To improve the coherence, a basic “production control” structure is designed. The design of this structure is based on the match between the research findings and theoretical principles of how decisions should be made in multi-project situations that are highly complex and uncertain. The design consists of four hierarchical planning functions (strategic resource planning, rough cut capacity planning, resource constraint project scheduling and detailed planning). After finalizing and presenting the design, the design led to new insights into resource allocation for the client and has been approved by the client and office management. The implementation of the design is however still in design proposition due to other priorities.

Key words: Production Control, Resource allocation, Multi-Project Scheduling, Matrix structure, Engineer to Order, Design situation. Paper size, Font, and number of Pages

1. INTRODUCTION

Larger architectural organizations are mostly involved in many building projects in parallel. This involvement leads often to undesired human resource scheduling problems (HRSPs) (e.g. Emmitt; 2007, 2010). Solutions are important, because these problems lead to less efficiency in the architectural organization, and could cause project delays or lower project quality and therefore lead to less profit for both the organization and its clients.

Architectural management theory that considers design control mostly focuses on the complexity of information inputs and outputs and tasks in the iterative processes of single design projects (e.g. Austin et al., 2000; Gray et al. 2001, Carmichael 2006). Solutions for the HRSPs poorly get attention in the literature compared to production control theory (e.g. Hendriks 1996, 1998; Schönsleben, 1998; Leus, 2003, Bertrand et al., 1990, 2009). However, mostly the attention is not focussed on architectural organizations, but on Engineer-to-Order (EtO) production companies. Architectural organizations can be regarded as a category of EtO organizations.
Because architectural management theory mostly focus on the complexity of the design project scheduling, and production control theory does not focus on architectural organizations, we believe there is a gap that deserves more development in architectural management practice and theory. Especially, because on the one hand large architectural organizations cope with similar HRSPs, and on the other hand each design situation is different and specific. An understanding of existing design control structures in practice might lead to better theoretical principles for architectural offices, which could improve design control in practice (Romme & Endenburg, 2006). A large architectural firm with EtO characteristics in a German speaking country faced problems as described and explained and asked the authors to investigate and improve its existing “production control” system for multiple design projects to find out how the firm’s efficiency level can be improved and be controlled.

To that account in the next chapter the research approach is described. In chapter 3 the situation of the firm’s design projects (the design situation) and control structure are described and explained, and the weaknesses in the existing design control structure are revealed. In chapter 4 the starting points for the redesign are formulated. In chapter 5 the redesign and its theoretical principles are described. Finally the conclusions are given and recommendations for further research.

2. RESEARCH APPROACH

To find out how the existing “production control” system for design projects functions, the firm’s resource allocation system was investigated in order to derive at causes that can explain the inefficiency. A case study has been designed (Yin, 2003) and conducted to that account. A qualitative method for the research was used focusing on management issues as Gummesson (1999) describes. The case study comprised a starting meeting with the whole group, a team workshop with the managers, interviews and participative observations to collect the necessary data. The interviews were performed with key persons in the management system using semi-structured interviews.

The focus of the research is on key concepts in production control literature to identify the weak points of the existing design control structure and to provide indications for resource allocation efficiency improvements. The research shows that the design control structure with only a mix of project management tools, resource allocation to whole projects, and regular updating of the project portfolio is too weak to keep effective control over the analyzed design situation. Therefore, a redesign with four hierarchical multi-project planning functions is proposed to improve the design control effectiveness. The mentioned theoretical framework, principles and methods can be useful in future design control research.

2.1 The formal resource allocation system

The resource allocation system as prescribed by the organization consists of three planning functions that are interconnected in a software program:

1. An aggregate planning function of assigning working hours to projects - responsibility of the aggregate manager-
2. A rough project planning function of assigning working hours to design unit parts of the project - responsibility of the Head Project Manager (HPM)-
3. A design unit planning function of assigning working hours to the design unit projects part and human resources - responsibility of the Design Unit Manager (DUM).
The aggregate planning was based on two ‘efficiency rules’: (a) all human resources have to be allocated to a project always, and (b) an amount of project working hours to projects has to be assigned. The fixation of hours had two goals. The first goal was to gain control over the project resources within the capacity as planned in the budget. The second was to make DUMs and HPMs co-responsible for the project profit.

At the start of a project the HPM estimated and assigned working hours for the design unit project parts in a rough project plan. The HPM’s responsibility was to keep the working hours for a whole project within budget. The design unit planning made by the DUM was used to allocate human resources to the project working hours. The DUM was responsible for keeping the hours of the design unit within budget. The DUMs could fill in the worked hours in the information software system.

The formal information system for resource allocation had three main overviews:

1. The aggregate managers had an overview of the resource allocation in the whole office, and on the organization’s profit;
2. The HPMs had an overview of the estimated Delta between the used and estimated hours for the project;
3. The DUMs had an overview of the resource allocation and on the Delta of projects’ working hours the design units.

To gain insight in the coherency between the design situation and design control structure from a theoretical perspective the research and development approach for organization design of Romme and Endenburg (2006) (See Figure 2.1) was used.

![Figure 2.1: The research and development cycle in organizational design (Romme & Endenburg, 2006)](image)

The cyclic approach was passed in the following order:

*Step 1: Implementation and Experimentation:* the implemented resource allocation system was analyzed; its usefulness and its weaknesses as perceived by the organization were obtained.

*Step 2: Organization Science:* the causes of the perceived problems were derived by analyzing and evaluating the existing control structure using key concepts of production control science.

*Step 3: Construction principles and rules:* construction principles and design rules of EtO production control theory that fitted the practical conditions were collected.

*Step 4: Organization design:* the redesign was constructed by the theoretical principles and rules found in step 3, the encountered organizational situation, and the preferences of the people who were involved in the redesign.

*Step 5: Implementation and experimentation:* experiments should be done to evaluate the usefulness of the redesign in practice. Due to the limited time period the fifth step could not be completed. Instead the design proposition was evaluated with the managers and key concepts for coherency evaluation between design control structure and situation were used. Experiments should still adjust defaults in the practical usability of the redesign. Due to other management priorities the redesign is still in a design proposition.
The execution of the research and design project consisted of three phases: 1) an orientation phase, 2) an analysis phase and 3) a design phase. In the first two phases the first three steps of the cycle were completed. The design phase included the fourth step. In the orientation phase, the design situation and the problem area were explored. In this phase, data was collected by 22 semi-structured interviews. If managers allowed it, the interviews were recorded and partly transcribed, Minutes of all the interviews were made. The questions were mostly how- and sometimes what- questions about the organization framed in a 7S-framework (Peters et al. 2004), the design control process, the used software system, and the strong and weak points in the process and the system. Additional data like formal documents, informal scheduling plans and interviews with control groups were used to triangulate the interview data to find causes for the perceived problems.

In the analysis phase, these causes were analyzed and evaluated. In this phase, 8 semi-structured interviews and a workshop were executed for data collection. Before an interview was executed information about project management approaches, complexity and uncertainty in design situations, together with how- and what-questions related to these subjects and the resource allocation in the organizations was distributed amongst the respondents. The purpose was to get a better understanding of the topics that were discussed during the interview. Interviews focused on questions related to the coherence between the design control and the design situation and on the relation between resource allocation and project scheduling. The interview data were again recorded and partly transcribed. Data about the relationship between the different hierarchical management activities with regard to project scheduling and resource allocation and possible solutions for perceived problems in this relation were collected in the management workshop that consisted of role playing games and reflection on these games.

The data of both phases were framed by theoretical production control principles as found in chapter 3. The orientation phase together with the analysis phase resulted in an evaluation of the coherency between the design control and the design situation. In the design phase a redesign was made by using the results of the practical analyses and theoretical principles found in production control and project management literature. The redesign was constantly adjusted after conversations with the concerned managers about the practical feasibility.

2.2 Sample and control groups

The architectural organization consists of several offices in various countries. Every office had its own separate resource allocation system. Due the limited research time of nine months in a big office in a German speaking country was taken as a sample for the research. The design control structure of this organization was investigated. The interviewees within the sample were chosen on the basis of their direct interaction with the resource allocation system. This implied that the aggregate managers, the HPMs, and the DUMs were interviewed. A minimal condition of one interviewee of each discipline and of hierarchical level was set.

To control if the sample’s information was useful for the whole organization and if it was coherent with the efficiency perceived on operational level two control groups were used. The first group was used to control if the resource allocation system of the other offices worked similar and had similar deficits. The interviewees were chosen on the same basis as the interviewees of the sample. The resource allocation system did not work the same in small offices, although the similar tools were used, because informal communication in small offices was of more importance as in large offices.

The second group consisted of the staff that was managed. The people of this group were picked ad randomly. This control group was used to control if the perceived problems on all levels matched. The comparison showed that this was indeed the case.
3. KEY CONCEPTS FOR PRODUCTION CONTROL STRUCTURES

Because production control theory has more key concepts and theoretical principles about HRSPs as architectural management theory does, the existing control structure in the analyzed architectural organization is evaluated from a production control perspective. The focus is on architectural design projects. Therefore in this case we write about design control instead of production control. In general cases we keep using the term production control. The control of production processes can be defined as "the coordination of supply and production activities in manufacturing systems to achieve a specific delivery flexibility and reliability at minimum costs" (Bertrand et al.; 1990). The production control objective is the coordination of the primary process, aiming at (1) the delivery speed and delivery reliability, and (2) the resource allocation efficiency (Bertrand et al.; 1990). Design control is defined as the coordination of supply and design activities in architectural design systems to achieve a specific delivery flexibility and reliability at minimum costs.

The production control perspective leads to three units of analysis: A) the characteristics of the design situation B) the design control structure, and C) the coherency between the control structure and the design situation. The units can be framed by concepts and principles derived from Bertrand et al. (1990). The work of Bertrand et al. is used, because their concepts and principles are intended as tools for the analysis of production control problems in practice and the design of adequate production control systems that are adjusted to a specific situation. The units of analysis and the frameworks are explained shortly in this section.

A) characteristics of the design situation
The three important characteristics of the design situation that should be considered to select an adequate control structure (Bertrand et al. 1990). These are the following characteristics:
(1) The uncertainty and dynamics of the production situation: a) uncertainty creates b) dynamics, because it is hard to anticipate in an uncertain situation. A situation is more dynamic, if there are more changes, which should be controlled. The degree of uncertainty in a situation becomes higher if changes in the situation will be more unexpected. Uncertainty and dynamics can be situated at the demand side or the resource side of an organization.
(2) The flexibility in the production situation; Flexibility of resources is the pendant of uncertainty and dynamics. Flexibility has a quantitative aspect and a timely aspect. It is of no use if it does not serve any purpose. Flexibility makes it possible to reduce fluctuations in the primary process.
(3) The complexity of the production situation; the more interdependencies between separate elements are given, the more complex a situation is. A high degree of complexity needs more information and coordination than a low degree.

During the research, these concepts got less abstract, and can be described as follows:
(1) a. Uncertainty is the number of unknown requirements, methods, solutions and resource assignments in the process,
   b. Dynamics are the number of changes in requirements, methods, solutions, and resource assignments during the process that occur due to the interdependencies and uncertainties,
(2) Flexibility is the ability to accommodate to uncertainty and dynamics by adaptation on the resource side.
(3) Complexity is the number of interdependencies between requirements, methods, solutions to requirements, and resource types needed to create the solutions.

The characteristics of the production situation can be depicted by mapping the relationship between the important aspects of the situation.

B) The control structure

A global control structure proposed by Bertrand et al. (1990) is used to frame different planning activities (See figure 2.1).

This structure can be decomposed vertically into aggregate planning and production unit planning, and horizontally into capacity planning and planning of inputs and outputs during the primary process. Aggregate planning gives an overall overview. Production unit planning gives a detailed overview over the resource allocation state in the unit. Capacity planning keeps track of the capacity to gain workload control. The primary process planning keeps control over the priorities in work order and task releases.

C) Coherency between the control structure and the design situation

The research model used in the analysis to evaluate the coherency between the design control structure and the design situation is also deduced from Bertrand et al. (1990). They express that an effective coherency between a control structure and a specific organizational situation should fulfill at least five basic rules:

a. The flexibility should be bigger than, or equal to the uncertainty, and dynamics;

b. The flexibility should be used functionally by means of a good information system and decision making process.

c. The flexibility itself, the authorization and the information for using the flexibility should ideally be available on organizational positions, where disturbances could appear.
d. The complexity should be reduced or clarified.
e. The complexity should be decomposed in such a way that rigidity and inefficiency will be avoided.

The coherence between the design control and the situation is evaluated by these five rules. The rules evaluate the effectiveness of the production control structure. If the structure is effective, there can be a reliable task scheduling and a good level of resource allocation efficiency.

These key concepts for production control structures were used to analyze the design situation and the design control structure and evaluate the coherence between these two. The findings of the analyzes and the evaluation are described and explained in the next chapter.

4. FINDINGS

4.1 Design Situation and Perceived Problem

The design situation in the investigated organization is depicted in figure 3.1.

The findings of the interviews show that in the investigated architectural organization high uncertainty, and dynamics can be noticed on the demand side of the projects. The situation has similarities to an EtO situation as characterized by Wortman et al. (1997). The findings reveal that uncertainty and dynamics cause more dynamics in the high complexity in projects and between projects. The high uncertainty and complexity is typical for EtO environments with several complex projects in parallel (Leus et al.; 2003). Flexibility on the resource side can be used to stabilize changes in the planning of the primary process.

Only few design unit managers (with human resources working on all projects) perceived the interdependencies between multiple projects as resource scheduling problems. Most managers
perceived the problems as “bad project management by others”, or as “relationship problems between design units”. Due to this perception, management blamed each other in a vicious circle.

### 4.2 The Design Control Structure

The formal organization used separate information systems for the resource allocation and project scheduling. The project schedules made by the HPMs contained the planned tasks and task outputs. The schedules could not be linked directly to the resource allocation information. This made the information of the resource allocation system almost useless. In order to have a neat overview of the project tasks in their design units, DUMs were forced to make separate informal information systems. The common formal information system was therefore not used regularly and information was not up-to-date. The information system was therefore also of less use for aggregate managers. It led to a situation that can best be described as an iceberg-metaphor (See figure 3.2). On top of the organizational iceberg the aggregate manager tries to control the iceberg by means of the formal information system. Under the water the iceberg is full of cracks between design units, because all design units use individual informal information systems.

![Figure 3.2: Iceberg-metaphor of the control structure in the analyzed organization](image)

Only through informal communication it is possible to adjust pragmatically resource scheduling information with each other. A total common overview is lacking. This pragmatic design control structure also led to political and cultural issues. The goals within the individual information systems of managers became the dominant trigger for a behavior that focused on own management results. This resulted in defensive behavior, avoiding conflicts and decisions that could cause problems in individual planning. A political game between HPMs and DUMs could lead to role conflicts for the functional staff as mentioned during the workshop. According to Jones and Drecko (1991) such a situation can be recognized as one of the most commonly identified sources of conflict in matrix organizations. The issues also explain the perceived problem, which is described in section 3.1.
4.3 The coherence between the design situation and the existing design control structure

The coherence between the design situation as described in 3.1 and the design control structure as elaborated in 3.2 is evaluated in this section by using the five basic rules for effective coherency listed in section 2.4. In this section we conclude that the coherency rules do not match with the analyzed design control structure.

The first conflict is provoked by keeping everybody allocated to a project. By using the maximum capacity limit of the organization as basic principle, the need for more or at least equal amount of flexibility in comparison with the amount of uncertainty and dynamics is not considered.

The second conflict arises because the information system gives not enough information to functionally use the flexibility. In the formal information system, hours are assigned to whole projects and not assigned into detail to tasks. Therefore there is no insight into the project complexity and no clear Delta between the estimated time and the actual time needed to complete project tasks.

The third conflict with the coherency rules is the unavailability of authorization for using flexibility on all the right organizational positions, because the real flexibility is needed in projects, but only the DUMs have authorization to schedule tasks and resources of his design unit, HPMs only have influence (this also led to the political issues).

The fourth and fifth conflict results from the lack of clarity with regard to the complexity between projects. The aggregate planning level does not gain an insight in the interdependencies between projects. Due to a lack of overview, the complexity cannot be reduced and not be decomposed.

It can be concluded that the five basic rules are not fulfilled. This indicates that the control structure can be more effective.

5. REDESIGN TO THE CONTROL STRUCTURE TO THE DESIGN SITUATION

In the redesign a design project is viewed as a network of tasks, where each task generates output. Each output is the input for one or more interdependent tasks until the end result is reached. In the design process, these inputs and outputs are mainly design documents and requirements (e.g. functional requirements, client requirements). Another type of interdependency originates from the fact that tasks require human resources that are shared between orders (projects). Both types of interdependencies can lead to an inefficient situation, in which either tasks wait for resource availability causing loss of time, or human resources wait for tasks that cannot start because input is not yet available causing loss of resource capacity. Both interruptions cause loss of profit. As a basic principle planning should aim at sequencing tasks of multiple projects in time over human resources in order to minimize both types of waiting times. The redesign combines principles of production control theory with project management principles of the architecture and engineering (AE) industry.

The redesign is based on four hierarchical capacity planning functions derived from the hierarchical multi-project approach of Leus et al. (2003). They argue that a scheduling approach with four hierarchical resource capacity planning functions is needed in situations with a high degree of uncertainty and complexity: 1) a strategic resource planning (SRP); 2) a rough cut capacity planning (RCCP); 3) a resource constrained project scheduling (RCPS); and 4) a detailed scheduling. For the RCCP approaches they conclude that RCCP approaches as investigated in literature deal with uncertainty on the tactical level and are all proactive approaches. The approaches aim at anticipating uncertain events.
Due to research limitations, the SRP was not investigated and therefore not redesigned in detail. Basically the first hierarchical level, the strategic planning gives yearly (long term) goals for the human resource planning and incoming projects.

The second level, the RCCP, should take the interdependencies between projects and the project uncertainties into account. Understanding (1) pace of work intensities in creative design processes and (2) project uncertainties is key to a proactive solution for the control problems occurring at the aggregate planning level.

The increase of work intensity in design projects when a deadline approaches is inherently rooted in the design process (Beeftink, 2008). The interviews undertaken in our research confirm this. When deadlines of multiple projects take place at the same time, the office’s resource capacity limit can be exceeded due to the increasing work intensity in more projects. By tuning deadlines with each other at the aggregate level high peaks can be avoided. (See figure 4.1).

![Figure 4.1: avoiding work overload peaks by tuning deadlines](image)

On the aggregate level resource capacity buffers for “uncertain, dynamic projects” could be planned to avoid work overload problems caused by uncertainty and dynamics. By planning buffers the chance of a snowball effect due to interdependencies of shared human resources between projects can be reduced. In order to plan an uncertainty capacity buffer, an uncertainty estimation of a project should be made. The uncertainty can be estimated by using the goal-and-methods matrix of Turner and Cochrane (1993). The goal-and-methods matrix indicates parameters for the project’s uncertainty: project goals and methods (See figure 4.2). The less these parameters are defined by the client, the higher the chance of a dynamic project situation. The research findings show that projects of the analyzed organization could be categorized in four uncertainty categories. This categorization could be used to estimate buffers at aggregate level. The buffer makes flexibility on the resource side possible (e.g. by outsourcing). By regulating project deadlines and creating uncertainty capacity buffers on the aggregate level the balance in the pace of projects can be controlled proactively.
To allocate resources to projects productively at design unit level, the coordination of task inputs and outputs of the project should be planned and the duration of the tasks should be estimated before planning human resources on projects. This procedure has five advantages: the project progress can be measured in terms of time, the errors in the estimated task durations are visible, the relationship between inputs and outputs of tasks can be better established in time, the resources can be efficiently allocated and the project profit can be estimated better. The division in capacity planning and the coordination of inputs and outputs also elucidates the difference in responsibility between project managers and DUMs. The coordination and planning of inputs and outputs in a project is the responsibility of the project manager. He should define project goals and requirements. The estimation of the design unit tasks and the capacity planning is the responsibility of the DUM.

Because most design projects are uncertain, the planning approach on the operational design unit level consists of two hierarchical capacity planning functions: (1) a planning to find resource constrained project scheduling problems in the medium term, and (2) a detailed planning in the short term. The medium range planning should be based on deadlines, but also on the output that should be delivered on these deadlines (Leus et al, 2003). The interviews show that also the input description of technical specifications could help to optimize the task duration estimations. Due to the medium range planning based on deadlines, output and technical specifications resource constraint project schedules can be based on better estimations. Resource scheduling problems can be overseen and solved by allocating the capacity buffer that is set at the aggregate level. In the detailed planning, human resources are allocated to task priorities for the coming two weeks. By keeping the human resources flexible till the last moment, the organization can cope better with uncertainties and will work more efficient on projects.

Due to all hierarchical planning functions, it is possible to have a multi-project overview with a focus on single project goals and at the same time an efficient resource allocation. These functions have to get simultaneously tuned, e.g. by the communication principle by Hendriks et al. (1996, 1998). The set of hierarchical planning functions is in line with the coherency rules we found in the literature, the only constrain is a supporting information system for these planning functions.

6. CONCLUSIONS AND RECOMMENDATIONS

Especially for large AE offices with multiple projects in parallel, a design control structure is considered to be an essential tool to manage delivery reliability to the demand side and at the same time create efficiency at the resource side. This paper proposes a design control structure with four...
hierarchical planning functions and explores how these planning functions can function in a large architectural firm with EtO characteristics. According to the latest feedback from the organization the design control structure is still not tested or implemented. However managers at design unit level are now asking for the planning functions of the redesign, which shows a good support to implement the redesign at operational level. Although the proposed control structure has not yet been tested, the positive response from the management is a basis for confidence in the approach.

This research gives an example how production control theory concepts, principles and rules can be applied to control multiple projects in the AE industry. Project management as familiar to the AE industry focuses on creating less uncertainty and dynamics in projects (Laufer, 1996; Turner & Cochrane, 1993), but does not give any principles or tools how to handle resource allocation in large architectural organizations. The research shows that a control structure should take into account the familiar project management practices in the AE industry in order to get management support for the new control structure. Therefore theoretical concepts, principles and rules of a multi-project planning approach have been combined with project management principles that are familiar for the AE industry. This led to a redesign in which a multi-project planning approach is suggested with room for project management at the operational level.

In the literature as explored in this research, design control in architectural firms gets too little attention in architectural management practice and theory. It is plausible that more AE firms face similar problems in resource efficiency and delivery reliability, because most architectural firms have human resources working on multiple projects in parallel (e.g. Beeftink, 2008). In order to generalize the results from our research, more research and design projects should be done to create satisfying design principles and rules for the AE industry. Therefore the authors hope this paper contributes to attention for this topic in AE industry which is neglected by researchers, by sharing the redesign proposition and its theoretical principles and rules.

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Addressing the architect/contractor interface: a lean design management perspective

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Abstract: One of the challenges in design and construction projects is the interface between the designers and the contractors. It is here that difficulties can be resolved, or conversely manifest, as a result of the effectiveness of interface management. The work reported in this paper is associated with a knowledge transfer project (KTP) that sought to embed a lean culture within a small design and build organisation. One of the issues arising from the KTP related to the effectiveness of design management and communication between the design and build organisation and its consultants. This resulted in additional research to better understand the contractor/consultant interface and hence devise an effective lean design management protocol. The research reported here is from the pre-construction phase, supplemented with data from the early construction phase of projects. Analysis of data from interviews, collaborative planning workshops and monitoring of processes informs the work presented in this paper. Tentative results indicate that attention to the social aspects of projects, the people factors, are fundamental to successful communication and collaboration within projects.

Key words: Impact, Integration, Interface management, Knowledge transfer partnership (KTP), Lean design management

1. INTRODUCTION

Lean has been, and continues to be, embraced by an increasing number of contracting organisations around the world. Originally developed in manufacturing, with Toyota being a successful exponent of the approach (Womack, et al., 1991: Womack & Jones, 1996), lean thinking has been applied to construction (e.g. Ballard and Howell 1994; Howell and Ballard 1998; Koskela, 2000). However, from a review of the literature it appears that most research relates to very large construction projects and/or large contracting organisations. Much less literature relates to small/medium enterprises (SMEs), of which there are many in the construction sector. Similarly, literature relating to lean in the design management phase is sparse compared to the construction phase (see for example Koskela et al., 1997; Jørgensen & Emmitt, 2009; Tribelsky & Sacks, 2011). This trend can also be seen in the architectural management literature, where lean principles have rarely been discussed. Thus there is a gap in our knowledge about the application of lean design management on small construction projects undertaken by SMEs. The research described here endeavours to address this knowledge gap by concentrating on the architect/contractor interface.

Work is drawn from a knowledge transfer partnership (KTP) between a small design and build organisation and a university, both based in the UK. KTP projects are part funded by the UK Government’s Technology Strategy Board and partly by a commercial/business organisation. This allows a KTP Associate to be employed by the university to work as a change agent within the commercial organisation, applying knowledge to a practical challenge. In this KTP the project associate’s role is to identify areas for improvement and make appropriate interventions, drawing on the knowledge and skills of the university to make informed decisions. The role of the university is to
provide expertise and facilitate appropriate changes in the design and build organisation. This should result in improved performance within the business and the generation of new knowledge. The aim of the KTP is to embed a culture of continuous improvement within the contracting organisation and reduce process waste to deliver improved value to building users and funders. The initial focus of the research was on construction site activities and the flow of directly employed trade packages. As the KTP developed it became evident that there were challenges relating to design management which impacted on the construction activities. This led the design and build organisation to develop a design management protocol document to help them better manage the design/construction interface.

The aim of this paper is to describe some of the issues relating to the interface between the design and build contractor and the design consultants (architects and engineers). The aim is not to try and further define lean design management. The four projects reported in this paper are social housing projects located in the greater London area. The research is grounded in the lean thinking philosophy; however the main issue addressed in this paper is the interaction between the design and build organisation and the designers. The result is a focus on interpersonal communication and the implications for interface management.

2. INTERFACE MANAGEMENT

Bringing different disciplines together is rarely an easy task, since even if the organisations have worked together previously, it is unlikely that the individuals involved will all know one another, and so the early phases of interaction are concerned with exploring and learning how to work effectively with new people from unfamiliar organisations (Emmitt, 2010). Creating a temporary project organisation (TPO) also creates a vast number of interfaces between organisations, organisational departments, teams, groups and individuals over the life of a project. Some of these interfaces will be new, some may be re-established after a (short) period of not working together and some may be continued from previous projects. Effort expended in forming relationships, testing new acquaintances’ abilities and trying to establish their trustworthiness at a very early stage in the project can be beneficial in quickly establishing effective working patterns. Trying to establish compatibility as early as possible in the life of a project can be a time consuming task, but this effort can have significant dividends in terms of quickly building effective working relationships, developing mutual trust and reducing the likelihood of misunderstandings and unnecessary conflict (Thyssen et al, 2010).

Interfaces between construction materials form physical boundaries or joints, which are relatively easy to design and manipulate to achieve the required technical performance for a building because they can be seen. Interfaces between project organisations form softer boundaries that are determined by legal contracts (which specify responsibilities), but which are often blurred as individuals work informally with others at the margins of the boundaries. Boundaries of responsibility and interests in the project are constantly in a state of flux. Obvious boundaries are the interfaces between client and brief taker; brief taker and design team; design team and contractor; contractor and sub-contractors. The interface of design and construction has been addressed from a lean perspective. Jørgensen & Emmitt (2009) found that a number of issues were fundamental in helping to integrate lean design and construction. In relation to the research reported in this paper the important recommendations were better management of design iteration, use of collaborative management tools and project team learning: issues addressed within the KTP.


2.1 Practical considerations

Interface management is concerned with the relationship between inter-dependent organisations working towards a common goal (Wren, 1967). Terms such as ‘interface coordination’ or ‘integration management’ are also used in project management literature (e.g. Meredith & Mantel, 2006). Given that the number of interfaces can be significant with a TPO, for practical reasons Emmitt (2010) has suggested attention be given to two fundamental types of interface that are constant throughout the project:

- Organisational (business) interfaces. Organisational interfaces are mainly defined by contracts and the project context. Inter-organisational relationships are concerned with organisational culture and the interoperability of management and ICT systems. Although the relationships can be dynamic, they are relatively straightforward to define, map and manage through the life of the project.

- Personal interfaces. Individuals interface with others representing other organisations, not the organisation per se, thus interfaces are coloured by the ability to communicate and work with representatives of other organisations. Effectiveness of the relationships is dependent on compatibility of the individuals concerned. These interfaces are more challenging to define, map and manage because over the course of a project it is not uncommon for individuals to move jobs or be allocated to different projects, thus introducing new interfaces.

Interface management is a particular concern of the project manager and increasingly the construction design manager, both roles being central to the coordination of information and resources and a feature of supply chain management. Some of the main areas to consider are:

- Interface definition. Map primary and secondary interfaces and identify areas of uncertainty.
- Responsibilities. Clearly defined and visible areas of responsibility can help to reduce disagreements and disputes.
- Communication. Clear and effective communication is central to interface management.

These areas should be considered both at the early planning stage of a project and on a regular basis as the project evolves because the interfaces will change over time.

3. BACKGROUND TO THE CASE STUDY

The case study company is a small design and build main contractor, operating within the social housing sector in the Greater London area. It employs its own workforce of project managers, site managers, plumbers, carpenters, bricklayers, decorators and other site operatives. Directly employing its own workforce has allowed the company to maintain and deliver work to high quality standards, through which it secures repeat work from social housing landlords. Based on the company’s reputation for quality, the majority of its work comes through cost negotiations with clients, rather than through competitive tendering. The majority of their work comes directly from social housing
providers. It is common for the architects and structural engineers to have been appointed before the contracting organisation. The effect of this is that the contracting organisation has little choice over the design consultants, thus for each new project it is common for the organisation to find themselves working with new, unfamiliar, consultants. Thus the organisational and personal interfaces are different for each project. The challenge for the contracting organisation is to manage these interfaces effectively.

As noted above, the attention to the flow of work on the construction sites and the various initiatives to develop and embed a lean culture (see Mann, 2010) within the contracting organisation helped to identify the importance of the designers/contractor interface. This resulted in the development of a standardised design management protocol, which aimed to address communication and responsibilities for producing and checking design information (see ‘step 1’ below). Although lean thinking can be interpreted and applied differently depending on the context, in this example lean design management was focused on reducing process waste from the contractor’s perspective. This may be different to the interpretation of lean within architect’s offices (see for example Emmitt, 2007; Hansen & Olsson, 2011).

4. METHOD

A key characteristic of knowledge transfer projects is the desire to bring about change and document that change. The KTP associate is embedded in the organisation and is ideally placed for gathering information from the workplace. Combined with data collection from the academic supervisors a degree of balance is possible within the data collection. Data was collected by conducting face-to-face interviews, observing meetings through non-participant and participant observation and analysing project documentation.

The projects, and hence the project participants, were self-selecting, in that all four projects started around the same time and coincided with efforts to bring about a lean culture within the contracting organisation and its supply chain. Two firms of architects and one firm of engineers were involved in the projects. The aim of the research is to collect data throughout the entire life of the four projects. These projects are currently under construction; therefore, the emphasis in this paper is the pre-construction phase.

Phase 1 - Pre-construction

Step 1 was to devise a design management protocol to help the contractor better manage design information produced primarily by the architects and structural engineers. The draft document was devised by the KTP associate and discussed with the contractor in terms of its practicality. Following feedback on the initial proposal the design management protocol was finalised and first used on a number of projects commencing in 2010. The aim was to monitor the effectiveness of the design management protocol and make practical adjustments in response to feedback from current projects, an activity which is ongoing.

Step 2 was to hold ‘orientation’ meetings between the contractor and architects and engineers before design work commenced. The aim of the orientation meetings was twofold. To identify any areas of concern in relation to the production drawing programme. To discuss the contractor’s approach to lean design management and familiarise the consultants with the lean culture (as interpreted and applied by the contractor). Feedback from the design consultants and the contractor indicates that this was a successful management intervention.
Step 3 was to interview the architectural practices (at the time the structural engineers were unavailable). Two architects, one ‘project architect’ and one associate/partner from each firm were interviewed. The aim was to better understand the needs of the architects from the contractor’s perspective. This is described in further detail below.

Step 4 was to conduct a number of collaborative design management workshops, two of which are described in fuller detail below.

5. RESULTS – INTERVIEWS WITH ARCHITECTS

Shortly after the commencement of the projects two researchers (the KTP associate and one of the academic supervisors) met with two representatives of each architectural firm for an open discussion about the architect/contractor relationship. Each architectural firm was represented by the job architect responsible for the projects and a partner/associate of the firm. Each discussion lasted approximately two hours. The question; “how can we (the design and build contractor) improve the production of design information?” was put to the representatives of each architectural firm as a means of stimulating discussion. The intention here was to identify broad themes, thus handwritten notes were taken by both researchers in preference to audio recordings.

5.1 Recurring themes

Analysis of the notes after the interviews were completed revealed striking similarities between the two architectural practices. These similarities are described under four discrete headings:

Production drawings

Unprompted by the researchers both firms of architects said that they were often prevented from completing their working drawings because they were waiting for decisions to be made by the contractor. Interestingly, both sets of architects independently and unprompted stated the same three problem areas:

- Not placing the order for the lifts early in the contract period. Until the lift order has been placed with the lift manufacturer the architects cannot get definite information on lift shaft sizes; which prevents the completion of the production drawings. They felt that that contractors delay the choice of lift manufacturer, and hence the placing of the order, until too late in the contract.
- Not deciding whether imperial or metric door sets were to be used. Because these door sets differ in size it is not possible to complete the production drawings without a decision.
- Not deciding on the kitchen layout. Again, this delays the completion of production drawings and also delays the positioning of water, gas and electricity points.

All three issues could be regarded as rather minor in the overall context of the project, but combined the uncertainty around these three areas prevent the architects from completing their drawings and hence delay the issue of information to the contractor.
Management of the design process

Both architectural practices had in place rigorous review techniques to analyse the conceptual design drawings to identify issues for clarification prior to commencing the production drawings. Both practices said that these procedures were in place to try and prevent the “unnecessary” revision of drawings. The only difference between the two architectural practices was that they conducted their design reviews at slightly different stages in the process (based on differing interpretations and application of the RIBA Plan of Work).

There was a difference between the two architectural practices in terms of their attitude towards, and use of, architectural management procedures. One of the architectural firms appeared to be extremely well organised and efficient. They applied standard working methods and appeared to be consistent in their approach to projects. The practice was experienced with working to management systems imposed on them by large contracting organisations. However, they claimed that many of the managerial systems used by the large contractors were too onerous and it caused them to do work that they felt did not add any value to the process. Their request was for “less, but better, design management” by the large contractors. The other architectural practice was less familiar with commercial projects and appeared to be rather poor at applying managerial procedures. Although the practice had managerial procedures in place, one of the architects claimed to be unaware of them and the other claimed to use them only when necessary. The overall feeling from the interview was that this practice was not well managed and had an inconsistent approach to management of their projects.

Communication

Again, both architectural firms expressed the desire for better communication between contractor and architect. Their desire was for one or two meetings early in the project to discuss the scheme with the aim of exploring and resolving uncertainties with the design. The architects claimed that the failure of contractors to make decisions early in the process often caused them problems with completing their production drawings, often resulting in unnecessary rework to accommodate late decisions. One of the architectural firms thought that there was a need for better procedures while the other claimed that from their experience more managerial procedures merely transferred the decision making responsibilities, with the result that decisions took longer than was necessary.

Knowledge of lean

Given that the KTP aimed to embed a lean culture within the contracting organisation, the architects were asked about their knowledge of lean and (as a response to the comments made in the interviews) their knowledge of design fixity. One of the architectural practices had a very basic understanding of lean construction; the other had no experience or knowledge of lean other than they were aware that the contractor was trying to implement a lean culture (from the orientation meeting). Neither of the architectural practices had any knowledge of design fixity, although after some discussion and explanation by the interviewer, the more management aware practice said that they would investigate it further.

5.2 The contractor’s response

A summary of the findings from the interviews was put to the directors of the contracting organisation. Although they were initially surprised to discover some of the issues that caused the architects concern, they were quick to respond and put in place measures to help the architects. The
initial surprise is a common response when people start talking; individuals tend to make far too many assumptions about the way in which others work. This is a fundamental part of lean thinking, seeing for oneself. The three issues identified (lift manufacturer, door sets and kitchen layout) could all be addressed and a decision made much earlier in the process without any cost implications. The request for better communication helped to justify the orientation meeting and also the development and implementation of a design management protocol. The difference in approach to architectural management by the two firms of architects had already been picked up by the contractors. Their initial dealings with the architects had suggested to them that one of the architectural practices was going to be more challenging to work with than the other. The findings of the interviews supported their initial perceptions, with the result that the contractors expected challenges to arise and were alert to the problems this might create for their programme of works. One of the efforts to address the architectural practices perceived managerial shortcomings was to invite them to a collaborative planning workshop in the hope that they would better understand the pressures faced by the contractor.

6. RESULTS – COLLABORATIVE PLANNING WORKSHOPS

As part of the KTP a number of collaborative planning workshops were introduced to address the flow of work. The collaborative planning workshops described below were organised by an academic and the KTP associate and observed by a second academic. The aim was to plan the construction programmes collaboratively, drawing on the expertise of those contributing. By discussing the flow of work and interactions between trades the intention was to try and save time and hence condense the programme. A secondary aim was to bring the main participants together to meet, share their knowledge and become better acquainted with the lean thinking philosophy.

Face to face meetings help the project participants to make better promises, which in turn increase the reliability of work flow. By engaging in the workshops the participants will develop a personal relationship with the other project contributors. As a result individuals are more likely to take personal responsibility for their actions and consider their actions in relation to others, as a result there is a stronger likelihood that individuals will do what they say. The intention of the collaborative planning workshops is that the project manager becomes a facilitator of relationships, rather than a commander in control.

6.1 Collaborative planning workshop – number 1

A collaborative planning workshop was held prior to the start of two of the projects to plan the project programme. Participants included the architect, the engineer, piling contractor, scaffolding foreman, bricklaying foreman, and carpentry foreman. Participants were encouraged to discuss their work packages with others so that they could explore how the work could be planned to be efficient. The outcome of the workshop was that two weeks had been removed from the twelve week programme.

One of the directly observed benefits of the workshop was the interaction between the designers and the trade foremen. At the start of the workshop the body language of the participants was defensive and it was clear that the architect was uncomfortable with the workshop approach and was reluctant to contribute. The engineer appeared to be more relaxed by comparison to the architect and took the lead in helping to plan the work. As the workshop proceeded the participants started to relax and the body language became much less defensive. Although the architect remained aloof, he did start to discuss issues with the trade foremen. In a few instances it was observed that the architect and trade foremen were discussing the type of information required on the drawings to help them build the building. For
example, the way in which a parapet wall was to be constructed necessitated some specific information that had not previously been considered. The discussion highlighted the requirement for additional information and agreement was reached very quickly about the most efficient way to construct the detail, and the information required by the site operatives. Although the architect did not stay for the entire duration of the workshop he had made an important contribution to the understanding of the key information required on the production drawings.

6.2 Collaborative planning workshop – number 2

A second collaborative planning workshop was held just after the two projects had started on site. In this workshop emphasis was on the flow of the work to the superstructure and roof, and the concurrent programme for both projects. Participants included the main trades employed by the contracting organisation, such as the scaffolding foreman, bricklaying foreman, carpentry foreman. The architects and engineers were not present. Emphasis was on the flow of work associated with bricklaying. The traditional approach of building long runs of wall was questioned and radically altered to reflect the much smaller runs (‘batches’). This allowed other trades to follow the bricklaying much sooner than usual, helping to condense the programme associated with each housing unit. It is important to note that the savings in time were though smarter working, using small batches, not the result of working quicker or under more pressure.

The workshop was successful in helping to plan the flow of work and also because a further week was removed from the programme. This workshop also helped to demonstrate that the employees were becoming comfortable with the lean thinking philosophy and significantly they were starting to question how they worked with a view to improving their efficiency. After the workshop the participants said that the interaction had helped them to better understand other trades, which helped them to think differently about the way in which they worked. This is evidence of the ‘next customer’ in the flow of work. There was also a growing understanding of the importance of seeing the whole building and the interface with other trades, rather than a narrow local optimisation that was prevalent prior to the KTP.

7. DISCUSSION

Although this paper is reporting the very early stages of the research project, the results provide some useful insights into the designer/contractor interface. The interviews revealed different cultures between the two architectural practices. One of the practices was fully aware of the value of architectural management. This practice was also critical of the large contractors’ application of design management, claiming that less administration (checklists and approvals) was required and better management. They felt that the large contractors were not adding value to the project by having overly onerous design management processes; they felt that this resulted in additional work and long periods for a decision to be made. The other architectural practice appeared to be rather indifferent to architectural management, applying management when deemed to be convenient. Similarly they appeared to have very little appreciation or desire to understand contractors.

With respect to interface management issues the interviews were instrumental in helping to improve communication between the architects and the contractor. It was evident that the collaborative planning workshops started to break down personal barriers, resulting in less defensive behaviour and interpersonal communication between architect and trades foremen for the first time. This had a direct benefit of helping to improve the clarity of some of the drawings provided by the architects. Observing the workshops it was also evident that the participants were learning to work with lean thinking tools.
Examples being: planning collaboratively, the importance of work flow, next customer, optimising the project as a whole, and using smaller batches to aid work flow. Seeing all of these mechanisms in a live project environment also provided a common learning platform which is a significant step towards standard work structuring. Standard work structuring is regarded as the primary route to innovation and continuous improvement in the lean thinking literature. Standard work structuring is also an important component of lean design management.

The organisations involved in this research are small and all have limited resources on which to draw: hence the need for simple and effective design management procedures. Lean thinking and the tools that fall under the lean umbrella, such as collaborative planning, appear to be well suited to small organisations. These tools not only help the project participants to understand the scope of the project they also help to emphasise the requirements of the client to the project contributors. This helps to make client value more visible and removal of waste from the process more effective. Participants have developed a better understanding of what is required, why and how they can change what they do to become more efficient. This is critical in the current economic climate, but it is also an important contribution to the longer term sustainability of the business in any climate.

8. CONCLUSIONS

One of the benefits of the KTP for the contracting organisation is that the research interventions highlight issues that can be addressed immediately within ongoing projects. For example, the realisation that the architects required confirmation of the lift manufacturer much earlier in the project could be easily addressed without any cost implications. This helped to give the architects greater certainty and in turn leads to more efficient drawing production. Taking our cue from production system design it is clear in the workshop examples reported above that not all building design is done by the designers and engineers. A lot of design is done by the operatives and therefore terms such as ‘lean design’ and ‘lean design management’ need to be understood from a system perspective.

Developing a lean thinking culture in the contracting organisation has resulted in greater awareness of the value of efficient interfaces between the contractor and its consultants. This has brought about attention to design management, and the first steps in the development of a lean design management protocol. Ongoing research will address the construction phase and also the post-construction phase through observation, interviews and analysis of project data. The final step will be to analyse the design management protocol and make improvements based on the analysis of the data. It is the intention of the paper authors to report this work at a future meeting of CIBW096 and develop the protocol into a generic tool that could be used by others on small construction projects.

The challenge that remains for the contractor is the uncertainty of the organisational interface. With each new social housing project they inherit a new firm of architects and engineers. This results in new personal interfaces between individuals. The contractor’s view is that they need to start again with every new project, trying to inform (one might argue educate) the architects and engineers about their lean culture. Yet it is the interface which is a constant denominator and which needs to be addressed further. Additional applied research is needed to address the organisational interface and the development of appropriate practical tools and methods will be crucial in helping the contractors to remain efficient. This should help to shed further light on aspects of lean design management.
9. REFERENCES


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Architectural Management: Exploring Definitions and Impacts

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Abstract: Since the emergence of the term ‘architectural management’ nearly 50 years ago in the UK there have been very few attempts to define the term, or indeed, the field of knowledge. Most of the work in architecture, engineering and construction (AEC) has been associated with the CIB commission W096 Architectural Management. Parallel to this has been the use of the term architectural management in the field of information technology (IT). With architectural management increasingly conducted in a digital arena the definitions from the field of IT appear to be increasingly pertinent to those working in AEC. By bringing together definitions from both fields a number of questions arose about the term architectural management, the role of the architectural manager and the impact of CIB-W096 on architectural practice. A questionnaire survey was designed and issued to individuals associated with CIB-W096 in an attempt to gather some informed views on these issues. Also, the websites of three well-known recruiting agencies were consulted regarding the architectural manager’s job description and qualifications. The results were combined with the findings of the literature review to propose a definition of architectural management that is relevant to our current, digital, era.

Keywords: Architectural Management, Definitions, Impact, Information Technologies, CIB-W096.

1. INTRODUCTION

The first emergence of the term Architectural Management (AM) was in 1964; since which time only a few attempts have been made to define the term. This is despite arguments that have articulated the importance and significance of architects adopting architectural management. Based on reviewing the literature, only eight attempts have been made to define AM: Brunton et al. (1964), Boissevain and Prins (1993), Bax and Trum (1993), Banks (1993), Freling (1995), Nicholson (1995), Akin and Eberhard (1996) and Emmitt (1999a, 1999b). Each of these studies proposed a definition based on certain types of methodology. As a result, different thoughts, scopes and functions were included under the umbrella of architectural management. Nicholson (1995) attributed the difference in definitions to the fact that each individual considered the term from different perspectives, as a result of their different backgrounds. Nicholson also argued that defining this term might differ in ‘interpretation’ among different construction professionals. Given that the most recent attempt to define AM was in 1999 (by Emmitt), it would appear timely to revisit and upgrade the definition in light of the following motivations:

- The vast amount of data and information of today’s knowledge society.
- The continuous changes within the construction industry: e.g. competition, changing roles.
- The recent advances in technologies, e.g. Building Information Modelling (BIM), which might reshape the character of the previously defined roles and concepts.
As claimed by Swartz (2010), defining terms aims to improve humans’ use of language as well as eliminate any kind of uncertainty. Further, developing a common definition is essential for future constructive debates in the field of AM. Thus, the research reported here does not aim to produce a new lexical definition, but it intends to articulate a description of AM, with the aim of eliminating unnecessary vagueness in its context and use.

2. RESEARCH METHOD

This research was conducted through five sequential stages. First, the previous endeavours to define the term architectural management were analysed chronologically based on a literature review. This stage aimed to identify themes and issues associated with AM. This was followed by an analytical comparison of how the term is used in the field of IT. Then, the role and job description of the architectural manager was identified through literature as well as through consulting several recruiting agencies’ job advertisements for architectural managers, which reflect the market needs. The fourth stage of this research was conducting a questionnaire survey administered to the CIB-W096: Architectural Management data base of members and friends. The questionnaire survey aimed to gather experts’ perspectives of AM definition and its impact. This data was then brought together and analysed. The result is a new definition of AM for the digital era.

3. LITERATURE REVIEW

3.1 Architectural Management

The starting point comes from when Brunton et al. (1964) launched the term architectural management in their book ‘Management Applied to Architectural Practice’. During the course of their discussion AM was defined as: “Architectural management falls into two distinct parts, office or practice management and project management. The former provides an overall framework within which many individual projects will be commenced, managed and completed. In principle, both parts have the same objectives but the techniques vary and mesh only at certain points”. Brunton et al. (1964) argued that the office is the vehicle through which the projects are delivered and these two parts “mesh” at certain points. According to Emmitt (1999a), this was the first appearance of the term. With the establishment of the CIB Working Commission W096 Architectural Management in 1993, Boissevain and Prins (1993), and Bax and Trum (1993) were asked to conduct research to define the term on behalf of the Commission. Boissevain and Prins (1993) attempted to develop a model to include all the possible areas encompassed by the ‘context of architectural management’. In their model they distinguished two environments (internal and external) to classify the place of each function within the context (Nicholson, 1995). From their model, it can be understood that managing architectural knowledge, design process and methods (internal functions-office activities) while considering the project context and supposed use (external functions-project tasks) leads to creating specific design strategies which are encompassed by architectural management. Then, AM was considered as a vehicle to monitor and control the project production and performance. The model did not mention the business side of the profession or market competition. Also, the model can be viewed as a call for architects to re-engage in practicing the administration of the whole project life-cycle.

Bax and Trum (1993) followed a similar approach by developing a model to categorise the location of ‘architectural artefacts’ into three levels: the urban environment of the building-level, the building-level, and the building details-level. They claimed that each of these levels represented a degree of
specialisation and thus a field of knowledge or ‘domain’, (Nicholson, 1995). In analysing these three domains and considering the qualitative nature of the domain theory, several functions with characterised similarities can be listed under each domain. But it is hard to decide which domain would encompass the managerial tasks as well as the business aspects of the profession, unless adding a new management domain.

Based on Bax and Trum (1993)’s argument, Boissevain and Prins (1993) developed their model into the ‘Architectural Taxonomy Model’, (Nicholson, 1995). In analysing the model, it can be argued that it failed to cover the two wings of architectural management highlighted by Brunton et al. (1964); hence it ignored the management of the office functions. Furthermore, the taxonomy theory aims to classify elements under a main category; in their model the main category was the ‘architectural concept’ not ‘architectural management’. This could misinform the advocating of the concept of architectural management and narrow it to a small part of its components, the ‘concept design’.

A simpler definition of architectural management was proposed by Banks (1993), cited in Nicholson (1995), as: “Architectural Management encompasses the more philosophical approach to management of the architectural processes covering management development theories and concepts with particular relationships to the wider construction industry”. This definition urges the adoption of the managerial concepts and theories to the construction industry and the utilisation of their potential advantages. It can be argued that this definition is wide ranging and does not specify what AM entails.

In his PhD thesis Nicholson (1995) proposed two definitions of architectural management. Firstly, AM was described as an academic specialty and a professional area that covers the following tasks: office management, design management, the management of human, technical and financial resources, construction supervision, facilities management, building refurbishment and demolition. Compared to Banks (1993) wide interpretation of AM, this definition narrows the scope of architectural management to include; managing different functions within the office and within the project life-cycle, but without illustrating the necessity to integrate them and managing them in parallel. This definition gave attention to the importance of AM as both an academic and professional discipline.

Nicholson (1995) tried to offer a further abridged definition of AM as: “All those areas of expertise of the architect which do not include design skills”. Furthermore, he concluded that: “The definition of Architectural Management extends the domain of and need for a broader educational base”. He asserted that it cannot be separated from design education and hence AM provides the necessary skills for architectural practice. In this definition, the problem of the management exclusion within the architectural design-focused programs was highlighted. After discussing these two definitions in his thesis, Nicholson (1995) argued that the first book with the title ‘Architectural Management’ (Nicholson, 1992) did not offer a definition of AM in order to give contributors of the AM conference in Nottingham the chance to present whatever they felt relevant to the field. He further claimed that the ranking of relevance of the included topics to AM was agreed upon based on the consensus theory as follows: design process, production process, process of use, product definition, maintenance, strategies for use, facilities, and definition of need.

Also in 1995, a simple philosophical definition which saw architectural management as a constant reviewing approach to evaluate the position of architects in the construction industry and the tools they needed for their practice was put forward by Freling (1995). This definition portrayed AM as a remedy to help architects return to their ‘lost position’ and regain prestige within construction.

In the following year Akin and Eberhard (1996) offered a description of architectural management as the combined management functions involved in the design, construction and operation of buildings, (Akin and Eberhard, 1996). Similar to Nicholson’s definition, this description stated the necessity to consider managing all the functions throughout the project whole life-cycle, but it went further, highlighting the importance of combining the managerial functions under one tool, AM.
Finally, the definition by Emmitt (1999a) states that: “The term architectural management is used to cover all management functions associated with a competitive professional service firm. Project management, design management, construction management and facilities management are all covered by the umbrella of architectural management, areas of specialist interest which are themselves interdependent upon quality management and human resource management, lying at the heart of a firm’s culture.” In Emmitt’s (1999a) definition, the concepts of competitiveness and firm’s culture were mentioned for the first time. Firstly, AM was interpreted as a range that covers all the managerial tools and functions which would increase the firms’ competitiveness within the business. Then the two components of AM, as highlighted by Brunton et al. (1964), were detailed and expanded by Emmitt (1999a & b).

Three simple definitions of AM are presented on the Wikipedia website. Although Wikipedia is not considered as a consistently valid or authoritative source of obtaining research data, it was decided to consider these definitions for the sake of covering every attempt to define AM. Architectural management can be considered as “an ordered way of thinking which helps to realise a quality building for an acceptable cost”. It is “a process function with aim of delivering greater architectural value to the client and society”. Further, it was described as “a subject of practical aspects for an architect to successfully operate his practice”, (Architectural Management Page: Wikipedia Website, 2011). The first two definitions emphasised the results given to the consumers, clients and society, but did not mention AM’s benefits to architects. The third definition resembled AM as a way of working for architects without describing what it entails. Thus, currently the material on Wikipedia does not add anything new to our understanding of AM.

On the CIB-W096 Website – Home Page, AM is described as “Architectural Management is about managing the Design of Buildings by means of the three P’s: Product, People and Processes to gain the highest quality of design within limited time and budget”, (CIB-W096 Website, 2011). This description narrows the scope of AM to the design management function. But, it can be interpreted that this was a reflection of the CIB-W096: International Conference on Design Management in AEC theme held in Brazil in 2008.

After reviewing these definitions it can be concluded that each attempt sheds light on aspects to be included under the AM umbrella. Table 1 summarises the key features extracted from each definition.

<table>
<thead>
<tr>
<th>AM Defined by</th>
<th>Year</th>
<th>Major Aspects of definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunton et al.</td>
<td>1964</td>
<td>Office management and Project management</td>
</tr>
<tr>
<td>Boissevain and Prins</td>
<td>1993</td>
<td>Contexts: Two environments (internal and external)</td>
</tr>
<tr>
<td>Bax and Trum</td>
<td>1993</td>
<td>Domains of architectural management</td>
</tr>
<tr>
<td>Banks</td>
<td>1993</td>
<td>AM is a philosophical approach</td>
</tr>
<tr>
<td>Freling</td>
<td>1995</td>
<td>AM is a reviewing approach and tools</td>
</tr>
<tr>
<td>Nicholson</td>
<td>1995</td>
<td>Academic &amp; Professional discipline</td>
</tr>
<tr>
<td>Nicholson</td>
<td>1995</td>
<td>All areas of expertise beyond design</td>
</tr>
<tr>
<td>Akin and Eberhard</td>
<td>1996</td>
<td>Combined management functions</td>
</tr>
<tr>
<td>Emmitt</td>
<td>1999</td>
<td>Competiveness, Office Environment. &amp; Project Environment., culture</td>
</tr>
<tr>
<td>Emmitt et al.</td>
<td>2009</td>
<td>AM as value adding</td>
</tr>
</tbody>
</table>

While conducting the literature review it was found that the world of information technology (IT) borrowed the terms architect and architecture from construction, but with better comprehensive descriptions. Thus, the following discussion is an analogical comparison between the construction and IT industries in their utilisation of the term and the position of architects within their organisations.
3.2 A Visit to Architecture in IT

In order to define architectural management accurately, it is essential to understand the words comprising the term, ‘architecture and management’. Instead of understanding the lexical meaning of the words, it is better to understand what they mean in practice. This section provides a brief analogy on how these terms are used and defined in the software and IT industries compared to the construction industry.

The terms ‘architect’ and ‘architecture’ were adapted from the building industry to the IT world. Paradoxically, IT professionals start defining these terms and assign job description based on the ideal situation in and lessons learned from building architecture. In the world of IT, the term ‘architecture’ was defined as: “the fundamental organisation of a system embodied in its components, their relationships to each other, and to the environment, and the principle guiding its design and evolution”, (IEEE Computer Society, 2000). The definition relates to ‘architecture’ as a managing and organising tool to design and operate systems.

Similarly, the American Society for Information Science and Technology defined the term ‘information architecture’ as: “the art, science, and business of organizing information so that it makes sense to people who use it” and architects were defined as: “…the members of the team who choreograph the complex relationships among all the elements that make up an information space…”, (ASIST Website, 2011). These two definitions describe ‘architecture’ as a combination of art, science and business of the organisation process and ‘architects’ as the responsible participants of arranging the different relationships of elements, two descriptions lacked in the current building architecture and building architectures.

Bredemeyer and Malan (2006) claimed that it is common practice for IT architects to utilise the lessons learned within the building architecture context. They described the building architect as being responsible for providing structural designs as well as managing the relationship between the project client and contractor, while on the other hand the system architect is mainly responsible for increasing the organisation’s competitiveness. Thus, IT emphasises the role of the system architect in managing and pioneering the business side of their profession.

Similarly, Jonkers et al (2006) define the role of the building architect as the professional responsible for specifying the design and construction of a building based on the requirements of its owner/ potential users and in accordance with the professional regulations. Ironically, even IT professionals claim that the word architecture is vague in the context of the construction industry. Jonkers et al (2006) explained that enterprise architecture entails several domains: information architecture, process architecture, application architecture, technical architecture and product architecture. These domains must be integrated as a whole to result in successful enterprise architecture, (Jonkers et al, 2006).

Muller (2010) described the role of the system architect (SA) based on three perspectives: deliverables, responsibilities and activities. Interestingly similar to the building architect, Muller described the final outcome as clearly visible as well as tangible compared to the invisible tasks and activities practiced by the system architect.

Analysing the analogy between the two industries has the potential to exchange and transfer lessons and strategies. In this comparison, the aim was to understand the roles and position of the ‘professional architect’ within the context of each industry.
This is in order to ease the process of updating the AM definition.

The following diagram was articulated from Bredemeyer and Malan (2006), and Muller (2010) to outline the tasks carried out by the SA, Figure 1.

The figure shows similarities to some of the tasks urged to be practiced by the building architect and outlined in the RIBA Plan of Work Stages. But, unarguably, IT industry was a step ahead in adapting managerial concepts and techniques.

Pulkkinen (2006) argued that enterprise architecture decisions must be taken on the highest levels of leadership considering: strategic business strategies, information, technology and systems. Also, the architect position within the organisation is at the highest level.

Within the construction industry, the common description of the architects’ role can be obtained from RIBA Plan of Work. This plan of work categorises the construction project into four major sections and these sections comprises twelve stages. It can be seen from Figure 1 that architects are considered business champions in the IT industry. Their roles and tasks are practiced at the corporate highest levels. On the other hand, architects are professionals who practice design and some narrow scope of management within the building industry.

