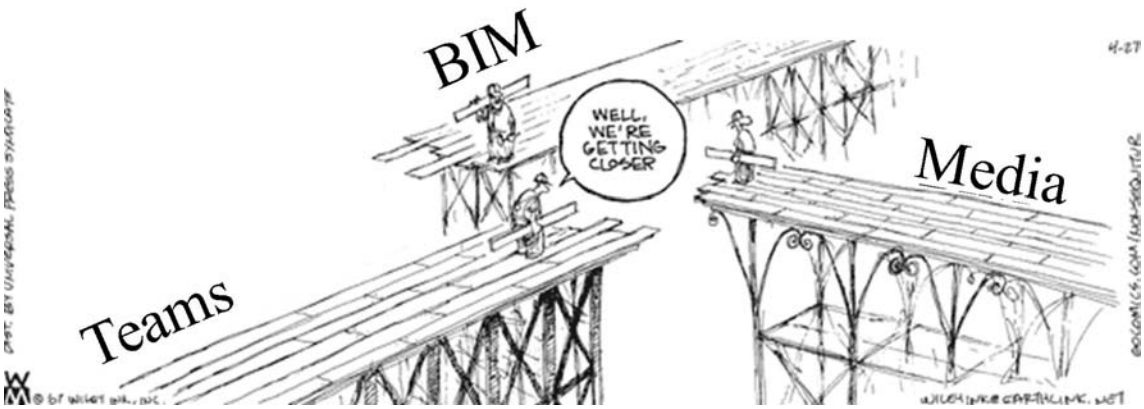

Building information models, display media, and team performance

An exploratory study

Robert M. Leicht, Stephen Fox, John I. Messner & Tarja Mäkeläinen

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Abstract

The use of Building Information Models (BIM) has been increasing in the building architecture, engineering, construction and operation (AECO) sector during recent years. BIM use is being encouraged by several large building facility owners, including Senate Properties in Finland and the General Services Administration in the USA. One of the main reasons cited for the encouragement of BIM use is expected improvements in the design and construction process through sharing of information. However, some communications theories suggest that the form of the information itself is not the only factor to be considered in process improvements. Rather, the media and the tasks being performed also need to be taken into consideration.

Apropos, an exploratory study was undertaken using a combination of research methods to determine the existence of a relationship amongst these areas as they appl-y to AECO. The research revealed that accompanying the planned implementation of BIM were some growth and change in the use of media. The fact that the media was important to utilizing BIM was agreed upon. However, most of the implementation was not planned strategically but was dealt with on an ad hoc basis. To determine potential implications, a quasi-experiment was performed to identify measurable differences in the impact of media. Then, a focus group was used to identify underlying factors which come into play in making decisions about media usage and how it relates to BIM.

This study was undertaken as a collaborative project between VTT and The Pennsylvania State University.

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Preface

The use of Building Information Models (BIM) has been increasing in the building architecture, engineering, construction and operation (AECO) sector during recent years. BIM use is being encouraged by several large building facility owners, including Senate Properties in Finland and the General Services Administration in the USA. One of the main reasons cited for the encouragement of BIM use is expected improvements in the design and construction process through sharing of information. It is suggested that BIM facilitates the early stages of project design. By improving information sharing at the early stage, design team collaboration and analyses may be improved with the long term potential for more effective design.

One of the main challenges in determining the impact of BIM on the delivery process is the accuracy of this assessment due to the extreme number of variables which come into play in building design, construction and operation. AECO projects vary significantly from one to the next due to a number of factors. These factors include: project type, makeup of the project team, the delivery method employed, and the location of the final building. Considering the wide array of factors which come into play, the impact of BIM needs to be considered in a broader context to ensure that BIM is objectively evaluated and implemented in an effective manner.

This working paper is a VTT (Technical Research Centre of Finland) contribution to the Engineering and Construction Project Information Platform (ECPIP) research project. Other participants in the project are Helsinki University of Technology; Tekes – Finnish Funding Agency for Technology and Innovation and a number of leading Finnish companies.

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1. Introduction

In this section, the background of the study is described. Further, the research goal and the research method are outlined. Subsequently, the overall structure of the working paper is set out.

1.1 Background

There has been recent growth in the use of Information Technology to support communication and information sharing within building architecture, engineering, construction and operation (AECO). In particular, Building Information Model (BIM) has been of growing interest. At the CIB w78 24th Annual Information Technology in Construction conference, held in Maribor, Slovenia, over half of the 110 research papers presented were focused on or strongly related to BIM (CIB w78, 2007). The use of BIM has been strongly suggested as a means of improving collaboration within the industry (McDuffie 2006). However, when considering BIM software and the impacts it may have on team interaction and collaboration, and the numerous papers presented concerning the uses of various visualization and display technology, none of these papers emphasized relationships between the use of BIMs and the media display being used in combination to impact collaboration. The research reported here is offered as an exploratory step toward defining the relationship between BIM software, media displays, and team interaction.

1.2 Research goal

The goal of the study reported in this VTT working paper was to explore whether relationships exist amongst BIM software, media displays, and team interaction. The purpose of the study was not to define the relationship and context, but to do preliminary work to identify how, if at all, BIM software and display media affect team performance. In particular, the research sought to identify current industry experience and perceptions about the state of BIMs; the use of media displays; and how these come together to affect team interaction. Further, the research sought to identify underlying factors which may affect how teams adopt and use different media display systems. Furthermore, the research sought to determine if, and how teams interact differently when different media are used in problem solving tasks.