4. RECRUITING AGENCIES

Based on reviewing the AM literature, the title of ‘architectural manager’ was, as far as we know, only mentioned in Nicholson (1995) and Emmitt (1999). The former strongly demanded the emergence of this profession; and claimed that the architectural manager is responsible for: design briefing, project management, safety planning and facilities management. While Emmitt (1999) expressed the architectural manager’s role in leading architectural practices by managing clients, individual projects, and the firm’s assets. In defining the term it is also essential to understand the tasks and duties carried out by architectural managers in industry and the market needs. The best source to obtain this type of data was through recruiting agencies’ advertisements for architectural managers. After consulting the websites advertisements of three well-known recruiting agencies, the tasks of ‘architectural manager’ was summarised under two different levels: strategic level and design management level, as follows:

<table>
<thead>
<tr>
<th>Table 2: The Architectural Manager Job Description – Recruiting Agencies Websites</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At the organisation strategic level, AM is required to:</strong></td>
</tr>
<tr>
<td>be the interface between construction sites, head office and clients;</td>
</tr>
<tr>
<td>assure achieving the organisation’s goals;</td>
</tr>
<tr>
<td>identify the organisation’s priorities;</td>
</tr>
<tr>
<td>participate in developing the organisation’s policy and development plans.</td>
</tr>
<tr>
<td>lead, monitor and motivate personnel;</td>
</tr>
<tr>
<td>act as a leader of various teams and coordinate their efforts.</td>
</tr>
<tr>
<td>develop/manage architectural designs and coordinates construction contracts;</td>
</tr>
<tr>
<td>plan, organise and manage architectural activities within organisations;</td>
</tr>
</tbody>
</table>

And the main requirement for the architectural managers’ position is that applicants must have the balanced skills and knowledge in design, management and technology as well as the expertise in both design and construction of projects.
5. QUESTIONNAIRE SURVEY

The last step on this journey of defining architectural management is analysing what context it operates in, what advantages it can bring and who is responsible for advocating its deployment. These questions were addressed by examining the views and opinions of the CIB-W096 community. This was conducted through an online-questionnaire survey comprising a list of eight open-ended questions. An invitation was sent to all members and friends of CIBW096 as held on the current database of email addresses. 50 people were contacted, with 14 people completing the survey, giving a response rate of 28%. This section provides a brief discussion of the survey results.

1) What does the term ‘Architectural Management’ mean to you?

The first question aimed to gather the perceptions of the CIB-W096 members and friends towards the meaning of AM. The replies showed a high degree of variety; and can be organised into three categories. Some respondents (5/14) defined AM as the management of the associated activities with design; others (2/14) claimed that it is about engaging and managing the construction process; while the third category (7/14) combined these two functions and extended the domain of AM to cover other aspects of the profession. Some of the different views regarding the meaning of AM are:

- “The gathering of the three most basic distinctions of a society, namely education, economy and culture. Architectural management is about all these subjects, thus about thinking, doing and feeling!”
- “Coordinating people and information towards the goal of getting the design of a building built”.
- “Managing our reasoning capabilities...........Thus, managing the meaning of life”.
- The management and organisation of aspects associated with architectural design.
- The term is mainly applied in construction engineering denoting a field of different strategies and tools for a more systematic approach in construction phases.

2) What are the impacts of Architectural management since the establishment of the CIB-W096 Working Group in 1993 until today?

The replies to this question varied from; the role of AM in increasing value through design to the positive impact on the construction process. Generally, the respondents agreed that the successful impact was the building of an international research group and discussion platform for those interested in AM field, but less impact (“if any”) is seen on the practice level. Some criticism was focused on the lack of clear guidance for practitioners to adopt AM. Similarly, some respondents claimed that AM is still not recognised by professional bodies and educational institutes. Some recommendations emphasised the need for further research and more published guide books in the field of AM.

3) What are the benefits of deploying Architectural Management?

The aim of this question was to understand the respondents’ perceptions towards the benefits AM, thus understanding what can attract professionals to adopt architectural management. Among the replies, respondents emphasised on the following: creating a better relationship between the different phases of the project life-cycle; more efficient management of designers within the practice; better interface with clients; increasing the efficiency and control of the final product delivery and outcome;
stimulating education, economic activity and our cultural identification; improving the understanding of ways architecture and related fields are practiced; and AM can help in creating “holistic societies”.

4) What are the duties carried out by the Architectural Manager?

The fourth question aimed to understand the tasks carried out by architectural managers and thus ease the process of defining AM. Based on their replies, respondents can be categorised into two groups. Three respondents claimed that it is not necessary to have a professional with this title; rather any design professional with adequate managerial tools can practice AM. On the other hand, the second group’s views (11/14) agree with what was found in section 4; especially regarding the strategic position of the architectural manager within organisations, shown in Table 3:

Table 3: The Architectural Manager Job Description – Questionaire Survey

<table>
<thead>
<tr>
<th>At the organisation strategic level, AM is required to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Managing the business aspects of the architectural organisation.</td>
</tr>
<tr>
<td>• Forecasting and analysing the potential impacts of any business decision, thus making the most informative and effective choices.</td>
</tr>
<tr>
<td>• Controlling and monitoring the achievement of the organisation’s goals.</td>
</tr>
<tr>
<td>• Managing the clients’ interests and relationships.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>At the design management level, AM is required to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Managing and supervising the different activities involved in the project whole life-cycle.</td>
</tr>
<tr>
<td>• Managing the design staff / and assuring their continuous education and development.</td>
</tr>
<tr>
<td>• Managing the value design and delivery.</td>
</tr>
<tr>
<td>• Sorting out and managing the complicated architectural process in each project.</td>
</tr>
<tr>
<td>• Assuring schedule control, cost control, and quality Control.</td>
</tr>
</tbody>
</table>

Interesting comment was emphasised by two respondents that there is a distinction between a design manager (usually project specific) and an architectural manager (responsible for projects and office effectiveness). Also, two replies claimed that other terms can be used to refer to the architectural manager based on different terminology in different countries.

5) Who is qualified to practice the role of Architectural Manager?

The responses to this question can be categorised into three groups; where five respondents state that this role can be carried out and practiced by any professional provided his/her experience and expertise in both design and construction in addition to some managerial skills. The second view (6/14) emphasised that architects are only the ‘gurus’ of architectural management and no one else is capable of practicing this role effectively. Both views agreed that the architectural manager should be a reflective practitioner and have a strategic “helicopter” view. The third view (3/14) argued that AM must be practiced by every member within the organisation and projects and it is about teamwork and team effort.

6) What would attract architects to adopt Architectural Management?

Respondents claimed and argued that the understanding of AM’s role in: surviving competition; practice growth/success; enhancing performance; competitiveness; value design and delivery; financial return and profit; efficiency; serving clients and society; adaptability; and better monitor and control of process/product is only motive of AM adoption.
7) **What strategies are needed to deploy AM in architectural practices?**

Most replies agreed that it is hard to define a set of strategies for AM deployment unless architects recognise the need to manage their organisation/business professionally. Also, respondents claimed that strategies shall differ to suit different organisations, but all these strategies can be characterised as being ‘long-term’ strategies. Some respondents emphasised the role of effective HR strategies, resource planning, effective communication and better education as basic strategies for deploying AM.

8) **Please use this space to add any further information regarding Architectural Management**

The final question of this online-survey was left open to the respondents to add any comments or notions regarding architectural management. Among the replies, the following list shows some repetitive thoughts by respondents regarding (AM in practice, education, and the role of CIBW096):

- “It is difficult to see how architectural management has evolved. There are still no clear philosophies, no clear guidance, and no clear message from CIBW096. CIBW096 is a good meeting place and encompasses a broad range of ideas and views, which is good to participate in, but the weakness is that to those outside the group there is no clear strategy - perhaps there should be”.
- “The practice must learn to think more universal, through holistic models, models that encapsulate the ‘entire’ reality”.
- “The day architects become interested in management will be a day for celebration - first there needs to be a revolution and this must start in education”.

6. **DISCUSSION AND CONCLUSION**

This research is an exploratory study to understand what the term architectural management means based on the recent advances in the construction industry and management science. After utilising different data collection methods and analysing the findings this paper is concluded with a new definition of AM. The new definition does not attempt to question the clarity of previous definitions; rather it aims to suggest a working definition that could be agreed upon by the members and friends of the CIB-W096 with the objective of developing the field of AM.

As claimed by Swartz (2010), any definition is composed of two parts: **Intension** and **Extension**. The former specifies a set of logically necessary and jointly sufficient conditions for the application of a term; while the latter defines terms by sampling and listing their extensions. Thus, if the extension is known and agreed upon, then the intension should fit the extension as closely as possible; otherwise, the definition is considered too broad and wide in its scope and description. During the course of this study, it was noticed that most of the early defining attempts are too broad; they admit too many members to the extension of AM as exemplified in Table 4; also the intension is not agreed upon as showed in Table 5.

All of the previous intensions and extensions of AM, summarised in Tables 4 and 5, are applicable to architectural management; but it was noticed that each defining attempt aimed to include whatever new aspect or innovation appeared in the industry or within managerial science. For example, the issues of sustainability; value design and delivery; competiveness; utilising BIM, did not appear in the early defining attempts, but once surface or debated, researchers included them in their definitions.
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Table 4: AM Extensions from the Research Findings


Table 5: AM Intentions from the Research Findings


The principle guiding strategy for this new definition was to present both clear and flexible intension and extension of AM, which describes its nature, what it entails, and what might be included in the future. It is argued that such a definition could ease and enhance further research work in the field.

First, it is important to distinguish AM from the Alternative Method of Management, (AMM) to avoid any confusion. AMM was invented as a procurement technique by architects in the 1980’s by eliminating the role of the general contractor and working directly as intermediate agent between clients and subcontractors. It failed in practice because of the architects’ weak position within the industry and because it was not accepted easily by their competitors, the contractors, (Emmitt, 1999a). Further, AMM failed because clients faced time and cost overruns when dealing with architect-led contracts, (Akintoye and Fitzgerald, 1995). All these issues can be attributed to architects’ lack of business and managerial skills and expertise, (Finnigan et al., 1992; Nicholson, 1995; and Emmitt 1999b). The aim of this defining attempt does not advocate reinventing the AMM, but it aims to understand and define AM based on six attributes: its nature (Intension), its components (Extension), its players (architectural managers), who does it affect (stakeholders), its benefits (outcomes), and its responses to the industry’s changes, (i.e. its response to the recommendations of the Latham (1994) and Egan (1998) Reports).

Starting with those affected by AM, the findings of literature review and questionnaire survey assure that almost everyone included within the construction industry is affected either directly or indirectly by architectural management, Table 6.

Table 6: AM affected Stakeholders

- Architectural professionals – architecture as a profession and its professional bodies – society (social environment + physical environment) – construction as an industry – the different stakeholders (clients – users – consultants – contractors – subcontractors – suppliers) – organisations (the business side as well as the structuring – at different levels) – projects (how they are managed) – education (as a giver and feedback receiver)

Moving to the issue of who is qualified to practice or lead AM: based on the study findings, the main qualifications of architectural managers are: design-oriented professional (with preference to architects); armed with managerial knowledge and skills; and has sufficient experience in both design and construction. And the main task of the architectural manager is being at the strategic position to integrate the management of both the business sides and the projects of the architectural practice.

As claimed by both Latham (1994) and Egan (1998), there is a need for a quantum leap in the construction industry. Egan (1998) emphasised the importance of five aspects of improvement: committed leadership; focus on the customer; integrated processes and teams; quality driven agenda; and commitment to people.
Comparing these aspects against the benefits of AM identified in this study such as its role in: organisational management; managing value design and delivery; managing sustainability; increasing professional competitiveness; serving the society; practicing ethically and professionally, shows AM as an effective response to Egan and Latham recommendations for creating a better industry.

Regarding AM’s Intension and Extension, which are the main components of any definition (as claimed by Swartz, 2010); and based on the research findings, the researchers decided to present their definition considering that it has both clear and flexible intension and extension of AM that describe its nature, what it entails, and what might be included in the future. Thus, the following guidelines were considered to compose the new definition, Table 7:

Table 7: The Research’s Defining Guidelines of AM

| AM is the management of architectural practices (Intension). So, the “management” term does not narrow the scope of AM as ‘tool, philosophy, framework…etc’; hence, the ‘management’ seeks always the continuous improvement and the utilisation of any new advances and innovations. |
| AM assures the integration of managing the business sides of the office with managing its individual projects. (Extension). All the extensions provided in Table 4 can fall in one of these two components which have been identified by Brunton et al. (1964), Nicholson (1995) and Emmitt (1999b). |
| AM is about assuring the value achievement for all those involved in the industry. (Extension). So, it is not utilised to underestimate or eliminate the role of the other key players within the industry. Besides that, such role is only managed by “strategic” position, (Intension). |
| AM is practiced by those qualified with a balance of: design, management and experience. (Extension). So, experienced architects are the best nominees for this role (in terms of design capability) if they were prepared with managerial knowledge and skills by their education, (a criticism of architectural education in literature review and by most of the survey respondents). |

Based on these guidelines combined with the study findings, the following definition was composed by the researchers: ‘Architectural management (AM) is the strategic management of the architectural practices that assures the effective integration between managing the business aspects of the office with its individual projects in order to design and deliver the best value to all those involved in the society’. This definition is illustrated in Figure 2:

![Figure 2: Architectural Management Definition](image)

The way forward: This definition will be presented in the CIB-W096 Conference in Vienna 2011 and will be further examined by conducting interpersonal interviews with the members and friends of the CIB-W096. The aim of this future step is to examine the newly-proposed definition and its suitability as a working definition for further research in architectural management.
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Tertiary Architectural Technology Education and Construction Health and Safety (H&S)

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**Abstract:** Designers influence construction ergonomics directly and indirectly. The direct influence is as a result of design, details, specification, and method of fixing, and depending upon the type of procurement system, supervisory and administrative interventions. The indirect influence is as a result of the type of procurement system used, pre-qualification, project time, partnering and the facilitating of pre-planning. The purpose of the paper is to determine architectural technologists’ perceptions relative to addressing of construction H&S in architectural technology programs. A survey of the related literature was undertaken and an empirical study was conducted among members of the South African Institute of Architectural Technologists (SAIAT) using a self-administered questionnaire. The following constitute the salient findings. There is universal support for the addressing of construction H&S in architectural technology programs. Respondents mostly support the addressing of construction H&S as a separate subject, followed by a component of a subject in terms of the form in which construction H&S should be included in an architectural technology program. The following predominate in terms of the importance of the inclusion of nineteen subject areas relative to construction H&S in an architectural technology program: hazard identification and risk assessment (HIRA); the need for construction H&S; the role of project managers in H&S; the economics of construction H&S; the environment and construction H&S; the OH&S Act & Regulations, and H&S specifications. The study realised a low response rate. However, the respondents are likely to constitute the more committed in terms of construction H&S, which enhances the credibility of the findings. It identifies shortcomings in tertiary architectural technologist education. Recommendations include the comprehensive addressing of construction H&S in tertiary architectural technologist education, and continuing professional development (CPD). The performed study constitutes the first of its kind, and provides insight relative to architectural technologists’ perceptions relative to tertiary architectural technology construction H&S education, and construction H&S in general.

**Key words:** Architectural technologists, Construction, H&S, Tertiary education

1. **INTRODUCTION**

Injury statistics in South Africa indicate that the construction industry contributes a disproportionate number of all classes of injury in the form of fatalities, permanent and temporary disablements, and medical aid injuries. Furthermore, the cost of accidents in South African construction was estimated to be between 4.3% and 5.4% of the value of completed construction (Smallwood, 2004).

Although, injury statistics and the cost of accidents constitute motivation to architectural technologists to address construction H&S, the need for a paradigm shift and focus on H&S is amplified by the complementary role of H&S in overall project performance cited by various authors (Levitt and Samelson, 1993; Hinze, 2006) – optimum H&S enhances performance relative to the
environment, cost, productivity, quality, and time. Conversely, inadequate H&S and/or accidents contribute to variability of resource, and uncertainty, which increases project risk. Damage to the environment, increased cost, reduced productivity, non-conformance to quality standards, and time overruns, are manifestations of such variability (Smallwood, 1996). Furthermore, poor performance results in an increase in project cost, which clients effectively finance in the form of the cost of construction.

The Health & Safety Executive (HSE) (2007) says designers are in a unique position to reduce the risks that arise during construction as designs develop from initial concepts through to a detailed specification, often involving different teams and people at various stages, and consequently designers from all disciplines can make a significant contribution by identifying and eliminating hazards, and reducing likely risks from hazards where elimination is not possible. According to WorkCover New South Wales (2000) the art of design involves consideration of a range of aspects, including H&S, and the environment in terms of legislation, codes and standards, experience, expertise, logic, and checklists. This contention is reinforced by Thorpe (2005) who says that designing for H&S is not a stand-alone consideration, but an integral part of the wider design process.

However, Hecker et al. (2006) contend that although H&S through design is a fundamental principle of construction H&S, and that although architects and engineers regularly address H&S and ergonomics in their designs, they do so with a significant limitation, namely that their concerns apply almost exclusively to the end-user of a facility, rather than the workers who construct it. Behm (2006) in turn contends that such an approach is problematic, in that there is growing evidence that the design of permanent structures has a significant impact on the risks to construction workers.

Given the aforementioned findings documented in international literature, previous South African tertiary built environment construction H&S related research findings, and anecdotal evidence, the paper reports on a study conducted members of the South African Institute of Architectural Technologists (SAIAT), the objectives of the study being to determine whether construction H&S should be addressed in tertiary architectural technology or not, and if so, then the form of inclusion, and the subject areas.

2. REVIEW OF THE LITERATURE

2.1 Recommendations and legislation pertaining to architects and architectural technologists

The role of designers in construction H&S was documented nearly two decades ago by the International Labour Office (ILO) (1992). The ILO specifically states that designers should: receive training in H&S; integrate the H&S of construction workers into the design and planning process; not include anything in a design which would necessitate the use of dangerous structural or other procedures or hazardous materials which could be avoided by design modifications or by substitute materials, and take into account the H&S of workers during subsequent maintenance.

Within the context of South Africa, and more specifically, legislation, comprehensive requirements are scheduled for all employers by the Occupational Health and Safety Act (OH&S Act) (Republic of South Africa, 1993). Design practices are also employers as per the definition of the OH&S Act, and therefore need to address H&S in terms of their business, which entails visits to projects during the respective phases. Given that designers visit projects, and given possible exposure to hazards and risk, the incentive to address H&S exists from an employer and an individual perspective. However, contrary to general belief, designers were required to address H&S prior to the promulgation of the
Construction Regulations, as in terms of Section 10 of the OH&S Act designers are allocated the responsibility to ensure that any ‘article’ is safe and without risks when properly used.

The Construction Regulations (Republic of South Africa, 2003) constituted a milestone in that the responsibility for construction H&S was extended to clients and designers, and in fact project managers, and quantity surveyors. However, the Construction Regulations are specific in terms of requirements relative to clients and designers. Clients are required to, inter alia: prepare H&S specifications for the construction work; ensure that principal contractors (PCs) have made provision for H&S costs in their tenders; provide PCs with any information that might affect H&S; appoint PCs for projects; ensure that PCs implement their H&S plans; stop work that is not in accordance with the H&S plans, and ensure that sufficient H&S information and resources are available to the PC where changes to the design or construction are made. Although the aforementioned requirements pertain to clients, many require the input of designers e.g. given that designers may specify materials that are hazardous due to the non-availability of alternative non-hazardous substances containing materials, or require hazardous processes, for which there are no alternatives, designer input may be required as H&S specifications must schedule the H&S requirements for a project, and PCs must be provided with any information that might affect H&S. Designers are required to, inter alia: make available all relevant information about the design such as the soil investigation report; design loadings of the structure, and methods and sequence of construction; inform PCs of any known or anticipated dangers or hazards or special measures required for the safe execution of the works, and modify the design or make use of substitute materials where the design necessitates the use of dangerous structural or other procedures or materials hazardous to H&S.

2.2 Designing for construction health and safety

Notwithstanding international recommendations such as those documented by the ILO and legislation specific to a number of countries, consideration for construction H&S is also motivated by professional ethics. The first Fundamental Canon of the National Society of Professional Engineers’ code of ethics in the USA: “Engineers, in the fulfilment of their professional duties, shall: Hold paramount the safety, health, and welfare of the public.” is cited by Gambatese (1998, 110) who questions whether it would be ethical or morally acceptable to exclude construction workers from the general ‘public’ when considering H&S.

Following the motivation for designer consideration on the basis of international recommendations, legislation, and ethics, is the holistic nature of design. This is highlighted by WorkCover New South Wales (2000), who state the art of design involves consideration of a range of aspects such as aesthetics, function, H&S, and the environment in terms of legislation, codes and standards, experience, expertise, logic, and checklists. The debate is reinforced by the HSE (2007) who say designers are in a unique position to reduce the risks that arise during construction as designs develop from initial concepts, through to a detailed specification, often involving different teams and people at various stages. Consequently, designers from all disciplines can make a significant contribution by identifying and eliminating hazards, and reducing likely risks from hazards where elimination is not possible. The latter highlights the thrust of the South African Construction Regulations, which constitutes the core of ‘designing for H&S’. Furthermore, Hecker and Gambatese (2003) highlight the ‘hierarchy of control’ adopted in generic H&S to eliminate or reduce hazards. The hierarchy entails a number of steps, namely: elimination; substitution; engineering controls; behaviour control through safe work procedures, and the use or personal protective equipment (PPE) as a last resort.

Despite international recommendations and legislation, ethics, the inclusive nature of design, and the established hierarchy of control, designers continue to endeavour to absolve themselves of responsibility for construction H&S. In response, Hinze (2006) states that contentions such as
designers contending that they are not responsible for construction H&S because it is not their responsibility to tell contractors how to construct, or that they do not have intimate knowledge of how they construct, and that they are only responsible for the design, are not reality. He adds that unfortunately this mindset of pleading ignorance is the most common one. Further response accrues to WorkCover New South Wales (2000), who contend that in spite of their being a balance of responsibilities between a designer and a constructor, the designer’s role is to alert constructors to the hazards and risks associated with the design, which they cannot reasonably be expected to know.

### 2.3 Need for inclusion of construction health and safety in tertiary education

According to Anderson (2002), although the United Kingdom (UK) construction industry’s poor accident record has led to calls for more stringent legislation, one essential aspect that has received little attention is the effective teaching of construction H&S to built environment practitioners when they are undergoing their tertiary education. During 2001, research relative to the provision of construction H&S teaching in built environment related undergraduate courses, namely architecture, building, engineering, and surveying, was commissioned by the HSE (2001) in the UK. Recommendations include, inter alia, that academia should recognise that H&S risk is part of construction risk management and an essential intellectual element of all construction related courses, and all courses / programs should be audited with a view to including H&S risk management in programs as an integral and cross curricula element. Furthermore, the Construction Industry Development Board (cidb) (2009) highlighted the need for the addressing of construction H&S in tertiary built environment education.

Previous research conducted among Architectural Technologists in South Africa by Smallwood (2009), determined that only 43.2% of respondents’ attributed their source of ergonomics knowledge to tertiary education, the predominating source being experience (83.8%), and the next major source being magazine articles (40.5%) (Table 1). This indicates a profound need for architectural technologist programs to address construction H&S.

#### Table 1. Architectural Technologists’ source of ergonomics knowledge

<table>
<thead>
<tr>
<th>Source</th>
<th>Response (%)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience</td>
<td>83.8</td>
<td>1</td>
</tr>
<tr>
<td>Tertiary education</td>
<td>43.2</td>
<td>2</td>
</tr>
<tr>
<td>Magazine articles</td>
<td>40.5</td>
<td>3</td>
</tr>
<tr>
<td>Journal papers</td>
<td>18.9</td>
<td>4=</td>
</tr>
<tr>
<td>Other</td>
<td>18.9</td>
<td>4=</td>
</tr>
<tr>
<td>Practice notes</td>
<td>16.2</td>
<td>6</td>
</tr>
<tr>
<td>Workshops</td>
<td>10.8</td>
<td>7=</td>
</tr>
<tr>
<td>Post graduate qualifications</td>
<td>10.8</td>
<td>7=</td>
</tr>
<tr>
<td>Conference papers</td>
<td>8.1</td>
<td>9</td>
</tr>
<tr>
<td>CPD seminars</td>
<td>0.0</td>
<td>10</td>
</tr>
</tbody>
</table>

### 2.4 Construction health and safety subject areas

Previous research conducted by Smallwood (2003) in South Africa investigated the extent to which tertiary built environment education programs addressed construction H&S. Based upon this research, Table 2 presents the recommended construction H&S subject areas for such programs in terms of an importance rating out of maximum of 3. A rating of 0 indicates that it is not recommended that the subject area be included in a program, 1 that it is recommended, 2 that it is important, and 3 that it is
very important. It is notable that only two (9.8%) architecture subject areas were rated 0. Four (18.2%) were rated 1, four (18.2%) were rated 2, and twelve (54.5%) were rated 3, out of a total of twenty-two.

Notable ‘3’ ratings include: ‘H&S / Productivity / Quality’, ‘Economics of H&S’, and ‘Measurement and statistics’ which inform with respect to the rationale for designers addressing construction H&S; ‘Pre-planning’ and ‘Role of designers’, and ‘Environment’, ‘Health and hygiene, and ‘Ergonomics’, which provide foundation knowledge relative to construction H&S.

**Table 2. Recommended construction H&S subject areas for tertiary built environment programs**

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Architecture</th>
<th>Construction Management</th>
<th>Engineering</th>
<th>Project Management</th>
<th>Quantity Surveying</th>
</tr>
</thead>
<tbody>
<tr>
<td>OH&amp;S Act and Regulations</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Management of subcontractors</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>H&amp;S / Productivity / Quality</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Role of management</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>H&amp;S culture</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Worker participation</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Programmes</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Education and training</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Pre-planning</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>COID Act (Workers’ compensation)</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Environment</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Role of project managers</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Project plans</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Economics of H&amp;S</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Health and hygiene</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Measurement and statistics</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Role of clients</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Role of designers</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Influence of procurement systems</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Role of the media and awareness</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Role of unions</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

3. **RESEARCH**

3.1 **Methodology, sample stratum, and analysis**

The study was descriptive in nature and the quantitative questionnaire consisted of two questions, one being closed end and one being open end, the latter allowing for the recording of general comments. The one closed end question required qualification of the response, and also included two sub-questions, and twenty-four sub-sub-questions.
The sample stratum consisted of the 101 delegates that had previously attended a half-day South African Institute of Architectural Technology (SAIAT) Construction H&S Seminar. Following the presentation of the seminar, two survey questionnaires were e-mailed to the delegates; the second questionnaire was entitled ‘Tertiary Architectural Technology Education and Construction Health and Safety (H&S)’. 12 Responses were received and included in the analysis of the data, which equates to a response rate of 11.9%.

Using MS Excel, the analysis of the data consisted of the calculation of descriptive statistics to depict the frequency distribution and central tendency of responses to fixed response questions to determine the degree of importance of subject areas. A measure of central tendency in the form of a mean score (MS) was required to enable a relative interpretation of the responses to the five point likert scale question, including an ‘unsure’ option, and to enable a ranking of the subject areas in terms of their importance on a scale of 1 (hardly) to five (very). The MSs were calculated as follows:

\[
3.1.1 \text{ MS } = \frac{1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5}{n_0 + n_1 + n_2 + n_3 + n_4 + n_5}
\]

where \(n_0\) = unsure; \(n_1\) = hardly important; \(n_2\) = less than important; \(n_3\) = important; \(n_4\) = more than important, and \(n_5\) = very important.

4. FINDINGS

In response to the question ‘Should construction H&S be addressed in architectural technology programs?’ 100% of respondents responded in the affirmative.

Three follow up questions followed this question in the case of an affirmative response, the first being ‘If Yes, please state why?’ The reasons have been categorised below. In essence, the three categories underscore the importance of the study in that they highlight: the importance of construction H&S; that construction H&S should be a consideration on projects; architectural technologists should consider construction H&S; historically architectural technology programs have not addressed construction H&S, and that architectural technology programs should address construction H&S.

Inclusion of construction H&S in tertiary architectural technology education:

- “The building industry needs to be more aware of H&S. Start at the beginning.”
- “When we studied in 1980 at the Technikon Witwatersrand there was no mention of health and safety technology. It might have changed in the meantime.”
- “Technologists should be educated in all important aspects of the profession.”
- “Professionals need more education to enable safer construction & a reduced medical burden on government, plus knowledge to advise, influence & motivate clients.”

Designing for construction H&S:

- “Part and parcel of the design – product and system used has a huge impact on the actual H&S on site.”
• “H&S should be considered by the architectural technologist as they are working on details and material choices, before construction takes place, therefore it should be part of their education.”
• “H&S regarding certain materials & technologies and how they are to be used / specified, is the responsibility of the Arch-Tech.”
• “An understanding of H&S issues can have important implications for the design of buildings (conceptual design, detailed design and for environmental conservation).”

Importance of and awareness for construction H&S:
• “It’s an important integral part of tackling a project when considering the overall facets of the concept.”
• “H&S is a necessity in construction.”
• “Maintain awareness.”

The second follow up question in the case of affirmative response ‘If Yes, in what form should construction H&S be included in an architectural technology program?’ resulted in the responses presented in Table 3. It is notable that the majority of respondents identified both optimum status in the form of a separate subject, and near optimum status in the form of a component of a subject such as construction management. Furthermore, slightly more than half of respondents identified ‘module in various subjects’ such as building construction.

<table>
<thead>
<tr>
<th>Form</th>
<th>Response (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separate subject</td>
<td>77.8</td>
</tr>
<tr>
<td>Component of a subject e.g. construction management</td>
<td>85.7</td>
</tr>
<tr>
<td>Module in various subjects e.g. building construction</td>
<td>57.1</td>
</tr>
</tbody>
</table>

The responses to the third follow up question in the case of affirmative response ‘If ‘Yes’, on a scale of 1 (hardly) to 5 (very), how important is the inclusion of the following subject areas relative to construction H&S in an architectural technology program?’ are presented in Table 4. Table 4 indicates the importance in terms of percentage responses to the five points on the scale and a MS ranging between 1.00 the lower point, and 5.00 the higher point. It is notable that all the MSs are > 3.00, which indicates that in general the inclusion of the subject areas relative to construction H&S in an architectural technology program can be deemed to be between important and very important, as opposed to between hardly important and important. This finding also underscores the need for architectural programs to address construction H&S.

However, referring to MSs > 3.00 ≤ 5.00 and > 1.00 ≤ 3.00 is generalist in nature, and therefore ranges that are more specific are necessary to enable an enhanced overview of the findings. Given that the difference between the lower and upper ends of the five point scale is 4 and that there are five points thereon, the extent of the ranges is determined by dividing 4.00 by 5, which equates to 0.80.: The first range > 4.20 ≤ 5.00, indicates that the subject areas can be deemed to be between more than important to very important / very important – six (31.6%) of the nineteen subject areas fall within this range. It is notable that ‘hazard identification and risk assessment’ is ranked first as it is an essential skill in terms of designing for construction H&S. Furthermore, in terms of the Construction Regulations designers must amend designs which will entail hazardous processes and exposure to hazardous materials. Designers should understand and appreciate second ranked ‘need for construction
H&S’, and third ranked ‘role of project managers in construction H&S’ is important for designers as they interface with designers and often report to such project managers. Furthermore, construction H&S requires multi-stakeholder contributions and therefore an understanding and appreciation of the role of other project stakeholders is important. Fourth ranked ‘economics of construction H&S’, underscores the ‘need for construction H&S’, and constitutes a financial motivation to designers to address construction H&S. The fifth ranking achieved by ‘environment and construction H&S’ highlights the reality in the form of many environment and H&S issues being interrelated. The sixth ranking achieved by ‘OH&S Act & Regulations’ is notable in that invariably legislation is ranked the highest in terms of the inclusion of subject areas. Furthermore, it constitutes the legislative motivation for designers to address construction H&S. This is relevant in that the Construction Regulations schedule a range of requirements relative to designers.

The second range $> 3.40 \leq 4.20$, indicates that the subject areas can be deemed to be between important to more than important / more than important – 12 (63.2%) of the subject areas fall within this range. Seventh ranked ‘H&S specifications’, which marginally falls outside the first range, is notable, as in theory, inter alia, residual design hazards, and design and construction method statements should be included therein. Furthermore, hence the importance of first ranked ‘hazard identification and risk assessment’. Eighth ranked ‘Specifying for construction H&S’, ninth ranked ‘Detailing for construction H&S’, and eleventh ranked ‘Designing for construction H&S’ are important as designing, specifying, and detailing have a direct, either negative or positive, impact on construction H&S. ‘Role of designers in construction H&S’, ranked tenth, is important as it engenders an understanding and appreciation of the role of designers and the related processes. Although ‘Role of construction H&S in project performance’ is only ranked twelfth, it in essence underscores second ranked ‘Need for construction H&S’. It is important that all project stakeholders understand and appreciate the catalytic and synergistic role of H&S relative to the environment, cost, productivity, quality, and time. Thirteenth ranked ‘Occupational safety’, fifteen ranked ‘Ergonomics’, and sixteenth ranked ‘Occupational health’ are important as they constitute foundation subject areas in that knowledge relative thereto is important with respect to conducting hazard identification and risk assessment, which subject area was ranked first. Given that construction H&S requires multi-stakeholder contributions and the importance of an understanding and appreciation of the role of other project stakeholders on the part of designers, fourteenth ranked ‘Role of clients in construction H&S’ and eighteenth ranked ‘Role of quantity surveyors in construction H&S’ are important. Although ‘H&S plans’ are ranked seventeenth, they are important in terms of the construction process. Furthermore, principal contractors evolve them in response to the seventh ranked ‘H&S specifications’ provided by the client and contributed to by designers, and hence designers should be involved in the review of such H&S plans.

The third range $> 2.60 \leq 3.40$, which indicates that the subject areas can be deemed to be between less than important to important / important, includes nineteenth ranked ‘Influence of procurement on construction H&S’. This finding should be viewed with circumspection as procurement has a substantial influence on construction H&S through, inter alia, prequalification on H&S, project duration, and adequate financial provision for H&S.

There were no subject areas that can be deemed to be between hardly important to less than important ($> 1.80 \leq 2.60$), and between hardly important to less than important ($\geq 1.00 \leq 1.80$).

Respondents were also requested to provide comments in general regarding tertiary architectural technology education and construction H&S. Table 5 indicates that 50% did, an equal percentage of which provided one, two and three comments. Given that there were twelve respondents and a total of twelve comments the mean number of comments is one.
Table 4. Importance of the inclusion of subject areas relative to construction H&S in an architectural technology program

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Response (%)</th>
<th>MS</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard identification and risk assessment</td>
<td>0.0 8.3 25.0</td>
<td>66.7</td>
<td>4.58</td>
</tr>
<tr>
<td>Need for construction H&amp;S</td>
<td>0.0 8.3 25.0</td>
<td>66.7</td>
<td>4.50</td>
</tr>
<tr>
<td>Role of project managers in construction H&amp;S</td>
<td>0.0 8.3 25.0</td>
<td>66.7</td>
<td>4.50</td>
</tr>
<tr>
<td>Economics of construction H&amp;S</td>
<td>0.0 8.3 50.0</td>
<td>41.7</td>
<td>4.33</td>
</tr>
<tr>
<td>Environment and construction H&amp;S</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>4.25</td>
</tr>
<tr>
<td>OH&amp;S Act &amp; Regulations</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>4.25</td>
</tr>
<tr>
<td>H&amp;S specifications</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>4.25</td>
</tr>
<tr>
<td>Specifying for construction H&amp;S</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>4.08</td>
</tr>
<tr>
<td>Detailing for construction H&amp;S</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>4.08</td>
</tr>
<tr>
<td>Role of designers in construction H&amp;S</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>4.08</td>
</tr>
<tr>
<td>Designing for construction H&amp;S</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>4.00</td>
</tr>
<tr>
<td>Role of construction H&amp;S in project performance</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>3.92</td>
</tr>
<tr>
<td>Occupational safety</td>
<td>8.3 8.3 16.7</td>
<td>58.3</td>
<td>3.92</td>
</tr>
<tr>
<td>Role of clients in construction H&amp;S</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>3.83</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>3.75</td>
</tr>
<tr>
<td>Occupational health</td>
<td>8.3 8.3 25.0</td>
<td>58.3</td>
<td>3.75</td>
</tr>
<tr>
<td>H&amp;S plans</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>3.67</td>
</tr>
<tr>
<td>Role of quantity surveyors in construction H&amp;S</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>3.58</td>
</tr>
<tr>
<td>Influence of procurement on construction H&amp;S</td>
<td>0.0 8.3 25.0</td>
<td>58.3</td>
<td>3.17</td>
</tr>
</tbody>
</table>

Table 5. No. of comments in general regarding tertiary architectural technology education and construction H&S

<table>
<thead>
<tr>
<th>Comments (No.)</th>
<th>Response (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>50.0</td>
</tr>
<tr>
<td>1</td>
<td>16.7</td>
</tr>
<tr>
<td>2</td>
<td>16.7</td>
</tr>
<tr>
<td>3</td>
<td>16.7</td>
</tr>
</tbody>
</table>

The comments are presented verbatim and have been categorised below. 6 of the 7 (85.7%) comments address the inclusion of construction H&S in architectural technology programs, and the other comment the importance of construction H&S. Clearly construction H&S should be addressed in architectural technology programs in the form of reference thereto in technical subjects, and also as a stand alone subject.

Importance of construction H&S:
- “Insurance component / government should reward safety compliance.”

Inclusion of construction H&S in tertiary architectural technology education:
- “Architectural Technology Education & Construction H&S can only work if the global built environment participates to a same minimum criteria / level of activity.”
- “The students should definitely be aware of H&S. This awareness should be carried through to their professional career and then developed. It should be addressed in their technology subjects, and be practiced in at least one project during their studies. It could be integrated at third or fourth year level, before they exit the program.”
- “In general, I think the technologist is responsible for informing the client about certain materials / services and how they should be applied, but the overall H&S regarding site works,
should rest on the project manager. H&S can really become complicated on really big projects, and could be considered a subject (if not a course) all on its own. And with the new regulations coming into place regarding R-U values for materials and how all the materials are tested etc… I really don’t think that the technologist will have the time to deal with what is essentially a new subject. Taking into account, that there are companies that specialise in H&S, one could say that it is a new profession all by itself.”

- “Whereas I see the need for a course of

- H&S for architects and architectural technologists, it probably would have to be a short course and nowhere as detailed as that given to QS and Construction Management students. The curriculum is already very full. Also, it is too specialised to be given as part of the Construction Technology courses, because it depends on who is lecturing.”

- “It must be included as a compulsory module of the main subject and part of the exam questionnaire with a pass mark of 70% or above.”

- “Clients find it difficult to understand the health and safety impact on projects and want their projects to get on and finish. As or addressing in tertiary architectural technology education is concerned, I do not know what is currently being taught, but definite attention should be given.”

5. CONCLUSIONS AND RECOMMENDATIONS

Designers are project stakeholders and are invariably involved throughout all phases of projects. Design also impacts on construction H&S and often the origins of accidents can be traced back to design. Designers are required to contribute to construction H&S in terms of South African and international legislation in the form of Acts and Regulations. These requirements are underscored by international recommendations as published by the ILO in 1992, and codes of ethics. Furthermore, the loss of life and injury to persons, cost of accidents, the catalytic role of H&S, and the synergy between H&S and the other project performance areas, amplify the need for designers to address construction H&S. Thus it can be concluded that architectural technology programs should address construction H&S, thereby empowering diplomats and graduates to contribute thereto when practicing architectural technology.

In terms of the form of such inclusion of construction H&S in a program, it can be concluded that ideally a subject ‘designing for construction H&S’, or at the very least, an expanded module should be included in programs. However, given the history of designer contributions to construction H&S in South Africa it could be argued that the aforementioned conclusion is idealistic, and that the South African Council for the Architectural Professions (SACAP), which Council is responsible for the accreditation of architectural related programs, should fulfill their mandate and ensure that ‘designing for construction H&S’ is included in their program ‘roadmap’ and assessed during accreditation visits to tertiary institutions.

Furthermore, given the fact that architectural technology related programs have not addressed construction H&S, it can be concluded that there is a deficiency in terms of architectural technologists’ designing for construction H&S competencies, and therefore the SAIAT should address this deficiency through continuing professional development (CPD). The SACAP should also ensure that such related CPD is expedited, and require registered persons to accrue a minimum number of ‘designing for construction H&S’ CPD points per CPD cycle.
The addressing of ‘designing for construction H&S’ during tertiary education and CPD, will enable architectural technologists to comply with the provisions of the OH&S Act and regulations, and more specifically, the Construction Regulations, which require a range of ‘designing for construction H&S’ interventions. Furthermore, such compliance will complement other stakeholders’ construction H&S related interventions, which collectively should reduce the number of hazards and consequential risk, particularly hazards which originate during design.

Given that respondents identified a critical need for construction H&S to be included in architectural technology programs, and the need to empower graduates through the development of an optimum program, in terms of further research: architectural technology programs should be reviewed to determine the extent to which they address ‘designing for construction H&S”; architectural technologists should be surveyed to determine their ‘designing for construction H&S’ interventions, and the areas which should be addressed during tertiary education and CPD, and accidents should be reviewed to identify ‘designing for construction H&S’ interventions that could have prevented the occurrence of such accidents, if any.

6. REFERENCES

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Propertisation of Building Information Modeling Mapped Against Firm Intellectual Capital

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Abstract: Building Information Modelling is an innovation which is in the process of diffusion across the construction industry and it is expected to be more prevalent in the future. Literature suggests that certain benefits of BIM are being delayed and overshadowed by legal and regulatory uncertainties related to technology adoption, business processes and integrated delivery. Although no significant law-suit has been filed based upon the use of BIM, litigation may occur in the future relative to risks, rights and responsibilities of the parties. At the same time, some authors indicate that BIM can also be seen as a platform for reducing disputes, claims and legal complexities. Hence, the legal and regulatory issues in relation to BIM need a comprehensive discussion. This paper begins this discussion by exploring the collective authorship and individual ownership of Building Information Models in the digital environment. In particular as we explore BIM ownership a theoretical model shall be developed synthesising a legal and economic value concept of BIM Propertisation. There are various legal frameworks and concepts that we can draw upon from intellectual property law, law of contracts and law of property to develop theory for BIM ownership. This work is positioned within the theory of virtual property and investigates the following constructs; rivalrous, persistence, interconnectivity, private vs public domain and integration within the framework of a firm’s intellectual capital and inter-firm collaboration in the construction projects. The paper presents some pilot study empirical work aimed at exploring the validity of the Propertisation conceptualisation.

Key words: Building Information Modeling, virtual property, propertisation, valuation

1. BACKGROUND

BIM (Building Information Modelling) is an IT (Information Technology) enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project lifecycle in the form of a data repository. The building information involved in the BIM approach can include geometric as well as non-geometric data. Geometric data refers to information such as 2D drawings, 3D models, and their dimensional and spatial relationships. Non-geometric data can refer to textual data such as annotations, reports and tables; visual data such as sketches, graphs and images; multimedia data such as audios and videos, as well as other forms of information generated during the building project lifecycle. BIM is expected to envision efficient collaboration during design and construction processes, improved data integrity (Ashcraft 2008, Ellis 2006), intelligent documentation (Popov et al 2006), distributed access and retrieval of building data (Ibrahim et al 2004) and high-quality project outcomes through enhanced performance analysis, as well as multi-disciplinary planning and coordination (Fischer and Kunz 2004, Haymaker et al 2005, Haymaker and Suter 2006). Other potential benefits include the use of the models by owners/facilities managers to manage and maintain facilities during operation (Ballestly et al. 2007, Olatunji and Sher 2010a).
While the potential benefits of the BIM approach in terms of information sharing and management, as well as project collaboration, and coordination may seem evident, the adoption rate of BIM has been slow. A number of factors, such as a lack of awareness and training, the fragmented nature of the AEC/FM industry, industry’s reluctance to change existing work practice and hesitation to learn new concepts and technologies, and lack of clarity on roles, responsibilities and distribution of benefits, have been identified in the literature as major barriers to BIM adoption (Gu et al 2010).

There has been much discussion in the literature assessing BIM adoption. Some of this discussion has more recently moved from the claims of the benefits and its potential to improve the industry to the reasons why adoption has been so problematic. BIM implementation issues have become a focus for researchers. There is an emphasis on the need for new and improved legal frameworks as a way to overcome current barriers to BIM adoption and allow the delivery of its technical benefits (Olatunji and Sher 2010b). Recently the discussion has focussed on strategic business implementation including decision frameworks for firms (London et al, 2010; Love et al, 2011), national guidelines and frameworks on standards and regulations (CRC 2009, AIA 2008, Smonian and Korman 2010) and the legal implications of creating, developing and owning BIM models (ConsensusDOCS™ 2010). BIM ownership has already become a significant topic as we move into the next stage of implementation and we need to give consideration to BIM as a product and an entity that is handed over to the next stakeholder in the process and eventually to the client/owner. Central to all these initiatives is the general assumption that BIM is a value added proposition.

However, to what extent do we really view the BIM model as a virtual asset that has value and characteristics associated with property ownership? What are the various legal environments this understanding of BIM as a virtual property would bring with it? How does the economics of information ownership and the various legal discourses contribute to our understanding of BIM implementation? Or is BIM model simply a process to enable a more efficient industry? Will the AEC sector eventually transform so that this becomes not ‘best practice’ but the accepted practice, and the market begins to segment into those clusters of firms that develop intellectual capital around BIM work processes? Interestingly this is perhaps where the concepts in the supply chain literature whereby chains compete against each other rather than individual firms within individual markets compete that has often been discussed in other industries may become much more realistic. There are suggestion then of cartels and collusion to consider although realistically the BIM technology will not necessarily be the root causal factor for such behaviour. The BIM model will really only succeed when there is a high level of collaboration and ultimately trust amongst the designers, contractors, subcontractors and suppliers. The sharing of information developed within firms between the firms will build stronger relationships and there will much more shared capital including social and intellectual capital enabling firms to tend to compete in a much more focussed manner.

The aim of this paper is to explore conceptualising the BIM model as an owned asset and thus towards the development of a model of BIM Propertisation. Significant considerations will also be given to the role of value and intellectual capital in relation to BIM Propertisation as well as the legal matters that this may raise. The findings reported in this paper are based on the pilot investigations to strengthen the research approach.

### 1.1 BIM Propertisation

The ongoing discussions and seminars across the industry and the various BIM initiatives across the globe (AIA 2008, CRC 2010) reflect a general consensus that BIM is a value added proposition, both as a product as well as a collaborative process. Various issues such as the roles and responsibilities, model development, level of details and authorship have been discussed and investigated in detail.
BIM ownership and risk management was raised in the BIM and Collaborative Model Server decision making framework proposed by London et al (2010).

While some suggest that with increasing use of BIM for project delivery litigations may occur relative to risks, rights and responsibilities of the parties (Negovan 2009), others (Cremonese and Wissinger 2010) point out that BIM can be seen as a platform for reducing claims unlike the traditional legal relationships in construction management which are normally fragmented and subject to uncertainties and risks. The transparency of information flow and the ability to track and document decisions in a more systematic manner may actually contribute to clarity in relation to disputes and to a more efficient claims negotiation environment.

Larson and Golden (2007) claim the use of BIM does not necessarily alter the traditional allocation of responsibility among designers, contractors and suppliers. They suggest that the fear of blurred “boundaries for roles and responsibilities” is based on the erroneous assumption that BIM results in the creation of a digital mix in which design, means-and-methods, and product information is irreversibly blended. Larson and Golden (2007) suggest that even though digital information and communication are considerably new to construction management, they will become routine methods in the future reducing the apprehensions such as the fear the reliance on the model, software errors, data loss, and the associated liabilities.

Literature (Larson and Golden 2007, Cremonese and Wissinger 2010) suggests a number of these issues and apprehensions can be sufficiently addressed through existing legal mechanisms such as contract agreements. Early drafts and attempts in developing contract agreements and guidelines to support BIM based collaboration and handover of models across parties and stakeholders have generally been received positively. As the AIA document (2008) states:

“...Integrated Project Delivery principles can be applied to a variety of contractual arrangements and Integrated Project Delivery teams will usually include members well beyond the basic triad of owner, architect, and contractor. At a minimum, though, an Integrated Project includes tight collaboration between the owner, the architect, and the general contractor ultimately responsible for construction of the project, from early design through project handover.” (AIA document 2008, p.1)

Such guidelines and templates have not only documented and created checklists of the key issues, but in many cases they have allowed demystification of some of the non-existent legal and regulatory issues attributed to BIM adoption (Larson and Golden 2007, Cremonese and Wissinger 2010).

However we should acknowledge that it is early days and these guidelines and contractual clauses have not been tested. We should also understand that there is a dichotomy with trying to consider the legal concerns in BIM implementation; a collaborative environment is fundamentally about an acceptance by all parties that ‘going to the contract’ is really not the framework and culture in which these sorts of projects are initiated and framed and yet we can never forget that ultimately there are products/services transacted and so a legal environment is immediately always created and supporting the construction project environment. Perhaps one of the most difficult areas to consider is the fundamental difference in BIM enabled environments is the situation whereby collaborative decision making is enabled thus making it more challenging to understand who has responsibility and thus liability for various decisions and advice. In that ‘virtual collaborative decision making space’ we support shared decision making but then who owns the decision at the end of the day and is responsibility traceable? Simplistic version document control is achievable in the BIM Model Server environment and this has already been tested (London et al, 2010) but decision monitoring in that highly creative design and design review environment has not been well considered. This is a much deeper discussion that needs to be had and further critical thinking on this is required.

It is also noted that in their present form these contracts and guidelines provide little support mechanism for assessing the value of the BIM model in a given project. We contend that if BIM models are considered virtual prototypes that reduce errors and effort in the construction of the
physical property, then there should be accepted mechanisms and norms for valuation and estimation of the components and efforts in creating a BIM model, considering it as a virtual property, just like the accepted valuation and estimation standards for real physical property. This argument is strengthened by the increasing interaction of the virtual and physical worlds across the wider society that has seen exchange of real money for virtual objects and vice versa (Schönberger 2009).

1.2 Propertisation clarified

A collective understanding of BIM as a property is important to assessing its values. As Radin (2006) suggests, what counts as property is malleable. Hence, Radin (2006) introduces the term propertisation, drawing attention to the following characteristics of property:

1. Control: something recognized by the society as a property and under the law’s control.
2. Change: property is not static; new property rights come into being.
3. Process: becoming a property is a process. Legislation can occur in response to public or industry debate.
4. Scale: things can be more or less propertised; a resource can be subject to a narrower or wider scope of owner control.
5. Contestation: there are grey areas and some aspects and zones of property that can be contested.

Similarly, Fairfield (2005) proposes that for anything to qualify as virtual property it should demonstrate the following three characteristics, typical of any real world property:

1. Rivalrous: Properties are rivalrous because some people own and control them, and others do not. For example, BIM model owners/developers can control and restrict the use of the model according to their needs and agreements.
2. Persistent: The artefact in question continues to exist in some usable form. For example, a BIM model once created can continue to exist across work sessions such that people can access and use the model at later point in time.
3. Interconnected: Other people can interact with the property. For example, in case of a BIM model multiple parties can or may want to use or interact with model even though it is possible any one party owns the model at one given time.

Fairfield (2005) argues that though virtual property is often treated as merely intellectual property, they show similar characteristics to real world property, and hence, the common law of property can also be used to protect virtual properties. Thus, following the common law of property, rivalrousness should give one the ability to invest in his/her virtual property without the fear that other people may take what has been developed. Persistence protects the investment by ensuring that it lasts. Interconnectivity increases the value of the property due to network effects, use and marketability.

The characteristics of property identified by Fairfield (2005) and Radin (2006) are equally applicable to BIM. BIM models are rivalrous, persistent and have interconnectivity as demonstrated in the examples above. Further, rivalrousness subsumes control and change, which also determines the persistence of the property, the BIM model in this case. Process and contestation are characteristics associated with interconnectivity as to how the community interacts with and recognises the property being developed by someone. Similarly, scale or the extent of control on property is applicable to BIM models. The different parties in a collaborative project may have varying levels of ownership and access rights to the model. Hence, at a conceptual level, there is enough evidence to claim that BIM qualifies as a property that holds values beyond the intellectual capital.
Therefore, following the arguments put forward by Fairfield (2005), the legal frameworks to facilitate BIM based project development requires the integration of the following three types of laws to deal with the potential complexity:

(1) The common law of property (also as a measure to limit anti-commons): According to Demsetz (1967), overlapping use rights in property creates incentives to misuse and overexploitation of the resources held in common. Such situations may arise in the use of collaborative BIM models shared across different parties.

Heller (1998) analyses an opposite situation, when overlapping rights to exclude, cause property to go unused or underused. If right-holders are allowed to block each other from making productive use of the resource, an anti-commons is created. For example, if multiple parties have collectively created a BIM model, unless otherwise specified, an anti-commons situation may arise if contributors refuse to share their model for a collective benefit, thereby devaluing the overall BIM model.

(2) The law of intellectual property: Fairfield (2005) points out that the ownership of an object is always separate from ownership of the intellectual property embedded in an object. For example, ownership of a book is not ownership of the intellectual property of the novel that the author wrote. Similarly, the copy of a BIM model may only be a representation of the design, while the intellectual property is held in the design, which may still be held by the designer or the developer.

(3) The law of contracts: A contract is a legally enforceable agreement between two or more parties with mutual obligations, mostly in written documented form. Contracts have been the preferred legal tool in construction projects and provide clarity on obligations and rights of the interacting parties, as negotiated in the document.

1.3 Firm intellectual capital

Intellectual capital is a firm’s collective skills, competencies and knowledge and is critical to the sustainability of firms, particularly in international markets (Stewart, 1997). In the last decade there has been quite a focus on knowledge management approaches to construction projects and the challenges of capturing tacit knowledge and codifying that tacit knowledge and converting it to some form of explicit and tangible ‘knowledge’ that can be used by others on future projects.

Learning from one project to the next is actually not a new concept at all. The post occupancy evaluation literature has been a well established field since the 1960s and has undergone various transitions of exploration of theories and methodologies in relation to capturing knowledge on projects, during projects and post projects (London, 1997).

Knowledge based theories have undergone an evolution as well from a more information processing perspective in 1960s and 1970s to then decision support systems in the 1980s when information technology became a focus for organisations. In more recent times we see the focus less on the organisation as an information processing entity and more as knowledge creation and transfer and thus knowledge as an asset (Senaratne and Sexton, 2010). This perspective of the firm explores two notions; knowledge as a process and then knowledge as an asset of the firm. Knowledge as an asset takes into considerations of knowledge as some form of ‘tangible’ entity and becomes the intellectual capital of a firm and is largely ‘commodotised’. The last decade has seen the commodification of knowledge and there are various theories that take this further.

The challenge is not to take such a strict approach that knowledge only becomes valuable if it indeed does move from being tacit to explicit; ie towards codification and eventually
commodification. There are many instances where knowing of and knowing how in highly creative and fast moving problem solving situations whereby the knowledge may not become codified into a tangible entity and embedded in a policy, procedure or system but lies within the realm of innovative leading edge practice. Such situations are already acknowledged on projects and thus the community of project team members within a firm becomes critical. The challenge of course is still how to take that knowledge created within the community of practice forward on the next project and across other projects in the firm.

BIM is both an example of knowledge moving from tacit to explicit and an information processing perspective could be useful. However that thinking may ultimately fail the industry and certainly falls short of the potential that the collaborative environment that BIM creates. The collaborative environment can sharpen a firms’ senior managements’ ideas in relation to how involvement in BIM projects can create an internal organisational community of specialised practitioners and also the constructed knowledge that is created from the community of specialise practitioners across organisations. The value of the BIM environment is both as a process of knowledge creation and knowledge transfer becomes quite significant.

The strength of a firm lies within its intangible assets and the intellectual capital of a firm is ‘the talents of its people, the efficacy of its management systems and the character of its relationships to its customers’ (Stewart, 1998). A recent study by London and Chen (2011) exploring intellectual capital on international projects in relation to joint ventures identifies that firm management in relation to intellectual capital requires a high degree of reflexivity. This study reported the results of an analysis of five Malaysian firms who have worked successfully on multi international partnerships and/or megaprojects. A case study methodology was employed to examine the barriers and successful strategies the firms used in decision making in various international markets. A common characteristic across the firms was the ability to self reflect and adapt their practices to different international conditions despite numerous differences between countries including cultural, social, project governance structures, regulatory, terminology and codes. A reflexive capability model developed from the social sciences theory of individual agent reflexivity was created to explain the way in which firms as an entity can develop awareness, responsiveness and adaptability for long term success in diverse international markets. The model of reflexivity capability is a useful way to interpret practices that are undertaken in multi partner relationships on larger more complex projects. Successful Malaysian firms within joint venture relationships display an ability to self reflect and adapt. This transformation process is critiqued in relation to the relationships between social, cultural and intellectual capital. Reflexive capability is a characteristic of the successful case study firms working within global models of practice. The reflexive capability model is explained in relation to common themes identified in relation to the management of intellectual capital in successful multi international partnerships and megaprojects. (London and Chen, 2011).

Engaging in BIM by a firm will create important practical implementation questions around - of what value is this process to our firm and how can we create more value both as an internal proposition and an external marketable proposition to our clients? Other important questions will then arise in relation to how do we manage our knowledge internally and within our creative firm clusters and maintain important competitive advantages in the marketplace? Leading practitioners are already grappling with model ownership, value creation, shared knowledge networks and contractual obligations however we have only just begun to explore and developed theoretical positions to interpret and perhaps guide practice.
2. METHODOLOGY

The study is based on literature review and focus group discussion with international experts. The focus group interview was conducted through a one and half hour workshop titled “Myth vs. Reality: Legal and Regulatory Aspects of BIM- Propertisation”, as part of the International Conference on Information Technologies for Construction in Cairo, Egypt, November 2010. The focus group involved eight participants representing five different countries and including academic researchers, a professional lawyer and a construction professional, each with competent knowledge and experience with BIM adoption issues and initiatives. The workshop was organized into the following sessions:

<table>
<thead>
<tr>
<th>Session</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation (30 Minutes)</td>
<td>Presentation and briefing on key concepts related to BIM legal and regulatory issues, and in particular relevant to propertisation of BIM as an IT enabled product and process, by the workshop coordinators. The key concepts.</td>
</tr>
<tr>
<td>Demystifying BIM legal issues (1:00 Hour)</td>
<td>Focus group discussion on each of the key concepts introduced in Session 1 as a step towards characterisation and development of a model of Propertisation of BIM.</td>
</tr>
</tbody>
</table>

The workshop discussions were recorded on tape and transcribed. The transcripts were independently analysed by two researchers to identify the key findings from the discussions. Besides the independent analysis by the two researchers, the comparison of the findings from the transcribed data to the minutes taken during the workshops allowed rigour in the qualitative analysis of the focus group data. The limitations of this research are clearly obvious – the limited number of participants as data source. This limitation is acknowledged and it is noted that this is reporting of preliminary empirical work on this topic.

3. RESULTS AND DISCUSSION

In general the workshop participants agreed that BIM qualifies as a virtual property. Participants agreed that BIM holds value as a product as well as a process, and the three characteristics namely rivalrous, persistence and interconnectivity sufficiently describe BIM conceptually as a property. However participants expressed doubts whether this conceptual clarity and the characteristics provide any useful lead towards developing a valuation mechanism for BIM. Though the concepts and characteristics that qualify BIM as a virtual property were expected to guide the discussions in the focus group, the participants regularly gravitated towards issues familiar from the literature review. This serves to confirm previous concepts already uncovered in the literature. The following are the key themes to come out of the focus group discussions:

3.1 Practice and initiatives

One of the main focus of the discussions was how the industry practices collaboration and alliancing and how that will evolve with BIM, and what kinds of legal approaches will be required. Often the participants referred to some of the recent initiatives in developing standards, guidelines and a shared understanding of the best practices to facilitate BIM projects. For example, participants agreed that the ConsensusDOCS™ (2010) developed in US have provided significant guidelines for BIM contracts providing clarity on a range of doubts about the roles and responsibilities, use and
management of the model. The discussions on industry practice and initiatives can be classified into the following sub-themes:

3.1.1 **Current and future practice**

In general participants agreed that the legal issues and apprehensions about the industry practices in BIM based projects are arising out of the fear of change. Resistance to change is not limited to BIM adoption but it is a widely acknowledged phenomenon where an entire industry or a group has to modify their existing ways of working, which brings along perceived insecurities and uncertainties. Hence, participants agreed that this is a transition phase, which is only partly a legal issue, as reflected in the following quotes:

“The building is the same whether or not there is a BIM model or drawings. Paper based is more stepped wise and separate and there is a clear exchange of information. BIM environment is no different. Collaboration does not change anything.”

“Legal issues and conceptions will smoothen with experience and become part of the standard contracts and legal documents.”

The collaborative virtual real time decision making environment that the authors experienced with a previous study in relation to Collaborative Platform Solutions which used a Model Server may not have been the experience of many of the participants and so were really only still thinking of the mode of working whereby each sub-discipline creates a model and then they are integrated and there is still a largely sequential and ordered process. The exchanges that can take place in the virtual shared communication space when participants are all seeing and working and contributing to decisions in the model reviewing process may be somewhat more complex than previously imagined. Of course it may be that because this takes place already and is documented and traceable through meetings, minutes and various other project documentation the virtual collaborative real time online space may not be any different. This may only really occur on those projects whereby parties are not collocated – however more and more this is actually a common mode of practice in many of the large scale projects that BIM supports.

3.1.2 **Processes developed with BIM**

Some participants argued that different processes and service models will evolve around the use of BIM. Innovative processes in BIM implementation and administration may result in creation of new intellectual capital. Hence, the organizations developing these innovative processes need to safeguard their intellectual capital through legal measures, especially in multi-party projects where such processes need to be disclosed and shared with the project partners. These sentiments are reflected in the following quotes

“Unless a process is copyright or a patent has been taken out then you don’t own the new BIM process. ... Can we do the same for the BIM model? But doing this are we taking away something from the whole philosophy of what we bring to the client?”

However, participants agreed that this is not a radically new challenge and the use of existing legal frameworks such as the “Non-Disclosure Agreement” can provide such legal protection.

3.1.3 **Alliancing and shared benefits**

Participants remained apprehensive about the distribution or redistribution of benefits in a BIM based alliance. Despite the references to the ConsensusDOCS™ (2010) which addresses these topics,
the participants argued over the lack of an assessment mechanism for relative risks and benefits across
the different stakeholders, as suggested in the following quotes:

“Commercial entities come together ... Value arises because of the sharing... but who benefits the
most”

“If designers are going to become more efficient they gain a benefit – owners gain a benefit ... Everyone is benefitting – so why should the owner pay?”

“Everyone benefits from the BIM model so everyone should share the cost of the BIM models... but
how do we determine who should bear what portion of the cost... i.e. do we have a mechanism to
measure the cost-benefit ratio...”

3.1.4 Dedicated roles to manage liability

Discussions over the perceived overlapping benefits and contributions extended to the allocation of
liabilities. However, in this case participants agreed that as recommended in the AIA documents, there
is a need for an information manager, who can be held responsible for the collaborative BIM model,
such that the information manager can be held liable for issues arising from the lack of coordination in
a collaborative BIM model. As one of the participant states:

“Information Manager is brought into the equation to manage the complexity of the model. Thus,
issues arising out of the inaccuracies in the model can be traced back through the information
manager.”

3.2 BIM as service

Participants agreed that BIM is eventually going to be a basic service, an integral part of the design
representation and communication across the collaborating parties. Hence, it is expected that
eventually best practices in managing BIM as a basic service will evolve. But until that happens; there
is a need for clearly stated guidelines and mutually agreed protocols for managing BIM as a service,
particularly in terms of the service charges and delivery.

3.2.1 Paid service

The discussions on BIM as a paid service overlapped with the lack of clarity with other issues such as
valuation, roles and responsibilities and shared risks and benefits. Some participants argued that
BIM is just a mode of data representation and management, while others argued that it requires extra
effort and investment for some parties developing the model, and hence, it needs to be considered as
an additional service, which should be separately charged. Some of these sentiments are reflected in
the following quotes

“Model developers are paid for a service and so there is no copyright on contributions by a
contractor to a BIM model. BIM model is a mere representation of the product, the design. Hence,
there is nothing new about that apart from the mode of representation.”

“The payment may be determined by whether BIM is considered as an additional service, optional
additional service or a basic service. Depending on how that service is viewed in the agreement, the
payments may vary.”

“As an architect you are paid and therefore you relinquish ownership ... Do you own the
drawings?”

Eventually these discussions on BIM as a paid service gravitated towards the contract agreements
and negotiations. As presented in section 3.3, participants agreed that finally the payments for the
service are determined by what the parties negotiated for and agreed in the contract, and whether BIM was stated as a basic service or an additional service to be charged separately.

3.2.2 Point of delivery

Participants emphasized that the protocols for the transactions and sign-offs during the service delivery needs to be clearly specified in the agreement to avoid conflicts. These specifications need to cover the aspects such as the mode of delivery, time of delivery, quality of delivery, and so on. The discussions on the point of delivery also overlapped with the concerns about the quality of the BIM model as well, as reflected in the following quotes

“How does the handover get signed off- accounting for completion, accuracy, quality control and so on. Specifications for these procedures need to be in place...”

3.3 Contracts and agreements

Participants agreed that contracts and agreements are the key legal tools to manage the complexity of a BIM project. Participants emphasize that the construction industry has traditionally relied on contracts and agreements, and there is nothing particularly new about the contracts and agreements for BIM project, apart from the fact that there is a greater need for multi-party agreements that clearly specifies the collective legal commitments, as opposed to the existing practice of multiple separate agreements between each of the collaborating parties. However, discussions often gravitated towards the factors such as negotiation skills and conditions and the presumption of trust and good faith, which determine whether the contracts and agreements are balanced or skewed because of power relationships.

3.3.1 Negotiation

Participants emphasized that negotiation conditions and skills hold the key for how the issues around the status of BIM as a service, and how that is valued, will evolve over time. As one of the participants stated,

“The payment for BIM as a service is determined by what is negotiated in the contract. This is nothing different to real property. Designers and developers build properties on behalf of the client and the ownership is transferred after the project completion. If the architect is paid for the design then the architect may not as well replicate the same design elsewhere without the consent of the owner, even if he retains the copyright. Nor can the owner replicate the building without the architect’s permission... it all depends on what you agreed for...”

3.3.2 Trust and good faith

Contracts and agreements were the primary legal mechanism discussed by the participant. The participants agreed that contracts and agreements remain the best option in safeguarding collective interests of the collaborating parities, and hence, there will always be an element of trust and good faith for the parties to work together on a BIM project, which is similar to any collaborative work. The following quotes from one of the participants sums up the collective view

“BIM is a representation of the collaborative knowledge of the group in IPD or Design Build scenarios... to have collaborative knowledge we need to have good faith. Hence, there is a presumption of good faith in signing the contract”
3.4 Risk management

Participants agreed that most of the apprehensions surrounding the use of BIM models as the basis of design and build is about risk mitigation and risk management, which is closely tied with issues of roles and responsibilities, liabilities, and so on. However, at the same time participants agree that contracts provide a mechanism to clearly identify and state the risk management clauses, as also discussed in the ConsensusDOCS™ (2010). These sentiments are reflected in the following quotes:

“*It is all about risk management* “

“But cost is a business issue... however there are other uses such as risks and rewards which can have a legal dimension... the risk management part is built in the contract...”

“*Potential risk clauses need to be identified and included in the agreements.*”

3.5 BIM as product

Participants raised various issues when discussing BIM as a product and these related to the ownership of the model and its rivalrous characteristics, the quality and finish of the BIM model, the purpose of the model, and the resources that go into the production of the model including time, cost and labour.

3.5.1 Model ownership

Participants agreed that model ownership remains an important discussion topic. However, discussions revolved around the types of models and how different models may be used across the different phases of the project. It was generally agreed that eventually the value lies in transferring the model to the client or the project owner as documentation of the built facility and to serve as the basis for facilities management, depending on the level of detail and agreed purpose of the model. As one of the participants commented:

“*Model ownership has been one of the most talked about topics. However, it is reasonably straightforward and requires clear specifications in the contract such as, who owns the model at what stage?*”

3.5.2 Duty of care

Participants concluded that the duty of care can be managed through clear specifications in the contract agreements. This is reflected in the following quotes:

“What creates the model and what are the associated roles and responsibilities? What is the “Duty of care” and what are potential liabilities associated with errors in the model or when the error in the model is transferred onto the site?”

“*Roles and responsibilities need to be clearly defined in terms of the legal dimensions of negligence of the relevant discipline, i.e., whoever is responsible for ensuring the quality of the model and that of the design.*”

3.5.3 Purpose of models

Participants agreed that the levels of detail in the BIM model may vary across the project or even the project phases depending on the purpose of the model. Hence, as discussed in the ConsensusDoc™ (2010) the purpose of the model needs to be clearly agreed upon and specified in the contract to avoid conflicts, as reflected in the following quotes:
"To what level should the model be detailed? Is there a classification of the different levels of models – and how much you can rely on models."

### 3.5.4 Persistence of the model

The issues of model version management, versions of softwares and standards, and archiving were discussed at length in context of the persistence of the model. Participants agreed at the measures needed to ensure the usability and integrity of the model for the entire project lifecycle and beyond need to be clearly stated and specified in the contract agreements. As one of the participants stated, "Does the model have as much persistence as we think – because it changes regularly...context changes, legislation changes, etc.... However all that needs to be covered within the contract ...things like how often updates need to created, how to ensure versions, usability of the stored data, and so on..."

These ownership issues, the resources consumed towards the production of the model and the discussions about the purpose of the model, lead to the discussions towards the value of the model and the need for valuation mechanism.

### 3.6 Value of BIM

Participants agreed that while BIM is generally acknowledged as a value added proposition, the actual value or the process of valuation is not well understood. Participants agreed that the time, labour and other resources utilized in developing a BIM model clearly suggest that BIM model has value to it, notwithstanding the intellectual capital in the design representation. Hence, even if there is no new Intellectual property in a project, there has to be some other value propositions in the model, which is not clearly identified. Some participants agreed that even in the non BIM projects, architects and model developers did not have a well structured mechanism to assess the value of visualization models. Their argument is that even though this lack of rigour in model valuation has not proved critical in the current practice such adhoc valuations of the models may not work for BIM models, which are universally acknowledged to have greater information content, collaborative knowledge, and applicability to the different phases of the project lifecycle. The following sub-themes related to valuation emerged out of the focus group discussions:

#### 3.6.1 Intellectual capital

The participants argued that the fascination with Intellectual Property (IP) issues may have resulted in the neglect of discussions over the other values of the BIM model. In general, participants agreed that the apprehensions with the IP issues with BIM projects are misplaced because IP issues in BIM project are no different from the traditional non-BIM projects. "IP has value and this has to do with value. There may be no new IP in a project even though there is some value in the BIM model. “But how is the IP held in a BIM based collaboration any different to the current practice?”

Some participants echoed the arguments put forward by some authors (Larson and Golden 2007, Cremonese and Wissinger 2010) that BIM projects may in fact reduce the efforts and conflicts in managing IP issues because of the inbuilt documentation and tracking of contributions and authorship in a BIM model.
3.6.2 Valuation mechanism

Some participants argued that a valuation mechanism is not a legal concern, and valuations mechanisms may never be required because value is a market driven entity. However, others argue that a valuation mechanism and estimation process for BIM models may be a prudent approach that can draw upon the valuation and estimation methods used for real physical buildings and properties. These participants argue that even though in general value remains a market driven concept, there are standard valuation mechanisms across the different industries for different entities to ensure that the market is regulated for the general welfare of the various stakeholders. These sentiments are reflected in the following quotes:

“Value is only what someone is willing to pay.” - “How do you value a BIM model? We have an ‘estimation’ process now on how to charge for the building to the owner. Can we do the same for the BIM model? But doing this are we taking away something from the whole philosophy of what we bring to the client? Is the model an entity that can be paid for? Is it just a process and we should not charge the client? “This is a marketing issue, not a legal issue... Utility – how useful will it be ...” - “Nervousness is that people may not know what the value is in what they do now and the value only becomes more and more apparent later on.”

In summary, following are the key findings from the focus group discussions:

1. Discussing the potential implications for design practice, participants agree that the significant change is the concurrent and collective development of the model by different parties who may or may not be contributing to the same model. However, participants consider that as a legally transparent issue because even with existing applications it is easy to track model authorship and contributions. However, participants emphasize that such documentations and tracking mechanisms need to be specified in the contract as mutually acceptable means to allocate risks and responsibilities. It was agreed that as suggested in the ConsensusDOCS™ (2010) it is the responsibility of the Information Manager to coordinate these handovers, with adequate documentation and proof of compliance with the specifications for model management and data transfer. Furthermore, participants agreed that the law of commons and anti-commons might be particularly useful in dealing with issues that may arise from sharing of the model in an alliance or joint venture. Participants regularly referred to the AIA initiatives and the ConsensusDOCS™ (2010), and agreed that apart from valuation mechanisms most other issues have been covered in these documents. There are suggestions that valuation of the models can also be stratified across the purpose of the model and the levels of detail described in the ConsensusDOCS™ (2010) but valuation has not been addressed sufficiently.

2. In general the participants in the focus group agreed that the law of contracts remains the most appropriate mechanism for manage BIM projects. The different parties and stakeholders in a collaborative BIM projects need to clearly specify and negotiate how BIM is managed across the project lifecycle. There is an agreement that the contract agreements are also the most critical mechanism for managing risks. How the risk is shared across the parties and stakeholders is subject to negotiation. However, participants view that negotiation, which may be determined by other market forces, may create a skewed agreement in favour of some stakeholders.
3. Reflecting on the current apprehensions with the IP related issues with BIM, participants agree that the IP issues may not be as significant as portrayed. Participants agree that most of these issues are similar to current practice as even in the current practice new created knowledge and IP is exhibited to project partners and used in the project. The same mechanisms that have safeguarded IP in existing practice can be used in BIM based projects. IP protection can be covered in the contract agreements with a presumption of good faith. It was suggested that the party that created IP may or may not include sufficient details of created IP in the delivered model, as agreed upon by mutual consent of the parties.

4. Though there is a general agreement that valuation is market driven and not necessarily a legal issue, it was noted that there is still a recognized process for property valuation and estimation. Hence, the discussion raised the question if there a possibility of the role for an arbitrator to conduct valuation of a BIM model? If there the possibility for a mechanism to estimate the value of a BIM model then what factors will constitute that valuation- e.g., accuracy, level of detail, man-hours spent in model development, speed of model development, purpose of the model, editability of the model, uniqueness and appeal of the model- and what else. The key question is, if the valuation of a model is left to the market factors only, is there a possibility of ethics and regulation where power relationships and cut-throat competition will lead to exploitation and undercutting? Afterall, such regulatory measures are in place to ensure fee structures and minimum wages in the industry to avoid exploitation.

4. CONCLUSIONS

This paper reports on the preliminary investigations into the notion of BIM as a virtual property that has value. The understanding of BIM as a property is validated through conformity with the features that characterise or qualify anything as property, namely, rivalrous, persistent and interconnectivity. Examples and focus group discussions demonstrate that BIM is rivalrous because it allows ownership and control of the model. BIM is persistent as the model can be used and accessed for extended period of time during the project lifecycle, and beyond. BIM shows interconnectivity as different parties are involved in creation, use and access of the model in different capacities. However, while these concepts are found to be theoretically sufficient to suggest that BIM is a virtual property that holds value, there are doubts if these concepts can lead to the development of a mechanism for valuation of BIM. Discussions suggest that most legal issues and apprehensions with BIM can be addressed through well specified contracts. The ConsensusDOCS™ (2010) provide a useful template in this regard. However, these preliminary findings suggest that the missing link in the BIM legal initiatives is the valuation process. While valuation is recognized as a market driven factor, there may be a need for an established approach for model validation and estimation, analogous to the estimation of real physical properties. The key question is, if the valuation of a model is left to the market factors only, is there a possible ethical and regulatory concern that power relationships and cut-throat competition may lead to exploitation and undercutting?

4.1 acknowledgement

The authors wish to acknowledge Dr. Simone Leao’s help in preparation of the works and the ethics clearance for this project. The authors also wish to thank all the participants in the workshop.
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Task Management System development for collaborative performance of building-yard workflows

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Abstract: Research about building information modeling (BIM) supports the complexity of building life cycle. This paper focuses the activities carried in and around a building-yard (building-yard workflow) to manage a design from its starting version to the delivery of the building to the customer. Many actors with different experiences and roles produce and exchange information often inconsistently, causing knowledge misalignment and lacking of relevant information. The evolution of CantiereOnLine vers. 1 is discussed, a BIM system focused to design management in building-yard. Adoption of end user development approach for designing workflows, workbench offered to users for semantic search from remote repositories, customization and integration of autonomous software components, and their storing; reinterpretation of the idea of Task Management System as a platform expandable with additional components realizing specific tasks; these main features led to COL vers. 2 as a TMS Editor. The workflow includes activities from the head office of a building enterprise to the building-yard; in the technical office, annotated and modified technical drawings and documents are validated and circulated in an accepted release, uploaded on mobile devices used in building-yards, where are annotated to indicate building variations and other additional information; the annotated drawings are sent back to the technical office. The workflow designer operates in COL workbench by means of visual commands and widgets representing task components, relations among them and operations which can be performed. Each component consists of its active part, based on Web Services technologies, and its semantic description expressed in Web Ontology Language standard, allowing organization of repositories based on a shared ontology.

Key words: Building technologies, building yard, design management, workflow, task management, Web Services, visual user interaction

1. INTRODUCTION

The Italian building field is characterized by a vast and fragmented reference structure, encompassing both technical and legislative aspects.

The overwhelming amount of technical standards, national, regional and local laws, European guidelines and directions lead to a growing difficulty in operating in this sector with awareness and safety; moreover, this complexity calls for lifelong learning by every practitioner involved in the building process.

This fragmented scenario, together with the constant evolution of technologies, makes very difficult to structure the building sector’s knowledge, giving birth to more and more specialized information and communities of practice that, in turn, generates new standards.

During the building process this knowledge, together with specific documents such as technical drawings, orders from supplying stores, certificates and projects, must be made available to different specialized practitioners and enterprises involved in the process; all the actors will then use this knowledge and in turn will produce new one that must be shared and updated. This gives birth to a very complex information flow, in which documents are browsed, updated and shared often by
different actors at the same time. Information and data management in general is a keypoint for the correct and effective execution of all the steps that goes from building design to its realization in the yard: the tool used to manipulate information such as technical drawings or written documentation must be designed taking into account not only the fact that different practitioners, with different culture, notation schemes and purposes have to edit them, but also the environmental conditions under which the tools are used. In particular, the same documents must be accessed and edited both in the head office of the building enterprise and in the yard, requiring two different user interfaces for the same editing tool: one for desktop PCs, with regular-size displays and interaction peripherals (mouse, keyboard), and one for mobile devices with reduced-size displays and haptic interaction style.

COL vers. 1, acronym for the Italian “Cantiere On Line” (Online Building Yard) is a software application that allows the management of site documentation in electronic format and the exchange in real time from one actor to another of documents in any case in their last version and corresponding to the real condition of the building. Both actors working in the enterprise and those working in the building site have the application software respectively installed on a personal computer or laptop and on a tablet PC. The main feature of COL is the possibility, for actors of the building site, of annotating documents, that is specifying what type of variant has to be done, by choosing the corresponding symbol and by adding a note, and where, on the document, it has to be placed. The modified document is sent in real time to the directly interested actors that can evaluate it and decide if the variant can be accepted, refused, deeper analyzed and so on.

From a technical point of view, COL is characterized by the integration of several modules. In particular, two of them, COL Workdefine and COL Field have been conceived for the enterprise and the building site that manage different kind of information. Concerning the second one, it offers different interfaces corresponding to the competences of the different professional profiles (site manager, surveyors, etc.).

The purpose of our work is to present an advancement of COL vers. 1 in (Fogli, Marcante, et al., 2005) (Fogli, Mussio, et al., 2006) (Fresta, Marcante, et al., 2006) (Oliveri, Padula, et al., 2004), on the basis of our recent works described in (Barricelli, Mussio et al., 2010a) (Barricelli, Mussio et al., 2010b) (Barricelli, Mussio et al., 2010c) (Ariano, Barricelli et al., 2011), by developing a more flexible, modular and customizable system that relies on the concepts of workflow, Workflow Management System, Task Management System, component-based system and on web Services technologies and semantic Web standards. In particular, an architecture will be presented, which: a) makes possible to easily update the tools used by practitioners following the ever-changing standards and local laws regulating the building sector; b) allows a collaborative design and development process in which practitioners and final users are involved; c) permits effective knowledge management for promoting its further reuse.

2. THE BUILDING YARD WORKFLOW

Each flow of information implies a workflow which describes the activities which yield it; a workflow is intended as a model which formalizes a work process for further assessment and manipulation (e.g. for optimization or iteration of specific sequences of tasks) (ISO, 2004); that is, a set of atomic operations (called tasks) that have to be executed in a specific order to reach a specific goal, in this case the management of all the activities carried out by the actors involved in the design and realization of buildings.

The workflow spans from the technical office, where all the documents produced will be stored and made available, to the building yard in which different practitioners will download those documents, modify and update them according to the activities performed in the yard. We have thus identified the
workflow represented in Figure 3: rounded boxes represent tasks, while diamonds indicate a choice that have to be made between two or more tasks.

The workflow starts with engineers and designers producing technical drawings and documentation covering various aspects such as plant design, building projects and plumbing system design.
At the same time, the chief director compiles a first project schedule, often in the form of a Gantt chart, that will be kept updated during all the building period.

Once these two activities are concluded, all the documents are uploaded on the technical office’s server, and a starting report is prepared and uploaded too; at this point the first macro-activity named “yard tracking” starts the building process in the yard. It includes the downloading of the progress and yard journal, their update and their subsequent upload on the server. It might also be necessary to produce certificates during the building process, such as the correct laying certificate.

Controls must be performed to ensure the correct execution of all the building activities, and events such as design variations or nonconformities must be recorded and treated properly. In the case of variations, they first must be defined with the help of the variants price list, and once defined uploaded on the server; after that, they must be checked against standards and technical documents, realized and recorded in the executive project. Finally, when the building process is completed, a certificate of habitability is produced.

This workflow is collaboratively carried out by various actors, each one of them performing a sequence of tasks that can also overlap another sequence performed by another actor. These sub-sequences can be considered workflows on their own, because they represent the path to follow to accomplish a specific activity. In Figure 3 each different shade of gray indicates the workflows which describe the specific tasks performed by a specific actor, while tasks with dashed outline are performed at the same time by more than one actor. Tasks in dark gray are performed by the yard foreman, tasks in black by one or more architects/engineers, and task in light gray by the head office.

As can be seen in the representation, some tasks are concurrently executed by more than one actor at the same time, that is, it is possible for the same documents to be accessed and updated simultaneously by different individuals. The tool provided to the practitioners have to take into account this kind of concurrency, to ensure integrity and correctness of the yard’s documents.

Therefore, we propose a network of software environments aimed at the meta-design, design and use of applications implementing the workflows pertaining to every actor. To do so, we have extended the idea of workflow management system, i.e. an application that permits to represent and execute a formalized sequence of tasks, with the revised concept of Task Management System (Miller, 2000) as a component-based system (Szyperski, 2000) that can be extended by searching and acquiring computational elements representing tasks and control structures to regulate their execution.

We call these computational elements tComponents (task-components), implemented as Web Services and semantically described using OWL, the Semantic Web Language (McGuinness and van Harmelen, 2004).

In this article we will focus on a specific environment, called TMS Editor, a visual interactive system used by Workflow Designers to search and retrieve existing tComponents from local or remote repositories to compose them in the desired workflow, or to aggregate them to obtain more sophisticated functionalities.

3. THE METHODOLOGY FOR SOFTWARE DEVELOPMENT

Workflow management by cooperative groups of people is supported by software tools to share information, manage communication, schedule and assign tasks to the co-workers.

Domain experts, who are not computer scientists, are involved in workflow management. We primarily consider: 1) Workflow Designers, who are in charge of designing the current workflow and supervising its correct execution; 2) Workflow Operators, who execute the workflow process. This
paper focuses on Workflow Designers and on the description of the software environment that supports their activities, called TMS Editor. A Workflow Designer interacts with the TMS Editor and performs an interactive semi-automatic composition of services representing the components (tComponents) at the base of the current workflow.

The whole TMS system is designed according to the Software Shaping Workshop (SSW) methodology described in (Costabile, Fogli et al., 2007); it adopts a meta-design approach which underlines a suited vision of system design. All stakeholders of an interactive system, including end users, are ‘owners’ of a part of the problem: software engineers know the technology, end users know the application domain, Human-Computer Interaction (HCI) experts know human factors, etc.; they must all contribute to system design by bringing their own expertise. Stakeholders need different software environments, specific to their culture, knowledge and abilities, through which they can contribute to shape software artifacts. They should also exchange among themselves the results of these activities in order to converge toward a common design.

An interactive system is thus designed as a network of software environments, called workshops, each of them being either an environment through which end users perform their activities or an environment through which stakeholders participate in the design of the whole system, even at use time. The network of workshops is organized in three different levels, based on the different types of activities the workshops are devoted to (see Figure 2): the use level, lying at the bottom of the network, includes workshops that are used by domain experts to tailor and use their workshops in order to perform their activity; the design level, located at the middle level of the network, includes workshops used to perform the collaborative design and development; the meta-design level, at the top of the network, includes workshops used to create and maintain all the workshops in the network, usually by software engineers, but sometimes also by HCI experts and end users.

In the specific case reported in this paper, the network of software environments allows end users of an organization to design, execute, and check the execution of a workflow. The attention is concentrated on the workshop used by Workflow Designers, i.e. the TMS Editor (see Figure 2).

Figure 2. SSW network for the Task Management System
In fact, Workflow Designers play a fundamental role for what concerns the design and the development of a workflow, and for this reason they are directly involved in all of the activities carried out during its whole development cycle. The TMS network is designed to allow Workflow Designers and Workflow Operators to collaborate in the design and the development of a software artifact. TMS coordinates the stakeholders in the team to search, acquire, describe, and aggregate services. Such services perform each one single autonomous task in the work processes. For lack of space, only the collaborative creation of a workflow is described (Software engineers and HCI experts are not considered in this paper). At meta-design level, domain experts use a system workshop to define the overall structure of the workflow. These domain experts use tools for task analysis to represent in a structured way concepts and activities that constitute the workflow, without referring to implementation issues. At design level, the Workflow Designer uses the TMS Editor workshop by which s/he transforms the task analysis document in a description of the needed components (tComponents) and the relationships among them. At use level, the Workshop Operators, use their TMS instances developed at the above levels.

Figure 2 illustrates the documents traffic in the network. Downward arrows show the flow of the documents from the upper to the lower level: documents from meta-design to design level describe the workflow task analysis, and from design level to use level, the executable descriptions of the TMS instance to be used. The upward arrows show the communication among the users at the lower level and the (meta-) designers at the upper level. All the stakeholders can communicate problems, difficulties or suggestions regarding the workshop in use to the other stakeholders, at the different levels. The case study described in this paper refers to the activities of the Workflow Designer, who interacts with the TMS Editor by direct manipulation techniques to visually compose the workflow.

This composition is semi-automatic: the TMS Editor, by exploiting two engines, i.e. the Semantic Search Engine (SSE) and Orchestration Engine (OE), retrieves and orchestrates the Web services components which satisfy the Workflow Designer’s requests. The graphic interface of the TMS Editor, together with the OE, supports the Workflow Designer to compose the desired workflow; s/he has not to worry about the technical details of the orchestration process and orchestration language (BPEL4WS) (Alves, Arkin et al., 2004), deferring them to the software engineers by communicating with them and exchanging the resulting orchestration document. Thus, the Workflow Designer does not need to be a computer science expert. The collaboration of the different communities of end users – e.g. workflow managers, workflow designers – in the workflow composition activity leads to a powerful and significant social activity, and all the stakeholders contribute in enriching, managing and updating the shared knowledge base of the TMS network.

4. THE ARCHITECTURE OF THE TMS EDITOR

The aim of the TMS Editor is to support the design activity of Workflow Designers by allowing them to exploit their tacit knowledge and expertise, and without boring them with technical details about the language used to implement, store and transmit the final workflow document. The TMS Editor interface is designed so that Workflow Designers can operate according to an EUD approach for designing workflows by means of visual commands and widgets. The visual widgets are used to show tComponents and their relations in a graphic way translating the semantic description of the tComponents and their relations into visual forms. On the other side, this semantic description enables a mapping between the Web Services Description Language (WSDL) (Chinnici, Moreau, et al., 2007) interface of the tComponent with a Conceptual Reference Model (CRM) describing its behavior, goal and structure. The CRM of a tComponent is a set of classes and properties, expressed in OWL,
describing its semantics in term of used field, input and output interfaces, interaction style, and algorithmic behavior.

Exploiting this information the Workflow Designer can use the Semantic Search Engine (SSE) for retrieving the tComponents useful to compose the final structure of the workflow according to the workflow structure defined at meta-design by domain experts (see Figure 3), and import them in a temporary local repository. Therefore, exploiting the visual representations of each tComponent loaded into the temporary repository, the Workflow Designer is able to design a workflow through the integration of heterogeneous tComponents matching their input-output interface. To support this activity the TMS Editor has to adopt specific techniques of composition and integration management services. An Orchestration Engine (OE) translates the composition defined by the Workflow Designer using the TMS Editor interface, into a BPEL4WS workflow document describing the correct sequence of operations in the workflow.

![Figure 3. The architecture of the TMS Editor](image)

These tComponents are stored in various knowledge bases, that can be local or remote. Information stored in those knowledge bases about every tComponent consist of three different elements: 1) a WSDL description of the tComponent to be invoked, describing the syntactical and computational-based aspects about the tComponent; 2) a semantic description of the tComponent’s functionalities; 3) a RDF (Beckett, 2004) description that maps the semantic description onto the WSDL of the tComponent. Interacting with the SSE through the TMS editor, Workflow Designers can search the more suitable tComponents, according to the context of use of workflow defined at meta-design. Then they trigger the orchestration activity to produce the final description of the workflow process as a
BPEL4WS document. This document is represented on the screen as a sketch of the widgets representing the tComponents and their relations.

5. USER INTERACTION WITH THE TMS EDITOR

The TMS Editor user interface is represented in Figure 4, and it is constituted by different widgets and active areas: the main area of the interface is represented by the composition canvas, where the Workflow Designer can graphically link together tComponents to obtain a workflow or an aggregation of tComponents, depending on the environment that has been activated using the tabs located in the upper right corner.

Pressing the WCE tab allows to activate the Workflow Composition Environment, for the composition of tComponents to implement a specific workflow, while the WAE tab activates the Workflow Aggregation Environment to aggregate already existing tComponents in more complex ones.

The functionalities offered by the button panel on the top of the canvas are context-dependent, i.e. the various operations (create a new document, open, save, validate and export) acts on workflows or tComponents aggregations depending on the selected active environment (WCE or WAE): besides the basic operation of creating a new document, saving and loading it, the “Validate” button allows the Workflow Designer to check if an composition or an aggregation of tComponents is corrects, that is, a check is performed to verify if all the tComponents on the canvas are connected, if there are no loops, and if, for every tComponent, a variable assignment has been performed.

The “Export” button relies on the Orchestration Engine capabilities, and automatically translates the graphical composition of the workflow (or aggregation) performed by the Workflow Designer in a valid BPEL4WS document. This translation can be saved in a storage device and represents, upon its deployment inside an execution engine, the TMS Instance used by the Workflow Operator at use level.
The vertical panel on the right side of the canvas allows the Workflow Designer to un-do or re-do the last editing operation she/he has performed, to delete a selected tComponent, and to group or un-group multiple tComponents: when two or more tComponents are grouped together, the Orchestration Engine at translation time will render the group as a set of concurrent actions.

When a tComponent on the canvas is selected by the Workflow Designer, a movable panel will appear on the left containing information such as the tComponent functionality, a brief description of what it does, its developer and so on.

One of the most important elements of the user interface is the toolbar situated under the top button panel: it is a scrollable area that will be populated with tComponents retrieved by the Workflow Designer using the “+” button. By hitting this button she/he invokes the Semantic Search Tool (SST, Figure 5) to graphically compose a query directed to local and remote tComponents’ repositories in order to acquire the desired tComponents.

These queries can be hard to handle for non IT professionals such as the Workflow Designer, so, by directly selecting operands (classes and properties representing sets of tComponents and their characteristics) and boolean or arithmetic operators from two different lists (operands in the list on the left and operators from the button panel on the right side of the SST), the Workflow Designer can easily search and acquire tComponents. The tComponents returned by the query will then be visualized in the table at the bottom of the SST, together with the values of their properties; the Workflow Designer can then choose to import them into the toolbar available in the WCE and WAE.

The toolbar then represents a temporary repository the Workflow Designer can exploit to get the latest components she/he fetched, thus avoiding to use the SST again: this lets the workflow designer to concentrate on the main activity she/he has to perform, i.e. the workflow composition. Finally, from the toolbar the components can be dragged and dropped into the composition area. If a tComponent is not needed anymore, the Workflow Designer can remove it from the toolbar by pressing the “x” button.

Figure 5. The Semantic Search Tool
tComponents are linked together by the Workflow Designer in the composition or aggregation area using direct manipulation of visual elements representing the tComponents: by clicking on a tComponent and dragging the mouse pointer towards a second tComponent, an arrow is drawn representing both the workflow and the information flow between them. A problem is that tComponents could have a large number of inputs and outputs, each one of them representing a variable in the WSDL describing them, thus using an arrow to indicate each association between an input and an output originates in a huge amount of lines drawn over the canvas. The result is an hardly-readable graphical representation of the workflow to be developed. To avoid this problem, the TMS Editor offers a tool called Variable Mapper to assist the Workflow Designer in this variables binding process (Figure 6).

![Figure 6. The Variable Mapper Tool](image)

By double clicking on a tComponent, the Variable Mapper interface is called and presents the user with two variables’ lists one aside the other, hierarchically organized: the list on the left allows to choose the tComponent’s outputs to be linked to inputs of other tComponents, shown in the list on the right. By using the same mechanism implemented in the composition/aggregation environment, the Workflow Designer will then trace arrows from output variables to input variables, deciding which tComponent is tied to another.

After this operation is completed, if two non-contiguous tComponents are linked together, a dashed arrow will be visualized in the canvas, representing the fact that there is a flow of information between them; alternatively, a full line is used to indicate data exchange between contiguous tComponents.
6. RE-DESIGN OF THE TMS EDITOR FOR COMPLEX WORKFLOWS

The TMS Editor has been designed referring to a specific case study in which the Workflow Designer needs to compose a workflow mainly characterized by a sequential execution of the tasks constituting it, managed at use level by a single Operator. The resulting TMS Instance in fact allows the Workflow Operator to execute the specific implemented workflow, regardless of possible interactions with other TMS Instances that could be needed to pursue her/his goals: this means that, in the case of multiple TMS Instances at use level, the coordination of their execution must be performed by Workflow Operators themselves.

The coordination between workflows and the actors involved in them is possible if a choreography language is considered for Web Services composition, instead of the orchestration language used thus far (BPEL4WS).

![Figure 7. Relationship between Web Services orchestration and choreography (adapted from (Peltz, 2003))](image)

The relationship between Web Services choreography and orchestration is represented in Figure 7: orchestration refers to a workflow that can interact with internal or external Web Services, by means of messages exchanges. Those messages define the order of execution of the activities, and the operations to be performed (Peltz, 2003).

We can say that orchestration defines the workflow by a single point of view, that is the one of the actor starting it. In contrast, choreography allows to define a collaborative approach to Web Services
composition, where different point of views are taken into account to represent a workflow, permitting to every actor involved to describe her/his role in the interaction.

Thus, choreography defines the exchange of messages between the different systems involved in the process.

The complexity of the workflow we have identified (Figure 1), referred to the building process, led us to modify the TMS Editor design to let the Workflow Designer to design the interactions among workflows, and at the same time to expand the OE architecture to support a choreography language other than the actual orchestration language. We are at present considering WS-CDL (Web Services Choreography Description Language) (Kavantzas, Burdett et al., 2005), an emerging language, a W3C candidate recommendation that offers an XML-based language to describe peer-to-peer collaborations of participants by defining, from a global viewpoint, their common and complementary observable behaviour, where ordered message exchanges result in accomplishing a common goal.

The WS-CDL model allows to compose interoperable peer-to-peer collaborations between parties by the means of different elements such as: role and relationship type, describing the role of each participant in the choreography and the kind of relationship established between parties, in terms of exchanged information; information types, variables and tokens, allowing to define the type of information exchanged and to permit the persistence of this information during the collaboration; choreography definition, consisting of a choreography life-line expressing the progression of a collaboration; channels definition, specifying where and how information is exchanged between participants; activities, that are the building blocks of choreographies, performs the actual work; they can be of different kind (perform activities, assign activities, interaction activities) and can be combined together using ordering structures (e.g. serial or parallel ordering structures).

7. CONCLUSIONS

This paper proposes an advancement of an already existing software application called COL (Online building Yard, “Cantiere On Line” in italian), that allows the management of electronic site documentation exchanged between the actors involved in the building process. The advancement consists of a Task Management System, realized through a three-levels network of software environments for the meta-design., design and execution of a Workflow Management System. The resulting WMS implements the identified building yard workflow i.e., the sequence of activities that need to be carried out during the design and the realization of a building. In this paper we focus on the software environment at design level, called TMS Editor and used by Workflow Designers to visually compose the desired workflow. The final section represents a perspective discussion for the future prototyping of a new version of the TMS already developed, which will take into account concurrent workflows implementation and execution by adopting a choreography language for workflow definition.

8. REFERENCES


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The cultural political economy of megaprojects
Governmentality and the social realm of client decision-making

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Abstract: In recent years the landscape for international design management has been fast changing and a key development, which has led to this, has been the unprecedented advances in digital technologies. Firms in the architectural, engineering and construction (AEC) sector are no longer constrained to working on domestic projects but now operate on a global scale. The rise of globalisation has not been without problems and in particular project challenges related to technological and social complexity, strategic behaviour, contested information and cost overruns are prominent. Effective design management and project success is significantly impacted by the internal workings of clients and its relationship with project decision-making which is often beyond the control of project teams. Yet the focus of past megaproject and design management research has tended to be on the industry’s role instead of the client’s. In their role as project initiators and financiers, clients are the driving political force on projects, occupying a central position within the power structure embedded on megaprojects. This paper is positioned within a PhD study which seeks to offer a theoretical contribution to the design management field by examining the governance context of megaprojects with a focus on the critical role of the client. There has been little research investigating the sophistication of the international client and their capacity to contribute to project success in relation to sound decision making regardless of the political environment. This research is concerned with two key gaps; firstly a lack of empirical research to explain the nature and structure of the power relations underpinning the client’s complex decision-making environment on megaprojects and secondly, a lack of theory and methodological framework to achieve this. A theoretical model is proposed based upon the concept of governmentality to explore the power relations underpinning megaproject decision-making. The outcomes of this research have serious implications for design managers in the AEC sector who are increasingly faced with project challenges in the international megaproject environment. Deeper understanding of how various forms of power come to be created, distributed and exercised on megaprojects may enable design managers to better shape and influence project outcomes at various stages of project decision-making.

Key words: Governmentality, megaprojects, clients, power, cultural political economy

1. INTRODUCTION

In recent years the landscape for international design management has been fast changing and a key development, which has led to this, has been the unprecedented advances in digital technologies. Firms in the architectural, engineering and construction (AEC) sector are no longer constrained to working on domestic projects but are now highly mobile with considerable potential to operate on a global scale. Therefore projects must now be recognised as undertakings by distributed teams with inherent characteristics which differ from those found in traditional co-located environments (Bourgault et al, 2008). The rise of globalisation has not been without problems and in particular AEC project challenges related to technological and social complexity, strategic behaviour, contested information and cost overruns are prominent (Flyvberg et al, 2005). Collaborations in the international environment often involve networks of dispersed team members who work on increasingly large and complex megaprojects. The scope and scale accompanying such megaprojects are often overly
magnified which create new challenges for effective decision-making as processes are often ill adapted for facilitating collaborative work (Bourgault et al., 2008). Megaprojects often bring together networks of people with different backgrounds and cultures to work in unfamiliar locations and therefore specific attention needs to be given to the “international” character of megaprojects. A global surge of international megaprojects in the 1990s set the agenda for developments in the AEC internationalisation discourse, which have typically sought to describe market entry strategies (Crosthwaite, 1998), barriers (Gunhan and Arditi, 2005; Dikmen and Birgonul, 2006) and success factors for international firms (Mawhinney, 2001; Howes and Tah, 2003; London and Siva, 2010).

Effective design management and project success is significantly impacted by the internal workings of clients and its relationship with project decision-making which is often beyond the control of project teams (Crawford et al., 2008). Yet the focus of past megaproject and design management research has tended to be on the industry’s role instead of the client’s. In their role as project initiators and financiers, clients are considered to be the driving force on projects, occupying a central position within the power structure embedded on megaprojects. As AEC clients and project teams continue to experience the global challenges posed in the digital arena and the associated changing nature and structure of work practices and project relationships it is important to understand the implications of these changes for design management theory and practice. Such changes demand new ways of defining project organisational boundaries and managing relationships within and across these boundaries. How well do existing theories and assumptions about design management research reflect the realities of these emerging megaproject work environments? What impacts do emerging forms of international work contexts have on project roles, client relationships and decision-making? How much do we know about the existing nature and structure of client relationships on international megaprojects and its relationship with how projects are governed?

This paper is positioned within a PhD study which seeks to offer a theoretical contribution to the design management field by examining the governance context on megaprojects with a focus on the client’s critical role. Clients are in a powerful position to influence project delivery. Clients establish a unique culture that project team members need to work within by setting the boundaries within which decisions affecting budgets, quality, design and procurement come to be made. The values that clients ascribe to their everyday practices inevitably condition how they act economically, which in turn impacts upon megaproject decision-making. Past research has demonstrated that high cost overruns and disappointing operating results can be linked to clients’ political economic decisions (Flyvbjerg et al., 2003; Flyvbjerg, 2009). The client’s centrality within a project network has long been recognised. Since 1944 there has been a continued trend in the quest for improved construction industry performance through client-driven strategies but with little evidence that the issues have been resolved (Siva and London, 2010). The various investigations and policy directions reflect a preoccupation with the development of prescriptive government standards, codes and best practice client guidelines which assume that the economy can be structured and controlled with little reference to the social networks, cultural norms and social obligations which influence project decision-making. Whilst there is no denying that the lack of uniformity in legislation regulating the industry has led to significant inefficiencies, it is argued that regulations and codes alone are not enough to drive change. Recommendations for reform through client leadership will have a greater chance of success if a deeper understanding of the characteristics underpinning the client’s commitment to the acceptance and implementation of regulations and codes is achieved. As Rose et al point out:

“…to understand how we are governed in the present, individually and collectively, in our homes, workplaces, schools, and hospitals, in our towns, regions, and nations, and by our national and transnational governing bodies requires us to turn away from grand theory, the state, globalization, reflexive individualization and the like. Instead we need to investigate the role of the grey sciences, the minor professions, the accountants and insurers, the managers and psychologists, in the
mundane business of governing everyday economic and social life, in the shaping of governable domains and governable persons, in the new forms of power, authority and subjectivity being formed within these mundane practices…” (2009, p. 26).

Therefore this research aims to move beyond the aspirations of policymakers and idealistic descriptions of how clients ought to behave to explain the reality of what happens in megaproject client decision-making. It seeks to examine the sophistication of megaproject clients who are often made up of representatives/agents across multiple units, political groups or departments in large-scale corporations or government agencies at the strategic, managerial and technical levels in terms of the challenges experienced in coordination, collaboration and cooperation management. Specifically this research focuses on the variety of agents within the client organisation and the diverse forms of power, authority and subjectivity formed and exercised in their everyday practices, which are embedded in social relationships, institutionalised rules, shared meanings and cultural norms.

The research problem is concerned with; firstly a lack of empirical research to explain the nature and structure of the power relations underpinning megaproject client decision-making and secondly, a lack of theory and methodological framework to achieve this. Firstly, there has been little recognition from the internationalisation discourse of the power structure, social relationships or processes which affect megaproject decision-making and the power and influence clients have in shaping the political economy of international design management. Although there is extensive literature on client briefing and participation methods seeking to give ‘voice’ to or empower clients as well as tools and methods for project teams to achieve successful projects there are few notions available to link these issues coherently, focussing on the international megaproject environment as a political economy and the client’s critical role within this context. Secondly, in construction management research there has been a propensity to conduct deductive studies. As this is an emerging area of research, more open-ended inquiry strategies should be explored towards developing a strong theoretical base in understanding megaproject decision-making. To explore this problem further, we can borrow ideas from political economy theory and in particular from the perspective of cultural political economy. Cultural political economy is an emerging perspective, which has had some application in a number of disciplines including anthropology, geography and sociology. It has however had limited application in the AEC research field. Cultural political economic analysis offers a way of drawing to attention the distributional implications of social and productive relationships and the ways in which the advancement of specific interests are facilitated by the political economic decisions of particular key players in positions of power (Anderson, 2004). In particular this research seeks to explore the critical role of the client who is placed in a central position within the power structure and the associated influence their actions and attitudes have over project outcomes. Therefore it proposed that a consideration of cultural political economy theory would provide valuable insights into the decisions of clients when working with various stakeholders to design and produce a megaproject development in an international environment. This paper seeks to develop an analytical model based upon cultural political economy theory and the concept of governmentality merging the techniques of social network analysis and narrative inquiry to examine this largely unexplored area of megaproject governance from the client’s perspective.

This study addresses two research questions:

RQ1: What is the nature and structure of the power relations underpinning the client’s decision-making environment related to the cultural political economy of megaprojects?

RQ2: To what extent can the merging of the concept of governmentality with narrative inquiry and social network analysis techniques assist in the description and analysis of megaproject client decision-making?
2. CULTURAL POLITICAL ECONOMY

Political economy is the scholarly discourse concerned with the study or analysis of power relations affecting the production, distribution and consumption of goods, services, income, wealth and resources in society (Munro, 2007; Babe, 2009). The political economy discourse has had a long history of commentary and debate which has undergone a process of revolution over the past three centuries. The seminal text by Adam Smith, “Wealth of the nations” which was published in 1776 marked the launch of political economy as a recognisable field of study. Smith’s (1776) book, which is often regarded as foundational to modern economic theory defined political economy as a “branch of the science of a statesman or legislator” seeking to help governments set conditions to stimulate economic growth. Since then researchers in the fields of political science, cultural studies, sociology, etc have devoted considerable effort to the study of political economy and it is not the aim of this paper to offer a comprehensive review of this literature. This paper focuses on recent research efforts in this area and in particular developments in cultural political economy to highlight its relevance for explaining the client’s position within the political economy of international design management.

Over the past three decades there has been a significant change in radical political sensibilities (Sayer, 2001). In the past, problems resulting from economic systems including inequality and unemployment were recognised and criticised based on an understanding that the development of alternative economic systems would lead to a resolution of those problems. During that time, issues of inequalities and differences associated with gender, ethnicity and sexuality went largely unnoticed, dismissed or treated as unavoidable. This is in quite a stark contrast to the current position where there is considerable interest in gender, ethnicity and sexuality issues underpinned by a general belief that even though such problems are deeply ingrained they can be opposed, challenged and changed successfully given better understanding of the structure conditioning everyday life (Sayer, 2001). Furthermore there is now remarkably less interest in economic systems and the associated resulting problems as well as a more philosophical approach to them (Phillips, 1999). This shift, also referred to as a cultural turn, from the politics of distribution to the politics of recognition or in the words of Habermas (1987), from a focus on system to lifeworld, has led to key developments in various fields as well as resulting in a new perspective of political economy, that is, the “cultural political economy” (Sayer, 2001). Cultural political economy is defined as one which (Sayer, 2001, p. 688):

“emphasises the lifeworld aspects of economic processes – identities, discourses, work cultures and the social and cultural embedding of economic activity, reversing the pattern of emphasis of conventional political economy with its concern for systems…[it] deals with the level of concrete and hence with firms, bureaucracies and households embedded in the relationships and meanings of the lifeworld…Insofar as it deals with concrete situations where system mechanisms are often present, it should combine and “work up” abstractions of both system and lifeworld”

The term lifeworld was initially coined by Habermas (1984), referring to both the world as given in experience and as influenced by the subconscious. It encompasses the informal aspects of life which is the product of the relation between embodied actors and the cultures into which they are socialised whereby one’s habitus as defined by Bourdieu (1990) is a major influencing factor (Sayer, 2001). On the other hand, systems can be defined as the formalised rationalities which have a logic and momentum of their own, going beyond the subjective experience of actors to impart, routinise or govern specific actions through signals and rules such as prices, money, bureaucratic processes and procedures (Sayer, 2001). These systems standardise, regularise and fix relationships and responses and therefore, even though these signals and rules require interpretations by actors, the manner in which systems operate is largely independent of their intentions and understandings or “delinguistified” and disconnected from norms and values (Habermas, 1987, p. 154). The intellectual
division, which has emerged between those in cultural studies and traditional political economy, has resulted in a split between the two camps with the primary focus of study of the former on the lifeworld and the latter on the system (Berry, 2009). In response to this, much of the debate surrounding recent political economy discourse has been concerned with a reintegration of both the lifeworld and system aspects of economic processes (for eg MacKenzie, 2006; Babe, 2009; Best and Paterson, 2010). Babe (2009) puts forward an argument for a ‘new integration’ of the two camps:

“Reintegrating cultural studies and political economy is of some urgency. On the one hand, to study culture without taking into account either the influence of the political-economic base or the political-economic consequences of cultural activities, is to be naïve in the extreme…on the other hand, to overemphasise the political-economic determinants to the neglect of human violation and freedom is equally detrimental. Denying or belittling human agency is tantamount to denigrating human dignity and to fatalistically understate the possibility of social reform….there is a balance, a dialectical middle ground, that must be sought after, achieved and maintained.

Therefore it is the ‘dialectical middle ground’ of the cultural political economy perspective which seeks to integrate both the lifeworld and system aspects of economic processes that the present study is located within. Specifically it seeks to examine the cultural component of those big ideas generated by major thinkers and policymakers which have largely been underpinned by an assumption that the economy can be structured and controlled without reference to the social networks, cultural norms and social obligations of those players in positions of power who inhabit and produce it. Two key characteristics can be drawn from the perspective of cultural political economy including:

a) distinction and balance between lifeworlds and systems

b) power asymmetries

2.1 Lifeworlds and systems

The complexity of the client’s social lifeworld within which economic action concerning megaproject decision-making is bound is composed of continuing social relations, institutionalised rules and shared meanings (Becker and Streek, 2008). As previously outlined, the habitus is a major influencing factor in the client’s lifeworld. The concept of habitus is a structural theory of social practice, which challenges the notion that individuals have the capacity to act as free and autonomous beings. It entails that whilst individuals have the power to choose and act freely, these acts are governed by some form of ‘structuring structures’ which are simultaneously subjected to past experiences and social norms. Group habitus revolves around the assembly of collective individuals encompassing group adaptations and acclimatisation, ‘naturally’ adjusted to the historical world they are up against” (Bourdieu, 1990, p.90). This enables an individual’s involvement, familiarity or sense of being at ‘home’ within a social milieu, manifested through deep structural dispositions of acceptable perceptions, outlooks and ways or rules of conduct. Individuals within a group habitus experience the world on a common sense level, justified through their exclusive understanding of the world (Chen, 2008). Therefore there are expected norms and ways of operating within a specific group habitus, necessitating social constraints and limitations on what is deemed ‘thinkable or unthinkable’ behaviour by members of the group. The concept of group habitus within the cultural political economy of megaproject client decision-making is an important concept to consider because it helps to explain how the client who is a member of a group habitus within a specific field in a specific country may differ from members of the project team who are located within a different group habitus and perhaps different country(ies). The values that international clients ascribe to their everyday practices and experiences inevitably conditions how they act economically on projects and therefore it is important to develop a deeper understanding of the international client’s habitus.
Given the cultural, physical, economic and institutional differences across regions and markets it is anticipated that there will be extreme disparity in the characteristics of the habitus from one international client to the next. However, through an analysis of a prominent, globally organised marketing campaign undertaken in recent years by a large international bank, HSBC, Best and Paterson (2010) highlight that the cultural character of contemporary political economy is “decidedly global” in that there is a set of shared language or understanding across different countries which enable similar marketing strategies to operate effectively everywhere. They further point out that it is also though such strategies of an international firm like HSBC that specific management cultures become globalised. It is therefore worthwhile to identify the extent to which the notion of the existence of a global language is applicable to the international design management environment and the client’s habitus and lifeworld. A number of questions are thus raised: Is there a global language in the cultural political economy of international design management practice? More specifically is there an international client habitus and what are its characteristics? Another key point to note is that even though systems presuppose and are reliant on the lifeworld, they produce effects which can over-rule or ‘colonise’ it. The relationship between systems and lifeworlds can be likened to the manner in which markets operate as Sayer (2001, p. 691) points out:

“The way in which systems develop out of but gain some independence from the lifeworld is particularly clear in the case of market systems, where the role of unintended consequences of actions is particularly important. “Market forces” are largely unintended outcomes of myriad individual decisions to produce, consume, buy and sell or change prices and of relationships that are not the product of any intentional design but that shape subsequent decisions. Once we have acted in a market, the wider effects of our actions in terms of movement of prices and stocks are largely beyond our control. Consequently, markets exemplify the way in which systems have a logic and momentum that are not wholly reducible to the actions on which they depend”

Therefore, no matter how much influence the project team may have over the design and procurement of a project and no matter how much firms may network and disseminate a certain project culture, they are still subject to powerful system forces associated with the client which they have little control of. There is thus a need to maintain a clear distinction and balance in the study of the client’s system and lifeworld without reducing the former to the latter.

2.2 Power asymmetries

A key characteristic of cultural political economy is its examination of the “embedded” nature of economic action in terms of how they are set within social relations and cultural contexts that impact upon those economic processes (Sayer, 2001). The cultural political economy of international design management practice is composed of power relations among stakeholders who occupy various strategic positions within it. There is a diverse range of stakeholders such as the client, project manager, architects, contractors, users, property owners, financiers, regulatory bodies, local community – each participating and attributing their own value at various stages of a project. Some of these stakeholders although may not be directly involved with the design and construction of megaprojects do have their futures or daily lives tied to the consequences of the development. A range of activities and processes are typically conducted on construction projects particularly on such large undertakings as megaprojects such as briefing, stakeholder management and community participation which are largely aimed at aligning project objectives and stakeholder requirements. Such efforts however, often do not prevent some stakeholders from pursuing their self-interests:

“Networks do not necessarily fuse the self-interest of different actors into a harmonious and egalitarian whole; they may be characterised by inequalities of power, strategic coalitions,
dissembling and opportunistic collaboration...even where such groups are associated with kinship networks, as many are, these are likely to be characterised by power asymmetries as well as a sense of moral obligation. What appears to indicate trust may be largely a consequence of domination or a lack of alternatives, or simple mutual dependency” (Sayer, 2001, p. 698).

In light of this perspective, even though stakeholders are positioned within an international design management project network, it is likely to be characterised by unequal power relations and/or domination by key players occupying strategic positions within the network. Power differentials on projects cause stakeholders to employ various strategies or tactics to place them in positions of advantage (CBI, 2000). The outcome of the production and distribution of power on international projects can be seen as resulting from the political economic decisions of the client. Clients occupy a central position in the process through which power come to be produced, distributed, exercised and maintained in the international design management environment, that is, the politics which determines, who gets what, where and how (Anderson, 2004). Therefore the client is a dynamic political force in determining whose interests are advanced on projects (Molotch, 1976). A number of important questions to this research follows:

How do ideas or propositions get disseminated, accepted or rejected on megaprojects? How and why do the interests of specific stakeholders get advanced whilst others don’t? How are projects shaped within the structure of power relations? How is power created, nurtured and employed on megaprojects? What other forms of power are available for the various stakeholders on megaprojects? How do responsible built environment professionals who can contribute to the quality of built environments enhance their power on projects to enhance project performance?

The concept of *governmentality* which was developed by Michel Foucault in the 1970s through his investigations of political power offers a useful language and analytical framework for exploring both the macro spaces of megaproject governance frameworks as well as the confined locales of workplaces of clients and the everyday practices and networks that they consist of where various forms of power come to be created, distributed and exercised.

3. GOVERNMENTALITY

Foucault defined government as “the conduct of conduct”, which is a form of activity seeking to shape or guide the actions of others through the exercise of various techniques of domination and techniques of the self (Christie, 1982; Gordon, 1991; Foucault, 1993). In his summary of the 1979-1980 course “On the Government of the Living”, Foucault described governmentality as the “techniques and procedures for directing human behaviour. Government of children, government of souls and consciences, government of a house, of state, or of oneself” (Foucault, 1997, p. 82). While the word *government* may imply a strictly political meaning today, Foucault placed the problem of government in a more general context embracing philosophical, religious, medical and familial sites (Lemke, 2008). Foucault’s analyses of government avoid descriptions which are limited to “the state” and instead extend the conception of “governmental authorities” to include families, churches, experts, professions and all the different powers engaging in “the conduct of conduct” thus blurring the boundaries between “public” and “private” or between “state” and “civil society” (Garland, 1997). Furthermore to define government as the “conduct of conduct” is to open up for investigation the notion of self-government encompassing not only how one exercises power over others but also how one governs oneself (Dean, 2010). Governmentality is thus concerned with the activity of governing,
which is the “how” or art of government; through the choices, desires, aspirations and lifestyles of individuals and groups (Foucault, 1991; Dean, 2010). It offers a powerful framework for analysing how client decision-making is undertaken on megaprojects for two key reasons:

a) It reveals that power is dispersed in both institutions and everyday life and it offers a view of power beyond a perspective that centres on either consensus or violence (Rose and Miller, 1992; Garland, 1997; Foucault, 1993; Lemke, 2000)

b) Rather than taking a reductionist approach, it focuses on open-ended empirical accounts of governance and contemporary practices in specific fields to highlight how their ways of exercising power depend upon specific modes of thinking (rationalities), ways of acting (technologies) and ways of subjectifying individuals and governing populations (Garland, 1997; Rose et al, 2009)

3.1 Power in the social realm of government

The concept of governmentality deepens our understanding of power by demonstrating that power not only resides at the centre of a single body – such as the state – but is also present in diverse locales with various “authorities” practicing governmental activity (Garland, 1997; Rose et al, 2009). Scholars who have taken up Foucault’s approach recognise that power is visible in both everyday life and institutions (Rose and Miller, 1992, 1992; Foucault and Gordon, 1980; Donzelot, 1979, Rose et al, 2009). For example, Donzelot’s account of public intervention in the regulation of family affairs through the schemes of doctors, social workers, psychiatrists revealed that various forms of authority operate in the space between the state and individual. Donzelot highlighted how state policies and the practices of various professions in social work, compulsory mass education, psychiatry and philanthropy transformed family life and turned everyday family members into agents of the state.

In his analyses of the art of governing practiced by state and other agencies in the political problem of population, Foucault traced a movement between the 16th and the 18th century and identified two distinct rationalities of governing: the sovereign model and the family model, which he positioned at opposite ends of a spectrum. Whilst the former (modelled on Machiavellian political art ie how a prince best maintains his power over territory) was concerned with large, abstract and rigid ways of thinking about power the latter model was devoted to matters to enrich the small family unit (Foucault, 1979). Distinctly, he identified a third form of rationality which took place from mid 18th century onwards, governmentality, which viewed power in terms of its populations with its own realities, characteristics and requirements; independent of government yet at the same time requiring government intervention (Rose et al, 2009). These populations cannot simply be controlled by implementation of the law or programs nor be thought of as a type of extended family. Through his investigations, Foucault highlighted that populations have their own characteristics which need to be understood through specific knowledges and it is through these emergent understandings that the art of governing and associated techniques are formulated. Rose et al (2009, p. 7) offer a useful summary of this art of governing:

“From this moment on, those who inhabited a territory were no longer understood merely as juridical subjects who must obey the laws issued by a sovereign authority nor as isolated
individuals whose conduct was to be shaped and disciplined, but as existing within a dense field of relations between people and people, people and things, people and events. Government had to act upon these relations that were subject to natural processes and external pressures, and these had to be understood and administered using a whole range of strategies and tactics to secure the wellbeing of each and all...To govern, therefore, whether to govern a household, a ship, or a population, it was necessary to know that which was to be governed and to govern in the light of that knowledge”

Factors relating to populations including birth rates, longevity, demography and public health thus became subjects of governmental knowledge and control (Garland, 1997). Significantly Foucault uncovered the emergence of a link between characteristics of populations in their techniques of the self and the governing practices of authorities promoting these specific forms of techniques as means to political ends (Garland, 1997). This is however not to say that individuals are incapable of choice or are regimented to strict conformity. Instead this form of power, termed “governing at a distance” coined by Miller and Rose (1992) presents technologies of the self to be taken up by wiling active individuals. Individual subjectivity is thus cultivated in specific forms to align with the objectives of governing authorities and as Foucault (1993, pp. 203-4) pointed out, governing people “is not a way to force people to do what the governor wants; it is always a versatile equilibrium, with complementarity and conflicts between techniques which assure coercion and processes through which the self is constructed or modified by himself”. Therefore it is this fine balance between consensus and violence that is termed the art of government:

“The relationship proper to power would not therefore be sought on the side of violence or of struggle, nor on that of voluntary linking (all of which can, at best, only be the instruments of power), but rather in the area of the singular mode of action, neither warlike nor juridical, which is government” (Foucault, 1982, p. 221)

The art of government in terms of governing at a distance is particularly suited to the study of practices requiring light and unobtrusive interventions (Garland, 1997) such as megaproject decision-making. Even though the design and construction of a megaproject itself is often a unique, one-off undertaking, agents within the client organisation are largely operating in their daily routine whilst being involved with the decision-making processes related to the megaproject. Megaproject involve “everyday managers and engineers seeking to work to create some sense in contexts of different and variable rationalities and cultures undertaking normal organisational practices” (Marrewijk et al, 2008, p. 597). These everyday agents are thus simultaneously involved with two networks which inevitably overlap at various stages; the former network being the permanent organisation within which members work routinely and the latter being the temporary coalition formed in response to the megaproject. Therefore the client’s decision-making on megaprojects is deeply embedded in formal and informal practices, rituals, networks and culture which can be easily disturbed by heavy-handed regulation. Given megaproject decision-making occurs in the course of routine social and economic transactions in the agents’ permanent organisations any form of intervention seeking to modify interests must seek to preserve ‘normal life’ or ‘business as usual (Garland, 1997). Such situations characterised by webs of ambiguity, paradox and contradiction require an art of government which is light and unobtrusive in the form of governing at a distance whereby power is exercised through working with and through agents. In so doing, everyday practices are allowed to retain their natural character but is at the same time achieve some form of outcome in relation to decision-making.

Foucault identified three key types of instruments of power or governmental technologies which include strategic games, government and domination (Lemke, 2000). Strategic games involve the construction of others’ possible field of action and takes shape in many contexts or spheres. While economic and political manipulation are the more common spheres of power there are other subtler
spheres of power including ideological, cultural, technological and environmental power (Carroll and Buchholz, 2006). This, however, does not necessarily equate to unequal or intrinsically “bad” power relationships whereby power is exercised by one party against the interests of another (Lemke, 2000). Rather power could result in the process of “responsibilisation” or “empowerment” whereby subjects become “free” agents in decision-making. According to Warner (2010) there are ways in which those stakeholders in weaker positions can “work out deals” to achieve stronger positions through smart linkages and bargaining where power disparities in one area can be compensated by another. It is expected that stakeholders seeking to influence project decision-making would attempt to develop linkages or relationships with other agents in central positions within the power structure in order to achieve a stronger position. On the other hand those in stronger positions may be interested in working out deals to achieve their own goals and as pointed out by Warner (2010), “even the powerful are ultimately interested in some levelling of the playing field to arrive at a constructive, durable result”.

*Government* goes beyond the spontaneous exercise of power over others referring to the “regulation of conduct by the more or less rational application of the appropriate technical means” (Hindness, 1996; p. 106). Foucault identifies the Christian pastorate as a spiritual government of the soul and state reason as a political government of the population as examples of different technologies of government. Such “governmental technologies” are responsible for the stabilisation and regulation of power relationships which may eventually lead to domination (Lemke, 2000).

Domination refers to asymmetrical power relationships which are both stable and hierarchical causing them to be difficult to reverse (Lemke, 2000). Through a detailed analysis of a complex large-scale urban project in Denmark, the Aalborg project, Flyvbjerg (1998) highlighted how the actions of stakeholders were revealed to be deeply embedded in the hidden exercise of power and the protection of special interests. A key lesson which can be learnt from the project is the notion that power defines reality in that “power defines what counts as rationality and knowledge and thereby what counts as reality” (Flyvbjerg, 1998, p. 319). In other words, the exercise of political power can overrule rationality and result in domination. This is of course not to say that stakeholders should ignore the environmental, social, moral and professional arguments based on rationality in support of their respective positions. Rather a strict adherence to rationality and logic alone without adequate acknowledgement and understanding of other forms of power will unlikely lead to successful outcomes. It is thus important to understand the various strategic games stakeholders employ in the exercise of power in megaproject decision-making.

### 3.2 Analytics of governmentality as normative “exemplary criticism”

The practices within the social realm of government are undertaken in their complex relations to the various ways in which “truth” is conceived by the different agents (Dean, 2010). Within the context of decision-making on megaprojects, the way in which clients govern themselves and others is reliant upon what they see to be ‘true’ about who they are which is in turn influenced by the rich and complex social networks, cultural norms and social obligations they are embedded within. It is thus important to capture what rationalities of governing are implicit in the clients practices and how they relate to the practices of those project team members working on megaprojects. How do the client’s practices of governing others link up with the practices by which they govern themselves? How do clients who are at the top of the governance structure of megaproject decision-making understand their powers and the problems and impact of their practices? Analysis of the art of government, with its focus on practices instead of institutions, theories or ideology is particularly suited for understanding the conditions and rationalities which make practices acceptable at a given moment:

“the hypothesis being that these types of practice are not just governed by institutions, prescribed by ideologies, guided by pragmatic circumstances – whatever role these elements may actually
play – but possess up to a point their own specific regularities, logic, strategy, self-evidence and reason. It is a question of analysing a regime of practices – practices being understood here as places where what is said and what is done, rules imposed and reasons given, the planned and the taken for granted meet and interconnect” (Foucault, 1991, p. 75).

Governmentality should thus not be viewed as a theory of power or governance. Instead “it asks particular questions of the phenomena that it seeks to understand, questions amenable to precise answers through empirical inquiry” (Rose et al, 2009, p. 3). The nature of governmentality work is one focussed on an empirical examination of the various strategic games, governmental technologies, states of domination and rationalities underpinning a regime of practices. It seeks to pose questions relating to power in the social realm of government without attempting to prescribe a set of principles or ideology for governing others and oneself. In doing so, we are practising a form of criticism which seeks to make explicit the taken-for-granted character of these practices (Foucault, 1988) in terms of the ways in which clients govern and are governed and in the practices, relationships and technologies by which they do. In so doing, we open up for analysis various forms of strategic games, governmental technologies and states of domination within regimes of practices in terms of contestations and negotiations which thus reveals how it might be possible to conduct different forms of practices. Dean (2010, p. 38) offers a useful summary of the analysis of governmentality as an “exemplary criticism”:

“Rather than prescribing a general stance against forms of domination…it allows us to reveal domination as a contingent, historical product and hence to be questioned. It offers no general prescription of what the result of such questioning might be… there is a normative character of the project of an analytics of government. The normative character is one of “exemplary criticism”…a type of criticism that demonstrates the contingency of regimes of practices and government, identifies states of domination within such regimes and allows us to experience a state of domination as a state of domination. It does not tell us how we should practise our freedom”

4. CONCLUDING REMARKS AND FURTHER RESEARCH

Decision-making on construction projects are not wholly predetermined by contracts but instead often emerge from the use of power by various individuals/groups, with clients occupying a powerful position to influence project delivery. There is often a discrepancy between the reality of power structures on projects and those formally prescribed by governing contracts. Client decision-making is deeply embedded in multilevel networks comprising social practices, rituals and cultural norms whereby power is exercised through an “art of government”. The reasons why certain decisions are made can be found not only in the intentions of actors within the megaproject coalition but also in the structure of the social environments in which actors are embedded. Megaproject decision-making is thus a network problem requiring an understanding of social structures.

Different types and forms of social networks may be essential for achieving different project outcomes at various stages of project decision-making. The structure of social networks in which client decision-making is undertaken may contribute towards understanding the way decisions and actions occurring at the confined locales of client workplaces can impact on project outcomes at higher levels. However, to date there is still little known in terms of the nature and structure of power relations in megaproject client decision-making where various forms of power come to be created, distributed and exercised.

This paper proposed an alternative analytical model based upon cultural political economy theory and the concept of governmentality as a way to more usefully explore the interplay between client networks and power relationships on megaprojects. The next stage of this PhD study involves the
development of an empirical research design to examine in real world situations the nature and structure of the power relations underpinning the client’s decision-making environment related to the cultural political economy of megaprojects through the narrative inquiry and social network analysis techniques. Diversity in methods and tools for data collection and analysis is critical in the production of accurate and reliable representations of social reality. The methodological value of the social network perspective in the analysis of the cultural political economy of megaprojects lies in its ability to complement qualitative methods of analysis to enhance understanding and provide interdependent explanations of the power structures underpinning client decision-making. SNA is a form of “organisational x-ray” which makes visible those network characteristics that are normally regarded as invisible in terms of the interdependency between stakeholders, demonstrating how the structure of network(s) influences client decision-making.

The possible outcomes of this research include a way of describing and measuring the nature and structure of power relations in megaproject client decision-making. In doing so it offers the opportunity to understand various ways in which changes can be implemented in light of various actors’ positions in networks.

The outcomes of this research have serious implications for design managers in the AEC sector who are increasingly faced with project challenges in the international megaproject environment. Deeper understanding of how various forms of power come to be created, distributed and exercised on megaprojects may enable design managers to better shape and influence project outcomes at various stages of project decision-making. Furthermore based upon an understanding of the nature and structure of power relations responsible design managers who can contribute to the quality of built environments may develop ways to enhance their power on projects to improve project performance.

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Integral design: the next step after Integrated design between engineering and architecture

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Abstract: In the present day design is understood as a highly complex process that requires the support of multidisciplinary design teams. Therefore a supportive design approach has been developed: Integral Design. Integral Design combines an engineering design method with an innovation strategy, to support innovative integrated design between engineering and architecture. The innovative Concept-Knowledge theory by Hatchuel and Weil is used in combination with the Integral Design method. Morphological Overviews, which are produced by combining mono disciplinary Morphological Charts, provide a tool to structure and to give an overview of the communication and information exchange between design team members, while C-K theory supplies the theoretical framework for the reflection on the Integral Design. The resulting synthesis between architectural concept and engineering functionality is as such a good example of a next step after integrated design.

Key words: creative architectural management, integral design, C-K theory

1. INTRODUCTION

The design of buildings is complex and to avoid risks the building industry is traditional in their approach to the design process and innovation is rare. In modern history, design of buildings is largely seen as an individual’s creative act. This is certainly the case for the conceptual design phase, where the architect is traditionally the one that lays down the vision of the whole building. Moreover, “the belief that a single designer should be in control of all levels of environmental form” [Habraken 2005, p.89] was even seen as a professional ideal. As a result the built environment uses 40% of all our energy for conditioning the buildings. This results in a major contribution to the emissions that increase the effect of global warming. Building designs thus need to provide solutions for increasingly complex programs of requirements, especially related to sustainability issues ranging from flexible use to energy saving measures while maintaining and even increasing comfort level of users. Therefore building design involves many designers/experts from different disciplines.

Sustainability is a real-world problem and as such cannot be solved by any one discipline alone it requires multiple disciplines with a shared theoretical understanding and an agreed interpretation of knowledge according [Dykes et al 2009]. However, just putting people with diverse perspectives and from different disciplines in the same room is no guarantee that effective boundary-spanning collaboration will occur [Joyce et al 2010].

As complexity and scale of design processes of buildings increase, traditional approaches may no longer suffice [van Aken 2005]. Through the creation of knowledge based on diverse skills, experience and information exchange, the quality of design process and the creative performance of design teams improve [Badke-Schaub et al 2010]. Due to the cognitive diversity among team members
in terms of knowledge and skills there is a broader access to information and knowledge, creating more and different insights into the current design task and its problem field [Badke-Schaub et al 2010].

Synergy between the different disciplines involved in the design process is necessary to attain the best innovative and sustainable designs. It no longer suffices to just merely solve the problems which arise at the level of detailing on the borderlines of disciplines. New approaches are needed to bridge the gap between the worlds of theory and practice in building industry and which looks at designing as a process in which the concepts of function, behavior and shape of artifacts play a central role [Vermaas & Dorst 2007]. Such integral design approach can eventually lead to an integral process, team and method – all the required conditions for innovation of the end product; the building [Seppänen et al 2007].

The main body of the paper starts (Section 2) with the development of the Integral Design (ID) method: a design method to merge the different perspective of all designers and engineers involved in the design process. The core of this method is the use of a process model to divide the design process in different phases and levels of abstraction. This makes it possible to focus on different design phases and to develop specific tools to support the process within such a phase. The tool used for the conceptual design phase is coming from the mechanical engineering domain: morphological charts. By combining morphological charts of each individual building design discipline, a morphological overview is created. This morphological overview represents the interpretation of the design task and the design knowledge within the design team related to the design task. As such this leads to a representation of the problem and solution space. The main aim of the ID-method approach is to improve conceptual design (the process level) in order to increase the potential for creation of innovative integral design concepts [the product level].

In section 3 the Concept-Knowledge (C-K) theory of Hatchuel and Weil is introduced to further enhance stimulation of innovative concepts. Further the relation between the morphological overviews and the C-K theory is explained to reach knowledge transfer and knowledge creation, both essential elements for innovation. To test the derived design method workshops for professionals in building design practice, architects and engineers, were held which are described in section 3. In section 4 the results are presented of the application of the ID-method within the workshops. A short reflection is given in section 5 on the developed ID-method use to stimulate innovation in building industry compared to another method, the KCP workshops. In section 6 a new set-up for Integral design workshops is presented which was tested in the 2011 Master project Integral Design with students and professionals. Finally in section 7 there is a discussion followed by some conclusions in section 8 about the added value of the presented approach for innovation and knowledge transfer/creation in the Dutch building industry

2. METHODOLOGY: INTEGRAL DESIGN METHOD

In the early sixties due to problems with the quality of products and projects people started to investigate new design methods as a way to improve the outcome of design processes. The origins of new design methods in the 1960s were based on the application of 'scientific' methods derived from operational research methods and management decision-making techniques in the 1950s [Cross 2007]. In the 1980s engineering design methodology of the systematic variety developed strongly and it was a period of substantial revival and consolidation of design research. Since then there was a period of expansion through the 1990s right up to day: design as a coherent discipline of study was definitely established in its own right [Cross 2007]. Still there is no clear picture [Horváth 2004, Bayazit 2004]

Methodical Design as developed by van den Kroonenberg [Blessing 1994] was chosen as a starting point, as it is based on Systems theory and a synthesis of the German and Anglo-American design models of the mid seventies [Zeiler and Savanovic 2009] and as such has exceptional characteristics [Blessing 1994]. Starting from the prescriptive model of Methodical design a method, Integral Design, was developed to articulate the relationship between the role of a designer as descriptor or observer within the design team and to reflect on the process [Savanovic 2009]. The Integral design method, though based on methodical design, is an extended design method; the cycle [define/analyze, generate/synthesize, evaluate/select, implement/shape] forms an integral part in the sequence of design activities that take place, see Fig. 1.

Figure 1. Four-step pattern of Integral Design

A distinguishing feature of Integral Design is the intensive use of morphological charts to support design activities in the design process. The morphological chart is formed by decomposing the main goal of the design task into functions and aspects, which are listed on the first vertical column of the chart, with related subsolutions listed on corresponding rows. The functions and aspects are derived from the program of demands. Possible solution principles for each function or aspect are then listed on the horizontal rows. The use of morphological charts within the integral design method supports step 1 and step 2 of the integral design method’s four step pattern, see Fig. 2. The morphological charts made by each individual designer can be combined into a [team] morphological overview, see Fig. 2, after discussion on and the selection of functions and aspects considered important for the specific design.

Figure 2. Building the morphological overview; Step 1; The Morphological overviews show the agreed functions and aspects of the different morphological charts. Step 2: The Morphological Overview with the agreed on sub solutions from the separate morphological charts.

The advantage of this approach is that the discussion begins after the preparation of the individual morphological charts. As each designer uses his own interpretation and representation, in relation with his specific discipline based knowledge and experience, this gives an overview of different
interpretations of the design brief resulting in a domain specific morphological chart from each design team member. Importantly, this encourages and allows engineering based disciplines to think and act in a more ‘designerly’ way than is common in the traditional design approach. In sum, this approach allows a greater freedom of mind of the individual designers and results in more creativity in interpretation of the design problem and generation of subsolutions from the different disciplines. Such a morphologic overview can be used by the designers to reflect on the results during the different design process stages.

2.1 Applying C-K theory to the conceptual Integral design phase

Design is process existing knowledge and information about the actual needs of the client forms the basis to work from. If solutions based on existing knowledge are not adequate, the needs have to be transformed into new unknown concepts. As such a distinction can be made between the known (knowledge) and the unknown (concepts). This distinction determines the core propositions of C-K theory [Hatchuel and Weil 2007]. C-K theory defines design as the interplay between two interdependent spaces having different structures and logics: the space of concepts C and the space of knowledge K. Within this research, in the case of a multidisciplinary building design team, space K represents all explicit representations of a design team’s knowledge [Hatchuel and Weil 2002]. From here, two types of synthesis are possible: either the representations are combined, using the $K \rightarrow K$ operator, or are transformed, using the $K \rightarrow C$ operator. Adding new properties ($K \rightarrow C$) to a concept, the set is partitioned into subsets, see par example C1 in Fig. 3; subtracting properties includes the set in a set that it contains [Shai et al 2009], see par example Co in Fig. 4. After partitioning or inclusion, concepts may still remain concepts ($C \rightarrow C$), or can lead to creation of new propositions in K ($C \rightarrow K$), see par example the Ck to Kk conjunction in Fig. 3. A design solution is given by a concept Ck which after a transformation, from the unknown to the known, becomes a true proposition in K, see Fig. 3. The other branches of C are concept expansions which do not reach a proposition that belongs to K [Hatchuel and Weil 2007].

![Figure 3. The C-K design square (Hatchuel et al 2009).](image-url)
2.2 Integral Design as tool to elucidate C-K in the conceptual design phase

Morphological charts and overviews are used to generate, define and record design aspects/functions and sub solutions. Within the Integral Design approach, after the first step of generating discipline specific morphological charts and discussing the results as a team, the individual charts are combined into one morphological overview containing all of the useful sub solutions from the individual team members. The next step is for the team to take the knowledge and ideas from the overview and translate them into a proposed design solution. This step can take two forms: either the design team combining known sub solutions into RE-designs (K-K) or the design team starts transforming object-design-knowledge into new concepts (K-C). The Integral Design model combined with the C-K theory enables the focus on the distinction between redesign (K-K transformation leading to RE) and integral design concept generation (K-C transformations leading to ID-concepts).

To illustrate this an example is presented in Fig. 4, where after step 2 there is a transformation of known sub solutions or from a specific aspect or function to a new concept of function (Y) or to a new concept as possible sub solution (IDx). The elements IDx6, IDy1 and IDy2 represent conceptual sub solutions as a result of the concept generation K-C, see Fig. 4. This distinction is crucial to generate creative solutions to the highly complex contemporary design problems that society faces. In this research the main area of interest lies in the conceptual phase of the design process. Here, the focus is on K-K and K-C relations. Nonetheless, C-K theory also offers value in subsequent building design stages, where it can be used to focus on C-C and C-K relations. In essence, in the current research ID-concepts are seen as essential for the creation of new, innovative building designs, which increase the possibility to ultimately realise sustainable building solutions. Perhaps more importantly, ID-concepts represent the potential for the definition of new object design knowledge, which can then be exploited to solve future design problems in the building design domain.

![Diagram](image)

*Figure 4. The ID-method steps according to the C-K theory operators*
Looking at the design process the knowledge of the individual designers is represented as a morphological chart and which makes it possible to project these ‘knowledge boxes’ into the space of C. Meaning that all that lies outside these Morphological Chart boxes are unknown concepts for the individual design team members, see Fig. 5. After the discussion in the group about the relevance of different functions and aspects in relation to the design task, a selection is made from the morphological charts and put into the morphological overview, see Fig. 5.

Figure 5. Morphological charts representing initial knowledge K, Morphological Overview representing the initial relevant team’s design knowledge and the thinking outside of the box.

Now the knowledge of the design team relevant to the design task is put in the MO box. Through interaction between the different designers with each their own disciplinary background sometimes an interaction and inspiration occurs which leads to the formulation of new aspects or functions, added to the MO box, leading to concepts, new additional possible subsolutions, added, see Fig. 6.

Figure 6. The expansion from the team knowledge within the morphological overview by K-C transformations: thinking out of the box.
So by using the morphological overview the design team has a overview of the interpretations and possible solutions by each discipline, which can lead to synergy between the different disciplines as well that it forms the starting point of going from the known to the unknown word of concepts.

3. FIRST EXPERIMENTS

The Integral Design approach has been tested in a series of 5 workshops, typically including around twenty participants and lasting for two or three days. A total of 107 designers participated in the workshop series. Here only a brief selection of all the results is given. More results and information are presented by Savanovic [2009]. From the analysis of the workshops it could be concluded that the number of functions and aspects considered as well as the number of subsolutions offered, was significantly increased by applying the Integral design method with its Morphological Overview. A good example of this increase can be seen from the results from session 1 (without morphological charts and overview) compared with the results of session 4 (with use of morphological charts and overview), see Fig. 7. The comparison of design setting 1 and 2 presents the effect of starting with all the different designers from the start.

Figure 7. The four different design sessions and a comparison of the results

This led to a decrease of the number of aspects and subsolutions, indicating a less effective design process. This is inline with literature about brainstorm experiments [Nystad et al 2003], were they also found out that by just bringing together more designers the productivity does not increase compared with the results from individual sessions. The team has to have a kind of guidance, in our case the Integral design method.

4. EXPERIMENTS WITH A NEW SET-UP FOR STUDENT WORKSHOPS INTEGRAL DESIGN

The results of Savanovic 2009 showed that the amount of overall integral concepts generated in the workshops was rather low. Therefore we looked for possible ways to stimulate the design team to expand their morphological overview with concepts. In the next stage of the research the use of so called C-constructs, some times called C-projectors, of the KCP-method by Hatchuel and Weil was
investigated to stimulate the creation of new concepts in the Integral Design workshops. The KCP workshops were held in different companies in France and more recently in Volvo in Sweden [Elmquist en Segrestin 2008, 2009]. The intended effect of the C-projectors is the expansion of the solution space in C, after which, by means of research and evaluation, is the expansion of space K, via the transformation of C-K. Applying C-projectors to the Integral Design approach enables to expand the knowledge domain, to expand the design task related morphological overview. This could be used to further stimulate connections between space C and space K. From these new connections it may be possible to derive new concepts. These C-constructs are domain strange concepts, which are used as a source of inspiration for further research to make a connection between the existing domain knowledge in space K, and so determine the possibility of concepts resulting from these new connections. After this evaluation these concepts become part of K, allowing the C-K transformation to take place.

To test the application of C-constructs, workshops were used within the masterproject Integral design (MIO). In this multidisciplinary master project students from the faculty of Architecture Building and Planning with different disciplines background (architects, structural engineers, building physics, building services and building technology) have to design together a building which always has to become a net zero energy (NZE) building. This year the task was to design a sixty stories NZE building for a specific location in Rotterdam. The workshops started with an afternoon setting consisting of two sessions and followed the next morning by another two sessions. The focus of the workshops was to learn the students the use of morphological charts and morphological overviews. This was done by giving starting with a lecture about the Integral Design method and its specific application of morphological charts and morphological overviews as design tools. The students were divided in design teams in such a way that to avoid a learning effect during session 1, 2 and 3 all students worked only once with the same students. In session 1, 2 and 3 the participants started individual working on the different design task and made their own morphological chart, see Fig.8.

After this first part of each session the teams put together the morphological charts to make a morphological overview as a team. The individual part of the sessions 1, 2 and 3 took 20 minutes and the team part lasted 40 minutes. In the first individual part of the sessions there was no communication between the participants. In session 1 the teams existed of an architectural student and an engineering
student, all together 15 teams. In session 2 the teams existed of two architectural students and two engineering students, in this way there were formed 8 teams.

In session 3 the students were again rearranged now in teams of 5 or 6 students. In addition each student design team was strengthed by an expert who joined the design team. After session 3 a lecture was given about C-K theory and the possible application of C-constructs. After which the design team continued in session 4 with the design assignment of session 3 and tried to generate concepts with the help of some C-constructs that were given to them.

In design setting 1 and 2 the teams were given the same design task as used in the Integral design research by Savanovic [2009]. The 3th design setting for students teams with an expert was to propose a conceptual design for a 60 stories net zero energy (NZE) apartment building on a specific location. The design teams were formed based on the actual teams of the Master project Integral design (MIO-project). Besides 2 or 3 engineering design disciples present in the design teams they had 2 or 3 architectural students. This meant that 5 or 6 students formed a design team. In addition each student team was strengthed by an professional expert. The members of the design teams started individual, making the morphological charts and after that worked together to make the morphological overview.

In the 4th design setting, students with an expert worked on the same assignment from session 3, the Net Zero Energy apartment building but the task was now to try to use the C-constructs as a stimulus to come to new ideas. Starting point for this session were the results of the 3th design session, the morphological overview of the design team. The teams stayed the same compilation as in session 3. The focus of the 4th assignment was on the expansion of the design team’s knowledge box, their Morphological Overview, so to stimulate thinking out of the box by applying C-constructs to make the step from existing knowledge to the unknown world of concepts. C-constructs were presented to the design teams and had to try to use these to stimulate their conceptual thinking process.

5. RESULTS WORKSHOPS INTEGRAL DESIGN

The participants of the workshops were master students of the faculty of architecture, building and planning and had an average age of 22 and no working experience. During the sessions 1 and 2 29 students participated and in session 3 and 4 27 students participated. In session 3 and 4 six professionals participated, in each student design team one, which were on average 50 years old and had around 25 years experience. The number of functions and sub solutions mentioned by the designers in their morphological charts were counted and are represented in Fig. 9. The same was done for the sub solutions mentioned by the design teams in their morphological overviews, see Fig. 9. This makes it possible to compare the results between the average number of functions and subsolutions mentioned in morphological charts and morphological overviews for all three different design sessions. Although the design tasks were different for all three sessions they were seen as a stable factor, since from former research it was found that the complexity of these design task were quite simular and no significant effect on the results as such [Savanovic 2009]. In all sessions combining morphological charts into a morphological overview leads to an on average increase of the number of functions and solutions as mentioned by the design teams, Fig. 9.
The increase in percentage of mentioned number of functions or solutions by the application of morphological charts and overview mentioned in the morphological charts and overview.

Overall there is an increase of the number of solutions mentioned in the morphological overview after session one compared to session two (on average 24.5 compared to 27.3), which could be an indication that the students learned to improve the process of combining the individual morphological charts into the team’s morphological overview. There is only a rather small difference between the students making the morphological charts in session 3 (MC3Stu) compared to that by the professionals (MC3Pro), which is quite remarkable. Quite remarkable is also the small effect of adding a professional to the students teams in session 3, MO3 (7,8 functions and 30 solutions), compared to the outcome of session 2, MO2 (7,1 functions and 27,3 solutions), however still there is an increase of 10% overall.

The first part of design assignment 1, 2 and 3 were the same for all designers, they all had to make his or her morphological chart based on their individual interpretation of the program of requirements and their individual knowledge relevant to the design task. After this first step the teams formation for the different assignments were changed from teams of two (session 1) to teams of four (session 2) and teams of five or six (session 3). From Fig.10 a is shows that there is no real significant difference in the average outcome of the morphological charts in the different sessions of the workshops. The professionals are a little more focussed on the functions (on average 7) as compared to students (on average 5.6) and as a result generate less sub solutions. Professionals must have much more knowledge about possible solutions than the students, thus you would expect that they generated more solutions.

Figure 9. Results of the different sessions of the MIO workshops, the average number of functions and part solutions mentioned in the morphological charts and overview.

Figure 10. (a) The average number of functions and solutions as mentioned by the students and professionals in the sessions (b) The increase in percentage of mentioned number of functions or solutions by the application of morphological overviews.
To focus more on the effect of the application of C-constructs as used in the 4th session of the workshops, the outcome of the average number of functions and solutions, mentioned in the morphological overview, were compared as a percentage of the average numbers of the morphological charts, see Fig. 10 b. Compared to the morphological overview of session 3 there is a significant increase in additional mentioned functions (+61.5%) as well as an increase in proposed solutions (+42.3%). Remarkable is the increase of the average number of additional functions generated by the interpretation of the C-constructs, which than can lead to new ideas for possible solutions. This shows that there is happening thinking out of the box, as the morphological overview of session 3 represents the knowledge of the design team that was inside the box.

6. DISCUSSION

Building design changes when the other building designers such as building services engineers, structural engineers and building physics engineers join the architect in the conceptual design phase. To analyse the building design process the distinction was made between the solution space of the known (K) and the possible solutions in in unknown, concepts (C) which have an undetermined status (either true or not), in analogy with the C-K theory of Hatchuel and Weil [2009]. This distinction between concepts and knowledge by Hatchuel and Weil [Le Masson et al 2007, Hatchuel et al 2008] is similar to the model for conceptual design by Jansson [1991], were the conceptual design process is described as movement between two spaces: configurations space and concept space. Hereby differs the concept space from the configuration space, in that the elements it contains are ideas, relationships, or other abstractions, which may later become the basis for elements in configuration space. C-K theory defines design as the interplay between two interdependent spaces having different structures and logics. This process generates the co-expansion of two spaces, space of concepts C and space of knowledge K. Since C-K theory defines a piece of knowledge as a “proposition with a logical status for the designer or the person receiving the design” [Hatchuel and Weil 2002].

Innovation is fundamental to the survival and advancement of society [Joyce et al 2010]. Collaborations that cross disciplinary boundaries are essential to innovation and the occurrence of boundary spanning, where ideas from one domain, discipline or functional area are importet into another [Joyce et al. 2010], in a way that solves new problems or presents new solutions [Burt 2004].

The size and specialization of modern professionals makes finding the right conceptual bridge between domains difficult for any one individual to solve the complexity on his own. Therefore, collaboration is required [Joyce et al 2010] for innovation to let experts recognize the analogous qualities of ideas from distant conceptual realms, identify ways they can be usefully connected and work to realize them [Burt 2004]. The Integral design method with its use of morphological overviews in combination with the C-K theoretical focus on concept generation is an important step to reach true collaborative building design.

The combining of the mono-disciplinary morphological charts into a design team’s morphological overview leads to a new approach for the support of knowledge transfer and knowledge creation. This is similar to the developed KCP [Knowledge Concepts Proposal]-workshops, derived from the C-K (Concept-Knowledge) theoretical framework in collaborative exploration in France at Ecole des Mines de Paris by Hatchuel and Weil [Elmquist and Segreslin 2009]. These KCP-workshops aim at structuring collaborative exploration of an innovation field. The results are a structured set of innovative concepts for further development [Hatchuel and Weil 2009]. The KCP-workshops were used in a number of innovative projects with industrial partners such as RATP [the French company operating the Paris subway], Thalès and Renault. The KCP workshops involve a series of three meetings [Elmquist and Segreslin 2009]: one for knowledge sharing (phase K), one for the conceptual
exploration (phase C) and one to structure the proposal (phase P). The KCP-workshop aims at structuring the exploration of a set of innovative concepts and offers a framework in which to collectively address the tasks. More information can be found in [Hatchuel et al. 2009].

There are similarities between the ID-method workshops and the KCP-workshops. In the KCP-workshops there is a strong influence by the organizers as they generate and structure the first concepts from which the connection with the existing domain knowledge is initiated. The integral design workshops C-constructs are presented to the participants to stimulate concept generation.

7. CONCLUSIONS

With the use of morphological overview of the Integral design method and the C-K theory to focus on specific transformations, for example from knowledge to concepts or from concepts to knowledge, it is possible to make the conceptual design phase more transparent. As such the proposed model will also have implications for new kinds of interactions between stakeholders and the design team. No longer does the conceptual design phase have to be a closed black box for client and project manager during the design process which means that they can intervene if they think it is necessary. This improves the quality and productivity of the architectural design process.

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Decision support tools for the early collaboration within sustainable building design

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Abstract: More effective and early collaboration is needed during the design process to make decisions so that the building meets the required sustainability goals. Often the specialist are included too late to influence the outcome of the design without major changes and resulting costs. Integrated sustainable design solutions are necessary, which will mean to make the step from sequential working practices to integrated design. Currently the building industry uses different sustainability assessment tools which are difficult to compare. These tools are designed for assessing different types of buildings and emphasize different phases of the life cycle. The paper discusses some examples of these sustainability assessment tools: BREEAM, LEED, Ecological Footprint and Greencalc+. Especially the focus will be on the role of sustainable assessment tools as decision support tools in the integrated building design process. As financial viability is considered to be the most important deciding factor in the selection of sustainability options our research is aimed on the development of a design decision support tool primarily focussing on that aspect. The first results are presented of such a new decision support tool. This development was done in cooperation with one of the largest Dutch consulting companies Royal Haskoning.

Key words: Sustainable assessment, Green building design, collaboration, architects & engineers

1. INTRODUCTION

Energy consumption by buildings accounts for around almost 40% of the total energy in the EU and US [Juan et al 2010]. The General Public came aware of the problems related to this energy consumption and sustainability as Al Gore sounded the alarm bells with his ‘inconvenience truth’ World tour. Sustainable development was brought into mainstream conservation on a global scale [Rivera 2009]. However the concept of sustainability is not something new, already in 1987 United nations (UN) commission defined sustainability as; “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [Brundtland Commission, 1987]. This definition however, was not really that helpful and as a result sustainability is still seen as a diffuse blurry term that mixed economic, social and environmental aspects [Podeva 2009]. Attempts were made to develop international consensus about sustainable building design in ISO 15392 entitled ‘Sustainability in building construction – General principles’, which confirms the understanding of sustainability suggested in the Brundtland report, but aside from this does not provide building designers with all the necessary valuable design principles [Hansen and Knudstrup 2009]. Sustainable Design, is known by different names such as ecological design, green design, green architecture, eco-effective, holistic and environmentally friendly design. Sustainable design is the philosophical basis of a growing movement of individuals and organizations that literally seeks to redefine how buildings are designed, built and operated to be more responsible to the environment and
responsive to people. It seeks to maximize the quality of the built environment, while minimizing or eliminating negative impact to the natural environment. [McLennan 2004].

Sustainability has become a cornerstone for many organizations. Clients have become especially sensitised to the value aspects of design to the point where project briefs are handed out with specific building performance-targets that need to be met [Holzer 2009]. In response to the demand for evaluation and management of buildings ‘environmental performance, several tools and methodologies are implemented in the construction sector, aiming at achieving the building performance-targets in sustainability [Papadopoulos and Giama 2009]. At present it is difficult in the conceptual design phase to define the life cycle performance of buildings in an objective way to efficiency and sustainability. As the design proceeds, more information and detail will be developed [Holzer 2009]. However the main part of the project performances are determined in the early conceptual phase of product development, still in this phase only few resources (manpower, money) are actually spent on the project [Buur, Andreasen 1989]. By the dichotomy of this design process at the early stages of design there is little information, even though nearly all the important decisions have to be made at this time, see Fig. 1a [den Hartog 2003] shows. The effectiveness of decisions, defined as the relation between the impact of the decision on the final building performance and the cost of the action needed to implement the decision, declines during the various stages of the life of a building. The decisions made early have the greatest impact on the performance and the efficiency of a building for its entire life, while the cost is often minimal [Heiselberg 2007], see Fig. 1 b.

The construction industry is in the early stages of a revolution to reinvent the design process that was used before the large scale application of HVAC systems [Heiselberg 2007]. Building design is conducted more and more in multi disciplinary design teams with a view towards integrating all aspects of the life cycle aspects of a building. Collaboration between architects, engineers, construction managers and owners is difficult as each group has different world views and different modes of practice that are almost incompatible with each other [Kalay 1998]. This makes design a complicated messy process [Hendrickson et al 2008]. All ready at the beginning of projects design teams include both architects and engineers and the building design is transferred into an iterative collaborative process from the conceptual design ideas to the final detailed design. Building energy use and HVAC equipment size can be reduced through an effective integration of the architectural and engineering designs with the use of sophisticated process and control technologies. The integrated design approach achieves this improved energy utilisation and an improvement in the environmental performance of the building due to the relationship that exists between the building, its architecture and the HVAC equipment [Heiselberg 2007].

Figure 1. (a) Relation between allocated and actually spent costs during a design project (b) Effectiveness of decisions made in different stages of a buildings lifetime [Heiselberg 2007].
One mode of practice [Holzer 2009], applied by specialists such as engineers, is dependent on precise problem and goal definitions before they can start to search for solutions, whereas architects – who apply a mode of practice through discovery - are often not capable of “defining desired effects until the design process is well on the way.” [Kalay 1998]. Architectural design often deals with the unknown where problems are defined and solved concurrently while designing and during construction. As a result architects are somewhat tardy when inviting engineers to join their projects. However by only introducing consulting engineers to participate in the later stages of the design process, engineers are commonly assigned a merely fixing role. This provides little opportunity for creative engineering solutions at the conceptual design stage [Holzner and Downing 2010]. An integrated design process however would provide opportunities for creative synergy.

The integrated design process is a holistic method to optimize building’s technical performance as well as aesthetic value which enables the designers to control the many parameters that must be considered and integrated when creating sustainable buildings. The decision method within an integrated design process needs to be capable of evaluating and weighting of very different building performance characteristics that are often traditionally non-comparable [Heiselberg 2007]. This would make it easier to share information and argumentation on which decisions are made within the design team. At the moment there are quite a few sustainable assessment tools for the commissioning of buildings. Synergy between design and assessment methods is necessary to really get transparent and understandable tools for supporting decision making on sustainability issues in the conceptual phase of building design. Goal of this project is to develope effective support tools for the early collaboration within sustainable building design.

2. METHODOLOGY: COMPARING BREEAM, LEED, GREENCALC+ AND ECOLOGICAL FOOTPRINT.

The four most popular sustainability assessment tools within the Netherlands at this moment: BREEAM, LEED, Greencalc+ and Ecological Footprint, these were then applied to a set of 8 state-of-the-art buildings [Lony et al 2006] and the results compared, see Fig 2.

For comparing the sustainable assessment tools not all aspects of the buildings can be used because Ecological footprint and Greencalc+ can only be compared at the aspects “materials, land use & ecology”, “energy”, “water” and “transport”. A complicating factor is that all assessment methods...
results are expressed in different values, namely: Global hectares (ecological footprint), Earth’s environment costs in € (Greencalc+) and Credits for the checklists (LEED and BREEAM) . To compare all assessment methods with each other, they need to be calculated in percentages of the maximum for a specific aspect of a building. That way they can be compared with one another. The total results of the 4 common aspects (energy, transport, water and materials, land use and ecology) of the assessments tools show that there is a rather big fluctuation in total score between buildings on some aspects, see Fig. 3, and the total combined score, see Fig. 4. Difference between the outcome of the different sustainable assessment tools occur of more than 20%. This makes it in fact rather uncertain to base the design decision on them.

Figure 3. Score in percentage of maximum of different environmental assessment tools for energy, transport, water and materials

Figure 4. Results of all four aspects by applying the different assessment tools
3. DISCUSSION

In order for environmental building assessment methods to be useful as a design tool, they must be introduced as early as possible to allow for early collaboration between the design and assessment teams. They also need to be reconfigured so that they do not rely on detailed design information before that has been generated by the designer in an Integrated Design Process [Thabrew et al 2009]. The concept of Integrated Design Process [Heiselberg 2007] is based on an understanding of the design process as Analysis/Synthesis (A/S); where the problem is broken down into sub-problems and individual problems, reaching individual solutions and sub-solutions until achieving the overall solution. Trebilcock [2009] proposes that the integrated design process in the practice of sustainable design is closer to a Conjecture/Analysis (C/A) model that suggests that designers would propose an idea (or conjecture) before attempting to do any analysis. Methods of Environmental Assessment, such as BREEAM and LEED, follow a typically A/S approach of dealing with the parts to assess the whole they concentrates on dismantling the parts as a way of reaching the whole [Trebilcock 2009]. The problem is that in architectural design “the whole or aspects of the whole govern the parts”, so tools that focus on the parts cannot guarantee that the whole is more or less sustainable and will be coherent. Therefore architects do not generally regard them as playing an important role in the design process and think that these methods provide only the certification required by the client. But in reality the sustainable assessment tool became a tool used by the clients for quality assurance.

However, the different current sustainability assessment tools all have still some flaws. The organizations behind the assessment tools are of course not ignoring the critiques and as a result the green building standards are ‘still’ under construction [Block 2009]. At the moment the current sustainable assessment tools are still not really adequate for supporting the early phase of architectural design. Often they are used as a check-list afterwards instead of being used early in the design process. They do not facilitate the proactive investigation of the creative solution space or the architectural aesthetics involved in building design [Hansen and Knudstrup 2009].

Although sustainability is a loosely used term to define all things environmentally friendly, the commercial real estate industry is increasingly turning to sustainability assessment standards [Mattson-Teig 2008]. However applying the different sustainable assessment tools leads to different choice for the best building, which means that applying such tools for decision support within the conceptual design phase, would lead to different outcomes [Wallhagen and Glaumann 2011]. The comparison of the tools and their results is difficult [Haapio and Viitanimi 2008, Vreene goor et al 2009, Roderick et al 2009]. The choice of the decision supporting tool is however of great importance for the results of the decisions. So before applying a sustainability assessment tool the sensitivity of the tool to specific aspects of the design program should be evaluated. This was done by applying the different sustainability assessment tools to a set of reference buildings. The result showed the difficulty of comparing these tools. As financial viability is considered to be the most important deciding factor in the selection of sustainability options our development is focused not on developing a new hybrid approach [Juan et al 2010] or to extract eco-indicators [Vakili-Ardebili and Boussabaine 2010], but on a method and a tool that supports the design team in the early stages of the design by using a dynamic instead of a traditional static approach. The dynamic approach consists of a LCC calculation based on discounted cash flows and the use of scenarios.

Synergy between design and assessment methods is necessary to really get transparent and understandable tools for supporting decision making on sustainability issues in the conceptual phase of building design. There is a need for further development of sustainable assessment tools however since the building sector contains many different stakeholders with different interests, there are many contradictory demands on assessment tools [Glaumann et al 2009]. Therefore the domain of Multi Criteria Decision Making was explored.
3.1 Multi Criteria Decision Making

Multi-criteria decision-making (MCDM) is a generic term for the use of methods that help people make decisions according to their preferences, in cases characterized by multiple conflicting criteria [Løken 2007]. MCDM methods deal with the process of making decisions in the presence of multiple objectives. In most of the cases, different groups of decision-makers are involved in the process. Each group brings along different criteria and points of view, which must be resolved within a framework of understanding and mutual compromise [Pohekar and Ramachandran 2004]. MCDM techniques have two major purposes [Hobbs and Meier 1994];
- to describe trade-offs among different objectives.
- to help participants in the planning process define and articulate their values, apply them rationally and consistently, and document the results.

The object is to inspire confidence in the soundness of the decision without being unnecessarily difficult. As a result it will be necessary to supply information about the sustainability of building service applications at a much earlier stage in the design process. And, since this stage is where most decision-making takes place, possible sustainable architectural concepts will then have a much better chance of actually being implemented. The sustainable quality can only be determined by a multi-criteria, multi-disciplinary performance evaluation, which comprises a sum of several satisfaction/behavior functions [Kalay 1999].

3.2 Further research: The Sustainability accelerator approach

Cook et al [2007] listed the most significant drivers and barriers for the use of alternative energy technologies, the research suggest that financial viability is considered to be the most important deciding factor in the selection of sustainability options in building projects [Alnaser et al 2008]. Therefore the development of a ‘Sustainability accelerator’ was started. Lifecycle cost calculations (LCC) approach plays an important role within the ‘Sustainability accelerator’ to compare several concepts with each other.

Some of the current sustainability assessment tools like BREEAM recognize the importance of such a LCC analysis, by granting points when an LCC analysis is performed and the results are implemented into the design. BREEAM assumes that the option with the lowest LCC has the lowest energy demand, decrease of maintenance, extending the life of systems and materials and disassembly and recycling of parts of the building. [Dutch Green Building council 2010] An important motivation for the LCC analysis is the increasing share of Public Private Partnership (PPP) and Design Built Finance Maintain Operate (DMFMO) building processes in the built environment. The financier of the building is therefore interested in the long term aspects of LCC.

From the outset of the design process a tool is needed for the LCC analysis to communicate internally within the design team as well as towards the customers concerning the LCC. This tool should supports the design team in its early stages of the design process and to encourage them to come forward with innovative sustainable solutions and to give clear insight for evaluating those solutions over the lifetime of the building.

To perform the required LCC analysis a generic tool has been developed to be able to compare several design concepts that help to meet the demands for a specific level of sustainability e.g. a specific BREEAM rating. The LCC method and tool, as part of the ”Sustainable Building – Accelerator”, is developed and presented in this article. The requirements for the development of this method and tool version were:
• Broadly applicable dynamic financial accounting tool where changes over the lifespan (including replacement and improvement investments, energy costs, other operating costs) are clearly specified for four design variants;
• Strong presentation / communication tool that gives insight and a good overview using indicators (per m²) and a graphically display of the results of the design variants, see Figure 2;
• Insight in the sensitivity of the results for variations in the different input parameters;
• Applicable to carry out a LCC-study fulfilling the requirements of BREEAM-NL (BRE Environmental Assessment Method for the Netherlands) credit MAN 12 [Dutch Green Building Council, 2010];
• Making clear the benefits: such as savings in labor costs by reducing absenteeism and/or higher productivity due to a better indoor climate. The LCC approach is thus extended to a LCP (Life Cycle Performance) approach.

The available version of the LCC is now a strong communicative and decision support tool. Changes over time can be discounted. The required input depends on the specific design question and should be determined before the "Sustainable Building - Accelerator" can be used.

**EXAMPLE - ENERGY STUDY**
To illustrate how the LCC method and tool works, it is applied to an energy study. This study has been conducted by Royal Haskoning in 2009. The energy study was performed using a traditional static approach and LCC was not applied. To illustrate the added value of the "Sustainable Building - Accelerator" it was now applied to four different energy generation systems for the project for which the study was performed:
• HR+CKM: Boilers and Compression Cooling Machine;
• WKO+HP: Long Term Energy Storage in the Soil (aquifer) and Heat Pump;
• WKK: Cogeneration of Heat and Electricity using Gas (CHP-gas) and Absorption Cooling;
• WKK (bio): Cogeneration of Heat and Electricity using Deep-frying Oil (CHP-bio) and Absorption Cooling.

Examined were:
• how the outcomes / design decisions change using the LCC assessment;
• how sensitive the outcomes of the LCC assessment are for variations in different parameters.

The results of the energy study performed in the past are presented in Table 1.

<table>
<thead>
<tr>
<th>Parameters / variation</th>
<th>HP+CKM</th>
<th>WKO+HP</th>
<th>WKK</th>
<th>WKK (bio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPEX [€/m²]</td>
<td>37,7</td>
<td>60,0</td>
<td>81,6</td>
<td>89,0</td>
</tr>
<tr>
<td>energy [€/(m²*yr)]</td>
<td>14,7</td>
<td>10,5</td>
<td>6,2</td>
<td>4,0</td>
</tr>
<tr>
<td>elect. [%]</td>
<td>13%</td>
<td>24%</td>
<td>4%</td>
<td>7%</td>
</tr>
<tr>
<td>gas [%]</td>
<td>87%</td>
<td>76%</td>
<td>96%</td>
<td>0%</td>
</tr>
<tr>
<td>other [%]</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>93%</td>
</tr>
<tr>
<td>OPEX [€/(m²*yr)]</td>
<td>1,79</td>
<td>1,61</td>
<td>4,65</td>
<td>5,04</td>
</tr>
<tr>
<td>end value [€/m²]</td>
<td>-20</td>
<td>-30</td>
<td>-40</td>
<td>-40</td>
</tr>
<tr>
<td>CO₂ [kg/(m²*yr)]</td>
<td>53</td>
<td>38</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>SPOT [yr]</td>
<td>-</td>
<td>5,1</td>
<td>7,8</td>
<td>6,9</td>
</tr>
</tbody>
</table>
Legend to Table 1:
- **CAPEX (Capital Expenditure):** Investments. In the statistical approach these are only the initial investments. In the dynamic approach the CAPEX also includes replacement and improvement investments;
- **Energy:** Energy costs are taken into account separately and are divided in the categories gas, electricity, and other;
- **OPEX (Operational Expenditure):** Operational costs (here excluding the energy costs), e.g., maintenance, operational management, and cleaning costs;
- **End value:** This is the value of the project at the end of the considered period;
- **SPOT (Simple Pay Out Time):** This is the resulting simple pay out time using the static approach. Only the initial investment costs and the estimated cost savings on Energy and OPEX after one year are considered.

For the LCC calculation additional data is required to calculate the real, discounted and non-discounted cash flows, see Table 2. These cash flows should also be calculated to fulfill the requirements of BREEAM-NL credit MAN 12, see [Dutch Green Building Council 2010]. The LCC calculation is performed according to the available standards, see [ISO 15686-5 2008]. The capital of the investor is also taken into account in the calculation separately, see "equity" in Table 2.

Table 2. Input parameters for LCC calculation (discounted cash flows).

<table>
<thead>
<tr>
<th>General parameters</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>period</td>
<td>n</td>
<td>30</td>
</tr>
<tr>
<td>electricity price increase</td>
<td>j_e</td>
<td>7%</td>
</tr>
<tr>
<td>gas price increase</td>
<td>j_g</td>
<td>7%</td>
</tr>
<tr>
<td>increase bio oil</td>
<td>j_o</td>
<td>9%</td>
</tr>
<tr>
<td>inflation</td>
<td>j</td>
<td>2.5%</td>
</tr>
<tr>
<td>equity</td>
<td></td>
<td>20 €/m²</td>
</tr>
<tr>
<td>internal discount rate</td>
<td>R_e</td>
<td>7%</td>
</tr>
<tr>
<td>external discount rate</td>
<td>R_d</td>
<td>6%</td>
</tr>
<tr>
<td>repayment period</td>
<td>n'</td>
<td>30 [yr]</td>
</tr>
<tr>
<td>financing interest</td>
<td></td>
<td>6%</td>
</tr>
</tbody>
</table>

Additionally, scenarios are specified for each variant. Scenarios are specified over a period (here: 30 years in compliance with BREEAM-NL MAN 12). A scenario consists of investments (replacement & improvements, see CAPEX), energy demand (see Energy) and other operating costs excluding energy (see OPEX) over time. In the calculation the following aspects are included:

- replacement investments are included in the scenarios for each variant;
- supply of energy varies over the specified period. The specified values are based on experience. The values indicate that after construction, the energy performance will be lower than expected and each year further it will deteriorate. After renovation, the energy performance will be better than after construction and each year further it will deteriorate again;
- operating costs excluding energy are assumed to be constant over time.

The results of the calculations are presented in Figure 5a and 5b.

In comparison to the energy study (static approach) the results of the LCC calculation (dynamic approach) show that:

- The payback period (intersection of line with the accumulated costs (cash flow) of the corresponding variant with the reference) differ from the static approach;
- The order of most profitable variants is changed. Application of BIO-Cogeneration of Heat and Power (BIO-CHP) is more profitable than Long Term Energy Storage (LTES = WKO) in the soil in combination with a Heat Pump (HP).
Furthermore, the results of the LCC calculation show that:

- The breakdown of costs is different for each variant;
- The energy costs are by far the largest costs. Investing in energy saving measures will therefore be profitable;
- Other operating costs excluding the energy costs are low for the reference system and thermal energy storage system (LTES=WKO), but are relatively high for the cogeneration systems (CHP).

The LCC-tool can also determine the sensitivities of the calculated results for variations in input parameters, with values each within a given bandwidth. The considered parameters and their bandwidths are presented in Table 3.
Table 3. Parameters to determine the sensitivity of the LCC calculation results.

<table>
<thead>
<tr>
<th>Estimating variables</th>
<th>Base estimate</th>
<th>Range</th>
<th>Cost outcome based on range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal discount rate</td>
<td>7%</td>
<td>6% to 8%</td>
<td>703 to 809</td>
</tr>
<tr>
<td>External discount rate</td>
<td>0%</td>
<td>5% to 7%</td>
<td>646 to 623</td>
</tr>
<tr>
<td>Inflation</td>
<td>2.5%</td>
<td>-0.5% to 6.7%</td>
<td>637 to 669</td>
</tr>
<tr>
<td>Electricity price increase</td>
<td>7%</td>
<td>0% to 9%</td>
<td>650 to 661</td>
</tr>
<tr>
<td>Gas price increase</td>
<td>7%</td>
<td>0% to 9%</td>
<td>631 to 702</td>
</tr>
<tr>
<td>Increase price (other)</td>
<td>9%</td>
<td>0% to 12%</td>
<td>653 to 853</td>
</tr>
<tr>
<td>CAPEX</td>
<td>38</td>
<td>30 to 45</td>
<td>612 to 686</td>
</tr>
<tr>
<td>Energy</td>
<td>15</td>
<td>12 to 18</td>
<td>581 to 778</td>
</tr>
<tr>
<td>OPEX</td>
<td>1.79</td>
<td>1 to 2</td>
<td>631 to 658</td>
</tr>
</tbody>
</table>

The calculated sensitivity and coefficient of variance for the reference system are shown in Fig. 6a and 6b.

*Figure 6a. Calculated sensitivity for the reference system (HR+CKM)*

*Figure 6b. Calculated coefficient of variance for the reference system (HR+CKM).*
The results of sensitivity calculation show that the LCC results are most sensitive to increase of energy prices and discount rates. Since the scenarios differ for each variant, costs differ for each variant and as a result the sensitivity for each parameter is different. In order to manage future cash flows these sensitivities can now be considered within the design stage of a building.

4. CONCLUSION

It is now widely accepted that architectures should encompass the environmental task of reducing fossil fuel energy consumption in response to climate change and ‘peak oil’[Chen et al 2011]. Through the last decades there has been a growing interest in quantitative sustainable assessment of building performance in line with the technical and practical development of sustainable buildings [Gylling et al 2011]. The current sustainable assessment tools are far from perfect and can influence the decision and design process of sustainable building in different directions. These divergent results emphasis the need for appropriate decision support tools in the early stages of the design process tools that are environmentally relevant as well as practically significant and useful. In this research the aim was to find new ways to express the sustainability of solutions into quantitative performances.

The selected important performances indicators are: The lifecycle costing; Emissions of the building; Improvement of comfort level; Results of sustainability assessment; End value & flexibility.

In 2010 Royal Haskoning formulated a research and development proposal in collaboration with Eindhoven University of Technology, SBR and the Dutch Green Building Council to develop the "Sustainable Building - Accelerator” as decision support tool for the early collaboration within sustainable building design. To perform research and development for the full scope of the proposal funding is still required. Nevertheless Royal Haskoning has already started the development of the “Sustainable Building - Accelerator” as their own product and service. The priority in the near future is now providing insight into: (a) variations in flexibility (functional changes, shrinkage, expansion) and (b) adaptability (new techniques) for each variant/scenario. This will support decision making in the early collaboration within sustainable building design, which will mean that sustainable options will have a better chance to be chosen.

5. REFERENCES

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Abstract: Design integration in the architecture, engineering and construction sector requires a multiplicity of skills, knowledge and experience. Design practice requires management tools and skills besides the design skills and the domain knowledge. Teams and design teams have been extensively studied, and it is widely accepted that the team management practices are contingent on the nature of collaboration. This research specifically investigates the critical success factors for managing teams for integrated design and delivery solutions (IDDS), which aims to involve virtual collaborative environments and various stakeholders and supply chain players such as architects, consultants, contractors, and suppliers across the project lifecycle. Since IDDS is a recent development, the associated teamwork factors and challenges are not currently well understood, especially for the design development phases. Therefore, there is an immediate need to investigate the teamwork requirements and challenges for successfully meeting the IDDS objectives. This paper reports the preliminary findings from an ongoing research that investigates this gap. This investigation builds on the rich literature on teamwork and organizational studies, design management and construction supply chain integration to identify the critical success factors necessary for an IDDS team. For teams to be efficient, team members need to have well developed mental models of each other, as well as the mental models for the task, process, context, and competence of the team. In particular, our question is what are the critical task, process, context and competence factors specific to the IDDS teams that involve multiple players representing the construction supply chain? How can the early identification of these factors help better team management and enhance team efficiency? This research adopts an interdisciplinary approach to investigate these questions. The findings reported in this paper are part of an ongoing research that aims to develop a framework for team management decisions and formation of IDDS teams in large construction projects. The research plans and objectives are presented in the paper.

Key words: Teamwork, mental models, construction supply chain, integrated design and delivery solutions.

1. INTRODUCTION

The construction industry globally is increasingly realizing the cost of inefficient processes and wastage that occurs with the traditional design delivery practice. It is widely recognized that the lack of integrated design and delivery across the construction supply chain and inefficient manpower management across the project lifecycle costs billions of dollars in waste (ACIF, 2010). Hence, there is a greater push for approaches such as Integrated Design Delivery Solutions (IDDS) that aim to create more productive environments through collaborative work processes involving information systems, enhanced skills, and integrated data across the entire project lifecycle (CIB, 2010).

Effective IDDS implementation involving integration of elements within the supply chain may reduce the waste by decreasing duplicity and increasing efficiency (King & Meyer, 2005). However, full service and process integration is challenging and many such at attempts at integration fail because of the varying effectiveness of the change management strategies and people engagement processes within larger teams and organizations (Glendinning, 2003).
For teams to be efficient, team members need to have well developed mental models of each other and that of the task, process, context and competence of the team (Badke-Schaub et al., 2007; Druskat & Pescosolido, 2002; Klimoski & Mohammed, 1994; Langan-Fox et al., 2004; Lim & Klein, 2006). Mental models are the internal representation of the external world (Smyth et al., 1994). Team members develop various mental models as they interact with and observe each other (Cannon-Bowers and Salas 1997). Well developed mental models allow team members to coordinate their roles and responsibilities with the rest of the team, and create a shared understanding of the team’s overall goals and objectives, which also facilitates the change management process. Well developed mental models of the team members can significantly improve the cost, schedule, and quality measures, especially in complex projects (Rouse et al. 1992), which is often the case with construction projects. However despite the importance of teamwork and the evident push for approaches such as IDDS that aim to integrate the teams across the construction supply chain, there is little research and understanding of the teamwork management issues with construction project supply chain teams. In an extensive literature review, London (2008) highlighted that the focus of past construction supply research can be organised into four key themes; logistics, construction production, strategic procurement and industrial organisation economics. Significantly there is little focussed research of the task, process, context, competence and team factors that constitute the mental models of the members of the construction project supply chain teams. Unless the various factors affecting the mental models are identified and understood, and unless corresponding team management and change management strategies are developed, it may not be possible to effectively achieve the objectives of the IDDS approaches.

This paper reports on the preliminary findings from a research study that aims to identify the critical factors affecting the formation of mental models in construction project supply chain teams, especially in view of the IDDS objectives. In particular we seek to explore such questions as:

What are the critical task, process, context and competence factors specific to the integrated design and delivery teams involving members from various stakeholder groups of the construction supply chain?

How can the identification of these factors early on in the project help better team management and enhance team efficiency?

Can we identify the potential bottlenecks and conflicts in the mental models of the team members at the different phases of the project so that effective resource allocation and monitoring plans can be devised?

How do the project conditions influence mental models, for example, how does the formation of mental models vary across distributed and collocated teams?

London et al (2005) have shown that the investment in human, cultural and social capital, which are constructs closely related to team mental models is critical to the success of construction projects and the development of the organization’s economic capital. This research will also analyse the task, process, context and competence factors from the inclusion of investment as a construct that provides potentially useful indicator and measure of individual and organizational motivation (von Treuer et al, 2009).

This paper details the research plan. The paper also reports preliminary findings based on focus group interviews (FGIs) with representatives from Australian AEC sector on the potential challenges to integrated design delivery practice using a collaboration platform, with Building Information Model (BIM) at the core of data exchange. Thus, while the objectives of IDDS are broader than achieving an integrated BIM delivery for the project, these discussions provide an insight into the potential challenges in managing the teamwork issues for an IDDS approach, which unlike the traditional design and delivery practice envisages including the client as an integral part of the information supply chain.
Furthermore, the challenges to IDDS implementation are likely to be greater for a fully integrated construction supply chain team, integrated across the entire project lifecycle, which will be investigated in future FGIs, interviews and surveys.

2. BACKGROUND

Inspired by the successful implementation of supply chain management in the manufacturing sector and their ability to integrate the design and delivery services, the construction industry policymakers have supported the adoption of the concept by construction industry participants (CIB, 2010; London, 2004). However there has been a general lack of wide-scale implementation in civil, residential and commercial sectors. The emphasis of management decisions in the manufacturing sector is on the modelling of volume production (Azambuja and O’Brien, 2009). The construction industry, however, has a very different structural organisation. The behavioural characteristics and the industrial organisation of the supply chains within the construction sector can differ markedly (London, 2008; London, 2004). The success from the supply chain management and integrated design and delivery services in the manufacturing sector cannot be directly translated to the construction commercial sector. There are similar characteristics in the residential sector with the volume house-builders. However, even in that sector there are limitations as the larger players are still not as significant in being able to make wide-scale change to the sector on their own. Coupled with this is that each tier in the supply chain has diverse players who have unique business environments and different work practices and mindsets. Therefore new research is required to understand these challenges and our project is precisely to carry this out.

In the construction industry, from commercial organisations to government agencies, it has been widely acknowledged that there is a need for more efficient and easy to use decision support methods to enable coordination and control of all parties involved in the construction supply chain network (Love et al, 2009). Figure 1 provides an indication of a generic supply chain including the various actors. This representation however belies the complexity of the construction supply chain and the complex interdependencies that arise as different supply chains form for different projects. Integration of key players in the supply chain is considered to be an important part of project success. As each player pursues its own contractual objectives, it is suspected that a lack of integration and teamwork has resulted in low productivity and low innovation.

![Figure 1. Construction Supply Chain Economics (London, 2008)](image-url)
Such challenges are likely to impede the IDDS initiatives envisioned by the construction industry as the design and delivery practice of the future. One of the biggest challenges for managers and organizations involved in the design and construction supply chain is to understand, and deal with, a distributed project team with diverse task, process, context, and team member mental models, resulting from the diversity in social, operational and functional backgrounds of the team members at individual as well as organizational level. The diverse backgrounds may result in different beliefs, cultures, goals, objectives, skills, norms, standards, and other factors that may result in syntactic as well as semantic conflicts (Druskat & Pescosolido, 2002; Langan-Fox et al., 2004; Lim & Klein, 2006).

Formation of mental models has been studied across diverse domains such as defence, psychology, information technology and so on (Badke-Schaub et al., 2007, Mohammed and Dumbville, 2001). It is well established that effective teamwork requires various kinds of competencies that can be discussed in terms of the knowledge, skills and attitudes that are specific or generic to the task, and specific or generic to the team (Ancona & Caldwell, 2007; Cannon-Bowers et al., 1993; Cohen & Bailey, 1997). Hence, well developed mental models for the task, process, context, competence and the team members are critical to effective team performance (Badke-Schaub et al., 2007; Druskat & Pescosolido, 2002; Klimoski & Mohammed, 1994; Langan-Fox et al., 2004; Lim & Klein, 2006). These findings suggest that organizational contingency theories (Lawrence and Lorsch, 1967; Donaldson, 2001; Levitt et al, 1999) also apply to formation of mental models in teams. Therefore, while general patterns and critical parameters related to the formation of mental models in teams can be identified, the results may vary according to the specifics of the industry and the project, i.e., which of these parameters are applicable, and what are their values in the given industry and the project, Figure 2.

![Figure 2. Mental models that team members need to develop for effective team performance](image)

The capability to predict the likely effects of pre-developed mental models of team members, based on the actual data related to their prior experience and existing mental models, and the specific project data, can significantly enhance project decision making. Such efforts are found to be useful in forming effective small project teams, where the scale of the project and the personnel data is manageable using a manual process. For example, Wilde (2007) reports how they use psychometric data and personality tests to consistently form high performing student design teams at Stanford University. However, in real world construction projects, the complexity of the supply chain, and, hence, the number of variables and the amount of data to analyze can be expected to be much higher. Personality assessments and psychometric tests are not uncommon in staffing and recruiting processes, but this approach is rarely applied to project team formation within and across the organizations. In large team sizes such as in construction projects, such tests may be useful in matching people not only based on their availability and expertise but also on their potential to collectively work together towards the project goals. However, while there is enough technical support to conduct tests for the individual’s fit
to the project and the organization, there is little support to analyze how the numerous individuals, selected through this process, will work together, in different phases of the project.

Hence, this research aims to address some of the related issues. Methodologically, one of the major areas of development will be to move from a static analysis approach to dynamic analysis, based on the likely emergent scenarios and interactions of personnel and project-specific data. The critical success factors pertaining to the teamwork in IDDS teams in construction projects identified from this research will be mapped to develop a framework that is intended to form the basis for a computer simulation based tool, which can support management and analysis of large data sets. The developed tool can be used to conduct predictive longitudinal simulations of how the construction project, and the project-related mental models, may evolve over time as a result of the diverse mental models of the team members at the start of the project. The simulation tool will build on the prior research on computational modelling of individuals and societies (Carley and Newell, 1994; Levitt et al 1999; Macy and Willer, 2002).

3. RESEARCH DESIGN AND ANALYSIS

This research will initially utilise a grounded theory approach (Martin & Turner, 1986) where data is collected from several sources (interviews, focus groups, surveys) in order to indentify the variables which are critical to measure in the decision framework. A case study will also be conducted and will validate and refine the framework. Participants will include various members of a construction supply chain project team. This research can be categorized in the following stages, Figure 3:

![Figure 3. Research design; stages in development of the computational framework](image)

3.1 Framework creation

The initial framework creation will be based on the identification of the critical factors that emerge from literature review, interviews, FGIs and the survey. FGIs will include representatives from each tier and discipline of the construction supply chain. Two FGIs will be conducted for preliminary data collection. The interviews and FGIs will be recorded on tape and later transcribed. The survey questionnaire design and measures for identification of critical success factors will build on similar surveys used in assessment of integrated delivery services in other disciplines such as healthcare (vonTreuer et al, 2009). Online surveys are also planned such that a larger sample size can be obtained to validate the findings from a smaller group of participants, accessed through industry networks within the Australian construction sector.
3.2 Framework development

Once the critical factors and their interdependencies have been mapped to create the framework, a case study will be conducted to refine the framework. The case study will map the mental models of the various members of a single IDDS team that is involved in distributed design and delivery. The selection of the case study will be based on the following criteria: (1) two different project teams from the same parent organization will be studied such that there is only partial overlap of members across the two teams; and (2) while project team members may be part of multiple projects at least some of the team must have committed 50% of their work hours to the current project.

3.3 Framework validation

The refined framework will be presented to industry experts and representatives of various disciplines in the construction supply chain to validate the findings. Follow-up FGIs are planned where these experts can collectively provide feedback and critique the framework. The refined framework will be formalized using an object-oriented approach to form the basis for a computational model that can be used as a simulation tool.

3.4 Development of simulation tool

The most critical parameters related to the task, process, context and team member mental models will be computationally modelled and implemented as a simulation tool. The simulation tool will build on the prior research on computational modelling of individuals and societies (Carley and Newell, 1994, Macy and Willer, 2002). Tools such as the Virtual Design Team (VDT) (Kunz et al., 1998) are widely used and recognized as useful simulation tools for advanced project management and decision making. Singh (2010) has demonstrated that computer simulations are useful in studying the formation of team member mental models.

Real world case studies and other measures of model validation will be conducted to ensure usability of the simulation tool.

4. PRELIMINARY RESEARCH DATA

The findings reported in this paper are based on data from FGIs conducted with representatives from various stakeholder groups in the construction supply chain that typically form an IDDS team. This includes architects, engineers, consultants, contractors, facility managers and collaboration platform service providers for construction projects. Representatives from large contracting firms and government organizations, who often work as clients in construction projects also participated in the workshop. The FGI discussions revolved around the potential challenges to integrated design delivery practice using a collaboration platform, with BIM at the core of data exchange. The FGI participants were encouraged to discuss the challenges to using an integrated information system and Building Information Models for managing the information supply chain across the project lifecycle. The FGI discussions were recorded on tape and transcribed by the researchers to categorize the discussions across the issues relating to task, process, context, competence and team member mental models.
5. RESEARCH FINDINGS

Verbal protocol analysis technique was be used to analyse the data and identify the underlying patterns and trends across the identified themes, i.e., task, process, context, competence and team. “Protocol analysis is a rigorous methodology for eliciting verbal reports of thought sequences as a valid source of data on thinking” (Ericsson, 2001). FGI discussions primarily revolved around the challenges in developing and using an integrated Building Information Model in a project, and the issues with managing the information supply chain. FGI discussions indicate that even at the outset of a project the different stakeholders are likely to start with conflicting mental models and apprehensions about each other’s beliefs and level of engagement in the project. Table 1 lists the key factors associated with the task, process, context, and competence and team member mental models.

<table>
<thead>
<tr>
<th>Themes</th>
<th>Factors and description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task (creating an</td>
<td><strong>Purpose of the model:</strong> In creating an integrated BIM for the project members need a shared</td>
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<tr>
<td>integrated BIM for the</td>
<td>understanding of the purpose of the model, which also determines how the task is shared and</td>
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<tr>
<td>project)</td>
<td>distributed among the team members.</td>
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<td></td>
<td><strong>Level of detail:</strong> Team members need clarity on the level of detail expected in the model. The level of detail in the model is contingent on the project requirements and the purpose of the model.</td>
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<td></td>
<td>Related aspects of task or model development where shared understanding is needed includes model types and sub-models, accuracy and completeness, as-built data for facilities management, and documentation and communication tasks.</td>
</tr>
<tr>
<td>Process (Process</td>
<td>Team members need shared understanding of the processes for managing the integrated BIM project development. This includes agreed protocols and practices for business processes, collaboration and information exchange, and interaction with the model. Mutual agreement and processes are critical for the following:</td>
</tr>
<tr>
<td>needed to manage an in</td>
<td><strong>Design review and clash detection:</strong> Team members need agreed practices for conducting design review using BIM models and tools that allow clash detection. Participants reported resistance among some stakeholder groups to change design review norms which are currently based on document sign-offs and approvals.</td>
</tr>
<tr>
<td>Integrated BIM project)</td>
<td><strong>Version management:</strong> Concerns were raised about potential conflicts that may arise from multiple files and versions of the model that are generated across the team. Besides the management of the different versions of the model concerns were raised about the software versions as well. In general, it was agreed that versions management requires measures such as standard file nomenclature system and notifications and flagging on model updates.</td>
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<td></td>
<td><strong>Data organization and management:</strong> In an integrated BIM project the amount of data generated can multiply significantly. At the same time, different disciplinary and functional groups may be working on parallel models that need to be integrated. Ideally it will be useful to have all the generated data across the entire project lifecycle stored for archiving and history tractability for legal reasons. But that may lead to data explosion. Hence, mutually agreed data management processes are required for decision making such as data pruning.</td>
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<tr>
<td>Context (team</td>
<td><strong>Work culture and practice:</strong> Project teams and organizations may vary significantly in their culture and work practice. Further, adopting IDDS approach will require adopting new work culture and news ways of working. The change in work practices often requires shifting organizational cultures from a focus on separate services to a focus on operating within a fully integrated service system. Cultural change refers to the establishment of norms, attitudes, and interpersonal relationships that will foster cohesive use of that system by all the team members.</td>
</tr>
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<td>situation, culture and</td>
<td><strong>Project phase:</strong> Team members need to have clear understanding of their roles, responsibilities and contributions to the integrated BIM model at different phases of the project. This includes clarity on the scope of the model and its usage across the different phases of the project.</td>
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<tr>
<td>practices)</td>
<td><strong>Regulations and standards:</strong> Building regulations and standards vary across states and countries. Hence, team members need to be alert about these conditions when working on projects or teams.</td>
</tr>
<tr>
<td>Themes</td>
<td>Factors and description</td>
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<tr>
<td>distributed across boundaries.</td>
<td><strong>Project requirements</strong>: How the team is organized, how the task is coordinated and what processes are adopted will vary according to the project requirements. Hence, team members need a shared understanding of the project requirements and the scope and objectives of the integrated design delivery approach specific to the project. FGI participants agreed that even though some of these requirements and project context will evolve midway through the project, considerable improvements can be obtained by discussing the project upfront with all the project holders. Discussions suggest that it may be useful to mutually develop and create measures that will help identification and agreement on emergent project requirements. Such measures and agreements will reduce the likely misunderstandings and disagreements that may arise out of unforeseen project conditions, which often occur in most projects.</td>
</tr>
<tr>
<td>Competence (Capabilities of the team and tools)</td>
<td><strong>BIM readiness and technical competence</strong> of project partners is a critical factor in determining the teamwork efficiency. Project managers need structured approaches and checklists to identify potential clashes that may arise due to the use of incompatible tools and technologies. Potential users need to be aware of the competencies and skills required to use the various applications and at the same time they need to be aware of the capabilities and limitations of the tools at the outset of the project. Issues of data format and import/export capabilities of the softwares need to be considered at the project planning stage itself. Due consideration must be given to the variable ability of the team members to learn new tools and processes, and their existing skills and specialities. Capabilities of the information systems and the collaboration platform may also determine the nature of collaboration and the opportunity for social learning and team building. FGI participants also raised concerns over the other capabilities of the information systems that include security; bandwidth; server capacity; visualization capabilities; integration capabilities; querying and archiving; usability and interface.</td>
</tr>
</tbody>
</table>
| Team member (about the team and team members) | FGI discussions revealed a concern over the tendency of some functional groups and disciplines to work in isolation. Lack of trust in accuracy and completeness of the information and models created by members of other disciplines was a concern. FGI discussions emphasised that roles and responsibilities need to be clearly defined, which often becomes a contentious issue, especially in changing team environments. Issues such as data authorship and access rights remain a concern. Some disciplinary groups expressed a fear of additional work, showing resistance to change. FGI participants discussed a range of strategies for dealing with the resistance to change including motivations and initiatives for the different user groups to adopt new ways of working, government and regulatory measures that will drive this change as a necessary condition, creation of communities of practice that can encourage and train the members of the various communities, and identification of the change leaders. The discussions suggested that willingness of the team members to learn and adapt to the project requirements reflects a measure of investment and the expected return on investment. Some of the factors that individuals and firms in multi-organizational collaboration consider as part of their assessment of the return on investment include:  
  - **Financial investment in technology**: Is it worth investing in a new technology unless the returns from the project cover it? Even if the returns in the current project are low will it provide long term advantages in future projects?  
  - **Effort and time invested** in creating a shared protocol for working with the team and other project partners: Am I likely to work with the same group in future or not? Is the project long enough or worthy enough to invest time and effort in creating a project specific protocols and culture?  
  - **Investing in new skills and specialities**: Adopting news ways of working or new technical skills requires commitment and time. Some project stakeholders who are recognized for their expertise and experience in their existing skills and capabilities, and have built a strong reputation for it, are reluctant to venture into developing new skills and specialities. The inherent uncertainties and lack of experience acts a deterrent to investing in the new skills and specialities, especially for people who have spent decades working and mastering a particular skill and expertise. |
Though the factors have been classified within one category often one factor is associated with multiple mental models such that the task, process, context, competence and team member mental models are closely interrelated and affect each other. For example, model validation is not only about the task but also the process involved in conducting that task. Similarly, skills acquisition is not only about the competence but also about what the individuals think of the team, and their roles and responsibilities towards the team. Further research is needed to build on this mapping and develop a dependency model that provides the framework for a computational application.

6. CONCLUSION

This paper discusses an ongoing research that aims to investigate teamwork challenges and opportunities in construction supply chain networks, especially with respect to the objectives of integrated design delivery solutions. The paper details the research plans and the steps towards achieving the research objective of creating the basis for a computational simulation tool as a decision support system for team selection and resource allocation for efficient management of teams engaged in integrated design delivery and solutions practice. This research adopts the construct of mental models as the basis for establishing the parameters of teamwork. Findings from the preliminary focus group interviews with representatives of various stakeholder groups are analysed and categorised into issues related to task, process, context, competence and team member mental models. The focus group discussions suggest that there are overlaps across the different mental models and the key issues concerning efficient teamwork and project management. Among other issues it is evident that team members have a sense of measuring their investment in the project and the returns on the investment. This investment involves multiple parameters such as time, effort, money, and reputation. Further research is planned to investigate these issues and develop the framework.

7. REFERENCES


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A review of different approaches to access and people circulation within health-care facilities and the application of modelling, simulation and visualisation

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Abstract: Evidence suggests that improving access and people circulation in hospitals can: improve staff performance and productivity; enhance patients’ safety, privacy and rate of recovery; minimise the risk of cross-infection; reduce the delay time of external service delivery; create a more welcoming environment for visitors; and reduce the evacuation time in emergency situations. Consequently the need to design hospital layouts that benefit from the most effective system cannot be over-emphasised. This paper focuses on identifying different systems of access and people circulation in health-care facilities in general and hospitals in particular. The research on access and people circulation reported in this paper comprises three main phases. The first phase involves a literature review of existing health-care environments to identify different types of access and people circulation requirements. The second phase focuses on categorising the adopted approaches and systems in order to compare and contrast the advantages and disadvantages of each. The final phase provides a critique of current modelling and simulation tools being applied during the planning and design phases to improve access and people circulation. The paper concludes with recommendations, which will be used to shape future research in the area.

Key words: Accessibility, Circulation, Layout Design, Hospital, Healthcare, Simulation, Modelling

1. INTRODUCTION

Research has linked the quality of care, patient health and wellbeing with the physical attributes of the healthcare environment (e.g. Gesler et al, 2004). It is understandable that supportive built environments with good internal layouts, accessibility, and circulation can create an overall inviting, calming, engaging, and more hygienic and productive healthcare environment for staff, patients and their relatives.

Design of a healthcare unit influences the patients’ quality of care in many ways. One of the known effects of the hospital layout on care quality is the amount of wasted time because of the unnecessary journeys by the staff. Some studies have investigated the impact of the unit layout on the amount of time spent walking (e.g. Shepley, 2002; Shepley and Davies, 2003; Sturdavant, 1960; Trites et al, 1970). They demonstrated that time saved walking was translated into more time spent on patient-care activities and interaction with family members in several studies.

Being an automotive industrialist, Henry Ford was one of the first to notice the inefficiency of former hospital designs in meeting their purpose and said that “in a normal hospital, nurses are forced to make many unnecessary steps. Hence they spend more time walking around than nursing the patients”. He then laid out his employees’ hospital in such a way as to avoid ‘superfluous steps’ (Kuhn, 2000).
This seems to still be a challenge, even now, in the 21st century. According to Dillani (2010) caregivers spend 49% of their time in corridors. Considering the time they spend in other spaces (e.g. nurse station 16%, patient rooms 19% and other rooms 16%), this emphasises the importance of layout design in enabling caregivers to release time for patient care.

Other than staff’s walking distances, many other aspects of healthcare quality can be affected by the layout design of the hospital. A good design is expected to improve staff performance and productivity; enhance patients’ safety, privacy and rate of recovery; minimise the risk of cross-infection; reduce the delay time of external service delivery; create a more welcoming environment for visitors; and reduce the evacuation time in emergency situations. It is, therefore, correct to state that the design of a hospital impacts all its users, including patients (inpatients and outpatients), hospital staff (nurses, doctors, managers, etc.), visitors and others. Among these groups, nurses are considered to be the users who spend the most time providing direct care to the patients; therefore, it is natural to give their needs the higher priority when designing a hospital.

This paper studies the effects of different designs on the efficiency of the nursing staff. The first step was to identify the different types of hospital layout design. This shaped the basis of the selection of layout types in regards to access and circulation systems, however, hospitals are normally large buildings and this means that deciding on the scale is also very important. The reason is that if a hospital is studied in its whole, the study will be limited to the general and overall layout of the building and its circulation systems. This will lead to overlooking the many issues that may exist in smaller scales inside the units. On the other hand, a too focused study, which deals with individual spaces, could mean ignoring important aspects such as adjacencies and people flow.

It is, thus, a reasonable choice to focus the study on a more intermediate scale to allow for conclusions that will cover the biggest part of the circulation issues. The ward seems to be a more appropriate scale here, because apart from being from that intermediate scale, it also accommodates most of the active time of the nurses and hosts the biggest percentage of the users of a hospital, meaning inpatients (MAPS, 2010).

For this reason, this paper will focus on:
- introducing a method for identifying different trends in designing wards; and
- reviewing available computer-aided simulation tools for comparing different ward design types.
2. **APPROACHES TOWARDS HOSPITAL WARD DESIGN**

Ward design can be studied from different points of view (e.g. size, function, environmental factors, aesthetics and psychological factors, safety, etc.). The ward layouts discussed in this section are categorised based on the system of access and circulation inside them; therefore, it is the circulation system and the way that ward spaces (patient space, nurses’ base and staff space) are arranged around the circulation system that formulates the type of ward layout in this paper.

Patient space may contain single-bed rooms, multi-bed rooms or both. In Scandinavia the preference is for single-bed rooms, in USA for two-bed rooms and in the UK until recently for 4 to 6-bed bays. New UK research advise that 50% to 100% of all patient rooms should be single occupancy in newly built hospitals (Dowdeswell et al, 2004) to provide for patients’ privacy and cross-infection control. However, the provision of single-bed rooms and multi-bed bays is the subject of a wide debate. In addition, a day space is required in wards and a toilet and shower should be provided for each bay.

The nurses’ base is a very important element in the ward’s environment, as it should allow nurses to monitor the largest possible number of patients. Hence, it is recommended to be central in the ward to act as an organisational hub to the ward. On the other hand, the staff space contains nurses’ room, doctors’ room, treatment room, staff lounge, clean utility, dirty utility and other rooms which are usually used by staff.

The types of hospital wards can be classified according to the arrangement of these three spaces together and around corridors within the ward. James and Tatton-Brown (1986) classified wards into seven types. These types were: simple open or Nightingale form; corridor or continental form; duplex or Nuffield form for greater amenity for patient and staff; racetrack or double corridor form to achieve more compactness; courtyard form which achieves better natural ventilation; cruciform or cluster for better observation and finally the radial form to reduce staff travel distance (Alalouch et al, 2009). More recently, HBN 4 (1997) also provides a list of different hospital wards in UK from a management point of view as follows: Nightingale ward; Sub-divided ward (early 20th century and post war); Nuffield ward; Falkirk ward; and Nucleus ward.

In this study, a combination of these two classifications is used, in order to cover a more comprehensive variety of different ward layout designs. As a result, five different hospital wards are introduced based on a geometrical rearrangement of the classifications given by James and Tatton-Brown (1986) and NHS Health Building Note 4 (1997). Five examples are also presented, in order to investigate the practical application of the ideas of each layout type.

2.1 **Corridor ward**

The Corridor ward is, in essence, the developed form of a historical form of ward known as Nightingale ward. The Nightingale ward or Long-nave ward (as called by HBN 04, 1997) was a type of hospital ward, which contained one large room without subdivisions for patient occupancy (Pattison et al. 1996). It was developed at the end of 1870s and was named after Florence Nightingale. It might have side rooms for utilities and perhaps one or two side rooms that could be used for patient occupancy when patient isolation or patient privacy was important (Pattison et al. 1996). According to Pattison, Nightingale wards contained open bed base for approximately 30 beds.
usually arranged along the sides of the ward. According to HBN 04, men and women were cared for in separate wards.

This design was later improved to what we today know as Corridor ward (or Continental ward) due to new concepts in reducing cross infections in hospitals as well as patients’ privacy and dignity (Pattison et al., 1996). To consider these concerns, in the Corridor design, patients are located on one or both sides of a corridor with four to six beds per room. The corridor design may be in a “T,” “C,” or “L” shape (Catrambone et al., 2008).

In an early 20th century variation of Corridor ward, known by HBN 04 (1997) as “Sub-divided ward”, the nursing station and a single room split the ward in two. The overall management and clinical supervision in this model were to a large extent similar to those of Nightingale wards with the difference that subdivided ward allowed men and women to be cared for in separate wings of the same ward (HBN 04, 1997).

Nucleus or deep plan ward is another variation of Corridor ward design, which originally belongs to 1980-1990s when the oil crisis of the mid 1970s recognised energy demands of deep planned buildings. Under this design, “Florence Nightingale’s original concept of hospitals with fresh air, light, and views was replaced by deep plan hospitals that prioritised efficiency over human comfort and healing” (Burpee, 2008)

The layout has a modular concept design, based on reducing energy consumption, maximising external wall area available for windows and reducing number of floors. Support facilities are located in the centre. The en-suite facility is provided in the case of a single room (HBN 04, 1997).

2.2 Duplex ward

This type of ward belongs to the 1950s. The Duplex configuration (also known as Nuffield) is, in fact, a combination of two Corridor wards, each including its own station, but sharing support space that is located between the two wards (Catrambone et al., 2008). The beds continued to be in small groups each with its own sanitary area, but the growing awareness of the problems of cross infection - coupled with the desire to avoid disturbance to other patients - introduced a special room on each ward for carrying out clinical procedures and treatments (Smith, 1966).

“The single nursing team largely remained, but on a day-to-day basis the team was split to cover separate areas of the ward. By this time, patients of several consultants might be accommodated in one ward.
Sometimes, the wings were used to accommodate the patients of different consultants or patients of different genders” (HBN 04, 1997).

### 2.3  Racetrack ward

Post-war Racetrack appeared in 1950s-60s with provision of 16-60 beds in various mixes of patient dependency. “This ward layout provided a mixed-sex ward with multi-bed bays for use either by female or male patients” (HBN 04, 1997). The ‘racetrack’ ward had patients rooms arranged around a central core of services. Sisters desk was replaced by a nursing station, where staff could sit instead of being on their feet all day by their patients. Privacy was fine for those admitted for elective surgery, but when seriously ill the constant observation and presence of the nurses were more important (Rivett, 2008). The racetrack design (also known as double corridor) has nursing work and support spaces between two corridors. This is believed to be one of the most common designs in the US (Page and Page, 2004).

A specific variation of Racetrack design was the Falkirk ward type that appeared in the 1960s (HBN 04, 1997). It has a core of facilities and dispersed work stations. Four bedded bays, which enjoy more generous bed space standards with internal glazed partitions, are one of the characteristics of this ward type.

An obvious shortfall of Racetrack ward type was its long corridors with no natural light and view. Barefoot (1992) stated that: “the racetrack ward is a failure; one should avoid too long corridors without windows. The reassurance of relating to outside orientation is vital. It can be done with corridor breaks giving pleasant views of the outside.” One of the most commonly used solutions to this shortfall was the introduction of Courtyard wards.

According to Catrambone et al (2008) the courtyard ward is another variation of racetrack design with courtyard for ventilation in the middle of the building. In this type of plan, courtyards of varying sizes are inserted into the core areas to provide natural light and ventilation.

### 2.4  Cluster ward

In this type of ward design, the geometry works as a generator. “The combination of orthogonal and diagonal axes can generate close packing plan forms for single room layouts” (HBN 4 Volume 2). “Geometric designs are used to gain more external wall area so that the use of natural light and ventilation can be increased. They also provide solution to deal with deep plans and internal corners.
which commonly produce “dead” space, which cannot be used for continuous nursing activity” (HBN 4 Volume 2).

The most common form for cluster ward is cruciform, which is a modification of the corridor plan to ensure that as many patients as possible are gathered around the nursing station while providing privacy enhancements such as walls and doors (Catrambone et al, 2008).

2.5 Radial ward

A study by a group of researchers lead by Catrambone (2008) found that, in general, a radial ward design was the most desirable (related to single and double corridor designs), both in terms of saving unnecessary ward travel and of increasing time with patients. Moreover, members of the nursing staff indicated a preference for assignment to the radial ward. The fact that nursing staff in the radial unit had more free time was interpreted as an indication that more patients could be housed on the ward. The radial design is a circle that permits a “fishbowl” view of each room from the nurses’ station (Catrambone et al, 2008).

In this part, a review of five most common ward design approaches in the last 150 years was presented. Their known points of strength and weakness as stated in the literature review were discussed and examples of each design were studied. The following sections will present a discussion on the tools available for a quantitative comparison between the quality of access and circulation in these types.

3. MODELLING DIFFERENT WARD TYPES

Computer-aided simulations enable the researchers and designers to study numerous scenarios in a short span of time in order to reach to the optimum solution for a problem. On the other hand, relying on case studies for studies like this could make way to unwanted factors (such as case study’s size, staff numbers, workloads, environmental factors, etc) that may confound the results expected from the study. It could also leave a lasting doubt about the representativeness of the case studies because of mentioned inevitable differences.

To suggest a method for comparing different designs available for a general ward, a set of different designs for a hypothetical ward is needed. This will facilitate a comparative study on the system of access and circulation in different types.

To keep the characteristics of these generic forms more repeatable and simple and to avoid the complexities that might obstruct a more systematic comparative analysis of the geometry of the types, a number of simplifying and coordinating measures are needed to be equally applied to all different types. This is to keep as many characteristics of the different types as possible similar to each other and therefore leave the geometry and layout of the ward as their main comparable characteristic.

The first and most important factor that should be kept equal and identical in all different types is their size and consequently the number of the beds. Another very important factor is the function of the wards and the activities of the nursing staff within them.
These design types must cover the common ward styles (as discussed above) and the main factor differentiating between them needs to be limited to the design of access and circulation of the staff in them. In other words, the design types studied here should cover all the most common combinations of the spaces in a general ward.

By eliminating hospital wards that need special considerations (such as paediatrics, cardiothoracic surgery and trauma and orthopaedics), general medicine wards and wards with similar architectural needs (like general surgery and geriatric medicine) form the biggest majority of the wards in UK hospitals (Figure 13).

The Department of Health measures the average number of beds in a general ward at 18.6 beds (DH, 2010) and demands that a minimum of 50% of all beds in every ward need to be in single rooms (Dowdeswell et al, 2004). As a result, archetypal models of each ward type are designed to accommodate a total of 20 patients in 4 single rooms and 4 multi bed rooms. Configuration of ward spaces is decided based on the characteristics of each type. A geographical representation of the archetypal models is presented below (Figure 13).
Apart from the geographic characteristics of different spaces in the ward, their technical specifications are also important. Activity DataBase (ADB) is the Department of Health’s briefing and design tool used to develop healthcare environments, which provides such technical specifications. ADB provides room data sheets and graphical room layouts, produced from Department of Health (DH) datasets - derived from Health Building Notes (HBNs) and Health Technical Memoranda (HTMs), and reflecting DH baseline standards. It has been estimated that ADB is used on over 90% of healthcare construction projects in the UK (DH, 2007). A combination of geographical and technical characteristics of each type provides enough information to build its model in any simulation program. The following is a review of some of the simulation tools available for this task.

Figure 8. Geometrical models of 5 types (1. Corridor, 2. Duplex, 3. Racetrack, 4. Cluster, 5. Radial)
3.1 A review of available simulation tools

Healthcare planners and designers have traditionally used best practice standards to guide organisation of spaces and provide appropriate facilities in a healthcare unit (Choudhary et al., 2009). However, recent developments in simulation and modelling techniques have promised a more dynamic alternative, wherein the healthcare delivery process can be modelled to compute appropriate amount of facilities required for different types of healthcare processes and analyse patient flows (Eldabi et al. 2007, Gibson 2007). The modelling, simulation and visualisation in the design of healthcare facilities in general, and in assessing their accessibility and circulation systems in particular, can facilitate:

- comparing, evaluating and examining numerous different design approaches within minimum time and budget; and
- exchange of visualised design ideas between designers, clients and contractors

People circulation is the process that incorporates reception, security, access control, visitor announcement, parking, taxi and other functions and services normally used to manage the people circulation in the hospital.

In order to select the most appropriate tool for modelling and simulating the ward categories listed above (Figure 13), a series of actions were taken as the process of software selection. These actions included:

• First) A general review of 52 available modelling tools in the market, in order to find those more widely used in healthcare facility design and eliminate those less relevant to the requirements of the research.

• Second) Comparing the details of the characteristics of the remaining seven tools (AnyLogic, Arena, Flexsim HC, MedModel, Simcad, Simio and Simul8) to find those most appropriate for this research. These seven programs are briefly introduced here:

3.1.1 Anylogic

AnyLogic is a dynamic simulation tool that supports all conventional approaches of simulation methodology: system dynamics, process-oriented (discrete event) and agent-based modelling. These methodologies can be mixed in one model.

This software enables the user to represent many corporate application fields, such as production, logistics, business processes, market and competition, or supply chain.

3.1.2 Arena

Arena is a simulation program designed for quick and low-cost animations in 2D with the potential for more detailed 3D post-animation processing. It has a design optimisation capability (based on OptQuest) that together with the possibility of automated input analysis (integrated within the software) and its ability to adapt with Visual Basic programming language, make Arena one of the easier-to-use options in the market. Special versions have been designed for modeling factories, call centres, packaging lines and flow processes.

3.1.3 Flexsim

Flexsim is a tool for modelling, analysing, visualising and optimising processes in different fields. Regarding shapes and layout issues, Flexsim is able to add realism to the model by using custom 3D
shapes of the buildings, machines, or products. Then it will import 2D or 3D CAD drawings to use as a floor plan or topographical layout. It is also interfaces with other programs and programming languages, such as C++, Access and Excel. Different specialised applications have been developed for Flexsim to make it easier for using with different scenarios. Among them is Flexsim HC, which is specifically designed for modelling different healthcare scenarios.

3.1.4 MedModel

MedModel is a specialised version of the simulation tool, ProModel, designed for visualising, analysing, and optimising the performance of healthcare systems. It is a predictive analytic tool, based on discrete event simulation, designed specifically for the healthcare industry to evaluate, plan, and design/redesign the processes, procedures and policies of hospitals, clinics and labs. MedModel models can be used to identify inefficiencies in an existing process and test a variety of scenarios. The animation and graphic output results show the behaviour of the system under any set of circumstances. Its realistic animation capabilities and the potential to be used in link with Visual Basic language makes performing simulations easier for non-professionals.

3.1.5 Simcad

Simcad is a dynamic process simulator with a built-in dynamic optimizer tool and integrated work order/schedule optimization. It allows experimental designs in a dynamic interaction in a model or through integrated optimization. It can also publish simulation results to an integrated tool called Simcad Scenario Analysis.

3.1.6 Simio

Simio is a Discrete-Event simulation software with automated scenario management and the ability to analyse the result of simulation as summary statistics or animations that can be exported to in different formats. Although it offers a good modelling speed and flexibility of process it still does not include solutions for design optimization. Simio is designed to simplify model building by promoting a modelling paradigm shift from the process orientation to an object orientation (Rossetti et al, 2009).

3.1.7 Simul8

Simul8 is a relatively easy-to-use tool, representing the simulation in a realistic 3D environment with the ability to model in 2D and 3D and produce Virtual Reality animations. Simul8 can be integrated with C++, Access, VB and Excel to make the transfer of input and output data easier. Another helpful potential of the software is its ability to optimise designs through: cost reduction, efficiency maximisation, future performance improvement and guesswork illumination.

Third) Further investigation with the aim of choosing the most appropriate program revealed capabilities and limitations of each of the seven tools. These have been summarised in the following table (Table 1).

As shown in the table, all of the shortlisted programs meet most of the requirements of the study. However, minor shortfalls in some of them lead to their elimination in the selection process. Since the ability to export animations, the potential of seeking online help from other users and optimisation capability are among important factors expected from the software to be used in this research, the last three programs in the table (i.e. Simcad, Simio and Simul8) are not considered the
most obvious choices here. MedModel data export is also mainly based on text format. Animation export, however, is not impossible if suitable secondary programs are used. On the other hand, MedModel together with Flexsim HC are the only two programs in the list that are specifically made

### Table 1 Comparing capabilities and limitations of shortlisted programs

<table>
<thead>
<tr>
<th>Software</th>
<th>COMSOL Multiphysics</th>
<th>AnyLogic</th>
<th>Arena Simulation Software</th>
<th>Flexsim HC</th>
<th>MedModel</th>
<th>Ns-2</th>
<th>Simpack</th>
</tr>
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<tr>
<td>Capabilities</td>
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<td>y</td>
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<tr>
<td>Limitations</td>
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Table adapted from: *Table 1 Comparing capabilities and limitations of shortlisted programs*
to simulate healthcare environments. This means that many of common spaces, equipment, agents’
behaviour and procedures are already implemented in the software. For this reason, these two
programs are kept in the shortlist of the high priority tools in the process.
Another software with a unique ability is AnyLogic. This ability is to integrate agent-based simulation
in the process. Agent Based Simulation (ABS) is a method of simulation that considers the probability
of the decisions made by different autonomous entities (agents) as a result of the existing conditions at
each phase of the simulation. This contributes to the ability of simulation agents to learn and to
optimise their behaviour within the simulation environment. This makes simulation results
considerably more realistic in comparison to Systems Dynamic and Discrete Event Simulations.
Apart from AnyLogic, a network-based product of Flexsim family (Flexsim DS) is the only program
in the initial list that covers agent-based simulation. But Flexsim DS, unlike Flexsim HC, is not
specifically designed for simulating healthcare environments and, for this reason, is not included in the
final shortlist.
Based on the above selection process, AnyLogic is decided to be the highest priority for the simulation
tool used in this study, followed by FlexSim HC and MedModel.

4. SUMMARY

This paper looked at the basics of modelling of ward layouts for simulation purposes and
particularly for comparing the productivity of the nursing staff in different layouts. It presented a study
of different hospital layout systems used in the last 150 years. As a result of this study, a list of
different architectural approaches towards ward design was presented. It was also discussed that most
of the main ward layouts of the present can be classified under one of the 5 layout categories
(Corridor, Duplex, Racetrack, Cluster and Radial). After deciding on different layout systems, each of
these systems needs to be simplified in form of a hypothetical medical unit (ward), including its
internal circulation needs as well as its links with other departments in the hospital. This simplified
ward will represent the access and circulation qualities of its system in comparison to other types.
To enable these simplified wards to be analysed, they should be modelled based on the design
standards and then analysed through one of the available simulation tools to evaluate the level of
access and circulation efficiency in each model. A list of some of such simulation tools was presented
and some of the most common ones were discussed in detail. Finally the simulation tools most
appropriate for the nature of such studies were selected.
As a result, all basics for a comparative simulation study have been established. Using these basics
(ward layout categories and their simplified models as well as suitable simulation tools), a variety of
different analytical and empirical studies are made possible. One of these potential studies is
comparison between the productivity levels of the staff in these different layout types using selected
simulation tools. The results of this study will be included in future publications.

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Communication vs Information in the Building Process

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Abstract: There are severe problems in the Swedish construction sector due to a communication gap between the actors involved. A report from Svensk Byggtjänst in 2007 declares that this gap costs 2.3 billion Euros a year. Can the digital arena replace the meetings between the actors involved or is it even more necessary to work with communication skills and human relations? All tools available that can be of importance for the process and the product must be used. Is it possible to combine low-tech and high-tech methods for communication?

With an end-user perspective, in order to keep focus on how to get the best quality of the product, this paper will discuss the risk to rely on the digital techniques to solve the problems with the communication gap. The discussion in this paper will use the report made by Svensk Byggtjänst (2007) as a reference where 240 interviews were done with different actors about how the investments were used in the construction industry.

The objective of this paper is the question of how digital techniques can support the communication between the actors involved, especially when involving the end-users into the building process. The method of performance of this research contains literature reviews and experiences from case studies. The result is an overview of how different communication tools can support the collaboration between the actors involved. The contribution of this research is a discussion of different kind of communication and a reminder of the dialogue as a basic tool for communication.

Key words: Communication, information, collaboration, dialogue, digital tools, arena for communication

1. INTRODUCTION

The building sector struggles with problems that sometimes can be repeated in different projects and new ones can be added. Information systems, web-based document storage and electronic documentation transfer can support the large scale of information that must be used in the building process. However, tools can only support the communication and any attempt to replace the conversation between the actors involved can be a risk factor for failings and mistakes. It is of great importance to clarify the difference between communication and information. Information is a one way communication where you don’t need to ensure neither the interpretation nor the understanding of the message. This paper will discuss some of the terms used when describing communication as a tool in the building process. Information technology is often supporting a complex process, but there can be obstacles to achieve a good result, if not used in a proper way. Experiences from case studies of large scale projects in Sweden (Svetoft, 2008) shows positive effects, due to the investments done, with the ambition to include all actors involved. All competence, knowledge and experience available can only be useful if all actors involved can be part of the dialogue and discussions, during the process.

There are severe problems in the Swedish construction sector due to a communication gap between the actors involved. A report from Svensk Byggtjänst (2007) declares that the negative effects from this gap costs 2.3 billion Euros a year. The answers from 240 interviews with different actors,
describes that each project where the conditions are normal, could be decreased in average 13 percent of the total investment. The most important effect on this phenomenon could be achieved by a better communication between the actors involved in the building process. The effects would be: to easier keep the time schedule and to avoid the risk of disturbance, better and more stabile level of quality and less risk for errors and mistakes due to misunderstandings. This could lead to better outcomes of the investments and a better working climate.

A report edited by Macmillan (2004) shows similar results in the construction industry in UK as the figures from the Swedish report from Svensk Byggtjänst. A whole cost reduction of 13,7 per cent is the result when working with a project called Building down Barriers in UK. The problems are also referred to the gap in communication and the difficulties with team work. Some of the common factors that attribute to the failings are: Inadequate planning, information is supplied to late, the information is uncoordinated, the drawings and specifications have been incorrectly interpreted. The author Peter Trebilcock describes in the report a positive effect when working with team integration. Different kind of techniques and tools to aid total team integration and the consequent smooth running of projects are: Common software systems and CAD systems, electronic documentation transfer, web-based document storage and retrieval, project intranets, integrated CAD/CAM software to ease the transfer and design information from consultants through to fabricators and regular client/team feedback sessions where key learning points are captured and incorporated in working methods.

An illustration from a project in the north of Sweden shows what the result can be if there is a gap between the actors involved and the tools that they are using. The photo shows the main door installed one meter above ground in a new building, or is it perhaps the ground that is situated too low? How can this happen when using so much knowledge and with high-technology tools? A tragic result for the people involved in this project, but also important as a reminder of the risk when we are not communicating efficiently. Everybody shares the responsibility and yet no one does, when it comes to paying for the mistakes. What if the sum of 2,3 billion Euros could be used in a more positive way than to pay for the mistakes and failings in the product?
2. **ARENA FOR COMMUNICATION**

The history behind the technological development in the digital arena for communication shows how fast innovations changes the way of working and thinking. Descriptions from the early days, when using computer technology as a tool for communication, can give us perspective on how we look at this today. Different positive effects can be achieved when using communication technology, but there is no auto-connection between the use of advanced tools and the quality of the product. For some reason, the use of IT in the building industry seems to differ from other industries. The people involved and how they handle the knowledge and supporting tools can be important factors for the outcome.

When entering a period of transformation from an industrial society to an information society we are standing at a threshold of a period of innovation in systems of societal technology based on the combination of computer and communications technology (Masuda 1980). The current innovation is not necessarily the productivity of material goods. Its substance is the invisible information and the core technology is the computer. Masuda describes three leading characteristics: 1. The complete objectifying of knowledge (from the written characters by the development of printing and mass distribution to the computer that amplifies man’s mental capacity). 2. The production of sophisticated cognitive information (information with projection of the future for problem solving and forecasting). 3. Information network (many systems are linked by complex network within the organization and to the external world). The unique character is the self-multiplying nature of information. It is not consumable however much is it used, both giver and receiver are able to access it, and the quality is raised by adding new information. The possibilities with the computer-communications technology can be to expand our problem solving capacity and quickly discover problems in rapidly changing circumstances.

The market for information and communication technology grew rapidly during early 1970s (Gann, 2000). The powerful impact on production and consumption is because it can facilitate automation of routine information processing and communication activities. It also provides new levels of transparency to activities that have previously been opaque. The systems can provide feedback and create new knowledge. Both new and old sectors have been affected, digital design and pre-production simulation tools have improved production costs and processes. The importance of location for the companies is replaced to bandwidth and the broadband data highways. This fundamental factor also changes the patterns of use and requires new types of buildings that challenge the design. Gann describes that the more demanding requirements from the users and the development of sophisticated structures towards a product complexity can be supported by the new digital tools. The variety of regulations and technical systems requires information, communication and control systems for their operations. These products and systems tend to exhibit non-linear properties through time and the effect can be that small changes in one part of the system can lead to larger changes in other parts. Modern buildings behave like dynamic systems that react on different circumstances and conditions. The use of interactive parts as facades, user information systems and smart structures requires a skilful integration of new technologies by the designers and engineers. Design embodies the knowledge to relate user requirements with technical possibilities. In collaboration with systems and component suppliers, more value is being added in design and engineering processes. In design positive support can be achieved in fitness for purpose, user-friendliness, efficiency in production and use of materials, safety environmental impact and durability. Design activities are poorly measured across the construction sector because there is a certain amount of tacit skills, and remain an intuitive and creative process.

In many industries the use of IT has lead to increased effectiveness and productivity but the construction industry has not achieved this in the same extent as others. Samuelsson (2003) describes
how the construction industry makes use of IT in comparison to other industries as well as to construction companies in Denmark and Finland. He states four reasons not to adapt to IT: economical, organisational, knowledge based and cultural reasons. There are only a few changes regarding processes and products when using IT and as a total there are only a few economical achievements or positive effects. Samuelsson describes differences in the content of information between the actors involved and the variety of processes that IT supports as reasons for the poor result. IT is today fully accepted as a tool to improve the work and the possibilities to collaborate with other actors involved in the building process and hopefully save some time. The obstacles when saving a lot of time can be vulnerability, information-overload and defective technology. Architects and different technical consultants have adapted the new technology very quickly probably because it supports the way of working with designs and models. The respondents in the survey by Samuelsson want a development of the digital arenas to be more useful and intelligent. Problems with communication and collaboration are mentioned but seem to be accepted. The actors involved describe the positive effect of using IT and digital arenas in the early phases of the process before entering the construction site. Sharing documents, only one original drawing and the active individual search for documents instead of delivering the drawings to the different actors are the best effect. The architects in the survey seem to miss the possibility to share ideas in meetings and the dialogue between the other actors in order to share information and experiences.

The user of computer software can allow the organic, fluid and creative structure in architecture and has altered the relation between the form of the building and the construction. Emmitt (2007) says that digital technologies have transformed the way in which we think of the buildings and helped to establish links between manufacturers and architects. Digital visualisation techniques allow all actors to see and experience space much more quickly and help to read drawings and to break down professional language. Teamwork between actors involved can be supported by web-based communication and increase coordination of skills and knowledge as well as facilitate communication. Good solutions include the client and all the key stakeholders in the design process by clearly communicate design ideas. Some designers can use digital visualisation but some designers still prefer the interaction between the pen and mind when sketching. Face- to face meetings are useful allows exchange of knowledge and different possibilities can be explored together in a discussion. If the participants with a dynamic interaction will succeed in realising the projects objectives effective communications are essential. “Communication difficulties are often caused by the inability of team members to meet and discuss their differences (Emmitt, 2007)”.

Visual design in the user interface is used to solve communication problems both functionally effective and aesthetically pleasing (Mullet and Sano, 1995). In communication-oriented design factors as statistical properties of communication channels, the structures of language systems, the psychological and social characteristics of message senders and receivers and the effectiveness of various coding techniques must be considered. In the fundamental field of semiotics the goal is to develop a message that can be accurately transmitted and correctly interpreted. After it has been understood by the recipient it must produce the desired behavioural outcome.

3. COMMUNICATION VS INFORMATION

Actors involved shares the responsibility to handle the large of amount of information in a building process. How people interact between each other and social skills, are basic factors for good communication. Organization, leadership and the amount of resources, like time and money, are important frames for the actors involved in a building process. Technology and digital arenas can support the process with the amount of information that can be stored. When it comes to
understanding the information, the possibility for individual interpretation seems to be more important, than the tools used in the process. The basic difference between handling information and communicating is the moment when you reassure the interpretation of the message. When using the digital arena there is a risk that you miss this fundamental part of the communication process.

Interpersonal communication is about communication between people where we use strategies when choosing our words in order to achieve some purpose (Dimbleby and Burton, 2007). The perception helps us notice the signs and make sense of them. If we do not listen it can be a barrier to communication as well as inaccurate assumptions, prejudices and other psychological filters. Social skills are important to make communication effective and satisfying. Key social skills are: to make sense of others’ feedback and to make appropriate responses. In a conversation paralanguage tells us how to interpret the meaning of words and the non-verbal signs. Some functions and characteristics are for example in what way and tone words are spoken, both body language and how you dress also affects our perception of others. All that we do and how we do it will be interpreted by others as meaningful actions. “One cannot not communicate” is an expression used by writers on communication.

The term “competence of communication” is described by Engquist (1999) as the ability that includes knowledge, experiences and creativity to establish a result together with other people in the dialogue. The term communication means “do collaboratively”, and when we communicate we have ensure ourselves that everything is understood by all individuals that are involved. He states that one-way communication should be mentioned as information and be used when you describe when a message is handed over from one person to another. A description is like map that shows something but have to be explained to be understood. Questions like Why? How? and What? have to be asked where attitudes and pre-knowledge either makes people verify and confirm or disconfirm the message. The dialogue is like a democratic exchange of thoughts but a discussion contains different opinions that have to be protected and hopefully make other people change the point of view. The competence of fully understand how another person thinks or feels is important when decoding a message and it is also a part of the sense making in the dialogue.

Even one-way information or monologues needs an audience. The monologue changes as the audience changes because human thinking and social functioning or interaction, are essential aspects of one another. Weick (1995) describes the substance of sensemaking: “Sense is generated by words that are combined into the sentences of conversation to convey something our ongoing experience. If people know what they think when they say what they say they see what they say, then words figure in every step. Words constrain the assaying that is produced, the categories imposed to see the saying, and the labels with which the conclusions of this process are retained”. The author also point out that a good story is necessary in sensemaking to make people see the message as reasonable and memorable with something that both captures feeling and thought. The effects of a good story can be to hold disparate elements together long enough to energize and guide action, plausibility enough to allow people to make retrospective sense of whatever happens, and engagingly enough that others will contribute their own inputs in the interest of sensemaking. The story telling in a complex process and organisation can help the actors to simplify the task because it can reduce elements of surprise and forecast emergencies. The key resource for sensemaking is the content and the meaning of the content embedded in cues frames and connections.

How members in a group perform and communicate can also be affected of the organization of the group. All forms of interaction in organizations are pervaded of power and influence affected by one’ level in the hierarchy. If there is a gap in the communication it can be related to ideological and gender patterns as well as use or misuse of power. The use of words and body language are fine details of performing power as well as specialist knowledge and creates a regime of control. “Ideologies and
dominant agendas create realities for others that may not be in their best interest (Fineman, Gabriel & Sims, 2010)."

4. THE COMMUNICATION GAP

There can be a gap in the communication due to how people interact and how they handle the tools used as support. In the report from Svensk Byggtjänst (2007) two common problems are presented due to the transferring of information and to the communication process. The first problem is that the actors involved do not receive the same information. The second problem is that consultants get inaccurate or insufficient information. Another problem that also connects to this issue is that all the conditions for the project are not substantiated which can lead to that the actors involved are not certain of what should be achieved. All these circumstances are linked to the early stages in the building process. Insufficient drawings and different information to the actors involved causes a lot of trouble at the building site as well and all the mistakes and failures raises the total costs. Example of comments regarding communication problems are: "You think that everybody understands, but they don’t. The consultants do not transfer all the information and they have too little contact with each other. Few meetings are held to coordinate the conditions for the project. You read the documents poorly."

Barriers to communication can be factors in the process that impede open communication between source and destination. Dimbleby and Burton (2007) explain that they can exist within individuals like psychological filters (attitudes, beliefs and values) and within the sign or message called semantic filters (words are only signs that must attached with meaning). If they exist within the context they are called mechanical filters (any breakdown of equipment). Barriers to communication can also be described as noise or filters. "It is useful to visualize how these three types of barriers or filters, affect the communication process. Mechanical barriers in particular exist in the context and in the coding process; semantic barriers in the formulation and interpretation of the message; and psychological barriers in people’s emotional processes”.

Which are the merits in electronic communication relative face-to-face communication? Fineman, Gabriel and Sims (2010) states that it has almost become a cliché to attribute all difficulties to communication. This discussion must be broadened and include factors like different media, different cultural contexts and organizational issues. Information technology can be used to improve the working process but it can also create risks and fail to fulfil its promises if it is used in a wrong way. In an era of great technological innovations there can be a danger of strong dependency of information technology says. They describes how the machines dominates our physical landscape how they control our daily routines and affect every moment of our lives. Wider social forces are also heading towards mechanization and routinization, machines they shape our physical, social and psychological world. People can feel meaninglessness, boredom and powerlessness if the machines dominate our working life. “The worker stuck in front of a terminal, sees the world shrink to a range of symbols on a screen and a sequence of voices at the end of a telephone line”. Important factors for creating a subjective meaning for the perception are; our needs, motivations and emotions. But the machine also creates new opportunities, maximize efficiency and rationalization, but it can also deskill and alienate man from intelligence and craft. The shortcoming of information technology can be documents lost in the system and the loss of the personal service to the customer, "if in doubt blame the machine". But people have different relations to computers, some are enthusiastic and some finds it threatening. The benefits are instantaneous, updated and multiple access of records, processing and communicating capacities and for planning, forecasting and organizing of production. Another
positive effect is flexibility and be able to work and be reached everywhere and shorter managerial hierarchies.

It is generally hard for people to make sense of what they are doing in front of terminals. The personal computer offers a restricted view of the world. Weick (1995) uses five deficiencies to explain this phenomenon: Action, the operator cannot see, hear or smell data from the outside world on a screen. Comparison, the operator cannot walk around and look at things from a different angel but have to rely on one contradicted data source. Affiliation, People can often work out what is going on by talking to other people, but working at screens discourages that. Deliberation, it is hard tell the important from the unimportant on a screen. Consolidation, material on a screen is imposing-looking information and does not look like work in progress and this makes it hard for people to go away and think about it.

Lack of a dialogue can also be an obstacle to the fact that with a good team work new insights and new knowledge can be achieved in a higher level than what each individual ever could. Senge (1998) also says that team-learning must have two parallel processes to communicate in a group, both dialogue and discussion. The dialogue is a free and exploring survey of complex issues where you listen to others and express your own point of view. In a discussion arguments and opinions will be delivered and will be defended. But it is a problem that these different processes are difficult to separate from each other. In team-learning the ability to manage the dynamic and energy in changing between dialogue and discussion is essential, in order to get a successful development. In a dialogue there is no winner, in a well performed dialogue everybody wins.

5. CASE STUDIES

The purchaser’s ambition and the attitude towards all actors involved can be of great importance for a good result in a building process. In a traditional building project, actors can be counterparts with different interests and roles, due to construction law. When working with a joint ambition, all the actors involved can use their energy to work with the issues that concerns a common goal, instead of “watching their back”. Using the dialogue in the early phases and listening to end-users and their requirements was common factors in two case studies made in Sweden a few years ago (Svetoft, 2008). Experiences from these two large scale projects in Östersund and Helsingborg shows that time and resources that are put into a project, in order to increase the communication between the actors involved, can be considered as well paid investments.

This way of working can lead to positive effects to the whole project organization and for the quality of the product: Using time to communicate the goals, listen to and understand the end-users requirements and then use them as a resource. When knowledge from different actors can be used and discussed, experiences from both end-user and craftsmen supports a process where problems are solved in the early phases of the building process. Essential information about the project can be shared and discussed in order to make sure that everybody understands the meaning of it. The discussions and conversations at the meetings with representatives from all actors involved can clarify questions and different perspectives are used to solve problems. Money can be saved due to less problems and obstacles in the process and at the building site. The efficient use of resources gave the product a better quality and was customized for the end-users requirements. Very little time were used to repair the negative effects of miscommunication that are the usual tradition. A digital arena was used as an information tool, but did not replace a dialogue, with conversations and discussions. In Östersund several full-scale models of rooms were used in order to invite all the end-users to an arena for a dialogue, concerning the design and details of the project. The positive bonus effect of this investment was that solutions concerning the craftsmen could be discussed and used as routines, in the
whole project. In the project in Helsingborg craftsmen at the building site could understand the link between their efforts and the effects for the future tenants. This was possible thanks to a person who reminded them of the end-users requirements throughout the process. On a question posed to the persons responsible for each project in these case studies: -“Was it worth to put in all this time and efforts to communicate in the early faces of the project?”, the answer was similar: -“It is only a matter of how and when the resources are used in a project”.

6. DISCUSSION

Digital visualisation is a very useful tool in the design process. The information technology gives all actors involved the possibility to share the same information and communicate with everyone in a web-based system. The architect can use the digital technology to visualize ideas and to communicate with other actors involved. When involving end-users into the design process, tools like 3D modelling can be of great use, especially when the receivers are people not used to interpret drawings. However there is a critical culture clash between the technical ways of dividing reality into little pieces, to store the information in a digital arena and the creative design process. The creative and intuitive dimension must be kept alive as well as the meeting between actors involved in the process. There is no contradiction for achieving the best result between the design processes and using tools to communicate and store all information. But, there can be a risk if we think that the management of information can replace the social and psychological process, when we interpret signs and messages from the screen. People must meet to tell stories, to discuss and to have conversations to really understand what is going on. To share the same ideas of what goals those are important in a project makes the process smoother and hopefully give a better quality in the product.

The building itself is communication to the surroundings; the architecture is a signal system and an expression used by the architect to tell the world something. When starting a building process the drawings, models and descriptions are the most important tools as well as the stories told by the actors involved. When there is a malfunction in this complex communication system problems will occur in the process as well as in the product. The interaction between man and machine is put in its most ultimate test when all the information needed is stored in the computer. The risk for incorrect interpretation is high if the actors involved rely too much on the technology. Combined with lack of time to reflect and analyse the flow of information during the process, can create gaps in the communication between the actors involved. The tools to store and communicate information of the project must be used in a considerate way - more like an adding to the important meetings between individuals and actors involved. A good team that can collaborate and communicate needs certain kind of skills, both individually and as a group. In a conversation it is of great importance to listen and to express opinions in a safe atmosphere where also experiences can be shared.

The total costs for mistakes due to the gap in communication could be used in a better way. The actors involved need to be supported to use their knowledge and their skills in a more efficient way. Making mistakes can be an important part of the development of individuals and organizations. But the problem if using them as a driving force in a large scale, like in the construction industry, are the negative effects for end-users, companies responsible for the product and for the society. Hopefully a future development of processes, organizational behaviour, industry culture and digital tools can support a more sustainable building process.
7. REFERENCES

Mullet, K. and D. Sano, *Designing Visual Interfaces*, Sun Microsystems, Mountain View, USA.
Abstract: Despite the historical, economical and socio-cultural disparities between the realities of different countries, it is also possible to see several similarities all over their design processes and practices. Building design is a unique process that has the same remarkable basic characteristics in any Western Nation, such as the need for design to be split up into stages, the multidisciplinary character of the design decisions despite the low collaboration level between design specialties and the inherent conflict between the viewpoint from market-based inception and further construction-driven requirements. These common points taken into consideration, each particular national context can lead to a singular environment in which the building design practices are embedded. Some of the most relevant context issues involve the construction regulatory and standardisation systems, availability of handbooks and guides, corporative patterns of professional activities, costs of manpower and education concerns. The aim of this paper is to present a contribution to the analysis of the building design process that emphasises the similarities and differences of the main practices actually conducted in Europe and Brazil. Research methods included a comprehensive literature review, records from case studies and interviews carried out by the authors. As a result, a set of influencing factors is presented in the final section of the text.

Key words: Architectural management, design process, Brazil, Europe

1. INTRODUCTION

The design process of building projects has deserved relevant research work, which generally has been done within the particular context of given countries. Additionally, several publications have dealt with the perspective of globalising design activities, highlighting the critical issues concerning a comparison of different realities.

Nevertheless, very few works focused on the understanding of a structural group of factors influencing the design process, and capable of explaining how to analyse and justify those different national practices in the building sector.

In this paper, due to their personal backgrounds, the authors make the choice for a comparison of the similarities and differences of the main design practices actually conducted in Europe and Brazil. The choice, even if it can be regarded somehow as a preference, can be of interest because of the emerging importance of the developing countries in the world economy and consequent opportunities for building projects, which are already in progress.

1.1 Research method, statements and definitions

The first author of this paper is responsible for a research group on Building Design Management since 1994. Currently, the research group involves 15 people, from undergraduate students to PhD candidates that are carrying out three major research projects.
In Brazil, several case studies and interviews carried out between 2004 and 2009, involving designers and design managers were facilitated by means of a research-action program involving design and consultancy firms.

In Europe, and most specifically in France and United Kingdom, the first author was involved as guest researcher in specific periods of time in the past years. His impressions issued from the intensive contact with design professionals and consultants were taken into consideration to write the present work.

In this paper, statements and definitions were assumed as a basis for the description and analysis as follows. Notwithstanding the multinational perspective of the analysis, those assumptions run the risk of being somehow specific, as they seem to be useful to a clear comprehension of the text. Thus, the considered main statements and definitions are presented below:

**Briefing** – process of identifying and analysing the needs, aims and constraints (the resources and the context) of the client and the relevant parties, and of formulating any resulting problems that the designer is required to solve (BSI, 1995).

**Client** – the individual or organisations commissioning the building project and directly employing the designers, the design managers and the contractors (Gray and Hughes, 2001).

**Designers** – architects, consultants and all the professionals or offices of any specialty that are involved in the design process of a building project.

**Design process** – a series of iterative events undertaken by the design team to identify the nature of the problem, develop appropriate solutions and transfer the solution from the collective mind of design team to those able to realise the design in a physical form (Emmitt, 2007).

**Design team** – the group of designers who will work together to provide the concept, scheme and detailed design information (adapted from Gray and Hughes, 2001).

**Design management** – a single function that starts with the understanding of design as a process, identifying the needs of at least the three main interested players (the client, the contractor and the user) and goes through models and tools to improve the design quality, thus having a comprehensive view of design with the aim of ensuring that appropriate design information is delivered within the project schedule to meet those needs.

**Design manager** – the individual or organisation responsible for performing design management in a given building project.

**Design for production** – expression used to designate the specialties of design that integrate the design phase to the construction works; design for production is used in the building construction with a twofold objective of improving buildability since the early stages of design but also to give a detailed view of the tasks to be completed by work contractors of the main parts of the building – formwork, masonry and facade coverings being the most common specialties (Aquino and Melhado, 2002).

**Standard agreements and contracts** – recommended conditions and terms for hiring or contracting design and consultancy services; general guidance on British typical contracts can be found in JCT (2009).

### 2. THE ROLE AND CONTRIBUTION OF DESIGN MANAGERS

Conventionally, the development of a building project is clearly divided into stages. In this divided and sequential process, the possibility for collaboration between the various participants is rarely ideal and often fragmented. Changes to the design could easily result in significant rework and errors due to the complexity of co-ordinating and checking multi-authored information (Fabricio and Melhado, 2009).
Certainly the source of many of these troubles is related to management, which can have two complementary approaches: (1) the client aims and practices that are mandatory to design activities; (2) and the internal processes carried on in design firms.

Winch (2011) analyses several case studies and concludes that organisationally, architectural practices stand at a three-way intersection between the creative industries, professional services, and the construction industry.

The construction industry is increasingly competitive and this is a strong source of pressure on the design process. Otter and Emmitt (2008) explain that “as a result of the multidisciplinary aspects of architectural design, the growing number of participants and increasing legislation and governmental rules, the task complexity of the individual team members is increasing”.

The general context would certainly lead to an increased search for design management knowledge and tools. But these needs are not really clearly perceived by every professional.

Rose (1987) establishes a clear understanding of their typical behaviour saying that “design professionals think of their work situations as unique” and, nevertheless, “design professionals are not unique in that they do have organisational systems”.

Emmitt (1999) noted that “management is often perceived by architects as time-consuming... something that detracts from creativity and hinders rather than helps”.

In their “unique world”, designers often behave as very reactive to management; to some extent, but not clearly, these professionals are questioning the real need of management, even though that need is perceived in their own daily practice. Another kind of typical designer behaviour can be illustrated by the “self learned” management, represented by the adoption of inefficient rules and very bureaucratic controls.

The trouble probably comes from the characteristic conflict between specialist and managerial activity; generally design professionals have had years of specialist education (in architecture or engineering) but only days of management training. As stated by Rees and Porter (2001) “the specialist culture that exists in so many organisations is perhaps the biggest single obstacle to effective management”.

From a somehow more positive view, Best (2006) affirms: the objective of design management is to familiarise managers with design and designers with management.

And if the design management may be influenced by the organization of the design team or the roles and responsibilities assigned to each designer, some of the difficulties faced by the design team are a result of deficiencies in the design management (Grilo, Melhado, Silva, Edwards and Hardcastle, 2007).

Clients are expected to choose either to have their own design managers or request that as a proved architects’ competence. Some of them will also assign part of that responsibility to contractors, when the latter have an engineering contract. Yet only few clients have the appropriate criteria to make the right choice in each case; most of them are thinking of having more control and others of risk transfer.

On the whole, design management is a field that naturally evolves from an experience-based activity to a more structured and systematic approach. Most design professionals will need complementary continuous education to improve their management skills, even if some of them still resist doing it. The main trend now is that undergraduates are revealing a growing interest in management and are fond of it, thus starting their careers more prepared; therefore, the scenario tends to change in a near future.

Concluding, design management has emerged as result of a real demand and intends to help either the general aims of the project or the internal processes of a designer. Design management comprises a series of tasks to be performed along the project stages, and design managers should (Melahdo, 2005):

- assist the client to establish the project objectives and parameters to be addressed in the design development;
• advise the client to constitute a design team and define the scope of each design and consultancy specialties to be considered at each design stage;
• analyse the needs of information flow and define deadlines for various designers along the design stages in accordance with the main project schedule;
• foster communication among design team-mates, coordinate the interfaces between designers and ensure compatibility between the specialties concerning these interfaces;
• perform or co-ordinate the design review to ensure the quality of the design solutions adopted and their compliance with project needs;
• validate or request validation by the client of the end results of each design stage;
• integrate the project with the following phases such as procurement, pre-construction and construction.

3. DIFFERENT COUNTRIES, DIFFERENT PRACTICES

3.1 Context in Brazil – São Paulo

As Brazil is a continental country and still underdeveloped in social and economic aspects, there is a very wide range of practices adopted in the construction sector. With regard to the Brazilian building construction, São Paulo is the most important site with about 5.7 million square meters of new buildings built annually (Grilo, Melhado, Silva, Edwards and Harcastle, 2007). Thus, due to the impossibility of having a single pattern of analysis, the authors took São Paulo as a reference to all the considerations made in this paper.

In São Paulo, since the 1990s, the entry of foreign organizations has exposed the technical and commercial weaknesses of local firms. In addition, the lack of mutual agreements to regulate the trade of building design services between countries has enhanced these limitations. Musa (1996) listed some relative weaknesses of local architectural offices as compared foreign firms, such as lack of responsiveness and flexibility, difficult relationships with technical designers and reduced involvement of clients in the decision-making process.

The construction industry experienced outstanding progress in the period between 2005 and 2008, and in spite of the slow-down effect from the recent global crisis, it is still growing and now attained the level of full employment. The fierce competition among construction companies in the Brazilian market due to the demand for housing and the opening of capital in the private sector provides an increase in the search for rationalized constructions methods.

The Brazilian construction sector has an insufficient background in terms of standards and recommended practices. The lack of reference for a technical scope of design services, as well as the lack of definition of the design contents delivered by the professionals, generates a distortion in hiring, stimulating competition by pricing without a clear relationship between the design price and its quality. This scenario leads to conflicts between design clients and designers during the process, in addition to allowing losses to the construction process and to the quality of the final product (Maneschi and Melhado, 2010).

Education and assessment of professional practices have some particularities in Brazil. As compared to the United Kingdom, for example, one of the most remarkable differences concerns the entry in the job market. Undergraduation, in Brazil, is the only real requirement to become a design professional, architect or engineer. Institutionally speaking, a National Council with local offices will be charged of surveying the practices. However, there is no systematic assessment for architects,
engineers and other construction professionals; thus, clients’ requirements for hiring and the strong market competition are the main barriers to the career.

In the field of building design, it is noticeable that designers’ attributions and obligations are very poorly developed in the documents of reference. Every person with a higher degree is considered equally a “chartered” architect or engineer, according to the certification issued by the school or university. In Brazil, no specific exams and no previous practice are requested to be a designer; moreover, continuous education is not an obligation and professionals can spend their entire career without any renewal of knowledge.

In the last years, a joint effort by unions and professional associations established a reference for the building design process through the publication of several best practices design handbooks, which are available on-line at http://www.manuaisdeescopo.com.br. Very innovative in their format and presentation, these handbooks cover almost all the design specialties, including design management, and they are all based on the same basis of statements and definitions. In those handbooks, the ideal of professional recommended practices has its rebirth. All the published issues have considered designers’ activities at the pre-construction and post-occupancy stages of the buildings. Those handbooks are intended to be an integral part of design agreements as a reference for client-designer relationship.

As recommended, but not obligatory practices, the design and design management practices described are distributed into the six design stages considered in the mentioned handbooks:
- Stage A: Product Conception
- Stage B: Product Definition
- Stage C: Identification and Solution of Design Interfaces
- Stage D: Design Detailing
- Stage E: Post Design
- Stage F: Post Occupancy

As the regulatory system has little control over professional exercise, designers’ Brazilian associations have an essential role in the best practices diffusion. Architects, landscape designers, structural engineers, systems designers and other specialised categories of professionals have their own associations. In the field of Design Management, an initiative by some professionals and academics created the “Brazilian Association of Design Managers and Co-ordinators” (AGESC) in 2006.

In recent years, Brazilian designers have revealed a growing interest in management, despite typically acting in small-sized and low-organised firms, which have few resources to apply in management systems. The governmental pressures of federal quality programs and some big clients’ requirements are forcing several design firms to seek management systems and methods. For this, in 2006, the University of São Paulo established a cooperation program with design firms to improve management through action-research methods (Souza, Oliveira and Melhado, 2007).

A relevant fact concerns the relationship between designers and the site construction. Maybe except for the structural engineer, almost all design specialties do not systematically visit the construction site but only under a very specific demand (e.g. design inconsistency that requires specification change).

For a large part of Brazilian architects, the commitment to visit worksites is not an obligation. Only aesthetical features really demand the architect’s involvement. In the public sector, due to legal restrictions concerning the involvement of designers with contractors, small and medium-sized projects can also be executed without the presence of the architect in the site.

Additionally, low manpower cost in Brazil still allows low-industrialised construction methods, thus leading to an intensive use of masonry and plastering that brings as a counterpart the need of extensive detailing in construction documents. This situation allowed the emergence of a new design
professional that is specialised in the so-called design for production. The most requested specialty of
design for production concerns the detailing of masonry walls for facade and partitions.

Therefore, amongst some private clients, as a response to the weaknesses of “traditional practices”,
there has been an increased demand for design for production, which is used as a tool for optimizing
and rationalizing construction, due to the inherent design interface between partition walls and
coverings, structure, services and all the other building systems (Maneschi and Melhado, 2010;
Oliveira, Melhado and Maizia, 2008).

As stated by Melhado (1994), "to achieve success in a building project, design cannot be restricted
to the geometric characterization in the role of the construction being built. The design must conceive,
in addition to the product, its production process; (...) must assume the fundamental task of adding
efficiency and quality to the product".

The design for production of facade and partition walls is not another detailed design. It is a
constructive design, which aims to integrate the information about construction methods as from
the building conception. Nowadays, in Brazil, due to its proximity to the construction experience and its
interfaces with several other systems, such as the structure, plumbing, water supply, waste and
electrical systems, finishing etc., design for production performs an important role in the current
design process.

However, the majority of the practices above described are connected to private construction.
Public building projects, e.g. housing construction, have not experimented significant evolution in
their processes for decades. Thus, the best practices concerning a building construction design remain
unclear for a considerable part of the professional community and often the performance of the overall
project management is somehow below the expectation.

In a brief approach, the most relevant of the structural weaknesses in the Brazilian building design
process in present practices are: insufficient and ambiguous briefing; lack of clear design agreements;
poor planning and scheduling of the design process; very superficial work in the early stages leading
to a huge effort in detailed design; lack of effective integration of design to construction; few site
meetings involving designers; reduced feedback from post-occupancy.

3.2 Context in Europe

3.2.1 United Kingdom

The Royal Institute of British Architects (RIBA) was founded in 1834 and was granted its royal
charter in 1837. No practitioner of architecture is obliged to join, although the substantial majority of
architects practising in the United Kingdom are members. The title “architect” is protected by law.
The Architects Act 1997 following earlier legislation dating back to the 1930s requires any person
who practices architecture in the UK using the title “architect” to be registered at the Architects
Registration Board (ARB).

Registered Architects have completed at least seven years of academic and practical training and
only practitioners who have prescribed qualifications and experience can be registered by the ARB.
While all architects in the UK must be registered at the ARB, not all of them are members of the
RIBA. A fully-qualified RIBA member is considered a “Chartered Architect” (RIBA, 2008). The
RIBA Code of Professional Conduct comprises three guiding principles relating to: integrity;
competence; and relationships.

The RIBA Plan of Work (RIBA, 2007) comprises five “super” stages and the traditional “A to L”
architect’s design services that are commented below:
Preparation

- A – Appraisal – identification of client’s needs and objectives, advice on feasibility, assessment of options and cost implications;
- B – Design Brief – prepared by or on behalf of the client, definition of procurement method, organisational structure and range of consultants and others to be engaged;

Design

- C – Concept – concept design including outline proposals for structural and building services systems and preliminary cost plan;
- D – Design Development – development of detailed design from approved concept, submit application for detailed planning permission;
- E – Technical Design – development of technical design(s) and specifications;

Pre-Construction

- F – Production Information – prepare information for tender purposes and further production information for construction purposes;
- G – Tender documentation – preparation of documentation in sufficient detail to enable a tender or tenders to be obtained;
- H – Tender Action – identification and evaluation of potential contractors;

Construction

- J – Mobilisation – issuing of information to the contractor;
- K – Construction to Practical Completion – provision to the contractor of further required information and review of information provided by contractors and specialists;

Use

- L – Post Practical Completion – final inspections, assisting user during initial occupation and review of project performance in use.

RIBA also published a series of handbooks such as the RIBA Architect’s Handbook of Practice Management (Cox and Hamilton, 1998), being very helpful to architects in the practice of management tasks, such as information management, quality management, staff motivation and training, risk management and other important issues.

The title “Chartered Engineer” is also protected by civil law in the United Kingdom. The Engineering Council is the UK regulatory body for the engineering profession.

Under the action of British institutions, codes of ethics and rules of professional conduct associated with recommended practices constitute a controlled environment that provides construction projects with a minimum frame of standardised procedures and contents. Thus, given this regulation scenario, a more predictable design process can be expected, which can facilitate the design management work.

Every design activity is affected by several standards, from those concerning construction itself to the specific standards related to each design specialty. British Standards Institution (BSI) is the world
first national standards body and provides complete guidance on a wide range of building and construction matters including materials, testing, health and safety and access. They are an essential reference for architects, developers, building owners, site managers, building contractors, structural engineers and quantity surveyors.

Yet control of costs deviation deserves a special consideration, since economic aspects are mandatory in all design decisions. In the United Kingdom, the quantity surveyors’ role is of paramount importance to ensure good quality decisions of design management all over the design stages. Quantity surveyors are able to help clients in cost planning, value management, feasibility studies, cost benefit analysis, amongst other consultant activities. By using a published standard method of measurement (SMM) as agreed to by the QS profession and representatives of the construction industry, these cost consulting professionals reduce the construction risk in such a competitive environment.

Although in other countries there are other professionals responsible for costs estimation and control, the institution of the QS profession is a typically British practice that deserves a special place in the construction scenario. While The Royal Institution of Chartered Surveyors (RICS) is related to the building sector, the Chartered Institution of Civil Engineering Surveyors (ICES) is the qualifying body in civil engineering; both institutions are concerned with the regulation, education and training of surveyors in the UK.

Another point concerns design to construction integration. While it is clear that the integration of design and construction is vital to project success, it is also a fundamental weakness in the British construction industry (Egan, 1998).

Construction documents present a relative low level of information, since conventionally work contractors and trade contractors are intended to play an essential role in detailing design.

Pre-contract meetings to ensure that the contractor and other members of the project team understand the requirements and check the information completeness of design details, as well as Site progress meetings, usually attended by the client’s representative, the architect, structural engineers and other consultants, project manager, contractors and the clerk of works, shall be scheduled to be weekly, bi-weekly or monthly in order to control progress and resolve any problems on site (Emmitt and Gorse, 2003).

Despite all those references to guide the professional activities, the building sector continues to evolve and change. Gray; Hughes (2001) recognized changes in architects and engineers roles in the United Kingdom, such as: emergence of new professions; redefinition in the traditional roles; loss of architect authority to project managers and specialized consultants; designers became generalists with less control over details; multiple control of the whole design and construction process; complex and restrictive fee agreements; and a wide variety of sophisticated procurement techniques to integrate design and construction.

The interviews carried out in England with professionals and researchers confirm some criticism about actual practices. As stated by of the interviewees “RIBA Plan of Work is not used that often, although the principles tend to be upheld most of the time. Again a personal view, but I would suggest that it should be updated to more properly reflect the latest procurement practices, with an ever-increasing proportion of contractor designed elements”.

According to Bibby (2003), “there is a need to educate an increasing number of people in design management techniques to equip them to manage today’s fast moving and demanding projects”. That author affirms that the improvement of design management in the UK building industry demands modification of current techniques to align them with the needs of the modern design manager.
3.2.2 France

In the French building sector, “maître d’ouvrage” and “maître d’œuvre” are traditional, strongly defined functions and have very important roles. There are several institutions in France that must be mentioned for their influence over this matter and among them the following: The “Ordre des Architectes”, the “Syndicat National des Architectes” and the “Union de Syndicats Français d’Architectes” (UNSFA).

A “maître d’œuvre” is defined as "a person or entity which the client (“maître d'ouvrage”) hires to coordinate the design team (“maîtrise d'œuvre”) and to take control of project development, as well as monitoring and control of execution until the delivery of the works” (Melhado and Souza, 2000).

The project phases considered in France are:
• “Etudes d’esquisse” (Concept design);
• “Etudes d’avant-projet sommaire” (Provisional scheme design);
• “Etudes d’avant-projet définitif ” (Scheme design);
• “Etudes de projet” (Detailed design);
• “Dossier de consultation des entreprises” (Tender documentation);
• “Etudes d’exécution” (Pre-construction design);
• “Direction de l’exécution des contrats de travaux” (Technical direction of works);
• “Assistance aux opérations de réception” (Assistance to delivery);
• “Dossier des ouvrages exécutés” (Report of practical completion).

In France, case studies performed between 2000 and 2007 involving design firms and projects in Paris revealed the force of traditions and the limits of their adoption in current practices, as well as the efforts to improve results by means of management techniques.

Normally attributed to an architect, the role of “maître d'œuvre” includes not only the relation with the client but also the co-ordination of the design team and the interaction with contractors trough the direction de travaux (works technical direction). The “maître d'œuvre” has an important leadership function in public projects.

Although the role of a “maître d'œuvre” is related to all the stages of a building project, the so called “mission complete” (complete assignment) is not always chosen by clients (maîtres d’ouvrage).

The 1984 law about public projects (called the “MOP” law) emphasises and consolidates the cultural and aesthetic character of architects’ role. This law established the modalities of professional assignments and responsibilities in public projects, then making hiring architects for “complete assignment” compulsory, i.e., from the stage of preliminary design to site works direction. As a result, architects became the privileged project co-ordinators of public project teams. On the other hand, however, for French architects committed to private projects, typical contracts have been shortened and they provide that architects are entitled to intervene only until scheme design and project approval in 32% of cases (Melhado and Henry, 2000).

In recent years, French architects have been losing their economic weight and the size of architectural offices has been dramatically reduced. The typical number of professionals being 1-2 persons in each office, design and managerial tasks must be executed by the same individual and processes tend to be very informal. An exception are the cases of few large French architectural offices that established a network of specialised collaborators, and also of a few medium-sized architectural offices, which are involved in all project phases, managing the technical, financial and production aspects of construction.
As one of the most remarkable points of French construction, knowledge and assessment methods for construction standardisation are assured by institutions such as the “Centre Scientifique et Technique du Bâtiment” (CSTB).

High manpower cost and a strong system of construction standardisation allows for less detailed design plans but requires on site management. Typical building procurement leads to a big number of specialised contractors besides the main contractor, thus generating a lot of interface problems. In this scenario the pre-construction period and the involvement of designers during the whole construction phase are of paramount importance.

The improvement of the pre-construction stage is assured by methods of site preparation, consisting of a plan that comprises organised site meetings and collective decisions about design detailing and adjustment, changes to construction documents, prototyping and on site testing of critical assemblies and products (Souza, Melhado, Henry and Sabbatini, 2003).

Finally, in France, it is verified that in such an intensive and extensive manner, public projects have much more sophisticated management practices than private ones. Comparing housing projects to private residential construction, for example, residential has simplified design practices and involves less management techniques.

4. **THE INFLUENCING FACTORS**

4.1 Discussion

According to Winch (2006), one of the required skills to the design activity is the ability to understand local regulations. The reasoning of Winch can be interpreted as an acknowledgement of the high degree of influence of building regulations over the design process.

Bibby, Austin and Bouchlaghem (2003) show the results of semi-structured interviews carried out within a UK construction company and conclude that the interviewees do not have a common perception of the activities undertaken during each project stage, thus stating that “if the activities that constitute design are not understood, it is not possible to manage design successfully”. This can lead to another important influencing factor i.e. the importance of a reference in terms of design process patterns to perform the management.

Behind the clear establishment of how a designer or a design manager should carry out their specialised work processes lies the system of protection for the professions involved.

In Europe, clearly the attributions and obligations of designers (and all protected professions) can serve as a reference of how they are intended to do their jobs. Even if some are probably more skilled and can take some profit from their networking to have better contracts, for all professionals in the building design field; the institutional guidance is somehow a warranty of a more predictable and reliable environment. That will also be considered an important factor for the aim of this paper.

The overall scenario is quite similar but can have some particularities in other European countries. Based on a survey among 110 Dutch architectural design firms, Klein and Volker (2010) state that, as compared to contractors, architectural design firms are relatively small (seven employees on average), generally have private clients and most of them seek for more control over construction processes and product quality. Several other papers stress the integration of design and construction as an important quality issue (Aquino and Melhado, 2002; Oliveira, Melhado and Maizia, 2008; Emmitt, 2007; Bibby, 2003) and that is surely another factor worth beinganalysed.

Along with it all, in these aforementioned developed countries, a remarkable characteristic concerns the manpower level of education, which is strongly associated to the cost of labour. The condition of better education for construction workers encourages dialogue among designers and workers, thereby
positively impacting the quality and the rationalization of the building processes. Training must be provided to construction workers by continuous education.

It is not only the manpower that needs this continuous education. For all professionals, and particularly for designers and design managers, if their institutions provide a specific education program to ensure good opportunities so that they can be recognised as more prepared professionals, this all contributes for better performance in the design process.

In the discussion of how to achieve the effective collaboration in construction projects Shelbourn, Bouchlaghem, Anumba and Carrillo (2007) say that “it is recognised that good collaboration does not result from information technology solutions alone” and address “people” and “processes” as important issues to plan and implement collaborative working. From the conclusions of those authors and taking into account the high level of IT solutions dissemination all around the world, the technological factor is not included among the influencing factors considered in this paper.

Another important comment is related to environmental requirements and certification. Nowadays, all of the influences on sustainability issues are globalised and European models have been applied to Brazilian building projects. Therefore, those concerns are similarly affecting the design process in all the countries analysed.

### 4.2 Outline of a proposal for comparing design practices

The choice of what should be considered in the analysis or not was arbitrary but it is still something intended to contribute to its main objective. It was based on the literature review, the advice of professionals interviewed and also on the experience of the authors hereof.

Case studies data and the impressions of interviewees were considered. Most design management professionals have some criticism against the traditional practices adopted in the building construction sector. Thus, their views of how limited the actual performance can be, have helped to establish a more realistic approach to the analysis.

In brief, the selected influencing factors can be listed as follows:

- Building regulations and standards;
- Design handbooks and guides as a reference for design management;
- Attributions and obligations of designers (and all protected professions);
- Integration of design and construction;
- Costs of labour and workers’ education;
- Continuous education and training for designers and managers.

Yet, even though there are noticeable differences between Brazil and Europe concerning building standards, Brazil has recently adopted a national performance standard. It is hence important to highlight the fact that the new Brazilian standard on Building Performance for Housing, NBR 15575 - Parts 1-6 (ABNT, 2008), establishes the minimum performance required for the most relevant building elements throughout their life cycle and this standard is expected to change the design and construction of buildings in Brazil. Applicable since May 2010, this standard has potential to increase the responsibilities but also the importance of designers.

Concerning continuous education and training for designers and managers, a separate general comment takes place here. All over the studied countries, the concept of continuous education and training for building professionals as a whole is becoming a key factor to the career. Nevertheless, as education is a consequence of several factors and among them the other five factors aforementioned, each national context reflects the particular context of its regulatory system and the actual relevance of
professional bodies. Thus, it is quite reasonable to justify that more developed countries that have also a long history of their building regulations and standards are the countries where professionals clearly recognize the value of technical knowledge, which must be continuously updated. Moreover, one remarkable effect of strong professional bodies is also the increase in value of skills improvement.

See Table 1 for a more comprehensive view of comments.
Table 1 – Analysis of factors influencing design process and its management: Brazil vs. Europe

<table>
<thead>
<tr>
<th>Influencing factors</th>
<th>Phase: Briefing</th>
<th>Phase: Concept / Scheme design</th>
<th>Phase: Detailed design</th>
<th>Phase: Pre-construction design</th>
<th>Phase: Construction until completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building regulations and standards</td>
<td>Brazil – recent performance standards would revalue technical briefing</td>
<td>Brazil – building regulation submission and approval at the end of this stage</td>
<td>Brazil – there is no approval at this stage</td>
<td>n.a.</td>
<td>Brazil – mostly fire safety inspection for completion</td>
</tr>
<tr>
<td></td>
<td>EU – such as BS 7832:1995 (ISO 9699:1994) are very helpful</td>
<td>EU – Application for detailed planning permission in UK</td>
<td>EU – design detailing must have submission and approval in the UK</td>
<td></td>
<td>EU – practical completion involve the inspection of the architect according to JCT contracts</td>
</tr>
<tr>
<td>Design handbooks and guides as a reference for design management</td>
<td>Brazil – poorly developed; quite new design and management handbooks as a reference</td>
<td>Brazil – influenced by clients’ aims, practice does not meet recommended activities</td>
<td>Brazil – insufficient background; lack of standard solutions; handbooks of <strong>design for production</strong></td>
<td>Brazil – few used but seeming to become a trend</td>
<td>Brazil – recommendation of designers involvement but still out of practice</td>
</tr>
<tr>
<td></td>
<td>EU – comprehensive and in-depth literature from professional bodies</td>
<td>EU – good guidance for professionals and clearly stated practices</td>
<td>EU – standard solutions; simplified drawings</td>
<td>EU – traditional in certain types of contracts and increasing interest of architects</td>
<td>EU – well defined role and responsibilities of designers</td>
</tr>
<tr>
<td>Attributions and obligations for designers and other professionals</td>
<td>Brazil – mostly informal and performed without a common fee reference</td>
<td>Brazil – product driven outputs and low committed to cost estimate</td>
<td>Brazil – mostly, design management starts here and does not advise on procurement</td>
<td>Brazil – weak but recommended and leading practices would change it</td>
<td>Brazil – no contractual obligation of designers regarding completion</td>
</tr>
<tr>
<td></td>
<td>EU – developed and formal; recognised as a specialised service; cost consultancy</td>
<td>EU – clear commitment to cost is an obligation</td>
<td>EU – involvement of architects and DM in the construction procurement</td>
<td>EU – important role of trade contractors; shop drawings</td>
<td>EU – designers’ involvement with construction completion</td>
</tr>
<tr>
<td>Integration of design and construction</td>
<td>i.a.</td>
<td>Brazil – adoption of the cheapest system capable of assuring construction delays</td>
<td>Brazil – in private projects, the anticipated integration adds value; the contrary in public projects</td>
<td>Brazil – in the private sector, increasing role of contractors in design decisions</td>
<td>Brazil – frequent design changes; most of designers do not visit sites</td>
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<tr>
<td>Costs of labour and workers’ education</td>
<td>i.a.</td>
<td>Brazil – prevalence of traditional construction systems and non-industrialised methods</td>
<td>Brazil – in a large number of different solutions and mostly craft-made techniques</td>
<td>Brazil – involvement since procurement to design improvement</td>
<td>EU – more cooperative work and clearer responsibility of designers</td>
</tr>
<tr>
<td></td>
<td>Brazil – technical choices based on productivity</td>
<td>EU – an sufficient number of standardised solutions</td>
<td>EU – public projects have leading practices</td>
<td>Brazil – education level of workers limits interaction on site</td>
<td>Brazil – cheaper human work, less equipment; exception to some fast-track and prefabricated construction</td>
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Challenges for Implementation of a New Model of Collaborative Design Management: Analyzing the Impact of Human Factor

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¹University of São Paulo
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Abstract: The ineffectiveness of current design processes has been well studied and has resulted in widespread calls for the evolution and development of new management processes. Even following the advent of BIM, we continue to move from one stage to another without necessarily having resolved all the issues. CAD design technology, if well handled, could have significantly raised the level of quality and efficiency of current processes, but in practice this was not fully realized. Therefore, technology alone can’t solve all the problems and the advent of BIM could result in a similar bottleneck. For a precise definition of the problem to be solved we should start by understanding what are the main current bottlenecks that have yet to be overcome by either new technologies or management processes, and the impact of human behaviour-related issues which impact the adoption and utilization of new technologies. The fragmented and dispersed nature of the AEC sector, and the huge number of small organizations that comprise it, are a major limiting factor. Several authors have addressed this issue and more recently IDDS has been defined as the highest level of achievement. However, what is written on IDDS shows an extremely ideal situation on a state to be achieved; it shows a holistic utopian proposition with the intent to create the research agenda to move towards that state. Key to IDDS is the framing of a new management model which should address the problems associated with key aspects: technology, processes, policies and people. One of the primary areas to be further studied is the process of collaborative work and understanding, together with the development of proposals to overcome the many cultural barriers that currently exist and impede the advance of new management methods. The purpose of this paper is to define and delimit problems to be solved so that it is possible to implement a new management model for a collaborative design process.

Key words: BIM, Collaborative Design, IDDS, Design Management.

1. INTRODUCTION

Collaborative work would lead to better results for professionals and design companies, whether that collaboration is internal or external (Akintoye, McIntosh et al. 2000; Bresnen and Marshall 2000). However, it is still a big challenge for everyone to achieve effective collaboration.

Companies are often investing resources in the implementation of new technologies without necessarily understanding the changes which it can enable or which it may even create through the act of adoption. As argued in Owen, Palmer et al (2009), the technologies are there to support processes; the processes are there to support the creation and maintenance of coherent and relevant information; and that is there to support the collaboration of people in a shared endeavour.

Collaboration is one of the central issues in studies for improving the design process, but it’s important that we look at this concept more accurately.

(Kvan 2000),(Gert-Jan de Vreede 2005), compare the concepts of cooperation, from the Latin cooperare (work with others) and collaboration, from the Latin colaborare (work in agreement with others) and define the main distinction between these two words is that in collaboration the holistic


and creative work aspects are hard to achieve and maintain, while working cooperatively like bees and ants is easier. The word cooperation was initially used by economists during the first half of the XIX century, and its concept was formally defined by (Marx 1890) as: “[...] multiple individuals working together in a planned way in the same production process or in different but connected production process”.

Collaboration requires bigger commitment than cooperation for achieving a common goal, and therefore risks are increased, implying on a deeper level of trust between the actors of involved groups. (Kalay 1998), defines collaboration as an agreement between the actors on sharing their abilities in a particular enterprise to achieve the goals of this enterprise. According to (Leicht 2009), three elements define collaboration:

- **Collaboration** is a process;
- **Collaboration** requires interaction between two or more people;
- People need to be working together towards a common goal.

## 2. STUDIES ON DESIGN COLLABORATION IN BRAZILIAN PROJECTS

Several Brazilian and foreign researchers have developed studies on the design process: (Melhado 2004), (Manzione 2006), (Kalay 1998), (Austin 1999), (Kvan 2000), (Hammond, Choo et al. 2000), (Carlos Formoso 1998), (Reinerstsen 1997), (K.T. Ulrich 1999).

As in other countries, the need of severe reformulation in the traditional design process is identified in Brazil; BIM technology and collaborative work have been considered the next stage to be reached in this evolution line. However, we must study collaborative work in the light of four key-resources in order to understand it: people, processes, technology and information.

To achieve a precise definition of the problems to be solved, we should start by studying the usual design bottlenecks that will have to be overcome by new technology and management processes, and evaluate the impact related to the human factor, constantly present in the process.

Based on professional experiences as a Design Coordinator, between the years of 2008 and 2011, the first author studied factors related to people and processes that were considered obstacles for the implementation of collaborative design process. Eleven designs were evaluated, with diversified scopes(residential, hospital and office buildings), most of them in the city of Sao Paulo – Brazil, and all involving the participation of several designers of different specialisations.

Based on these case studies, the main obstacles to collaboration between design management and the design team are listed below:

<table>
<thead>
<tr>
<th>Table 1. Main barriers to Design Collaboration in Brazilian Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Obstacles referring to Project management:</strong></td>
</tr>
<tr>
<td>Fragmented and Sequential Process</td>
</tr>
<tr>
<td>Planning with inadequate method: control of deliveries and not the process</td>
</tr>
<tr>
<td><strong>Obstacles related to people (design team):</strong></td>
</tr>
<tr>
<td>Resistance to collaborative work</td>
</tr>
<tr>
<td>Heterogeneity of conflicts involving the design team</td>
</tr>
<tr>
<td>Little relevance given to building performance</td>
</tr>
</tbody>
</table>
The related problems occur frequently in the traditional design system, and they configure obstacles to collaborative work in an environment where BIM doesn’t exist, demonstrating the inefficiency of the design management process and pointing to the need for evolution in design management.

In that context, BIM can be considered a collaborative work revolution, for it will change how actors collaborate, when they collaborate and the contractual base in which they work (Brandon and Kocaturk 2008). But we have to analyse whether we are not moving to a new stage without dealing with the current issues in design management.

3. **ASPECTS OF COMPUTER SUPPORTED COOPERATIVE WORK**

*Computer Supported Cooperative Work (C.S.C.W.)* is a concept created by Greif (1988) as an abbreviation for referring to a research line that studied how to support multiple actors working together in computer platforms.

Researches on this subject develop from two viewpoints: the first, focusing on technology, try to develop technologies to support the collaborative work, while the second focus on the production, emphasizing the understanding of work processes and systems (Mills 2003).

We can find references for production/work focused study lines in (Anumba, Ugwu et al. 2002), (Mohsen Attaran 2002), (O.O. Ugwu 2001), who describe collaboration processes based on classifications of space and time:

<table>
<thead>
<tr>
<th>Table 2. Patterns of Collaboration (Anumba, Ugwu et al., 2002)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>At the same place</strong></td>
</tr>
<tr>
<td>Face to face collaboration</td>
</tr>
<tr>
<td>Distributed collaboration</td>
</tr>
</tbody>
</table>

(Winograd 1986) raises questions related to people behaviour in their work according to different perspectives. According to him, while working people perform the following acts and these affect design:

- Process information and make decisions;
- Fulfil their functional roles according to stable rules;
- Create and maintain authority structures;
- Negotiate and promote interests competition;
- Establish personal relationships that are expressed through their activities;
- Act through languages.

Winograd (q.v.) also defines several questions concerning collaborative systems development, considering that when designing them for usual situations we have to concentrate efforts on issues related to its context and application more than internal structure and operation of the computer system.

On the other hand, the design of collaborative systems is ontological, meaning that when a computer-based management system is introduced, we’re not only designing its structure and function, but participating in a broad organizational design: designing a work system and not only a tool.

Therefore, when describing and building a system, we are being guided by a perspective that determines the type of questions that will be raised and the type of solution needed.
**Groupware** is the name given to several user-collaboration software products, and it is often confused with collaboration itself.

Authors such as Baldwin, Sehn et al.(2009) ponder the word collaboration refers to a broad meaning of established working social relationships, while *groupware* has a more purely technological focus, and therefore shouldn’t be used as synonyms.

Bannon and Schmidt (1989) consider the groupware concept to be restricted to a technical problems approach and human-computer interface, while the central issues in Computer-Supported Cooperative Work (CSCW) are to achieve the following aspects in collaborative work:

- Articulating collaborative work;
- Sharing an information space;
- Adapting technology to organization and vice versa.

Collaborative work articulation, the first main theme in CSCW, assumes a big effort in activities, schedules and resources coordination, besides implicating a large number of intermediate tasks, mediation and control of individuals, definition of quality and time criteria, and precise description of what needs to be done.

In semi-structured production of design tasks also consider uncertainty and interactivity, making them harder to plan (Manzione 2006), and turning the coordination process into a continuous negotiation and renegotiation effort between the actors (Melhado 2004).

A complex and creative process is involved in the elaboration of a design to meet the common vision accepted in the many typical bureaucratic organizations, where people develop their activities according to a group of ‘procedures’, which are well specified and developed by the central administration as effective and efficient ways to achieve certain goals.

In this traditional model, deeply entrenched in the AEC sector, many assumptions are made on a rational basis, meaning to achieve common goals between the employees and the organization. According to this vision, the traditional chart indicates the real authority lines and specifies the ‘correct’ pattern for information and communication flow (Bannon and Schmidt 1989). However, such an approach is typically discreet and fails to appropriately incorporate the dynamic requirements of a complex system.

Computer systems that try to rigidly answer these patterns tend to fail for not taking into account the informal social relationships that exist in companies and that are not represented in the formal company chart.

The informal interactions that occur in workplace environments have an essential role in conducting routine work and processes, and its importance should be considered in the study of improving collaborative processes.

An evidence of that is that when people work “by the book”, which is commonly called in Brasil “standard operations”, the results are mediocre and inefficient.

But what does this imply in system development?

Systems whose goal is just the workflow organization neglect the necessary coordination for making this workflow possible, and may fail (Bannon and Schmidt 1989), (Mills 2003).

The development of a shared information space, the second theme in CSCW, is strongly influenced by the intensity of collaborative work relations, for it requires interaction between people and the conceptual structures of a diversity of decisions, originating concurrent situations and control problems in applications for multiple users.

For this reason a shared information and decision space needs to be transparent and clear, implying the need for deeper research in issues such as authorship, propriety, origin identification and adopted strategies for the production of the information contained in the shared space, such as the responsibility involved in its propagation.
The notion that organizations are monolithic entities that can be unified through a database model is quite naïve; the idea of a transparent accessible database seems to be unrealistic when we consider human nature factors (Ciborra 1985).

Instead of that, and on the contrary to a traditional Cartesian view, it seems more realistic to believe that an organization is a continuous and dynamic mixture of collaboration and conflicts, of transparency and hiding.

Much of the information created and processed in companies can be considered inappropriate, as it may have been generated and communicated in a context of goal incongruence or motive and interests disagreement. Still, the need for transparency is amplified by this contradiction and the transparency must be more delimited. An employee engaged in a cooperative decision process needs to have the skills to control the propagation of the information relevant in his work: What should be revealed, when should it be revealed, for whom and how? These realities in organizational life need to be investigated, and ignoring the differentiation between strategies and incongruences of conceptual structures reduces the problem to the technical nature of multiuser systems, being only a technology oriented approach, with all its approximations and limitations (Bannon and Schmidt 1989).

The third CSCW theme is the reciprocal adaptation between technology and the organization. Understanding the complex interactions between technical subsystems and work organization requires a social-technical approach as part of the approach for overcoming obstacles in the implementation and improvement of collaborative work systems.

(Bannon and Schmidt 1989) raise some reference issues to be considered in this analysis:

- The privilege and losses in task distribution;
- Institutional ways of expressing and regulating conflicts of interests;
- Social control in work environment;
- The impact of the company role in the social economic system;

We also consider as a necessary reference the study of process(es) impact and their relationship(s) with other processes linked with actors of the company supply chain.

4. THE COMPLEXITY OF BIM IMPLEMENTATION IN A COLLABORATIVE CONTEXT

Amor and Owen (2011) observe the tendency to utilize BIM more as a technology, which he defines as simple BIM (sBIM), and less as an integrated intelligent process, defined as iBIM, although in this second form there are many more financial advantages, especially if connected to lean construction processes and new forms of collaboration processes, such as the IPD (Integrated Project Delivery). Several points of view have shown the need of deeper researches on the improvement or management methods. They also recognize that a new tendency between advanced users and industry leaders to look for a new concept already exists, on account of the observed tendency of users of using BIM only as a design technology.

(Rekola, Kojima et al. 2010) and (Moum, Koch et al. 2009), identify that developing improvements for the interorganizational and efficient use of BIM requires changes in fields other than technology, and for realizing the benefits of the BIM technology, companies need to coordinate and develop interoperability in their business processes.

The AIA (American Institute of Architects), according to Fallon (2006), identified the lack of understanding of industry members on how to obtain the integration of workflows through an integrated technology as the number one obstacle for using interoperability.
(Rekola, Kojima et al. 2010) mention that there is still little understanding of how workflows and business practices can be aggregated for IT-supported interoperability for obtaining the benefits of BIM in the AEC processes. They also select as a problem in their research the understanding of BIM slow development rhythm, and how to help the industry to solve problems that prevent the transformation of their processes towards adopting the IDDS philosophy. This research concludes that the lack of new Design Process Management knowledge is one of the greatest barriers to achieving integrated projects using BIM, and that its slowness is caused by the bottlenecks in the combination of technology, processes and people. He comments that there are a lot of factors involved and that some mechanisms are still missing; tools and rules to select what and when to optimize the cost-benefit relation in a project using BIM, changing its optimization into a hard task. In addition, BIM imposes many challenges for activities planning, meaning that the planning of the BIM design process is hard to be elaborated, on account of the complexity of information exchange and involved processes.

In practice, the design process management needs more information to be collected from new researches, aiming for the construction of a stable basis for design process planning decisions and the development of new human competences for managing BIM designs.

5. **THE IMPLEMENTATION OF BIM IN THE IDDS PERSPECTIVE**

CIB (International Council for Research and Innovation in Building and Construction) defines IDDS (Integrated Design and Delivery Solutions), as:

“[...] Integrated Design and Delivery Solutions use collaborative work processes and enhanced skills, with integrated data, information, and knowledge management to minimize structural and process inefficiencies and to enhance the value delivered during design, build, and operation, and across projects(Owen, Palmer et al. 2009)”.

IDDS is intended to integrate the CIB’s other priority research themes and to help provide a unifying focus to the majority of their Working Commissions and Task Groups through development of research trajectories, thus helping to steer the four to five thousand active CIB researchers through an interactive process.

Owen, Amor et al(2010) comment that innovations such as BIM and the IPD have been developed in an isolated way and without righteous consideration of the global relations between people, processes and technology.

The authors identify the four biggest issues to be solved:

- Collaborative processes across all project phases;
- Enhanced skills;
- Integrated information and automation systems; and
- Knowledge management.

As examples of the changes to be made, the authors comment that whilst the diffusion of BIM technology is increasing, in many cases its implementation happens analogously to what happened in CAD technology implementation, as it reproduces a current process practically unchanged.

To maximize BIM technology potential, an analysis and reengineering of the affected processes are required, as is the re-evaluation of the role of professionals in all of these processes. The same conclusion is shared by Taylor (2009) and Kiviniemi (2008).

These researchers understand that the cultural aspects to be modified are challenging, especially when it comes to developing trust inside a suspicious and risk shedding environment such as the AEC sector.
In AEC, culture and mentality remain isolated, and exchanges occur only based on a direct link between professionals, and also within the supply chain, where information exchange is disordered and based on low intelligence processes.

Decisions are frequently made autonomously and without multidisciplinary participation between the actors, and lack a holistic and precise comprehension of the whole team.

The use of an interactive design process developed from the client’s needs is virtually impossible to achieve in the current structures (Owen, Amor et al. 2010).

Taking human factor into consideration, Prins and Owen (2010) comment that interoperability between platforms and team partners is frequently remembered for the effective use of BIM technology.

However, to achieve the new technologies’ whole potential, team members should be capable of using technology to adapt to new forms of collaboration and integrated practices, and it will only be effective when this ability is incorporated in organizations in an institutional context for every actor, it also being absolutely necessary that all members have approximately the same maturity level.

Prins and Owen (2010) conclude by certifying that the present research focus is on construction IT, and not into new ways of producing, collaborating and sharing knowledge, and that besides that, IT tools will have to provide more knowledge sharing capability, instead of just allowing the exchange of information, aggregation and storage.

6. SURVEY: FACTORS THAT IMPACT AEC PROFESSIONALS

With the goal of evaluating the factors that impact AEC professionals, a survey was elaborated in order to study collaboration-related issues. The survey received responses from thirty-five professionals in the Brazilian AEC sector.

The results and the detailed questions are available for consultation at the link: https://files.me.com/lmanzione/94h3ei

This survey is a part of the PhD thesis of the first author, whose primary goal is to propose a new management model for the collaborative design process using BIM.

- From the researched sample, 72.1% are architects, 18.6% are engineers and 9.3% are professionals of other specialities.
- The whole research group, 100%, is either using or understanding BIM as a design tool, which was observed even among professionals that didn’t work directly with design (48.8%). Most part of the group (51.2%) still isn’t working with BIM, while (48.8%) are already implementing it.
- From the BIM users, approximately 50% intend to expand their services by adopting BIM to management related services, building performance analysis or construction management.
- Half of the BIM users are already using BIM in all of their designs, whilst another 25% are using it in try-out designs.

Three levels of maturity of BIM implementation were defined from Succar’s (2009) model, given the reduction and simplifying needed for use in this survey. It is of our understanding that the use of the whole of Succar’s model can only be appropriate to a study of the whole AEC sector, and with a wider breadth of interviewed participants. According to the Brazilian reality, the use of this model would need refining and the introduction of other sublevels of granularity before stage 1 is achieved, as it is defined by this researcher.

The following stages were defined from the simplified model and submitted in the survey:
Stage 1: Basic modelling knowledge, BIM designs only in your design expertise, file exchange through email or collaborative extranets, BIM design process still unstructured, BIM used as a 3D and clash detection tool, low level of design details, design contracts haven’t been reformulated for BIM, BIM used only as a design tool, not enough hardware with the minimum configuration for supporting BIM software, few software licences, lack of performance indicators to measure quality or productivity improvement.

Stage 2: Model development supports 2D and 3D Exchange, IFC format and other file format exchange between different design disciplines is supported, there’s already a model breakdown structure allowing the whole team to work simultaneously, the information Exchange is based in a model Server in a local net, equipment and licenses fully answer the demand, the design company has the BIM design process structured internally, BIM is already understood as a methodology that changes processes, design quality and productivity indicators have begun to be defined.

Stage 3: The exchange between different design disciplines is usual and with only little interoperability problems, information exchange is processed through a model Server in a WAN, interorganizational work processes are defined including client participation, BIM is understood as a process changing methodology by the whole design team, work procedures are already structured and detailed in operational level and design performance indicators are already defined.

The results shown that more than 75% of the researched group is still at Stage 0 (48%) or 1 (55%), demonstrating that BIM is still in its very early stage understanding or of adoption by the interviewed professionals.

- About the understanding of collaboration, 63,6% were found to understand this concept only as “respecting design deadlines and scope”, demonstrating lack of comprehension of the concept, which can lead to failure in their relationship with the other process actors, as shown in the first author case studies referred in this paper’s second topic. The same percentage of professionals interviewed consider as collaborative the alerting of the client when problems are found in other design disciplines’ production, when only 54,5% worried about warning the design authors.
- About the perception of design management process, most of the researched group (63,2%) sees it as only keeping up to the assigned dates, which reinforces previous studies that define the most used design process as delivery based (Manzione 2006), (Austin 1999).
- Only 15,8% shared schedules with other design partners, indicating low collaboration from inside the company level.
- Productivity and quality increases are the most perceived benefits from using BIM (73,7% and 68,4% respectively)
- Even though 60% realize BIM will allow work through a shared working model, 30% see the new process as a repetition of the 2D model, where work production will remain isolated and the disciplines will only exchange their designs for clash detection specific purposes.
- From the professionals that still don’t use BIM, 60,0% blame this decision on the fact that their design partners from other disciplines also don’t use it, showing low initiative, risk aversion or lack of competitive incentives. 48,6% understand that software investment is too high and 34,8% think the biggest restriction is the low number of component families designed for Brazilian parameters, which leads us to believe that they understand that BIM is only a change of software and design tools and will try to maintain the same work methods adopted in the 2D system. Only 22,9% answered that they don’t use BIM because their clients don’t see any benefits or won’t pay them accordingly.
• Among those who have adopted BIM technology, the biggest identified difficulties were: 78.9% difficult collaboration between partners, 36.8% low number of component families designed for Brazilian parameters, and 26.3% see trouble related to the necessary changes that will occur in their work processes, which could be interpreted as high resistance to adoption, but we find this result is associated to the lack of understanding that these process changes will happen.
• 71.4% of the interviewed that still don’t use BIM would feel motivated to implement it as a clash detection and 3D visualization tool, while 20.0% would use it if it were a requirement from a client (showing design contractors still don’t see BIM as a priority. As this survey isn’t directed to design contractors, this conclusion is a speculation).
• A total of 26% of BIM non-users have scheduled its implementation from 1 to 5 years from now. Another 21% still don’t intend to adopt it.

7. RESULTS DISCUSSION

The survey showed preliminary results that confirm this paper’s hypothesis and point to the need for deeper research and the development of specific collaborative design process methodologies.

The lack of specific and standard methodology for BIM adoption remains without a clear solution, although we recognise that such adoption should consider the specific business practices of the adopting organisation, even though these practices will inevitably change during or soon after that adoption.

It also shows that people and process-related obstacles defined in the literature and the case studies are likely to be reproduced in BIM environment.

With the management methodologies yet to be defined, design indicators will be necessary to evaluate the stage of the companies and the level of BIM process implementation they have reached. We will call them Key Performance Indicators (KPIs)

These KPIs should be divided in two branches:

a) Objective KPIs that will measure information flow and lean design aspects, as shown by Sacks (Sacks, 2010), relating to conventional design environments but that could be transposed to BIM;

b) KPIs related to social and technical aspects, where the measurement will happen through case studies, as shown by (P. Coates, et al. 2010).

We have developed provisional social and technical KPIs, based on the main impact factors developed from the survey results:

• **Commitment Level**: Foreknowledge of the commitment level of the design team by defining selection criteria to be achieved prior to contract definitions and hiring of the design team.

• **Collaboration Level**: Should evaluate the intensity and quality of collaboration during the process, e.g.: control of the amount of contribution by each actor in developing the model, as in how much information is associated to them as author of the model, and if there were any commentaries or suggestions given to partners during the process.

• **Solution Integration Level**: Should measure the extent that the BIM process is being developed in an integrated way, e.g.: evaluate the main decisions and model systems and verify if they were accessed and/or created by more than one actor; measure the number of updates made in the central model from the several designers.
• **Level of BIM utilization**: Should measure how broadly and how deeply each BIM analysis and output is being adopted. E.g.: measure the level of detailing, interoperability achieved, integration with 4D and 5D applications.

• **Productivity**: Should measure productivity improvement that could be associated with the integration and reach of the process. E.g.: measure how long it would take to complete a design phase or determine definitions between several disciplines, that in opposition to the traditional process, can update the basis of their design with the information their partners are developing simultaneously in one single command.

• **Client satisfaction and retention** (P. Coates, et al. 2010)

• **Employee skills and knowledge development** (P. Coates, et al. 2010)

8. **CONCLUSIONS**

   This study explored the human aspects within the design collaboration problem. According to the literature and case studies, the design management issues were related to poor collaboration among involved actors.

   The main conclusions of this paper related to collaboration problems are the following:

   a) BIM is still primarily understood only as a design development tool.

   b) In its present state of development, BIM can be read as a construction information technology with no defined design management methodology.

   c) The development of new management methodologies should include key performance indicators in their proposition that will allow their performance evaluation.

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The as built monitoring plan, a supporting tool for building management.

Dwellings in Cava dei Tirreni (SA, Italy)

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Abstract: The paper introduces the first results of a research in progress at the Dipartimento di Configurazione e Attuazione dell’Architettura, dealing with procedures and tools for managing buildings’ life cycle, fulfilling the contemporary challenges posed by the processes of degradation in the environment. The proposal is aimed at new buildings, providing a management response to issues of degradation, focusing on anticipating failures, organizing works. The emergences posed by climate changes and the new awareness of energy efficiency, are the scientific starting point of an investigation on procedures and supporting tools to prevent and control the occurrence of unknown dynamics of aging, degradation, failure. The research introduces the as built monitoring plan, a multi-scalar control register for new buildings, structured on the basis of a critical de-composition of the building system in environmental units and constructive analysis of the technical elements. The plan reports the as built information, systematizes knowledge in a relational grid, links performances data to spaces. The research is scientifically founded on a vision of building as a yard, a set of interconnected nodes of monitoring - located inside and outside -, dedicated to the systematic detection of changes in status indicators on the basis of an experimental integration among different procedures. The principles underlying the drafting of the plan are: integrity of the object observed, fast relief, ability to provide quantitative and qualitative data, ease of return. The plan realized for new dwellings realized in Cava dei Tirreni (Sa) provides an opportunity to reflect on the completeness and incisiveness of the approach, relating it to: 1) sources of knowledge; 2) sensitive indicators; 3) frequency of data acquisition and analysis.

Key words: Dwellings, management, preventing, aging

1. INTRODUCTION

Triggering a new system of relations between science, society and technology, is the starting point of a research, which aims to review methods and timings of building management. The contribution is in the cultural segment of active protection, combining the scientific disciplines of conservation with the advances in theoretical and operational maintenance.

Problems posed by sudden and unpredictable changes in the processes of aging and deterioration of buildings, which recorded in recent decades, require to introduce a vision of the monitoring as an essential action in building management. The theoretical foundation of the paper are the studies of constructive elements degradation processes and the studies on management approaches. The research responds to the instance of acting in a predictive relation to the onset of degradation for new buildings. To this end it is necessary to have drawings and technical documents testifying the status of the site after construction. Implementing the as-built documentation already existing; the research proposes to integrate it with a record of constructive choices made for each environmental unit and spatial element. The record accords to the Italian standard UNI 10838, which defines the building system as the composition of different functioning subsystems or components with precisely designed interfaces,
controlled to operate robustly, and always meeting performance within known bounds under changing environmental conditions and use.

The search focuses on the creation of a supporting tool for life cycle management referred to buildings under construction, preventing elements aging with the introduction of a vision of the just built, as a permanent monitoring site. A monitoring record, the “as built plan” is designed to outline the set of critical points to observe, for the systematic detection of changes in vulnerability status indicators.

2. INNOVATING THE MANAGEMENT APPROACH

Facing the challenges of the post-Lisbon process that aimed to make EU "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth by 2010"², the conceptual approach that informs the research, is aligned to the intentions of the Strategic Vision 2030, developed by the Platform of Construction which compared scientific needs of the next 25 years and the possible directions of technological changes and organizations. Referring to the evolution of culture regulations on buildings’ management, the search takes note of changes in the scientific approaches (Caterina G., De Joanna P., Molinari C., 2006), with the slow passage from a vision of the operations, matured inside the industrial production, to evolutes principles devoted to built patrimony. The theoretical approach adopted, derives from the integration of two different cultural assumptions, born at different times and developed with the support of several operational tools:

- Built heritage maintenance is the result of specific activities designed to preserve a state of equilibrium between two opposing processes: on one hand, the ever-changing needs of users, on the other, the impact of physical and chemical agents capable of changing the initial conditions of the construction³.

- Built heritage maintenance is the set of subsequent and integrated steps, the result of information exchange and cooperation between experts in different disciplines. The qualifications of operators, the circulation of information and the continuous improvement of activities are some of the criteria that lead to a new approach in building maintenance⁴.

² It was set out by the European Council in Lisbon in March 2000, and was heavily based on the economic concepts of: innovation, learning economy, social and environmental renewal.

³ Referring to the evolution of culture regulations on maintenance, the search takes note of the changes in the scientific approaches, with the slow passage from a vision of the operations, matured inside the industrial production, to evolutes principles devoted to built patrimony (Wood, B., 2003, a). The British Standard 3811 (1964) defines maintenance as a combination of activities to maintain or restore an object in an acceptable condition. It introduces a systemic approach to the idea of maintenance as a plurality of activities that complement each other. The contribution of the approach to buildings management can be traced back to a new concept of functionality for spaces and elements, both before and after the onset of the fault (Molinari C., 2002). The Building Maintenance Committee (1972) defines maintenance as work undertaken with the aim to maintain, restore or improve every facility, every part of the building, the facilities, the surrounding area in order to reach an acceptable standard and ensure the functionality and value of the building complex.

⁴ At the beginning of the ’90s, the first official definition of the term maintenance is given, within the activity of the Italian National Agency of Unification (UNI); the idea of maintenance, as combination of all the technical and administrative actions, includes also the actions of supervision, and is referred directly to the European terminology, by now consolidated. The Commission UNI “Quality and reliability,” writes the UNI 9910: 1990 terminology on reliability and quality of service recovery in the UNI 10147: 1993 Maintenance - Terminology. Maintenance is a combination of all technical and administrative actions, including supervision actions, intended to maintain or restore an entity in a state where it can perform the required function. It introduces the criterion that the maintenance action is not only technical but also administrative.
Based on theoretical studies and direct experiences, the research in progress at the Dipartimento di Configurazione e Attuazione dell’Architettura, prefigures to exceed the common praxis and opens to the idea of service, signed by an organizational and procedural order. Manage built assets raises a number of complex problems related with the fact that the original design documents are often modified, the construction events are difficult to define and to model, degradation processes are unknown or difficult to evaluate. It is therefore, necessary to structure devoted tools to support the issues of components and systems, investigating failure modes and effect, for non-structural technical elements, relating age, obsolescence and degradation dynamics with environmental impacts. Overcoming any reference and link with industrial production, the research team proposes a management model for built heritage, founded on the principles of anticipation, vigilance and planning, informed to the logic of sharing responsibilities between users and managers, coordinating design choices. Following this approach, building management is far from a sequence of repair actions activated when there is a situation of non-functioning entity; on the contrary, it is assumed to be the set of interconnected phases of planning and monitoring, carried out continuously over time, based on a design capacity of foretaste and organization. The process, which follows the whole life cycle, is conceived as a creative and rigorous succession of stages with the aim of governing the complexity of the assets in the absence of detailed information about the vulnerability and durability of each technical element and space. Condition for this active management is the complementarity of knowledge, experience and expertise of various scientific domains, for the preservation and promotion of the built capital. In this perspective, the management procedure assumes the role of unitary strategy of reliability control and forecast, aimed to guarantee the permanence of a satisfactory relationship between users requirements and spaces performances. Reliability referred to buildings, is therefore, assumed as the probability that sub-systems or spaces will survive a given operating period, under specified operating conditions, without failures, always meeting performance within known bounds, under changing environmental conditions and uses (Bloom B. N., 2006). Linking levels of tolerable degradation to monitoring procedures for buildings, central issues, are:

- predicting life expectancies with the help of monitored key performance indicators,
- understanding the difference between the requirements of an assets from a user perspective, and the design reliability of the asset,
- defining several basic routine maintenance tasks (Amaratunga D., Baldry, D., Sarshar M., 2000).

Ensuring efficiency and functionality to external and internal elements – such as walls, floors, windows, with the help of a governance process of change characterized by complexity and disciplinary involvement of multiple actors, Europe can meet the Lisbon process targets with the achievement of the economic, social, and environmental objectives. Monitoring procedures, integrating prior knowledge with the control of new factors, can rise to the role of procedural opportunity for innovation in the service, devoted to investigate the evolution of new failure processes, against the criticities of reactive operations after failures.

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5 In Italy such passage is explained in the Dlgs. 157/1995 in performance of Directive 92/50/CEE in matter of contracts publics of services and in the standard UNI EN ISO 9001 of 2000.

6 According to the scholars Nowlan and Heap (Nowlan, F.S, Heap H.F., 1978) reliability centred maintenance (RCM) is a logical discipline for the development of scheduled-maintenance programs. Referring to buildings, RCM can be defined as a highly complex analytic process, aimed at integrating Preventive Maintenance (PM), Predictive Testing and Inspection (PT&I), Repair (also called reactive maintenance), and Proactive Maintenance to increase the probability that spaces and elements will perform in the required way over their design life-cycle, with a minimum amount of maintenance and downtime.
3. THE AS BUILT MONITORING PLAN

Moving on to a detailed description of the efforts made to define the conceptual plan for monitoring new buildings, with the aim of granting the lengthening of buildings life cycle, the research introduces a multiscale approach, linking the environmental/urban/architectural scales, in the organisation of a database devoted to spatial elements, where technical elements properties are linked to probable evolutions of decay and loss of performances. In this way, the theoretical reliability assumptions for building elements are matched together with the failure identification, according to an open management process, aimed to select and interface tasks (Wood, B., 2003, b).

Prerequisite to ensure the welfare and safeguard of users, is the systematization of knowledge about the process of building, through the return of a careful survey of the "as built" state. The experimental research realized with Dwellings in Cava dei Tirreni (Sa), put in place procedures for systematize the data related to a settlement under construction in order to guide later the continuous monitoring of characteristic variables that signed the spaces of the residence. The conceptual approach informing the record is based on the ISO standard 6240: 1980, Performance standards in building – Contents and presentation, and the Italian Standard UNI 10838:1999, “Building - Terminology for users, performances, quality and building process”. A multi-scalar conception supports the analysis that singles out spatial units, assuming them as the direct object of observation, and tying to them all the technical elements that constitute them. The building is not a simple sum of spaces, technical elements, materials and equipments but is a system in which every aspect is related to another in complex ways, to meet the needs of users.

Selecting the elements to be analyzed requires the definition of system boundaries, specifying precisely what is included and not included in each sub-system so that an accurate and complete list of components can be identified and no overlap with component lists of other systems. Once the elements to be analyzed have been selected, it is time to describe them. Identifying and documenting the essential details of the system is necessary in order to perform the remaining steps in a thorough and technically sound manner. Adopting a theoretical model, the research proposes the decomposition of collective spaces by use, distinguishing:

- prevailing transit function,
- prevailing function to meet and socialize,
- main function of trade,
- main function of recreation,
- main function of rest,
- prevailing standby function,

The monitoring plan includes the as built technical drawings, with the systematization of information aimed at controlling the performances offered by single spaces and elements. The as-built monitoring plan must be designed during the construction of the building to be sure to report all information regarding manufacturer's technical choices taken during construction. The as built monitoring plan is founded on the register of spaces elements, configured as a tool to summarize data acquisition and organization, it is therefore directed to a multi-disciplinary reading of the building which addresses the technological and functional analysis. The decomposition, classification and transmission of information meets the requirements of implementability, flexibility, adaptability and uniqueness of the elements required by the dense and diverse network of information and interface with operators. The classification system has been organized by distinguishing between:

- procedural classifications, which follow the procedures of the production process, construction and assembly of the elements;
• functional classifications, taking as a criterion the prevailing mode of operation and use of the system and are, in any case, partially structured by the logic of building construction process;
• product classifications, which systematizes according to the marketing arrangements of the elements, in this case the products.

Being the purpose of the *as built monitoring plan* to record variations during the life cycle, it has been divided into three sections:
• as built relief,
• as built register of space and technical elements,
• as built monitoring.

*Figure 1: Dwellings under construction in Cava de’ Tirreni*
Figure 2. The as Built Relief

Figure 3. The as built register of space and technical elements
### Table 1. The monitoring plan

<table>
<thead>
<tr>
<th>CLASSES TECHNICAL ELEMENTS</th>
<th>COD.</th>
<th>TECHNICAL ELEMENTS</th>
<th>COD.</th>
<th>Technical elements</th>
<th>COD.</th>
<th>Materials</th>
<th>EXECUTION / INSTALLATION</th>
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<tr>
<td>Structures (the plots)</td>
<td>20</td>
<td>Structures</td>
<td>20.2</td>
<td>Pillars- beams</td>
<td>E/q4</td>
<td>Mixture of concrete, sand, gravel, water</td>
<td>Preparation of formwork Provision of armor Casting of concrete Disarmament</td>
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<tr>
<th>PARTITIONS</th>
<th>21</th>
<th>Exterior walls</th>
<th>21.5</th>
<th>Nonbearing walls</th>
<th>F/f4</th>
<th>Foam concrete blocks silica, calcium oxide, aluminum oxide, water</th>
<th>Laying of the blocks with a mixture of cement Alignment and Block level</th>
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<tr>
<td></td>
<td>22</td>
<td>Interior walls</td>
<td>22.3</td>
<td>Nonbearing walls</td>
<td>F/g4</td>
<td>Brick blocks in clay</td>
<td>Wetting of the blocks Laying of the blocks with a mixture of mortar Alignment and Block level</td>
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<td></td>
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<td></td>
<td>P/q4</td>
<td>Mortar mixture of sand, lime, water, cement</td>
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<td></td>
<td>23</td>
<td>Floors</td>
<td>23.3</td>
<td>Composite floors</td>
<td>E/q4</td>
<td>Mixture of concrete, sand, gravel, water</td>
<td>Preparation of provisional scaffold Provision of the joists and brick blocks Concrete casting Disarmament</td>
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<td></td>
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<td>H/h2</td>
<td>Steel Joists</td>
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<td></td>
<td></td>
<td>F/g2</td>
<td>Brick blocks in clay</td>
<td></td>
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</tbody>
</table>

## 4. CONCLUSIONS

Usually the approach to the theme of the prevention of degradation for existing buildings, has been addressed by focusing management efforts on a case by case basis, sometimes under the emotional drive of tragic news events. The search opens up new scenarios in the within of the widest process that...
is interesting the fields of computer science, average and electronics of consumption, pursuing the penetration of a new technological thought to traditional ways of acquiring, managing and exchanging information. The two dimensions of hard and soft innovation, are central in the research, that outlines a new processuality for buildings monitoring, safeguarding constructive elements identity and fulfilling of the requirements imposed by law. Assuming the new residential complex of Cava dè Tirreni (Sa) as case study, the research delineates the applicative potentialities of new technologies to non structural elements for failures finding, life expectancies prediction, knowledge and technical registry, basic routine tasks management.

Taking down the term "monitoring" from industrial environments, the search outlines a management approach grounded in scientific measurement repeatability and reliability of assessments through the specific organization of acquisition methods, data analysis and return, always reproducible. The aim of the monitoring plan is to testify - over time - the transformation occurred; identifying and describing transformative processes it can prevent conditions of risk, disease, degradation, discomfort, obsolescence, implementing users safety, and comfort.

The experience in Cava de 'Tirreni, shows that the effectiveness of the monitoring approach is related to the integrity of the observation, totality of information, rapidity of survey, ability to provide quantitative and qualitative data, ease of return(Viola S., Diano D., Napolitano T., 2008). For this purpose, a significant role was given to boundary conditions - environmental and use – that can affect spaces and elements performances. The most significant results from the outlining of a monitoring plan for the case study are attributable to the acquisition of a new awareness on how to organize sensitive data referred to the building system, defining performance indicators, describing performances, keeping them under constant observation to assess trends over time and systematically collect data. Complementary to the establishment of a classification record is the determination of sensitive indicators of the state of conservation of space and elements: in the new future, the research will open to the enucleation of few sensitive observation points, testing them with the support of non invasive technologies. The monitoring approach to Dwellings in Cava dei Tirreni lead to the development of a management vision for building not any more based on the use of tools and equipment "invasive", "heavy" and "dirty", with the help of principles and methods of work organization, distribution functions, equipment and personnel, in terms of equipment and instruments to operate directly and new technical skills (Viola S., Caterina G., 2009).
5. REFERENCES


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Implementation of Quality Management System on architecture offices as a requirement for sustainable design

Case Studies

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Abstract: The concern with quality management systems initiated on 1990 through ISO 9001 regulation. In Brazil, the improvement of quality on civil construction industry have been stimulated after 1998 through the Federal Government PBQPh – Brazilian Program for Quality and Productivity in the habitat – which proposes the quality improvement of construction enterprises through the progressively compliance with the requirements of ISO 9001. The architecture offices were the last to join this initiative with the establishment, ten years later (on 2008), of a program created specifically for them. At the same time, during the last part of 20th century, design methods for sustainable buildings have emerged all over the world. Europeans have taken the sustainable construction as an important goal to be achieved, particularly considering the necessity of reducing energy consumption. Among the methodologies for sustainable design that have made their way to Brazil, the French one (HQE®) has been adapted, resulting in the AQUA Brazilian certification. The main contribution of this paper is to analyze the relation between the existence of an implemented quality management system on design offices and its influence on the design management process for sustainable buildings. Constructors and architects have been interviewed in order to get their opinion about this subject. Results obtained testify the relation between an organized quality management system as a requirement to produce sustainable buildings through the integrated design.

Key words: Sustainable Design, Design Management, Architecture management.

1. INTRODUCTION

The concern for quality during the development of the designs (architecture, structure, etc) initiated when the researchers proved that most of the problems identified during the construction were due to failures in the conception.

It would be necessary to develop a model that would help the design management process: a development plan where the main activities and their priorities - as well as roles and responsibilities of the main participants of the process and information flow - would be defined. It became necessary to map the design process and organize companies to ensure proper production flow in design management.

The quality management system created for help the organization of design offices must help the management of the information, thus making work easier and contributing indirectly to the quality of the designed building.

Unfortunately some aspects compromise the implementation of a quality management system in design companies. One of them is the resistance to complying with ISO 9001 requirements. Some professionals consider that the proposed model is not applicable to small companies, which are common in the building design sector. Despite of difficulties, architecture offices are organizing their management system and achieving best results on design management process.
At the end of 20\textsuperscript{th} century architecture offices had to face a new challenge: the requirements for sustainable design. It is known that interoperability among professionals is a pre-requisite for sustainable design, and it demands the organization of procedures to guarantee the exchange of information among professionals during the design process and a documented management process. On the other hand, some authors suggested the concurrent engineering logic as an answer to integrate design process and, consequently, to sustainable design.

This paper highlights the contribution of a quality management system for sustainable design in architecture offices. Two case studies had been carried out. The first one presents the results obtained through a pilot-experience with a collaborative project among the researchers of Federal University of Rio de Janeiro - Brazil (Universidade Federal do Rio de Janeiro) and architecture offices. The firms have been selected considering their interest on quality management systems (SALGADO, 2010). The second case study analyse the French experience with the HQE\textsuperscript{®} certification through interviewees with design offices, consulting firms and construction companies. Testimonies assure the contribution of ISO 9001 requirements for the organization of a design method to achieve high quality environmental design.

2. DESIGN MANAGEMENT SYSTEMS: FROM SEQUENTIAL MODELS TO CONCURRENT ENGINEERING

The design management process has sparked the interest not only in researchers, but also in professionals of the field, which see a possibility to improve their productivity with quality and efficiency.

Some architects had severely criticized management models for architecture offices, pointing out the importance of drawing the distinction between “design process certification” and “product certification” to avoid the use of the “ISO 9001 quality seal” as misleading advertisement, since the simple certification of an architecture office quality management system does not ensure the quality of the projects themselves.

This discussion confronts the two meanings of “design” (SALGADO, 2007):

- design as product – refers to the building or building complex to be built;
- design as process – refers to the sequence of activities that are required to turn the original construction idea (concept) into guidelines that have to be followed by the construction company in order to create the product, i.e. to build the building.

Brazilian Architecture Office Association (AsBEA - Associação Brasileira dos Escritórios de Arquitetura) prepared in 1992 a basic routine for the development of architecture designs with the objective of establishing information, subsidies, requirements and procedures for each phase or step of design process.

Five years later, the Building Technology Center (Centro de Tecnologia de Edificações), in partnership with the Union of Construction Industry of São Paulo (Sindicato da Indústria da Construção Civil de São Paulo SINDUSCON-SP), prepared a “Quality Management Program in Design Development for the Construction Industry” that intended to gradually self-implement improvements to the design process, by understanding the flow of design process activities, mainly the need to develop the strategic planning of design companies (TZORZOPOULOS, 1999).

The Brazilian Architecture Office Association (AsBEA, 2006) focused again on the topic of the design management process, when published, in 2006, a series of manuals, whose objective was to establish the scope of the services related to the development and coordination of projects. Discussed topics range from the hiring of services to the scope of the projects to be presented. AsBEA does not
suggest any specific management model, but points out the issues that the companies have to consider when organizing their way of operation. According to Koskela (2007) the evolution of design management practice can be grouped into three different periods:

- design as a craft,
- sequential engineering and
- concurrent engineering (a systematic approach to the integrated concurrent design of products and their related processes, including manufacturing and support).

Traditionally design and engineering has been viewed as transformation, whereas concurrent engineering is based on mostly intuitive understanding of design and engineering as flow and value generation. This author concludes that the tools and methods of concurrent engineering derive from new conceptualization of design, which thus provides the seed towards further development of the theory of design as well as new design management methods.

3. FIRST CASE STUDY: QUALITY MANAGEMENT SYSTEM APPLIED TO BRAZILIAN ARCHITECTURE OFFICES

Brazilian Federal Government addressed the concerns of the Brazilian construction industry, specifically the design sector, by creating in 2008 the Compliance Evaluation System for Companies that are specialized in preparing projects (SiAC-Projetos) (PBQPh, 2008). This system was created within the Brazilian Program for Quality and Productivity in the Habitat (PBQP-H) and has the following main properties:

- Four implementation stages;
- Four standard guidelines – one for each stage;
- STAGE 1 – Statement of Adhesion to Standard Guideline of Stage 1;
- STAGES 2, 3 and 4 – Certification by Certification Bodies (CO) or Authorized Certification Bodies (CCO) with in loco audits

On previous paper (SALGADO, 2010) have been presented the results obtained with the experience of following up on SiAC-Projetos implementation in design companies located in the city of Rio de Janeiro. Table 1 show the characterization of the design offices that had participated to this project. This experience had highlighted some important aspects to be considered related with the implementation of a quality management system as follows:

- The TIME dedicated to organizing the company’s management system: the implementation of a quality management system cannot be done in your spare time. The company should allocate some time to perform this task;
- the implementation of the system has to become a PRIORITY: if it is not perceived as a priority, it ends up ranking second and being forgotten;
- a professional of the company has to be assigned to be EXCLUSIVELY dedicated to follow up the tasks that are required for the organization of the quality management system.

The first phase of the discussion on design management process at Brazilian architecture offices has relativized the importance of aspects such as the quality in the design conception of the building, user satisfaction, among others. This happened due to the urgency in reducing design errors, such as incompatibilities between the different specialties, the discrepancies between the last reviewed version
of the design and the one that is actually being executed on the construction site, and the problems in tracking design team decisions.

Table 1 – Characterization of offices that participated to this pilot experience. (SALGADO, 2010)

<table>
<thead>
<tr>
<th>Companies</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation year</td>
<td>1987</td>
<td>2006</td>
<td>1986</td>
</tr>
<tr>
<td>Number of employees</td>
<td>6</td>
<td>33</td>
<td>39</td>
</tr>
<tr>
<td>Activity</td>
<td>Architecture projects, including all phases, and coordination of residential and business projects.</td>
<td>Real estate, schools, special projects (dealers, stands, squares, etc)</td>
<td>Architecture projects: coordination and development of executive projects. Engineering projects: infrastructure for developments and groups (implementation, earthwork, drainage, sewage system, drink water, power supply, lightening, etc).</td>
</tr>
</tbody>
</table>

| What do you expect from implementing a quality management program at your company? | To improve the company’s performance; record the adopted operation and organization; improve the workflow and information management. | To organize the company’s management system by establishing routines in order to comply with contracts, reduce errors and rework. | To standardize the procedures used by the company (from internal administrative processes to the services rendered to clients) in order to ensure the quality (deadlines, costs and technical quality) of the services we render to our clients. |

NOTE: Data obtained on December 2008.

It is important to add that design valorization should consider conferring a higher priority to aspects related to the quality of the designed spaces, which shall not be surpassed by the needs of the companies’ design management system.

4. RECOVERING THE QUALITY IN THE DESIGN CONCEPTION THROUGH THE PRINCIPLES OF SUSTAINABLE DESIGN

It is generally accepted the current era of rating tools commenced in 1990 with the introduction of the BREEAM (UK) rating tool. This was followed by the French system HQE® and then by the U.S. LEED™ in 2000. Further analysis of, confirms that the evolution of rating systems into different countries is largely based on the initial rating systems (REED et al., 2009).

BREEAM (Building Research Establishment’s Environmental Assessment Method) sets the standard for best practice in sustainable design. Credits are awarded in ten categories according to performance. Where a performance target has been achieved the number of available BREEAM credits can be awarded. The majority of BREEAM issues are tradable, meaning that a design team/client can pick and choose which to comply with in order to build their BREEAM performance score. As a certification body accredited by the UK Accreditation Service (UKAS) BRE Global Limited maintains an open and accountable governance structure. The operation of BREEAM (and indeed all our assurance activities) is overseen by an independent Governing Body and a Standing Panel for Peer & Market Review (BREEAM Offices 2008, 2010).

The Leadership in Energy and Environmental Design (LEED™) Green Building Rating System represents the U.S. Green Building Council’s effort to provide a national standard for what constitutes a “green building”. Through its use as a design guideline and third-party certification tool, it aims to improve occupant well-being, environmental performance and economic returns of buildings using established and innovative practices, standards and technologies. To earn LEED™ certification, the applicant project must satisfy all the prerequisites and qualify for a minimum number of points to
attain the established project ratings as listed. Having satisfied the basic prerequisites of the program, applicant projects are then rated according to their degree of compliance within the rating system. All prerequisites must be achieved in order to qualify for certification. Points add up to a final score that relates to one of four possible levels of certification. (SALGADO and LEMOS, 2005)

In France, the HQE® – *Haute Qualité Environnemental* (High Environmental Quality) association – was created to develop environmental quality management in the building construction industry. This association produced a report containing recommendations in the form of environmental targets to be pursued by architects and engineers. Among the targets, it is important to highlight: Eco-Construction; Eco-Management; Comfort (thermal, acoustic, visual); and Health (air and water quality, among others). This report led to the methodology for support of the high environmental quality design, where each target should be divided into several requirements and recommendations which should be reviewed for each building, it is not possible to establish a single formula for all types of construction.

The development of projects that consider the principles of the High Environmental Quality (HQE®) method may be divided into two phases: the first phase may be called "setting parameters" and the second "the design concept." The “setting parameters” phase can be divided into:

- The study of the environmental potential of the land - specifically related to the parameters set by the HQE® method
- The Pre-programming HQE® - with the ranking of the 14 targets set by the methodology;

Table 2 presents the 14 targets of HQE® methodology.

**Table 2: 14 HQE® Targets**

<table>
<thead>
<tr>
<th>OUTDOOR ENVIRONMENT</th>
<th>ECO CONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target 1: Harmonious relation of the constructions with their immediate surroundings</td>
<td></td>
</tr>
<tr>
<td>Target 2: Integrated choice of construction processes</td>
<td></td>
</tr>
<tr>
<td>Target 3: Building site with few disturbances</td>
<td></td>
</tr>
<tr>
<td>ECO MANAGEMENT</td>
<td></td>
</tr>
<tr>
<td>Target 4: Energy Management</td>
<td></td>
</tr>
<tr>
<td>Target 5: Water Management</td>
<td></td>
</tr>
<tr>
<td>Target 6: Management of waste from the activities</td>
<td></td>
</tr>
<tr>
<td>Target 7: Technical Assistance and Maintenance</td>
<td></td>
</tr>
<tr>
<td>INDOOR ENVIRONMENT</td>
<td></td>
</tr>
<tr>
<td>COMFORT</td>
<td></td>
</tr>
<tr>
<td>Target 8: Hygrothermic Comfort</td>
<td></td>
</tr>
<tr>
<td>Target 9: Acoustic Comfort</td>
<td></td>
</tr>
<tr>
<td>Target 10: Visual Comfort</td>
<td></td>
</tr>
<tr>
<td>Target 11: Olfactive Comfort</td>
<td></td>
</tr>
<tr>
<td>HEALTH</td>
<td></td>
</tr>
<tr>
<td>Target 12: Sanitary Conditions</td>
<td></td>
</tr>
<tr>
<td>Target 13: Air Quality</td>
<td></td>
</tr>
<tr>
<td>Target 14: Water Quality</td>
<td></td>
</tr>
</tbody>
</table>

Source: ADEME, 2002

A comparison among those three rating systems is presented on Table 3

**Table 3 – Comparison among BREEAM, LEED™ and HQE®**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>BREEAM</th>
<th>HQE®</th>
<th>LEED™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CO₂</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ecology</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Economy</td>
<td></td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Health and Wellbeing</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Indoor environmental quality</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Proceedings Architectural Management in the Digital Arena

<table>
<thead>
<tr>
<th>Innovation</th>
<th>X</th>
<th>?</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land use</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Management</td>
<td>X</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>X</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Pollution</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Renewable Tech.</td>
<td>X</td>
<td>?</td>
<td>X</td>
</tr>
<tr>
<td>Transport</td>
<td>X</td>
<td>?</td>
<td>X</td>
</tr>
<tr>
<td>Waste</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Source: Adapted from REED et al., 2009

About the certification methods, it is relevant to add that BRE Global, CSTB and CERTIVEA have signed a MoU to initiate joint programme with the overall objective of aligning the certification schemes delivered by the two institutes in the countries in which they operate. This will ultimately allow the development and promotion, at the European level, of a common assessment method and a common brand run by a European council.

The building production life cycle extends from the stage of preliminary study to construction. The possibility of changing the characteristics of the building to satisfactorily meet all the HQE requirements may vary, depending on the stage of this cycle. According to PLATZER (2009, p. 67), the building production life cycle occurs within six phases: Programme needs - which can be divided into environmental needs and user needs; building design; materials and methods; construction; post-occupancy activities (including the use, operation and maintenance of the building) and demolition. According to this author, most part of the goals defined by HQE® must be accomplished during the two first phases. So, to achieve high quality environmental performance in building construction it is important to incorporate the sustainable solutions since the beginning of design process.

Currently, Brazilian’s architecture offices are initiating their search for methods that could give some orientation about the design process for sustainable construction. LEED™ and HQE® have made their way to Brazil. The French methodology has been adapted, resulting in the AQUA Brazilian certification. It is assumed that Brazilian architecture offices must though organize their management system in order to accomplish the sustainable requirements along the design management process.

5. QUALITY MANAGEMENT FOR SUSTAINABLE DESIGN IN FRANCE

At the same moment design sector had faced the sustainable challenge, the discussion over design management process had been intensified. Architects and engineers are not interested on ISO 9001 certification but they understand that to achieve best design solutions (particularly considering the environmental goals) it is necessary to integrate the design solutions and also the professionals involved (architects, engineers, etc).

French experience with HQE® method had lead professionals to rethink design management process in order to integrate the new environmental goals into architecture solutions. For this reason, AFAQ AFNOR, Fédération des Promoteurs Constructeurs de France and CERTIVEA (a subsidiary of French Building Research Centre – CSTB) proposed the referential QUALIPROM® created precisely to be applied by a constructor that needs to integrate the HQE® goals into all its operations and demonstrate their capacity to accomplish the client’s necessities and regulations related, answering positively to the environmental requests. (QUALIPROM, 2007).

This methodology is based on ISO 9001 requirements and also the exigencies of HQE®. Table 4 presents a comparison among different regulations about quality and environmental management.
In order to accomplish the necessary requirements to produce sustainable building, it is important to understand the design phase (which is pointed out to be the most impacting), and also the selection of building materials, components and processes.

6. **SECOND CASE STUDY: IMPLEMENTATION OF ISO 9001 REQUIREMENTS IN FRENCH OFFICES AS AN APPROACH TO ACCOMPLISH HQE® EXIGENCIES**

In France, based on their concern with the energy performance of their buildings, professionals have started to rethink the design and construction process. A survey was conducted with some professionals that work in large French firms in order to understand the relation between a quality management system and an architecture process that could allow the accomplishment of the design with sustainable principles. Eight firms have been contacted:

- four architecture offices – one of them close to obtain ISO 9001 certification and one certified;
- two consulting firms specialized in acoustic projects;
- two construction firms certified by ISO 9001

It sought to identify not only their opinion with respect to the HQE® method but also concerning sustainable construction in France in general. Those surveyed were also asked about possible modifications incorporated into their design process, as a result of high environmental quality requirements for their building design.

The results obtained had shown that, with respect to design process management, in the opinion of those interviewed, it is not possible to achieve any design that takes the environmental issue into account, without preparing a system to help managing the necessary data for executing the design. In this area, all those interviewed claimed that they have a specific control system for documents and data.

In order to point out, however, that specifically in relation to certification according to ISO 9001 standards, although all the companies recognise the importance of establishing a working
method, this does not have to be formalised in the manner set forth as being required by the standards. Furthermore, some of those interviewed did not see their companies as being sufficiently large to implement an organized management system.

In the four companies where the quality management system exists and is certified, the professionals confess that they would no longer know how to work without the documental base required by that system. It was stressed that all those interviewed should recognise the potential of a quality management system in handling designs with high environmental quality. As said by one of interviewed professionals:

“The HQE® has a qualitative approach, therefore the organization of the firm on the requirements of the standard ISO 9001 for quality management, makes it easier to have some organization for the environmental approach, because professionals are already accustomed to work with the procedures, with documents.”

7. DOCUMENT MANAGEMENT FOR SUSTAINABLE DESIGN

Two difficulties are been faced by Brazilian and French architecture offices in order to organize their management systems: the document management and the functional structure formalization – particularly on small offices. Amor and Clift (2007) had established a list with the standard documents in a construction project. Traditionally those documents are generated and stored in paper form. Table 5 presents a list of those documents.

The document management is a challenge because normally architects cannot predict the whole design management process and, consequently, they don’t know how many types (and versions) of documents must be prepared in order to execute the complete task of producing a new building. The result of this situation is that, sometimes when a new document is produced, it is nominated without any specific pattern and archived without obeying a determined logic. Consequently, to find a document sometimes professionals spend a lot of time. This wasted time is subtracted from the working time and the result is the loss of productivity.

By discussing document and data control, some doubts came up regarding document management, which includes the creation, nomination, classification and archiving process. Routines have to be established for the following situations:

1) Control of technical documents and data (projects) – it is necessary to define the nomination (codes) to be used and the archiving procedure, and to establish the security level of each document (if anyone at the office can open and make changes/reviews or if only the design team can open and alter the archive).

2) Control of administrative documents and data (payroll, issued invoices, delivery receipts, etc) – the nomination (codes) must be related with the type of data to facilitate users to find when necessary. It is very important to discuss the process with all the collaborators in the office (not only architects and engineers).

3) Control of Quality Management System documents and data – ISO 9001 indicates several new procedures to be discussed, produced (formally registered), validated and implemented by offices in order to allow the accomplishment of the requirements to a quality management system. These procedures must also be controled and archived.

4) Backup of documents and data (digital and printed) – Design offices are made of “ideas”. Those ideas are registered in several different documents that form the portfolio of the architecture (or engineering) office. It is not possible to conceive an office without an appropriate system to
protect those several documents (printed or digital). The backup process can be automated or manual. It depends on the type of the documents to be protected.

5) Registration of system users (access to the network) – Different phases of design are developed by different professionals. So it is necessary to develop a system to define which professionals must have full access to all documents (“full access” in this context, means the possibility to open the digital archives, make changes and save with another code considering the reviewing process) and which professionals will only be authorized to see documents, but not to change them.

6) Time of disposal – As offices normally do with printed documents, digital documents must also be deleted after a time. Not defining disposal time will lead to slowness in processing data from over-stored documents.

Table 5 – Standard documents in a construction project – the UK viewpoint (AMOR and CLIFT, 2007)

<table>
<thead>
<tr>
<th>Type</th>
<th>Author</th>
<th>Legal/contractual status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brief</td>
<td>Client/owner</td>
<td>High</td>
</tr>
<tr>
<td>Contract/commission</td>
<td>Client</td>
<td>High</td>
</tr>
<tr>
<td>Drawings</td>
<td>Designer/contractor</td>
<td>High</td>
</tr>
<tr>
<td>Specifications</td>
<td>Designer</td>
<td>High</td>
</tr>
<tr>
<td>Bills of quantities</td>
<td>Quantity surveyor</td>
<td>Medium</td>
</tr>
<tr>
<td>Tender documents</td>
<td>Designer</td>
<td>High</td>
</tr>
<tr>
<td>Valuations</td>
<td>Quantity surveyor</td>
<td>Medium</td>
</tr>
<tr>
<td>Payment certificates</td>
<td>Designer</td>
<td>High</td>
</tr>
<tr>
<td>Program/schedules</td>
<td>Contractor</td>
<td>High</td>
</tr>
<tr>
<td>Calculations</td>
<td>Designer/contractor</td>
<td>Medium</td>
</tr>
<tr>
<td>Site diaries</td>
<td>Supervisor/contractor</td>
<td>Medium</td>
</tr>
<tr>
<td>Change orders</td>
<td>Client/designer/contractor</td>
<td>High</td>
</tr>
<tr>
<td>Progress records</td>
<td>Supervisor/contractor</td>
<td>Low</td>
</tr>
<tr>
<td>Claims/compensation events</td>
<td>Contractor</td>
<td>High</td>
</tr>
<tr>
<td>Letters</td>
<td>All</td>
<td>High</td>
</tr>
<tr>
<td>E-mail</td>
<td>All</td>
<td>Low</td>
</tr>
<tr>
<td>Fax</td>
<td>All</td>
<td>Low</td>
</tr>
<tr>
<td>Request for information</td>
<td>Contractor</td>
<td>Medium</td>
</tr>
<tr>
<td>Confirmation of instruction</td>
<td>Designer</td>
<td>Medium</td>
</tr>
<tr>
<td>Notices</td>
<td>Client</td>
<td>High</td>
</tr>
</tbody>
</table>

It is clear that, in construction industry, physical documents will not disappear, however, as pointed by Amor and Clift (2007, p.186) the short term benefits which could be realised by utilization of DMS (document management system) are mostly in the automation of non-value adding processes, for example, automatic forwarding of documents to a set of team members on completion of a particular process or activity. Standards functions could also automate many of the tracking and verification activities required for dispute resolution by recording who received what documents, at what time, and by recording when the recipient opened the document. Standard function will also allow security to be implemented through digital signatures to ensure that original versions can be identified and encryption should be used to ensure that unauthorized access to documents can be controlled.

8. CONCLUSIONS

The implementation of a document management system is the main challenge Brazilian and French design offices have to face in order to achieve sustainable design goals. It have been noticed in France some offices that decided to create their own software for document management and it has been considered the first step not only for the certification ISO 9001 but also (and mostly) for helping to
accomplish the requirements of HQE® methodology – particularly on registering the QEB (Quality Environmental of the Building) goals and the design decisions to achieve the desired results.

<table>
<thead>
<tr>
<th>Entrance of Documents</th>
<th>Direction</th>
<th>Responsible for Quality Management</th>
<th>Coordinators</th>
<th>Collaborators</th>
<th>Documents Support</th>
</tr>
</thead>
</table>

![Diagram]

*Figure 1, Workflow of ISO 9001 document management (proposed by a French construction enterprise interviewed)*

Figure 1 presents a proposal for the workflow for ISO 9001 document management. It is important to highlight that the “validation” is considered an important phase not only for the control of ISO 9001 document management but also for design document management.

An information system becomes important for acquiring, structuring and exchanging information during the design process. The intrinsic complexity of the information during the architecture design process has become yet more complex with the adoption of environmental goals. The interoperability during the building conception process is necessary in order to select, among the set of possible solutions, the most accurate in terms of high quality environmental.

Considering that a quality management system organized according to ISO 9001 requirements must define procedures to document management, we can conclude that an office organized by this
regulation will, at least, have the necessary structure to rethink the design conception process considering the sustainability principles.

However, although the first steps had been taken, there is still too much work to be done. The new possibilities offered by BIM – Building Information Modeling – for example, have not been totally explored by the construction sector. The parametric design allows decisions to be done by different authors simultaneously, with the on-line discussion about the best solution for the building. On the other hand, professionals have to be trained on these new possibilities, which demand a new workflow for the design process, and represents a new challenge for document management process.

9. ACKNOWLEDGEMENTS

The author thanks all directors of Brazilian and French companies that agreed to collaborate with this research, and also the fundamental financial support of CAPES (for post-doctorate scholarship) and FAPERJ (for the participation to this conference).

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Abstract: The aim of this discussion paper is to propose an inclusive definition of design management for the construction industry. This definition is based on reducing the separation between several fields of activity that have, to date, mostly been elaborated independently. These fields of activity can be broadly grouped into the phase-based and disciplinary design conceptualizations. The differences between the conceptualizations are mainly a result of domain-dependent approaches to the design problem in construction. Based on these differences, construction projects form their design supply chains and delivery methods. Urban planning and architectural design, for example, strongly implement criteria of aesthetic and social value into their processes, whilst focusing less on technical aspects of the project. In such a constellation engineering design can be considered as a commodity in the process. In this traditional representation, engineering is embedded into the architecture of the facility and, respectively, architecture is embedded into the urban planning of the area. Instead of traditionally emphasizing the differences between different planning tasks, this discussion argues for a common representation of design operations in the construction sector. This representation defines design as a group of tasks that share characteristics of the planning problem. Preliminary conclusions of this theoretical discussion suggest that the design process can be grouped into its conceptual and detailing components. In this vein, each discipline reaches the concept solution in a different time-frame and subsequently elaborates the concept solution. In conclusion, this discussion proposes that the flow of design should not be divided in terms of disciplinary and phase-based boundaries, but in terms of conceptual solutions and detailing of each of its constituent parts. The implications of this discussion can be generalized at the level of both construction project management, as well as public policy development.

Keywords: Design management, Planning problem, Construction project management, Interdisciplinary processes.

1. INTRODUCTION

“Engineering, medicine, business, architecture and painting are concerned not with the necessary but with the contingent - not with how things are but with how they might be - in short, with design.” (Simon 1996)

Most artefacts and other achievements that the human kind is collectively proud of are a result of long and laborious mental work, also known as design. Although the invention of wheel and fire may have happened as a sudden “spur of the moment” without any previous planning, this is definitely not the case with achievements that are embodied in complex artefacts such as the automobile or the skyscraper. This is not any different for a construction project. Any facility needs to exist in an artificial form before it can exist in the physical form. Although this form of existence is not tangible, it is still as realistic as the physical existence in the form of, say, concrete, asphalt, bricks, and steel. This artificial form of existence belongs to the realm of planning and design and the aim of this paper is to discuss these terms in the context of the built environment.
A construction project results in a new product with many different levels of content. From the inside shell of the project, and, without going into a detailed disciplinary elaboration, those levels of content would be the project’s overall spatial layout, architecture, engineering, and construction. Every construction project is, by definition, also embedded into its external context that consists of the environmental, economic, and societal systems. Currently, different domain-dependent conceptualizations determine what is here meant with the term design. How, then, to integrate this seemingly omnipresent decision making process that overarches every imaginable aspect of the construction project? As in any planning process, the designs will most likely never be embodied to their full extent, but the decision making process that underlies the designs is, nonetheless, indispensable. Overall, as the complexity and size of projects is increasing, the design industry becomes increasingly fragmented as markets become increasingly saturated with highly specialized firms. Furthermore, what used to be considered the realm of designer’s authority, now oftentimes falls under the auspices of the project manager. In order for this situation to be improved, the design process calls for its reintegration under the leadership of designers who, on the way, need to also assume the role of project managers (see, for instance, Gray and Hughes 2001).

As the following sections will demonstrate, however, organizing the decision making process across different levels of content is something that needs to be addressed more deeply than what the current state of knowledge provides insight into. This discussion will attempt to achieve a small step in charting the path towards an integrated domain-independent definition of design in the built environment.

2. TRADITIONAL AND EMERGING PARADIGMS

The dominant paradigms of design in the built environment have been fragmented along the disciplinary boundaries. Urban planners, for instance, share an ontological understanding of design that is substantially different from both what architects and, even more so, engineers conceptualize. This has been common practice since the split of architecture and engineering professions and has been widely acknowledged in literature (e.g., Vermaas and Kroes 2007). In this traditional paradigm, urban planning and architectural design are defined as planning activities with a broad impact on not just physical world as we know it, but also on the society that comprises it. On the other hand, the same paradigm reduces engineering to a technical support role, outside the realm of creative design. This is also evident in terminology that clearly distinguishes the two concepts in the widely-used term design and engineering.

Vermaas and Kroes (2007) illustrate this situation as “engineers make things that work and architects order space, giving visual expression to the built environment.” Moreover, “architecture is perceived to be similar to the fine arts. Building owners may seek to enhance their own social position through association with the artistic authority of the architect.” On the other hand, “engineering is an objective science applied to specific problems” is an interpretation which makes the disciplinary boundary of the design and engineering seem logical.

How justified, however, is the dominant paradigm that differentiates between the fields of design and engineering in the built environment so clearly? Table 1 below summarizes some features that distinguish designers from engineers within the traditional paradigm.

In this paradigm, designers are perceived more in terms of artistic creativity, while engineers are in their mental programs more aligned with hard-sciences approach. Indeed, as Cross (1982) points out, mental models are significantly different between design and scientific thinking:

“The designer is constrained to produce a practicable result within a specific time limit, whereas the scientist and scholar are both able, and often required, to suspend their judgements and decisions until more is known—‘further research is needed’ is always a justifiable conclusion for them.”
Table 1 – Differences between design and engineering

<table>
<thead>
<tr>
<th></th>
<th>Design</th>
<th>Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of systems dealt with</td>
<td>Socio-technical, ill-structured, non-linear, dynamic</td>
<td>Technical, structured, linear, static</td>
</tr>
<tr>
<td>Problem formulation</td>
<td>Wicked problem</td>
<td>Tame problem</td>
</tr>
<tr>
<td>Mental model</td>
<td>Creative, artistic expression</td>
<td>Application of scientific principles</td>
</tr>
<tr>
<td>Solution domain</td>
<td>Infinite</td>
<td>Bounded</td>
</tr>
<tr>
<td>Authorship</td>
<td>Individuals are acknowledged</td>
<td>Collective, non-recognizable</td>
</tr>
<tr>
<td>Organization structure</td>
<td>Flat</td>
<td>Bureaucratic</td>
</tr>
</tbody>
</table>

Although this conclusion is hardly debateable, it also clarifies that the list of claims from Table 1 is based on an implicit assumption that designers are artists and engineers are hard-core scientists. Indeed, a claim that is in many cases far from reality. The next question that arises is how to sort out the terminological confusion that arises from terms as, for instance, engineering design or design science? On the one hand, engineering implies a scientific mental model based on analysis, whereas design implies the constructive and creative mental model based on synthesis. The answer to this question is to abandon the traditional disciplinary concept of design and engineering and begin using a more inclusive definition of design.

To improve this situation, scholars have coined various conceptualizations for design activities in the context of the built environment. This formed a consistent research stream of architectural management (see, for example, Emmitt et al. 2009). Within this research stream, communication is identified as the core substance in the (architectural) design process. Researchers focus on both more formal aspects of communication that is enabled by technology (den Otter and Prins 2002) and more informal collaborative aspects of multi-architect collaboration (Sebastian 2003). The second research stream attempted to map the interdisciplinary aspects of design, which resulted in a different body of literature that structures the design process across time, roles, and proposes practical methods for its management (Anumba and Evbuomwan 1997; Austin et al. 2001; Formoso et al. 2002; Yassine and Braha 2003).

The first research stream has advantages over the second one because, indeed, architects have traditionally been designers of the built environment and the profession most certainly embodies vast amounts of knowledge on the design process. However, the view in which architects are assumed to be natural leaders of the design process can also be considered a shortcoming in its own right. Although this leading role may still be true in a large number of projects, the increasing number of disciplines participating in even more projects necessitates decentralized leadership of the design process (Gray and Hughes 2001). This implies that, while the concept of design in terms of architectural value will never be lost, it needs to be complemented with design paradigms from other participating disciplines. The advantage of the second research stream is that it creates a practical toolbox that enables seamless management of the design activities. Similarly to the first research stream, this can, however, also be considered a shortcoming. Namely creating structures and processes is of limited value for a field of activity that is essentially ill-defined: design.

In conclusion, literature review reveals that an inclusive definition of design management is still missing for the built environment. As the next section will show, this definition should abandon the disciplinary constraints and move into the realm of conceptual theorizing and the nature of the design problem.

3. DESIGN AS A PLANNING PROBLEM

“Everybody designs sometimes, nobody designs always. Design is not the monopoly of those who call themselves “designers”. From a downtown development scheme to an electronic circuit; from a tax law to a marketing strategy, from a plan for one’s career to a shopping list for next Sunday’s dinner, all of these are products of the activity called design.” (Rittel 1987)
That said, it is reasonable to reconsider the purpose of the design process. Most certainly, it is to construct useful artefacts that will meet the needs of its users. At the front end of the design process is, therefore, a set of requirements, which should have been negotiated with the client previously. On the back end of the design is the construction process that will eventually turn the artefact into existence. The designer’s position is in between the project requirements and the actual construction process. In spite of this intermediary position, the transitional phase of decision making that we call design has the power to determine the faith of the product. Dealing with the back end interface of the design process has proven as particularly problematic. It has led to the emergence of a new field, constructability, whose main goal is to align the design and construction processes so that the design is buildable. This corroborates the above-introduced claim that that not only “designers” have legitimacy to participate in the design process. On the contrary, a number of actors assume the role of designers as they influence project decisions. Therefore, design is essentially a planning problem that is:

- Socially negotiated: Design adheres to rules of social construction of reality where the knowledge is contingent upon the actors constructing it rather than any inherent quality that exists in its own right (e.g., Calhoun 2002).
- Highly interdependent: Parts of the design decision making process cannot exist in isolation, they are reciprocally interdependent in that one task cannot be altered without the need to alter all the other (Thompson 2003).
- Uncertain: Because information about the project is “under construction”, there is an inherent lack of information that would be needed to reach a decision unambiguously (Galbraith 1974).
- Wicked: Wicked or ill-structured problems, as opposed to tame problems, are such that their complete formulation is not possible (e.g., Rittel 1977). All planning problems are essentially wicked problems which makes them inappropriate for traditional mathematical optimization methods.

Because of these characteristics, a cognitive approach from behavioural sciences is more appropriate than traditional scientific reasoning for studying and defining design management. Namely, although designing aims to be rational planning, the actual cognitive process is at the same time spontaneous and fraught with uncertainty. Therefore, planning by designing does not adhere to rules of optimizing and utility maximization and evidence for this can be found using introspection as the next section will show.

### 3.1 Behavioural Aspects and Retrospection

“Traditional economic theory postulates an "economic man," who, in the course of being "economic" is also "rational." This man is assumed to have knowledge of the relevant aspects of his environment which, if not absolutely complete, is at least impressively clear and voluminous. He is assumed also to have a well-organized and stable system of preferences, and a skill in computation that enables him to calculate, for the alternative courses of action that are available to him, which of these will permit him to reach the highest attainable point on his preference scale."

This is how Herbert Simon (1955), in one of his works about decision making, introduced the conception of bounded rationality as the basic condition of human rational choice. Decision making is, therefore, an intendedly rational process, but only limitedly so. Consequently, a large number of decisions are made in an ad-hoc manner under conditions of uncertainty and the decisions are only assigned their final meaning retrospectively. Karl Weick is one of the scholars who brought the concept of sensemaking into organizational studies with having that in mind. In sociology literature, sensemaking is the process by which people give meanings to their experience by retrospectively assigning meaning to past events and thereby shaping the organizational context for present and future
events (see, for instance, Weick et al. 2009). In his analysis of sensemaking in the 1949 Mann Gulch disaster where thirteen firefighters died, Weick (1993) argues:

“Sensemaking is about contextual rationality. It is built out of vague questions, muddy answers, and negotiated agreements that attempt to reduce confusion.”

The cognitive perspective is, in fact, a relatively common representation of the management decision making processes, because of the social systems’ complexity that is inherent to every project. With that in mind, Jackson (2000), for example, makes a reference to some of the seminal work on soft systems:

“Checkland and Scholes (1990) reasoned [that] managers are absorbed by the pressures and concerns of their immediate environments. They act and react according to their personalities, knowledge, instincts and so on and are unlikely, on an everyday basis, to operate according to the rules of a methodology. Rather than being methodology driven they are situation driven. They may wish, however, from time to time, to step outside the hurly-burly of ongoing events to try to make sense of what is happening or to apply some structured thinking to proposals for change.”

This situational approach could be the main reason why a very limited amount of articulated knowledge exists in the field of facility design. Design as a constructive activity is not so much prone to analysis and methodology-driven structure. In fact, the very nature of design, in a way, opposes analytical thinking. This situation is not different in other fields of design and new product development. Friedman (2003), for example, observed that:

“All knowledge, all science, all practice relies on a rich cycle of knowledge management that moves from tacit knowledge to explicit and back again. So far, design with its craft tradition has relied far more on tacit knowledge. It is now time to consider the explicit ways in which design theory can be built—and to recognize that without a body of theory-based knowledge, the design profession will not be prepared to meet the challenges that face designers in today’s complex world.”

Although design is a creative mental process, it is still being conducted mainly in the context of economic organizations. In this case, the economic goals of this decision making process should not be forgotten. In reality, the decision-making is not fully rational, but incorporates cognitive limitations of economic agents as elaborated above. This decision making constitutes the planning process of design in terms of economic decisions.

The interpretive nature, therefore, of the cognitive processes that constitute virtually every design and new product development process, there is a considerable gap between the research and practice of design. The cognitive approach has been already implemented into the construction context by contemporary scholars of construction project management (Winch and Mayorena 2009).

Applying the retrospective sensemaking reasoning to design in the built environment appears to be particularly advantageous to fill this gap in knowledge. The first set of advantages of this approach arises from the fact that taking an ex ante perspective would in a certain sense imply that the researcher knows more about the decision to be made than the decision maker, indeed, a situation that is highly unlikely to occur. Secondly, in a situation so complex and with so many participants, it is highly unlikely that all the decision makers are presented with the exact same information. For that reason, there will be a number of different interpretations of the analyzed event. In such cases, Weick and his colleagues argue, interpretation should precede choice as a unit of analysis (Weick 1993; Weick et al. 2009). This will form basis for the decision making process.

In conclusion, designers aim to think about problems first and set up a course of action correspondingly. However, due to the cognitive limitations in the design process, the meaning of actions can in many cases be reached only through retrospection. This constitutes the paradox of design that states that, although actions need to be planned for in advance, the true meaning of the plan only becomes available when the full range of its consequences are known.
3.2 Design Organization

Organizing the above described process of design is a challenging undertaking. Because the main planning problem constitutes in defining the problem itself, the form of organization should follow the ill-structured nature of design. Indeed, organizational hierarchies can cause problems in design consistency as people will use fragmentation of structure to delimit their domain of influence. As Rittel and Webber (1973) point out in one of the seminal works on planning theory:

"Under these circumstances it is not surprising that the members of an organization tend to see the problems on a level below their own level. If you ask a police chief what the problems of the police are, he is likely to demand better hardware."

This is precisely the reason why a design organization should be as flat as possible. In the traditional architect-led model, the responsibility of failed design would casually be passed back and forth from architects to engineers and vice versa. The same phenomenon holds true for the design/construction interface. The solution to this problem would be an ideally flat organization with equal contribution by the participants. Pahl and Beitz (1996), for example, advise the following strategy for engineering design in new product development:

"Simultaneous or Concurrent Engineering involves goal-oriented, interdisciplinary (interdepartmental) collaboration and parallel working throughout the development of the product, the production process and the sales strategy. It covers the total product life cycle and requires firm project management."

At least theoretically, this organizational strategy includes a flat professional organization where leadership is collaboration- instead of discipline-driven. The question of whether this kind of organizational structure is achievable within the built environment context is, however, subject to debate.

4. TOWARDS FINDING COMMON GROUND

This discussion suggests that the definition of design should be more inclusive than the current conceptualizations, to be able to represent reality more appropriately. At its most fundamental level, design can be categorized either as a disciplinary or phase-based series of interdependent activities that have, to date, mostly been elaborated independently.

- Phase-based conceptualization: In terms of a formal process model, such as the one published by the Royal Institute of British Architects (RIBA) (2007), those would be the tasks carried out as part of the preparation, design, and pre-construction stages.
- Disciplinary conceptualization: Based on the disciplinary domains, this would include a combination of the disciplines that participate in the design process: real estate development, architectural, and engineering design.

Covering all the above-introduced fields as constituent elements of design is purposeful because all of the components share characteristics of the planning problem. As a consequence, there is significant overlapping between the fields that can be observed at both the project and the firm levels of analysis. The most common property of the design process is that, as Cross and Knovel (2000) point out:

"...it can be easy for the designer to become trapped in an iterative loop of decision-making, where improvements in one part of the design lead to adjustments in another part which lead to problems in yet another part. These problems may mean that the earlier ‘improvement’ is not feasible. This iteration is a common feature of designing."

However, there are still some important differences between the components. These differences are mainly a result of domain-dependent approaches to the design problem. The three most widely cited
categories of design are architecture, engineering, and software development (Lloyd and Scott 1995). Even when combined together, the different design disciplines need to adhere to the properties of the construction process. Firstly, the one-off and uncertain nature of construction projects requires significant innovation and improvisation in the design decision making process. And secondly, construction projects need to also meet their respective institutions. As construction projects affect their societies, environments, and economies for prolonged periods of time, those are the constraints that need to be addressed in the innovative development process.

What would, then, be a common ground for defining, executing, and managing design and how would a design in the built environment be defined? Overall, the nature of the design problem, not professional membership or educational background, dictates what a designer should do. As Cross (1982) defined the general design discipline, this should not be any different when applied to the built environment:

“Designers tackle ‘ill-defined’ problems, their mode of problem-solving is ‘solution-focused’, their mode of thinking is ‘constructive’, they use ‘codes’ that translate abstract requirements into concrete objects, they use these codes to both ‘read’ and ‘write’ in ‘object languages’.”

If designing is considered profession in its own right, from the above discussion it becomes clear that design is more aligned with the innovation industry than the service industry. Therefore an inclusive definition of design has implications not only for the activities themselves, but also at a level of public policy. Although the institutional context of design has in many countries been regulated as a service within professional “chambers” or similar formal entities, an inclusive definition implies that design belongs to the domain of innovation and should be regulated accordingly.

5. CONCLUSIONS

The built environment can be considered a physical embodiment of the information created in the decision making process for which this discussion coined the term design. In its broadest sense, the process of developing the built environment is a plan for bringing the project into physical reality by means of a construction process. This discussion has laid out the foundations for mapping out a conceptual landscape of facility design from multiple perspectives. The discussion firstly introduced the basics of the general planning problem and the interpretive sensemaking approach to analyzing the design problem. The discussion offers an inclusive definition of design management for the built environment, in which the process is not constrained to mere architectural design or engineering of systems to be fitted into the facility. It includes the entire range of decisions made by diverse stakeholders in a construction project. Design is also not constrained to the initial phases of the project, which is to be discontinued as soon as construction activities are beginning. It is a continuous process that does not stop at any point in time in the project. Design is not even finished when the facility is fully operating or building occupied. It stretches well into the lifecycle of the building with its maintenance and, even, demolition.

The current concept of design management is the traditional division of labour along the design supply chain. One the one hand, urban planning and architectural design strongly implement criteria of aesthetic and social value into their processes, whilst focusing less on technical aspects of the project. On the other hand, however, engineering design is mostly considered a commodity in such a constellation of the process. In this representation, engineering is embedded into the architecture of the facility and, respectively, architecture is embedded into the urban planning of the area.

This paper differentiates between the conceptual and detailing components of each of the design processes. In this vein, each discipline, or part of the physical scope of the designed facility, reaches the concept solution in a different time-frame and subsequently elaborates the concept solution. In this representation, each part of the design affects its other parts. Therefore, the flow of design is not divided in terms of disciplinary boundaries, but in terms of conceptual solutions of each of its
constituent parts. This view calls for tight integration of the conceptual design tasks within a flat and collaborative design organization.

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Main Aspects for Modelling Networks of Practice
Probing network organizations for small- and sole- architectural practices

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Abstract: Networks of practice are increasingly important as resources to organizations. They are means to satisfying an objective or need, such as sharing knowledge or bringing products and services to the market. Practitioners and members of networks of practice have indicated the need for theory-grounded network models that respond to the members’ needs and ambitions. This paper presents a theoretical approach to the design of network models for sole and small architectural practices, with a specific focus on three main attributes: the production-oriented, the knowledge-sharing and the innovation oriented network. Using axiomatic design theory as a framework, we propose three design network models, each dealing with six main aspects of network activity coordination. The prescribed models give practitioners in emerging design networks the means to better understand, define and manage their organizations.

Keywords: architectural design; design theory; network models; network design; axiomatic design;

1. INTRODUCTION

In a broad sense, networks of professional practitioners (e.g. architects) can be described as complex systems with the primary function of facilitating “boundary-spanning cooperation, coordination and communication” (Gilchrist 2009); the emergence of networks can occur either in an ‘organic’ manner or can be ‘engineered’ (Gilchrist 2009). Previous studies have indicated that approaching networks with a unitary view of their morphology and properties prevents us from comprising all types of networks that can be found within and between various practices (Tegland 2008) (Seely Brown and Duguid 2000). In industries where networks are considered ‘strategic resources’ – even when regarded as merely ‘context for action’ – they become all the more relevant when shaped with a clear ‘managerial intent’ (Madhavan, Koka and Prescott 1998).

The literature about network and network design in particular, primarily draws on the social sciences to describe and explain what networks are made of and how they evolve (Podolny and Page 1998) (Hakansson and Svelota 2006). This literature typically fails to provide pragmatic clues and guidelines for creating and sustaining such an organization. In this paper we explore whether an axiomatic (engineering-like) approach to network design can be developed.

In this respect, axiomatic design theory has been mainly applied to the design of mechanical and technical artefacts – e.g. (Sang-Gook 2004), (Kwang-Hyeon, et al. 2003), (Clapis and Hintersteiner 2000), (Do and Suh 2000). Design work pertaining to social artefacts has mainly been drawing on non-axiomatic design approaches (e.g. (Boland and Collopy 2004); (Romme 2003); (van Aken 2004)). This article is part of an effort to develop an approach for defining and coordinating the activities specific to design networks. Its main focus is describing the use of Axiomatic Design (Suh 2001) and the Smart Business Networks theories (van Heck and Vervest 2007) in the development of three Design Network Models for design collaboration of small and sole architectural practices. The focus of the research is establishing a paradigm for creating and sustaining a formal network.

Design question:
How can a network organization be designed, given a specific theoretical framework and employing a science-based design method?

The paper proceeds as follows: in the first section, the theoretical framework used for defining the network organisation is described. In the second section an overview of the design method is presented, together with the questions driving the research. The third section focuses on elaborating the design steps. Subsequently, we will discuss the implications for researching and designing network organizations.

The framework provides the coordination mechanisms/processes of the network, which is to say they are the answer to the “what should be possible within the network” question, but they do not specify “how” and the outcome they entail. The design method is expected to provide the necessary steps in the mapping out of all the domains of the design: customer, functional, physical, and process.

The purpose of this study is explore whether an axiomatic approach can be effectively used to develop a design tool for creating and sustaining professional networks that is robust as well as practically relevant.

1.1 Defining networks

In the extensive network analysis theory, we come across a large variety of aspects through which a network can be described. The main aspects of network organisations encountered are the network structure, type, linking between the network’s nodes, the types of network users, or the network attributes. These aspects, however, have static qualities when attempting to translate them into organizational specifications, and as such, a more amenable and dynamic framework was needed. The adopted model for the framework was found in the Smart Business Network theory (van Heck and Vervest 2007). They are hereby introduced as the Network Coordination Mechanisms.

When having to define a network, we will have to consider all the above aspects and properties in the most efficient and effective manner. The structure, type, linking, attributes and users of a network assume, however, various values from network to network, and can change in time – even when dealing with one given network organisation. Therefore, in order to deal in “constants” we must look on a more abstract level, namely the mechanisms that shape the network’s structure, linking, attributes and user types – the network coordination mechanisms. They encompass the basic aspects of network activity coordination, and provide the primary indicators of the network performance. Based on the theory developed by van Heck and Vervest, they can be defined as follows:

| **Goal Setting** | The coordination mechanisms through which goals are set within the network, and the tasks and responsibilities assigned to each member; it has direct influence on the quality of set network goals (primary, secondary), and it affects other aspects of the network, such as the network members pool, and main domain of interaction and activity. |
| **Membership Selection** | The governance mechanism through which a network can decide which business entities can act as nodes of the network; it impacts on the selection procedure and criteria, and it influences the homogeneity level of the network values |
| **Linking** | The explicit choice of positioning and connecting of nodes to the other parts of the network; its outcome is the network topography, and it can influence the overall collaboration procedures within the network. |
| **Risk and Reward Management** | The protocol for the division of material results (profit and loss in a monetary but also in a fairly loose and generic sense) and the perceived value by each... |
of the participating business entities of its share; its direct outcome is a higher level of professionalization of the network activity, and has potential influence on the network’s goal, linking structure and the clustering within the members’ pool.

Continual Improvement
The organization’s policies and processes for joining and leaving the network over time – of network renewal and sustainability; its outcome is an intensification of focus on membership selection, and collaboration protocols, with an influence on the dynamics of the network itself and on the external contacts the network acquires.

Fault Tolerance
The network tolerance towards the malfunction of a node, or discontinuity by incapacitation; its outcome is reflected in the network’s internal policy stipulations on fault tolerance, and it influences the network’s support for individual members, as well as determining the network’s strength.

As we can see, the above mechanisms directly influence the relevance of each network attribute; they determine how the network is structured and how the network members are linked with each other. The network coordination mechanisms deal with the protocols behind the network goals, membership selection criteria and how the network conducts its internal and external issues.

1.2 Methodology

The following aim was set for this study (see Introduction section): can a social artefact, in the form of a network organization for design collaboration, be designed by employing a theory-grounded (engineering-like) axiomatic design method? We adopt the axiomatic design theory developed by Suh (1990; 2001) to develop a framework for network design, because this theory has set a standard for design methodology throughout the engineering sciences. As such, Suh’s The Principles of Design (1990) is one of the most cited publications on design methodology. The axiomatic design method (Suh 2001) involves four main stages, corresponding to the four design world domains: customer, functional, physical and process domain (see Figure 1 for an overview).

In the first stage, the designer delineates the customer domain, by means of establishing the client needs and attributes [CA]. The second stage focuses on defining the essential functional requirements [FR] of the design. These will then be used as starting points for mapping the third domain, by establishing the relevant design parameters [DP]. Fourth stage involves determining the process variables pertaining [PV] to the production process of the design. In any practical application of this
framework, designers go through many iterative cycles of identifying, (re)defining, developing and adapting client needs, functional requirements, design parameters and process variables (Suh, 2001).

(Suh 1990; 2001) provides two axioms that serve to make the design process and outcome more straightforward. They are the basic postulate for the axiomatic approach to design: the Independence Axiom and the Information Axiom. The first axiom states that “the independence of functional requirements (FRs) must always be maintained, where FRs are defined as the minimum set of independent requirements” (Suh 2001, p 16). The second axiom governs the informational content of the design, stating that “among those designs that satisfy the Independence Axiom, the design that has the smallest information content is the best design” (Suh 2001, p 16).

The subject of the research presented here was brought forward by the initiative within the industry: the XS pilot project which generated four collaboration networks who have contributed with information and feedback to the research and design process. The network program was created to support the activity of small and sole architectural practices from the Netherlands in developing their professional skill and increase their acquisitions, without having to expand their business. The pilot, known as the XS Rijnmond network, was initiated in late 2007, with limited experience on building formal networks for design collaboration, but with the support of Syntens.

The data collected during the case study from interviews with network members and the literature survey on network theories served as starting point for the design research presented here. From the data gathered during the interviews, we concluded the (members of the) networks:

• have little knowledge on how to define a network
• have an ill-defined scope/image for their network
• have individual/professional needs that they expect the network will meet
• have high levels of ambition for the network and their individual practice (they want to achieve various distinct goals)

As such, during the case study concerning the organization and optimization of design collaboration networks, the following aims were set:

• providing the networks with a shared definition of a network organization
• outlining Design Network Models based on the ambitions of the network members (continuity/professionalization, knowledge sharing, shared creative platform)

Figure 2 provides a schematic representation of the design method undergone for the development of the design network framework. In the remainder of this section, we elaborate on the aspects that each stage of the design process entailed.
The mapping and definition of the customer needs and attributes, functional requirements, design parameters and process variables draws on a literature review as well as on empirical data. The focus of the literature review of the network literature was to identify key parameters and variables in collaborative networks – such as network types (Tegland 2008), topography, linking and user types, network attributes (van Alsyntte 1997), and coordination mechanisms (van Heck and Vervest 2007).

Empirical data were collected by means of several case studies conducted in the Netherlands. We collected empirical data by means of semi-structured interviews with members of design collaboration networks (the XS networks) of sole practitioners in architecture that were recently created in the Netherlands, the technical chairmen of two such networks, and one former member of the pilot program for the XS networks. A preliminary version of the framework was tested during a validation and feedback workshop in March 2009. Members of four XS networks participated in this workshop.

The combined input from the needs and attributes of the network members in our case studies, the design and functioning of the collaborative networks themselves, and the reviewed literature were subsequently used to define initial Functional Requirements, Design Parameters, and Process Variables. These requirements, parameters and variables went through a large number of iterations, which served to further specify, demarcate and align the key elements of the framework for collaborative network design. The Independence axiom was instrumental in guiding this iterative process towards functional requirements that cover all primary aspects of the (intended) network organization, while being independent of each other. The Information axiom served to make the final framework as straightforward as possible.

2. FINDINGS

In this section we define and discuss the components of each design world domain. In the first part, we introduce the customer attributes and needs, as inferred from the empirical data gathering. The second part covers the selected design parameters, as established by the network theory considered for the research. Having established the customer needs and design parameters, we then define the corresponding functional requirements in the third part of this section. The fourth and final part covers the components of the process domain – the process variables.

2.1 Customer Attributes and Needs

By interviewing members of three XS networks in the Netherlands, and two of the technical chairmen of emerging XS networks, we gathered data on the attributes all XS network members share:

- an XS network member is a BNA architect
- the member is owner of a sole practice or partner/owner in an architectural practice with no more than five employees
- the member is geographically located and active in the region of a network
- the member shares an interest in the goal of the network

The empirical data gathered in the case studies imply the members of the XS networks (may) have the following customer needs:

1) Forming a network that would support the shared acquisition of design projects. The network should guarantee for its clients (and members) a shared standard of professionalization and
service, so that when one of the practitioners is incapacitated, a colleague would be able to take over the project work. The main attribute of the network should be the support and continuity of production (completing projects). We identify the network as production-oriented.

2) Forming a network that would enable practitioners to exchange practice-related information (pertaining to both professional and administrative activities). Through the exchange of information and insight, the network members aim to acquire relevant and up-to-date knowledge, contributing to their ongoing professional development. The network should enable the exchange of knowledge and information on the design practice; therefore it is identified as knowledge-oriented.

3) Forming a network that can serve as a motor and vehicle for collaborative projects between members and other creative professionals. The network should support the practitioners’ creative ambitions by serving as a platform for addressing creative challenges. Members have identified this as an innovation-oriented network.

These ambitions were expressed as most desirable aspects of the network activity, and although they were mostly mentioned together, each interviewee prioritised them differently. One of the primary reoccurring examples of a knowledge-oriented network need is for the collaboration and sharing of information for the advancement of the individual practices/network members. An example of a production-oriented network need is the requirement to obtain large-scale projects on a regular basis, whilst acquiring more interesting and challenging work is the key requirement for an innovation oriented network. Practitioners put personal emphasis on each of the described needs and ranked them according to their individual preference, therefore the above network attributes were identified as the starting points for the network design—the customer attributes.

2.2 Functional Requirements and Design Parameters

The next step is to outline the functional requirements for each type of network, according to each main Customer Need. In order to do so, we use the main six elements for designing networks, derived from the Coordination Mechanisms adopted in the first stage of network design research, as the Design Parameters. The generic framework presented therein (see section 1) is adapted here to the issue of designing design networks.

These six Design Parameters (initially derived from Van Heck and Vervest (2007) and subsequently validated in the interviews and workshops we conducted) provide a standard set of parameters for the all types of design network derived from the Customer Needs. The values of these parameters need to be optimized in relation of the network’s requirements and the three modalities stated above, as explained in this section.

The design parameters are as follows:

First design parameter indicates the nature of goal-setting and decision-making processes within the network, and how tasks and responsibilities are distributed amongst network members - network goal-setting. The need for an overall network goal and a goal-setting procedure that can bring practitioners together and focus their efforts was emphasized throughout all the held with the network participants. They signalled the lack of overlap between their individual professional goals, and stated

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7 Interviews were conducted with Nico de Gooier (XS Rijnmond), Tatjana Trzin, Robert van Kats and Jasper Klinkhammer (ISAC Amsterdam – currently Anet) and Sybren Steensma and Elly van Wattingen – technical chairmen from Syntens.

8 They were subsequently validated through a series of workshops in which network members were invited to describe their respective organizations using the proposed attributes. Network members found that the attributes help them to better understand and define their own organization.
that an explicit network goal that would incorporate their individual goals, to a certain extent, is desirable.

Second design parameter, as derived from the membership selection mechanism, is the member pool congruence. It is the parameter that dictates the quality of the member pool, in terms of homogeneity/heterogeneity level. The issue of member pool congruence emerges from two main aspects, intrinsic to network affiliation: the common characteristics that brings networking practitioners together (in this case their profession and the size and type of their practice) and the differentiating skills/knowledge/goals each member can contribute with. All interviewed network practitioners indicated that one of the main motivations to join their respective networks was exposure and interaction with professionals of similar statute, but with complementary assets. It is the balance between what is considered common desirable features and the diversity range of a members’ pool that this particular design parameter is regulating.

Network structure is the third design parameter and it determines the positioning and connecting of network members, namely the network topography. Network structure is closely determined by the type of activity being tackled. When asked about their practice of structuring the network topography for their usual activities, practitioners indicated they were not entirely aware of any specific structure they used. When asked to identify the how they grouped or divided themselves while undertaking a specific task for the organization, they were able to differentiate between several instances of network topographies, pertaining to one type of activity or another. This was taken as an indication that, even though not explicitly indicated and appointed, a network will adopt a specific structure that best enables its members to complete a given type of network activity. Therefore, addressing the issue of an explicit structure was selected as one of the network’s design parameters.

The fourth parameter indicates the balancing of risk and reward resulting from the network’s activities. Whether it concerns profit and loss, time, ideas or other resources, this parameter addresses the intra-network reciprocity. The assessment of what joining a network can require, but also yield for a practitioner is the only process all network members go through – on an individual level. From the self-assessment exercises the networks underwent during the validation workshops we were able to collect information that none of the participating networks had any system or scale for evaluating the intra-network reciprocity. Bringing the issue for discussion on a network level helps members understand the wider context of what is expected and desired throughout the entire organization. This parameter is necessary because it helps the network regulate the exchange of resources, and division of risk and profit between its members.

The fifth design parameter governs the network’s continual improvement process. Members’ in-flow/out-flow management determines a network’s capabilities and processes by which members can join and/or leave the network over time. At the start of the network design research, all participating networks were what can be considered as “young” networks, only in their first year of activity – with the exception of the pilot network, who had already past their one-year mark. As such, their concern with network member turnover had little if no time to develop. However, as time passed, networks experienced several members leaving their organizations while other practitioners expressed interest in joining. How these changes were to be managed and regulated was not translated into a network strategy, yet the network practitioners did experience the lack of such a strategy as a source of discontent with how the network functioned. When their attention was drawn to the possibility of addressing the matter through a network parameter, the network members recognized the value of adding this dimension to the network organization.

Members’ Integrity Level is the sixth and final design parameter considered, and it designates the values a network can assume for the assessment of a member’s ‘malfunction’ or incapacitation – a network-shared standard for fault tolerance. Much like the previous parameter, it was not an aspect that the networks considered and discussed in an explicit fashion. So why do we deem it necessary? A shared concept throughout the network of what separates a performing network member from a non-performing one allows the network to clearly assess its actual human resources. More so, a shared
notion of what is considered “operational” status for a members both sets a frame of reference for all members, and includes all members’ perspectives on what they expect to give to and receive from the network organization in terms of resources. While, each member has his/her own “yardstick” for assessing the organization’s viability for their own goals, the network should also adopt such an assessment standard, based entirely on the combined standards of its members. When this notion was proposed to the networks participating in the validation workshop, all participants agreed that this should be adopted as a key parameter for the development of their respective organizations.

Functional requirements represent the minimal and necessary conditions for the design of each network. In the axiomatic design approach, functional requirements reflect the customer needs and are governed by the two fundamental axioms: the Independence axiom and the Information axiom (Suh 2001). This ensures that the functional requirements are the minimum set of independent requirements that characterize the design goal, and that they are the smallest information content to ensure the best design.

We showed in section 3.1 that the design has to satisfy three separate customer needs: the production, knowledge-sharing and innovation oriented networks. The first part of this section implies that we will draw on one standard set of design parameters, their assumed values varying according to the functional requirements. In this respect, our analysis of the data from interviews and workshops suggested that the three customer needs, although complementary from the perspective of the user-customer of a network, are entirely antagonistic in terms of their design and implementation: for instance, while a within knowledge-sharing network, knowledge clusters are polarized by demand in a certain type of knowledge that is disseminated to members who require it, and thus aiming for a uniform distribution of knowledge – the same will not hold true in the case of a innovation-oriented network. Here, the knowledge and information available in the member pool is polarized by a design question/assignment, and the dissemination of knowledge takes a step back to the need for grouping complementary sets of skills and knowledge that can bring an innovative solution forward. While differences may seem subtle, the premises for each type of network are very different, from the requirements of the members’ pool variety to the procedures of exchanging knowledge.

Thus, our hypothesis is that, in order to satisfy the three main customer needs, three independent sets of functional requirements are needed. In the remainder of this section, we define the three sets of functional requirements based on the values of the design parameters that align to the specific customer need. The first set of functional requirements describes the production-oriented network:

- **Goal-setting** – in the production-oriented network we define the functional requirement for goal setting procedure as a formal one. The network has to operate under a well coordinated, top-down distributed set of goals and tasks, in order to ensure an efficient and effective production.

- **Quality of network’s member pool** - Low heterogeneity is desirable in the production-oriented network, as members have to join their efforts and knowledge in completing project tasks. Low heterogeneity ensures diminished differences in professional practice and increased efficiency in production.

- **Network structure** – Network structure influences/shapes the topography of connections between the members, how members group and how tasks and resources are distributed; therefore, it also varies with different network types. Because the production-oriented network operates with well coordinated, top-down distributed goals and tasks, its structure must accommodate this aspect. Therefore, a centralized network structure is recommended.

- **Intra-network reciprocity** – Within the production-oriented network, reciprocity will be desired and expected regarding the shared time and workforce for production - whether in equivalent service or remuneration.

- **Management of member turnover** – In order to establish a successful production network, members must be acquainted with each other and be able to establish long-term working
relationship. As such, it is preferable that the member pool does not change frequently and/or significantly over short periods of time. This network type requires a stable member turnover with carefully planned members acquisitions and exit strategies.

- **Standards for assessing members’ performances within the network** – for the production-oriented network we identified as a requirement the shared performance standards for all members. This is necessary in order to ensure that all network members adhere to the same guidelines for practice, and that project collaborations are not hindered.

In practice, the production-oriented network model is recognizable in the XS Rijnmond network organization. From interviews with two of the network’s former chairmen (Emile Quanjel, Nico de Gooier) and the network’s initial technical assistant on organizational aspects (Elly van Wattingen, Syntens Amsterdam) conducted during a case study on network organizations for architecture practitioners.

The aim of the network - at the time - was the consolidation of its members’ practices, and creating a common standard for the professional practice. These ambitions were expressed in a triple goal: professionalization, continuity and visibility. XS Rijnmond aimed to achieve these goals through market analysis and positioning of their organization within the market, defining their network activity focus, boundaries and profile, and developing a quality certification pilot together with TNO, for the assessment of organisational processes within the member practices. The quality assessment criteria subsequently became the network’s selection and yearly evaluation criteria for all network members. The current network profile describes the organization as a compact group, which can be easily identifiable and recognisable, and can work together efficiently, with their main focus on organisational processes, rather than architectural design. In their constitutional chart, they also stipulate that network goals are to be set through network meetings and periodical assessment.

To a lesser extent, the same premises for network organization were encountered (during an interview with network’s technical chairman Sybren Steensma) in the sister-network organization developed in the Haage Landen region, known as ArchiXS West. Its goals emulate those of XS Rijnmond: professionalization and visibility. ArchiXS West also uses similar selection and certification criteria and methods (same TNO certification). The network activity occurs in five work groups, each focusing on a particular topic, from PR to creating knowledge databases. Such a model of organizing network activity, however, is an illustration of the knowledge-sharing network model, which we will expand upon in the next paragraph.

The knowledge-sharing network model can be described through the following set of functional requirements:

- **Goal-setting** – in the knowledge-sharing network, the goal-setting is of consultatory nature. Knowledge-sharing activities have to be inclusive and accessible, but also have a clear and shared scope; therefore the decisions pertaining to how knowledge-sharing is achieved must also share these characteristics. Goals and task are assigned and coordinated horizontally.

- **Quality of network’s member pool** - Medium heterogeneity is preferable in the knowledge-sharing network in order to ensure that the network’s knowledge is periodically renewed and extended so as to not become obsolete with time. Perceived differences in knowledge and expertise between the members ensure a continuous flow for information, while perceived similarities guarantee the relevance and actuality of the shared knowledge.

- **Network structure** – Network structure influences/shapes the topography of connections between the members, how members group and how tasks and resources are distributed; therefore, it also varies with different network types. Horizontal distribution of tasks and goals benefits from a
structure that allows for several central nodes, but does not impose a formal hierarchy. As such, a decentralized network structure is recommended in this case.

- **Intra-network reciprocity** – for the knowledge-sharing network, the implicitly desired and expected reciprocity is the sharing of relevant knowledge of practice.

- **Management of member turnover** – In the case of the knowledge-sharing network, a steady flow of members entering and exiting the organization is expected. This is important for keeping the network knowledge from becoming obsolete, and also for expanding the areas of expertise covered by the network. As such, the organization is a permeable network.

- **Standards for assessing members’ performances within the network** – the knowledge-sharing network requires shared standards for the quality of knowledge. It ensures that the collected network knowledge is of quality and relevance to the members, but also that all members make relevant contributions.

The knowledge-sharing network model is embraced to a greater extent by both the XS Rijnmond and ArchiXS networks: the former through keeping a focus on aligning their production skills and administrative methods, and the latter by gathering information that would support their first network artifact (a public event to raise the network profile). Throughout discussions with representatives from ArchiXS, XS Haage Landen, XS Rijnmond and XS Zuid it was stated that knowledge-sharing activities were considered of great importance – if not vital – to the ongoing development of their organizations. Even so, the aspects of knowledge-sharing each network chose to focus differ from case to case. The main variable is in the aimed level of heterogeneity for the member pool: while ArchiXS was poised to include professionals other than architects, XS Rijnmond opted for a homogenous member pool so that the network professionalization would not be hindered.

For all networks interviewed, though, one aspect of their knowledge-sharing needs was found common: knowledge on gaining acquisitions. Most members had join their respective networks (as indicated in various discussion) with the aim of gaining knowledge of, and possible access to, new clients and new acquisition opportunities. As reported, the information – although in demand – is not readily available, and most members expressed concern over the terms upon which they could make such information available. Through discussion with two of the networks, it was identified that those organization lacked specific arrangements for ensuring satisfying intra-network reciprocity. Ultimately, the lack of this specification, combined with the lack of a clear goal-setting procedure, led to the disbanding of the XS Zuid network (as of December 2010).

The third set of functional requirements describes the **innovation-oriented network**:

- **Goal-setting** – the innovation-oriented network depends on the versatility and novelty of its activities. As such, it has to provide a favourable climate for participative goal-setting, both at the overall network level and within subgroups of the network. Thus, goals and tasks are defined and assigned from the bottom up.

- **Quality of network’s member pool** – High heterogeneity in the member pool is recommended in the innovation-oriented network so that it can access and use as many areas of expertise as needed for completing a given task. This requirement also ensures that non-standard associations and collaborations are not only possible, but also purposefully coordinated.

- **Network structure** – the network structure influences/shapes the topography of connections between the members, how members group and how tasks and resources are distributed; therefore, it also varies with different network types. In the innovation-oriented network it is essential that all members have access to each other and are fully connected. The structure of the network will, therefore, reflect this network necessity.
• *Intra-network reciprocity* – the innovation-oriented network relies on the reciprocity of *shared ideas*, as they are the main currency of the innovative practice.

• *Management of member turnover* – within the innovation-oriented network it is important that both ideas and people move freely. This should be reflected also in the network’s continual improvement policy, and therefore we recommend that the network adopts an *open access* stance with regards to member acquisition and exit decisions.

• *Standards for assessing members’ performances* – within the innovation-oriented network, members need to have a shared and detailed data bank on the *domain and level of expertise* of each network member. Its purpose is to serve the full connectivity of the network and encourage efficient project-grouping.

### 2.3 Process Variables

When mapping the final design domain – the process domain – we define the design’s process variables. They represent the ‘key variables in the process domain that characterize the process that can generate the specified design parameters’ (Suh, 2001). In the case of network organizations, this translates into the process variables which characterize the main processes through which the network’s design parameters are generated. Observing how this is achieved in the practice, we found that the process variables have different values from network to network; therefore it is of use to define the process variables for a network model on a more abstract level. In this section, we describe the function of each process variable, and leave its values to be decided by the practice – according to the needs of the network and its members.

The first process variable characterizes the process that generates the network’s goal-setting process. This design parameter satisfies the network’s functional requirement of having a formal, consultatory or participative goal-setting procedure. Depending on the choice of procedure, the time for participants will vary. A formal goal-setting procedure (typical of a production-oriented network) will require all network members to be present at one time, thus significantly increasing the duration of the procedure. Correspondingly, the participative goal-setting procedure being more flexible in its attendance requirements will be expected to show greater variations in the duration of its proceedings. Another aspect to consider as a variable aspect of the goal-setting procedure is the structure of the procedure itself: while the formal goal-setting procedure may require advanced preparations and a clearly defined structure made known to participants in advance, a participative goal-setting meeting can easily take on an informal character being conducted similarly to a brain-storming session. As such, we identify the procedure for (re)assessing and defining goals and availability/available time for participants as the first set of process variables.

The second process variable identified is linked to the parameter of member pool congruence. The process characteristic that determines the level of heterogeneity/homogeneity in the member pool is the full network profile for the existing members, and a shared perception of what is a desirable member profile. Therefore, we propose as the second process variable a comprehensive members’ profile database.

The third process variable pertains to how the network structure is defined. When asked to give information on this aspect of their network activity, practitioners indicated that their respective network’s structure is dependent on the type of activity the network is performing, and can change from activity to activity, according the specific linking needs of each network pursuit. We identify the third process variable as the type of network activity undertaken at a given time.

When considering the intra-network reciprocity parameter, we find that networks have particular approaches to regulating the network reciprocity. On an abstract level, these can be summarized as a
combination of shared perception of values/valuables, and an explicit “exchange rate” between the available/shared resources. We propose the above as the fourth set of process variable.

The fifth process variable set is defined in relation to the network’s procedures for the members’ in-flow and out-flow management. Regardless of whether the network organization requires having a large or small member turnover, it is essential that members’ in-flow/out-flow is managed by using entry and exit interviews, as well as periodic feedback from both current and former members.

Lastly, we consider the process variable pertaining to the procedures of our last design parameter: the members’ integrity level. In practice, this network design parameter seems to be the least acknowledged, considered implicit and fulfilled by a member’s wish to be part of the network – and his subsequent acceptance. During several self-assessment sessions, network members have indicated that this aspect of their network organization is based on the shared level of expected and desired trust members have in each other. This notion is further supported by the members’ expected professional growth within the network. Thus, we propose the level of mutual trust and individual growth as the sixth process variable.

Although the components of each design domain are presented here in a linear succession, the process of identifying and defining said components was of an iterative nature, with a number of intermediary steps. In order to summarize the notions discussed in this section, we offer an overview in Table 1.
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3. DISCUSSION AND CONCLUSIONS

In the first section we formulated two main goals to be achieved with this article: a) to test the framework selected to define networks, and its applicability in practice; and b) to test whether the application of a theory-grounded design method offers us additional insight in understanding and solving the network design problem. In this section, we will discuss the conclusions we reached in the course of this exercise.

Even from the early stages of this study, when the basic framework of coordination mechanisms was presented, there was a positive reception of the insight and structure it brought to the network practices of architects. Subsequent developments in the design framework were repeatedly tested in workshops held together with one of the networks who decided to apply it. The networks indicated that the provided information on how to define and design their networks is comprehensive and clear. They also evaluated the framework as an open concept which allows them to customize the organization to their needs, rather than being a constraining “to do” list. This comes in support of our secondary design aim: providing professional practice with a model for defining and structuring their networks, rather than a predefined organizational model. As a result, two of the networks that provided feedback indicated that the proposed models enabled a certain separation and differentiation of network activity goals.

The ambiguous nature of intended activities was a major difficulty that networks encountered in achieving their goals. Our analysis demonstrates that network needs and design criteria can get easily mixed and therefore network organizations fail to deliver what they promise. As such, we concluded that small and relatively under-resourced networks benefit from limiting themselves to one type of network or activity focus (using the models provided in this study as a framework) in order to ensure network productivity. As the networks grow, and their resources become more substantial, they can also support multiple needs simultaneously by differentiating their organization in subsystems that are managed differently (according to the particular need addressed).

When it comes to designing a social artefact such as a network, and developing a model for it, the methodology of Suh (2001) proved to be instrumental in structuring the design. This is achieved by compelling the designer to look for one-on-one connection between the design components and to apply the two axioms ensuring that the end design is as lean as possible. Another positive outcome is that by using axiomatic design, the designer is encouraged to pursue and achieve the appropriate level of abstraction, when it comes to instrumentalizing a social artefact, by means of design parameters and process variables, which are – to a certain extent – generic.

We also found that by applying the axiomatic design method, a connection was made between the theory behind the coordination mechanisms of a network and the current needs of the practice. While the literature (van Heck and Vervest 2007) discusses the organization of networks for members with complementary professional backgrounds and services, previous studies proved insufficient when implemented for networks where members offer the same (or very similar) professional backgrounds and services, and have limited resources in participating in network activities. The design premise for the network models presented here thus became an exercise in differentiation, rather than creating and all-purpose network model. By mapping the design into the four domains, and using the axioms as the iterative framework, we were able to ask the right questions when defining the main components of the design. Nevertheless, we continue considering and scanning for other relevant network designs, as further research in the specifics of defining the network design process variables will serve to respond to more specific network needs.
4. REFERENCES


Assessment of Buildability Information by a Bayesian-based Evaluation Model

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Abstract: Construction design is a process through which the designers render the client’s needs into a practical solution. The processes during construction rely heavily on the availability and transfer of information between all stages and parties involved. The construction process is a fusion of several disciplines and so requires a multidisciplinary information flow. In the digital information age there is an urgent concern that the right information needs to be transferred in the right format and quantity at the right time to the right person at a reasonable cost over a multi-principles information platform. This paper aims to examine the optimum level of information quality and value for construction sites in order to minimise errors (e.g. human error, drawing error, and information interpretation error). A questionnaire survey was conducted among designers and site managers in the UK to collect their perspectives on the quality and value of information being produced by designers and its utilisation on site. An information evaluation model was developed on the basis of Bayesian network theory to evaluate the collected data. The result of the research indicated that information from the various disciplines must be integrated to enable collaborative design and production in construction; although it is clear that high value and quality information is needed, the interpretation of high quality and value information varies significantly among the stakeholders. This paper examines the attributes of information value and quality for use by designers and site managers. Further research is recommended into the costs and benefits of high value and quality information generation.

Key words: value, quality, evaluation, collaborative production.

1. INTRODUCTION

Construction design is a process through which the designers render the client’s needs into a practical solution. Every activity within the construction process i.e. designing, planning and management, is done to ensure the smooth flow of activities in the future. The progression through construction stages depends on the availability and transfer of current information for future application. The main disconnection is the transformation of information from virtual to practical (Johnson, et al., 1998). The significance of information is known by every stakeholder from the start to the completion of the project (Mitchell, 2006). The construction processes as a whole, the information at every stage in each phase needs to be reviewed and as a result grows in maturity. It is processing and accumulating in maturity accordingly until the information being produced by the designers reaches a satisfactory level of maturity for its use.

The application of digital design tools, such as Building Information Modelling (BIM) breaks down certain information flow barriers and at the same time bridges communication between extended design and construction teams. It is recommended to adopt BIM to meet the demand on “new levels of quality in construction and new services in order to deliver the 40-year carbon reduction programme” (BIS, 2010). A mechanism for the justification (e.g. costs and benefits) on using BIM has to be provided (BuildingSMART, 2010). Commercial data from the UK construction sector also showed
that a consistent reduction of 8-18% of cost associated with design stages C to E of RIBA, including concept, design development and technical design and 8-10% during pre-construction stages including production and construction stages, while the upside potential of saving could be as high as 40% (BIS, 2011).

This paper focuses on designers’ and site managers’ benefits from the utilisation of optimum level information being produced by designers, as designers and site managers directly utilise information during construction stage. In an ideal scenario, the value of information can be interpreted as the information capacitated to a level of optimisation where it can convert itself into practicality without any influence from external influence (Lee, et al., 2000). However as a construction process is an amalgamation of multiple disciplines, the information consists of the data from a range of disciplines (Isikdag, 2008). It is essential to understand the perspectives from designers and site managers about information value, to establish the link between the significances of diverse information attributes towards information value and quality. In this research, the perspectives were collected by questionnaire method addressed with designers and site managers. In order to examine optimum level of information (value of information) provided on site in a way that it minimises the scope of errors, an information evaluation framework was proposed by introducing Bayesian network method to evaluate the information value and quality (Friedman et al., 1997).

2. CONSTRUCTION INFORMATION

Information as an aspect of every action during construction process is a key unit for progressing, processing and understanding an activity (Engeström, 1999a and 1999b). Information generates from the data accumulated by the stakeholder, in construction the accumulated data becomes the information when it is mature enough to flow from one discipline to another, which is called mature information. Information that is not capacitated enough so that it will flow from one stakeholder to another is considered to be immature information. Figure 1 below presents the information generation among the stakeholders in a construction process.

![Figure 1. Information generation on construction](image)

Construction is a unique discipline; it is a process, it cannot stay alone, and it is an amalgamation of different disciplines to create anything, everything, and sometimes nothing (Isikdag, 2008). The construction process is a way through which design gets synthesised into practical form. The most important process is the information flow from origin (client) to the end (user/product). Flow of information in business terms is known as communication. Communication is exceptionally a multidimensional flow of information as shown in Figure 2. In construction stage, stakeholders are
dependent on each other for information exchange, because every action becomes practical, based on the information provided to them. Built form is a unique combination of different disciplinary information. All the information is uniquely designed, structured and applied to complete a project.

As for the increasing complexity if a contemporary construction project designers or site manager X has to communicate and work with different stakeholders A, B, C, D, E and F within the project (see as Figure 2), it is hard for designers/site manager X to bring out all the information for the resolutions against decision problems during construction stage, so they have to aid for help from other stakeholders, such as his/her colleagues or documents, drawings, models and databases. In other words the capacity of designers/site manager for retrieval and utilisation of high value and high quality information is vital to the success of the project during the construction stage.

During communication process one of the difficulties is to predict the information, on which the future action of an individual or an organisation depends. This happens because information becomes mature and optimum along with the progression of practical activities taking place in the process, the greater the value and quality of information on which the practical activity depended, the greater the information maturity is, and therefore the greater the progress on information certainty.

3. DESIGN AND KNOWLEDGE MANAGEMENT IN CONSTRUCTION

The Latham (1994) report proclaimed that the main reason of poor communication between stakeholders in a construction project is the fragmented nature of construction industry, which in a way impedes delivering collaborative production or construction in constructional context. Management of any aspect is the business side of the said discipline. Similarly both design and knowledge management are the business side of design and knowledge respectively. Design management (DM) as a discipline acts on two different thoughts first being organising a design firm, and second aims to better understand the design process (its nature, stages and activities) in order to improve communication and coordination mechanisms (Tzortzopoulos, et al., 2007).

In terms of handling design, it is a complex activity which has various managerial issues. “Complexities lie within the technical knowledge, information availability, the uniqueness of design and interactions between different stakeholders” (Sebastian, 2005). Design and its management became a necessity when projects got more complex and the market competition pressure started playing major roles in deciding the fate of projects. DM is always seen through the eyes of design stakeholders and not all, that is a gap between design and construction professionals (Tzortzopoulos, et al., 2007). In the digital information age, designers and site managers get the information and data from the mediums including blue prints soft copies, telephonic conversation, email, intranet and so on. Knowledge in construction is available in abundance, the trick is to manage this wealth in a way that it is properly communicated and applied. Knowledge management (KM) is a process which helps in
integrating different construction issues in a space containing people, process and technology. Knowledge is personal and stays in people’s head, while information needs to be recorded/codified and the processes of their transformation process called personalisation and codification. (Tang et al., 2007; Raisbeck and Tang, 2009; Tang et al., 2010). “It has been estimated that defects in the UK construction industry costs at least £1 billion to repair or rebuild every year (Crocker, 1990)”. Most of this loss is due to the inefficient use and communication of information. It is very difficult to a balance or optimum point between these two processes.

The basic difference between design and DM is that design is the information and DM is the process which gives meaning to that information. Similarly DM and KM cannot function in each other’s absence. BSI9 knowledge Management vocabulary (PD 7500) KM is defined as “The creation and subsequent management of an environment which encourages knowledge to be created, shared, learnt, enhanced, organized and utilized for the benefit of the organization and its customers.”

![Figure 10. Data to knowledge transformation in a construction process: A DM and KM integrated perspective](image)

Figure 3 shows the relation of design and knowledge. It is reflected that a construction project as a whole not only in the construction stage but in every discipline of construction process needs knowledge to be managed effectively so that products and services can be delivered successfully on time and under budget. There are different approaches being introduced for DM or KM in the construction sector, i.e. Adept (Austin, et al., 2001), Microsoft project and process protocol. Although some models like these are associated with streamlining information flow however there is no single approach which integrates KM and DM together to create a singular platform (Alavi, et al., 2001), in particular focusing on the value and quality of information. Management of design involves managing routine and non-routine design information produced by designers, in a way that it corresponds to further buildability stage. It strengthens information to a level where information is gathered and integrated from every discipline involved in the process to make it contactable (Alavi, et al., 2001). If the process, of knowledge management is analysed, then it resembles the similar path adapted by any management including DM. KM is about an environment, which facilitates knowledge, production, enhancement, learning and utilization to its complete benefit. So, DM and KM are the parts of an information-integrated system (Markus, et al., 2002).

4. VALUING INFORMATION

“When information needs to be valued – for example, in the calculation of either costs or benefits of information – the commonly used evaluation methods are inadequate because of its tangible and intangible characteristics” (Zhao, et al., 2008). Value is the essence of every action in today’s information age wherein every action is judged and dependent on its value. Information is considered as a commodity and posses as an asset, it has become an element of commerce (Fenner 2002), e.g. a

9 BSI: http://www.bsigroup.com
piece of physical product information goes through quality control before getting distributed. In today’s world information is either purchased or exchanged with other information. Masterman et al. (1994) developed five significant customer wants or value in a construction process: final cost certainty, completion date certainty, value for money, and finally having the lowest possible tender for work. So it is difficult to set value for construction process itself, its unique to the project and stakeholders involved.

In general value is perceived in many ways, for example (Darlington et al., 2008; Zhao et al. 2008): Value = profit / loss, worth / cost, benefits / sacrifices etc. These relations are more general which everybody uses in their day-to-day life to make decisions. The decision of value is based on the expected reaction of that action. The expectancy factor introduces the important aspect of value which is probability. Probability of every expected reaction affects the value of any action or information. So equation 1(a) can be rewritten more correctly as: Value \( \approx \frac{\text{profit}}{\text{loss}}, \frac{\text{worth}}{\text{cost}}, \frac{\text{benefits}}{\text{sacrifices}} \). But it is very difficult to measure the value of information according to the cost system because of its explicit and implicit characteristics. Explicit information cannot stand-alone, it does not have any value singularly it must be accompanied by implicit characteristics in order to get processed. Information characteristics are also non physical in nature e.g. Information is not necessarily a physical product. Information can be produced at little or no cost. Each unit of information is different from every other. But buying the same product again and again does not include the cost of information because buyer already knows that. For a product based industry the majority of the information is hidden for the buyer. Further, “anything that makes it easier, faster and better value for money to find and deliver a relevant document adds value” (Philipp, 2005). By placing value on information a decision-making process gets quite evident. Questions like what to retain, discard and process start to have more meaning in any process. Many technologies came into being since last 20-30 years to achieve value on information i.e. concurrency management, new push technology, intelligent agents etc.

Although there are stresses on the needs of value on information in the construction industry, the characteristics of information flow during a construction process get numerous errors and gaps (see Figure 4). The act of converting the futuristic contextual information from virtual to real comprises of many steps and hence the probability of confusion and errors increases. Many different professionals are working in parallel on different facets of the same projects. The idea is to fill the gap and get rid of errors involved in order to make the process more efficient. The simplest example is client oriented design information (Leite, et al., 1995) for assembling furniture for ex-IKEA furniture. The cost of information is included with the product when customer is buying. So the principle of cost and benefit analysis can be tested in the programme. If one sees clearly in the product brochures of IKEA the integrated information is segregated accordingly and it is simple to understand by the user e.g. as shown in Figure 5.

![Figure 4. Occurrence of errors in the information flow](image-url)
The information IKEA provides that are affixed with the features of high value information presented by Philipp (2005). The design information is published as 3D graphics that is in a form of pamphlets as the marketing strategy. Every product comes with detailed instruction documents, which is graphical in nature, which helps customers in assembling their respective products. These detailed instruction documents act as high value information documents to both customers and the company, which support an optimised approach of conversion between implicit and explicit knowledge (Tang et al., 2007; Tang, et al., 2010). As information is multidimensional and every action will have multiple effects on different aspects of value of information (VOI), interestingly this action of taking customers into the process has incorporated cost as well into the VOI.

![Figure 5. A high value information document (Source: IKEA Furniture’s: http://www.ikea.com/gb/en/)](image)

Similarly it seems like a plan for information flow (or a high value design plan) before the construction phase commences. The planning is needed to reduce the errors and cost overruns. Planning is a way through which a programme is formed to act on a particular project. It is a programme, which facilitates information to flow throughout different stakeholders for the on-going project. As for an adoption of IKEA added value information concept, the scenario working on a construction site would be, a designer/site manager X receives the design information published in a form of 3D effect manual, every activity or process at each stage comes along with this detailed instructive document, he/she or other associated stakeholders will get the ideas of what they are doing and going to do after at their respective work stage. Furthermore this high value information flow helps stakeholders to be aware of others’ progress, this enables every stakeholder to have an overall picture on the underway project progress and work cooperatively. It also facilitates collaborative production that is relying on this high value information flow.

5. **RESEARCH METHOD**

Information value and quality analysis ensures any potential losses explicitly stay away from errors and uncertainties during a decision-making process (Mussi, 2004, Yokota, 2004, Cox et al., 2006,
Knowledge, as from valuable and quality information, can be advantageous for companies, furthermore for the success of companies (Walters and Lancaster, 1999). However it can be negative to daily and even overall operation of company if the value and quality of information cannot be measured and managed properly and hence to select the optimised decision during the life cycle of a project. There are some researches in relation to the value and quality of information being undertaken by various scholars, such as Fenner (2002) who gave a summary about how to place value on information; Weissinger (2005) who raised a theoretical basis and analysed the perspectives and perceptions towards the evaluative nature of information, for instance its materialism, idealist and metaphysical; Oppenheim et al (2000) who focused on how to value information as an asset in companies from peoples’ stand-point. The above methods covered issues and considerations and some of factors that need to be taken into account in this subject domain. Regretfully none of them provided specific technique that can be applied to the evaluation of construction design.

A questionnaire, in this paper, is used as the core tool to collect data. A questionnaire has been shown to provide the sort of experimental understanding that the study aims to achieve, in the consideration of this the questionnaire was designed based on a previous study by Gunhan and Arditi (2005) which coincides with the aims of this research. Subsequently an information evaluation process model using Bayesian Network (Zhao et al, 2008) will be adopted and tailored which can help evaluate the information value and quality by metrics.

5.1 Model Training and Validation Pilot Sample

The measures for constructs in the research model are on the basis of Bayesian technique, which is adopted to extract knowledge from information by converting qualitative data into quantitative. It has several stages, which take researcher from data to the probabilistic results. This research focuses on benefits of buildability information being produced by designers to site managers (Heckerman 1996). The model training and validation tests comprise of a small sample of designers and site managers in construction teams within the UK. Based on Nueman’s (2003) recommendation, a sampling frame was developed by searching various, including the designer firms, main contractors. 30 individual including both designers and site managers were invited directly because of the nature of work at the time of the study that was closely related to the context; it was at the time where designers handover design information to site managers. The survey was conducted from June to August 2010. A total of 30 questionnaire packages were sent by e-mail. In each pack, there was one invitation letter and one questionnaire (see section 5.3 below). When the survey was completed, a total of 10 questionnaires were received, producing a response rate of 30%.

5.2 Data Analysis

5.2.1 The Bayesian Network Model

The probability of the attributes to site manager’s perspectives on information value and quality is derived from a developed Bayesian network. Zhao et al. (2008) explained the framework and information attributes interdependencies (see Figure 6).

Information quality can be assessed by breaking information down into its attributes. Information value to site manager needs to be analysed by measuring benefits. According to Zhao et al. (2008) the information evaluation framework evolved from an equation, which depends on two hypotheses considered in the engineering organization study.
Two hypotheses were: (a) The context more specifically, the relevance is an explicit factor that affects the value, judged from the result of analysis” And (b) The information attributes in the model does not include costs because there are other losses such as time, effort, resources, opportunities as well as negative outcomes which are hard to get included in cost. Saving attribute of information is the inverse which is considered in place of cost as an attribute.

Equation 1 (Zhao, et al., 2008)

(a) Information value = Benefits of Having Information / Resources Speding on Storing and (b) Retrieving information = (Quality + Relevance) x Saving

“It’s shown that BNs are directed acyclic graphs (DAG) with a set of probability tables” (Zhao, et al., 2008). This network establishes the dependency between each attribute and the combined dependencies with the respective parent attributes. These dependencies and interdependencies work on the probability of one attribute over the other. Zhao et al. (2008) explained the same with formulae; basically Bayesian roles are for any two events, A and B,

Equation 2

\[ P(B|A) = \frac{P(A|B) \times P(B)}{P(A)} \]

Where \( P(A) \) = Probability of A, \( P(B) \) = Probability of B, \( P(A/B) \) = the probability of A given that B has already occurred and similarly \( P(B/A) \) = the probability of B given that A has already occurred. For example taking two attributes from information evaluation framework as shown in figure 6, i.e. value and accuracy, the probability of ‘information value’ (in the ranges of high, mid, or low), can be calculated from equation 1 as:

Equation 3

\[ P\left( \frac{Value}{Accuracy} \right) = \frac{P(\frac{Accuracy}{value}) \times P(Value)}{P(Accuracy)} \]

So, the joint probability function will be:
For the above equations, a systematic model is designed on Bayesian network model basis.

5.3 Information Evaluation Model for Designers and Site Managers

The information evaluation framework for designers and site managers is tested in the Bayesian model to define the essential attributes of information value and quality. To achieve the objective a questionnaire technique is adopted because it acts as a basis of data collection to transform into Bayesian network system (Zhao, et al., 2008). The statistical data received is transformed in to CPT (conditional probability table) based on equation 4, which is the basis of BN model. Steps involved in defining information evaluation model are as follows:

Step 1: A questionnaire is prepared considering the established information attributes (see Figure 6), which affect information value and quality as shown in Figure 7. Questionnaire is designed such that all the answers received in the format of opinion (Agree, Disagree and neither of the two) for example ‘the information provided on site has errors’ can be answered as agree, disagree or neither of the two. This question indicates to the accuracy attribute of information. The relationship between the answers and variables of high, mid and low is done as follows: Agree = high, disagree = low and neither disagree or agree = mid. The data from the questionnaires is transferred and reorganised to summary sheet.

Step 2: The data from the summary sheet helps in building up the CPT. The CPT represents every linkage in Figure 6 mathematically.

<table>
<thead>
<tr>
<th>Information Attributes</th>
<th>Value to the site manager</th>
<th>Questions</th>
<th>Decisions</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>Degree of conformity of a measure to a standard or a true value. Level of precision or detail and closeness to reality.</td>
<td>Information provided on site has errors. Information cited is by recognised authority. Information is reviewed before handing over to site.</td>
<td>Agree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Trust</td>
<td>The confidence level of the information.</td>
<td>• Information authorising organisation is identifiable. • Author’s qualification, position, rank and experience increase the credibility of information. • Purpose and reputation of the organisation increases the creativity of the information.</td>
<td>Agree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Usability</td>
<td>To be user friendly in all aspects.</td>
<td>Information provided is clear and descriptive. Graphics of the information adds value to the understanding. Information is readable, legible and complete. Information is structured appropriately and logically.</td>
<td>Agree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Currency</td>
<td>The quality or state of being up-to-date or not out-dated.</td>
<td>Information is structured appropriately and logically.</td>
<td>Agree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Quality</td>
<td>The totality of features that fulfil stated or implied needs. The correspondence to specifications, expectations or usage.</td>
<td>Information is good in general terms.</td>
<td>Agree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Relevance</td>
<td>The overall closeness that the information can be fitted into the context.</td>
<td>Information is relevant to your needs. Content of information is suitably general/detailed. Content of information is novel/accepted. Coverage if the information is sufficiently broad for your needs.</td>
<td>Agree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Saving</td>
<td>The time or money that can be saved by using the information.</td>
<td>Information provided is of a standard that it save money, time and can be archived.</td>
<td>Agree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Value</td>
<td>Benefits/Sacrifices</td>
<td>Information is valuable to me and my department.</td>
<td>Agree</td>
<td>Disagree</td>
</tr>
</tbody>
</table>

Figure 11. A sample questionnaire for collection of designer and site manager’s perspective on information being produced by designers
Step 3: CPT data is then transferred to BNs to get an information evaluation assessment model as shown in Figure 8.

Figure 8 shows the full process of getting an information assessment model through 10 designers and site managers. The value judgement of the attributes relies on all the attributes. Similarly, the value for designers and site managers depends on the attributes for which the information is being analysed. Figure 9 shows the frontal evaluation model before any judgement has been made. All data from the CPT is transformed to BNs and dependencies can be analysed by changing the variables of any attributes. If accuracy variables are increased or decreased then the effect on value and quality increases or decreases respectively. For example, as shown in the latter model in Figure 10, the ‘accuracy of information’ attribute reaches ‘mid value’ that is increased to 100%, simultaneously its information quality of ‘mid value’ is changed to 64.5%. While before doing this sensitive analysis, ‘accuracy of information’ is on 61.3% and its quality is on 52.8%. This phenomenon indicates that every attribute of information works together to yield an optimum value and also the quality of information as the designers and site managers perceive.

Figure 9 indicates that if the ‘accuracy of information’ is 61.4% then the probability of information being qualitative and valued to the designer or site manager is only 52.8% and 33% respectively. As Figure 9 shows that information value is not directly affected by context-independent attributes including ‘accuracy of information’, ‘trust of information source’, ‘currency of information’ and ‘usability of information’, they do affect but via information quality. So, there are only three context-dependent attributes which are ‘savings’, ‘relevance to the decision problem’ and ‘quality of information’ whose changes will affect information value. Please note that in this case, the numbers in Table 1 shows that site managers are not completely sure about the information they are getting on site.
Figure 8. Process for the information evaluation model (running with the first 6 site managers)

Figure 9. Frontal information evaluation model

Figure 10. Latter information evaluation model
6. COST AND BENEFIT ANALYSIS

As said, the scenario of applying IKEA information flow theory shows that information in forms of readable, visible, sensible and accessible can bring certain benefits to different stakeholders. The relation of value to stakeholders, such as information providers and information users, is displayed in Figure 11. It clarifies that information value means differently to different stakeholders, which can be measured by two main factors, benefit and cost.

![Figure 11. Value relations between the information provider and user](image)

In this paper, one of the focuses is on information cost at the construction phase. All clashes like, stakeholders’ interests, clashes in information provided and misuse of personal knowledge and so on are taking place at this stage. Suitable cost estimations against its associated benefits received are necessary. This comparison must be executed to assure an optimised decision is made for a decision problem on site. In practically designer or site manager uses two types of tools to do estimation (Jones, 2010), one is top down estimate and the other one is bottom up estimate. Table 1 shows the comparison of these two approaches.

<table>
<thead>
<tr>
<th>Table 1. Comparison of cost estimate approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Top down estimate</strong></td>
</tr>
<tr>
<td>Advantage</td>
</tr>
<tr>
<td>Disadvantage</td>
</tr>
<tr>
<td>Suitability of project type</td>
</tr>
</tbody>
</table>

A proposed relation developed in accordance with the cost estimate approaches for the project are:

\[
\begin{align*}
Ce &= Be \\
Ce &> Be \iff Ca &> Ba \\
Ce &< Be \iff Ca &< Ba
\end{align*}
\]

Where, \(Ce = \) Cost estimated, \(Ca = \) Cost achieved, \(Be = \) Benefit estimated, \(Ba = \) Benefit achieved.

The most ideal situation is therefore:

\[
(Ce < Be) \iff (Ca < Ba)
\]
But in reality the cost estimated \( (Ce) \) is different from the cost achieved \( (Ca) \). So it is essential to keep a check on this relation on every stage of the project. Generally every project has three significant costs available for every activity i.e. the estimated cost, the processed cost and the final cost. These costs are different by default for every project because of project specifications being altering in every aspect e.g. Client requirements changes, unavailability of material, and force majeure and so on. Cost and benefit are two sided of the same coin. In informational context of construction, benefit is the value of information provided to an individual working in that context. Cost is the straightforward cost of producing and delivering that information to that individual. To conduct this in the construction sector, it is necessary to break down the information cost from every discipline and then combine the segregated costs for particular information. That is a tedious job and there are no tools available to do such informational costing while it has been addressed in this paper. The model presented herewith can provide feedback information for the designers to improve the value and quality of production of design information. There is a necessity to carry further development of the tools along the life cycle of a project e.g. in the post-construction, use and facilities management stages with more real case studies which is the major future work of the research. This further contributes to the tool development on the justification on using digital design models e.g. BIM throughout the life cycle of a project.

7. CONCLUSIONS

Construction is a process that is multi disciplinary in nature. The call for collaborative production in construction gives pressures to the industry to have an integrated platform. This paper found that the way for construction process integration is to have integrated information for construction productivity based on design and knowledge management perspectives. Information earns its value or adds its value after the application when it is converted from virtual to practical. Construction process is an information flow process; the information becomes mature or optimum along with progressing construction activities, an improvement of information will increase the information maturity and its optimisation level. It is always the certain, high value and high quality information upon which successful practical activities depend. Information is also an aspect of every decision or activity, the relationship of design and knowledge shows that the construction project as a whole not only in the construction stage but in every discipline of a construction process needs knowledge to be managed effectively and efficiently. An efficient working process facilitates a communication environment which the creation of environment encourages the process of creating, sharing, learning, enhancing, organising and utilising information. As shown in Figure 10 accuracy variables are increased or decreased then the effect on value and quality increases or decreases respectively, the ‘accuracy of information’ attribute reaches ‘mid value’ that is increased to 100%, simultaneously its information quality of ‘mid value’ is changed to 64.5 %. While before doing this sensitive analysis, ‘accuracy of information’ is on 61.3 % and its quality is on 52.8 %. This phenomenon indicates that every attribute of information works together to yield an optimum value and also the quality of information as the designers and site managers perceive.

In this paper, the study of IKEA information flow concept showed that the significances and benefits of establishing an integrated high value information platform helps reducing the errors or misinterpretations during the conversion of contextual information at the construction stage and improving the conversion of personal knowledge and codified knowledge.

Although the application of high value information created by the concept of IKEA information flow, shows that how information in forms of readable, visible, sensible and accessible can bring certain benefits to different stakeholders, however information cannot be meant as high value as the same for every stakeholder in a general terms because every stakeholder has a function to perform. So the high value information towards each stakeholder they are looking for, in a document is always
different. Hence the value of information to everyone is different from the other. Figure 9 indicates that if the ‘accuracy of information’ is 61.4% then the probability of information being qualitative and valued to the designer or site manager is only 52.8% and 33% respectively. As Figure 9 shows that information value is not directly affected by context-independent attributes including ‘accuracy of information’, ‘trust of information source’, ‘currency of information’ and ‘usability of information’, they do affect but via information quality. So there are only three context-dependent attributes which are ‘savings’, ‘relevance to the decision problem’ and ‘quality of information’ whose changes will affect information value. Please note that in this case, the numbers in Table 1 shows that designers/site managers are not completely sure about the information they are getting on site.

Questionnaire undertaken in this study focus on designers’ and site managers’ benefits from using high value information. Questionnaire was prepared around pre-identified information attributes to collect the perspective of a site manager on the completed design information from designers. The Bayesian network technique is adopted to convert qualitative into quantitative data in order to identify which information attributes play a significant role in enhancing information value for the site managers from designers as there are no available tools that help extracting the cost information attribute. Essentially this approach gave users an information analysis framework to analyse whether the information they are getting is of any use to them in terms of construction productivity. Recently there is a trend of application on digital building information modelling (BIM) in the industry, this framework should support BIM to provide high value information through addressing its defects.

8. ACKNOWLEDGEMENTS

Thanks for the support of the industry respondents in training and validating the model developed in the study. In addition, a special thank you is given to Mohammed Shah who helped proofreading the final paper.

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INTERNATIONAL COUNCIL FOR RESEARCH AND INNOVATION IN BUILDING AND CONSTRUCTION

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CIB has since developed into a world wide network of over 5000 experts from about 500 member organisations with a research, university, industry or government background, who collectively are active in all aspects of research and innovation for building and construction.

Purpose, Scope and Objectives
The purpose of CIB is to provide a global network for international exchange and cooperation in research and innovation in building and construction in support of an improved building process and of improved performance of the built environment. The scope of CIB covers the technical, economic, environmental, organizational and other aspects of the built environment during all stages of its life cycle, addressing all steps in the process of basic and applied research, documentation and transfer of the research results, and the implementation and actual application of them. The objectives of CIB are to be: a relevant source of information concerning research and innovation worldwide in the field of building and construction; a reliable and effective access point to the global research community; and a forum for achieving a meaningful exchange between the entire spectrum of building and construction interests and the global research community.

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At present about 500 organisations are members of CIB from whom about 5000 individual experts participate in over 50 CIB Commissions. These extend over the whole area of building and construction research and innovation.

Amongst the CIB member organisations we can now find almost all the major national building research institutes in the world, as well as many other types of organisations in the building and construction sector who have joined us since. And although within the CIB programme considerable attention is still given to technical topics, there are now also activities focused on topics like organisation and management, economics of building, legal and procurement practices, architecture, urban planning and human aspects.

It is no exaggeration to say that at present CIB is the world's foremost platform for international cooperation and information exchange in the area of building and construction research and innovation. And we continue to increase our membership, to expand our scope, to initiate new activities while constantly striving to improve the quality of our products and services.
A CIB Commission is a worldwide network of experts in a defined scientific area who meet regularly and exchange information on a voluntary basis. The scope, objectives and work programme of each Commission are defined by its members and officially approved by the CIB Programme Committee. Most Commissions have one Coordinator, who is appointed by its members and by the CIB Programme Committee. Some Commissions have not one but two Joint Coordinators and some have a Secretary also. Some Commissions have set up Working Groups to focus on specific parts of the work programme and some have established their own projects in which Commission members or their institutes collaborate. Most Commissions have annual plenary meetings, which are organised by a CIB member organisation represented in the Commission. Certain Commissions however, have more frequent plenary meetings and/or additional meetings of their Working Groups. Also most Commissions at regular intervals organise an international symposium, conference or workshop. Although there are a few Commissions which only act as a platform for an informal exchange of information between their members, most also produce official publications featuring their output which are then distributed within the CIB community and sold externally on a commercial basis. A growing number of these Commissions now have their own Home Page and there are also some which have a liaison with an officially CIB Encouraged Journal covering their particular area of expertise.

For each Commission detailed information on its Scope and Objectives, Work Programme, Meeting Schedule, Publications, External Relations, Membership and Electronic Addresses is given in the section "Commissions" of the part "Data Base" of the CIB-World Home Page.

The CIB organization is facilitated by the CIB General Secretariat, which is located in the Netherlands and which operates under the supervision of the CIB Secretary General.

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