1.3 Research method

The research comprised a literature review and a field study. The literature review encompassed AECO and non-AECO areas. The field study comprised quasi-

experiment, interviews, focus group and questionnaire. The observational quasi-experiment was undertaken to identify differences in the manner different media are employed in interdisciplinary problem solving tasks. Interviews were performed to determine the perceptions in the industry. A focus group research technique was used to probe more closely the factors affecting the adoption and use of display media. The questionnaire was developed and distributed to a group of industry members to see if the feedback from the interviews matched the general perceptions of the industry.

1.4 Paper Structure

The remainder of this working paper comprises five sections. In the next section, the research methodology is presented. Subsequently, the results of each part of the literature review and field studies are presented in sections 3, 4 and 5. In the final section, conclusions from the research and directions for future research are presented.

2. Research methodology

A brief overview of the research strategy and the research techniques used in this study is provided in this section of the working paper.

2.1 Research strategy

The research sought to explore relationships between BIM software, media displays, and team interaction. A composite methodology has been found to be effective in exploratory studies (e.g. Bowen, 1995). The composite approach consisted of: literature review, an observational quasi-experiment, semi-structured interviews, a focus group, and a questionnaire. This combination of techniques was used in an effort to identify the potential relationship from different points of view. Though the use of multiple methods may not allow a single comprehensive set of results, the combination of viewpoints was used to provide enough preliminary evidence to identify the likelihood of a relationship, and an indication of the best methods to use in proceeding further with the research. All of the research was carried out during the first half of 2007. Details for each method employed are explained in the following sections.

2.2 Observational quasi-experiment

A quasi-experiment is a study wherein a true experiment cannot be developed with full control of the variables affecting the study. The variation used in this study was a post-test only design with non-equivalent groups (Campbell and Stanley, 1966). The limitation of such a design is that there is no means of verifying that the groups would have performed equivalently to each other if they were not given the treatment. They were used in this study to test team interaction in problem solving, and the nature of the participant pool did not allow a method for verifying exact matches of skills, experience, and team interaction dynamics.

The task performed was a problem solving task associated with excessive heat loss in a building. The participants were asked to use the building design geometry they were provided to develop a list of potential design alterations for improving the building performance, and to rank the three options they believed were the best. The task description can be found in Appendix 1. The independent variable utilized for the study was the media used to display the information. To minimize impacts, each of the teams consisted of: an architect, a structural engineer, a mechanical engineer, and a construction professional. The groups were assigned to balance the gender makeup of each team; beyond these two criteria the individuals were randomly assigned. Each of

the groups had the same amount of time to perform the task and worked in the same environment, and none of the groups had met before the experiment.

To track the data from the experiment, the conversations amongst the groups were coded using a variation of the conversation coding scheme used by Wang et al. (2007). The coding was done by two observers at 15 second intervals, and cross compared for accuracy. In addition to coding the conversations, the group members were given post-experiment questionnaires, found in Appendix 2, to obtain their evaluations on the usefulness of the media employed and the impact they felt it had on the team interaction and performance.

To improve this study in the future, it is suggested to video-tape the meetings for more accurate review of the conversation and interaction. The use of taped sessions offers the ability to verify the information in the coding (Poole and DeSanctis, 1992). Also, repetition of this experiment would be helpful in verifying that the independent variable was the main reason for observed differences between group interactions and outcomes.

2.3 Semi-structured interviews

Semi-structured interviews offer topics of discussion to the interviewee focused on obtaining their ideas and opinions on a given topic. Semi-structured interviews were employed for this study due to its early stage of development. They allow for a consistent flow of concepts and development for the interviews, but still let the interviewees provide unexpected comments and insights and allow the questioner to utilize these new directions (Zorn, 2005). At an early stage, the expected outcomes are at schematic level of definition and question responses can lead to very useful and insightful directions for the research to take (Yin, 1994).

The interviews performed were semi-structured interviews with a base set of questions to draw on the industry members' experiences with BIM and different display media. The interview schedule is presented in Appendix 3. The questions were augmented with probes to offer consistent directions of consideration if the participants had trouble explaining the impacts they have seen. Also, visual prompts (Mathers et al., 2002) were developed to supplement the questions on topics of a visual nature such as modeling. The prompts can be found in appendix 4. Once the questions were developed they were mapped, as shown in Appendix 5, to determine the paths the participants could take and ensure the maximum value could be derived from all interviews. After mapping and revising the questions, they were piloted to work out ambiguities and ensure the schedule of questions could be easily used by more than one interviewer (Hollway and Jefferson, 2000). As the English language was used during the interviews, while most

industry members' first language was Finnish, the questions were reviewed more thoroughly for potential language ambiguities (Fox, 2007).

The interview participants were drawn through their involvement in the Engineering Construction Project Integration Platform (ECPIP) research project. ECPIP project focuses on improving utilization of Information Technology in project delivery, with the main emphasis on software use and improved processes (Hirvensalo and Kiviniemi, 2007). The companies involved were given a brief introduction to the exploratory study. The outcome of participant recruiting was a range of firms, from owners, to designers, to construction companies. During the interviews, responses were taken down in thorough note form. A recording device was not used for the interviews.

There were a few challenges noted in the preparation of the interviews. The busy schedule of the interview participants made scheduling interviews difficult. Having a more extended period would be beneficial for future efforts of this nature. While performing the interviews, there were some challenges found due to language barriers. Developing more visual aids and alternative phrasing for each question would improve the likelihood of consistent responses.

2.4 Focus group research

Focus group research is based on eliciting insights and understandings from a group of individuals through facilitated discussion (Kreuger, 1988). In focus group research, there is no standard instrument for eliciting information, only a central topic to be explored. The discussants have strong influence on the insights which are obtained. Focus groups have commonly been employed in market research mainly to determine motivations for purchasing which do not lend themselves to questionnaires (Morgan, 1988). They were employed in this study to explore the underlying factors associated with the implementation of different display media in conjunction with BIM software in AECO.

The central focus of the focus group was the identification of underlying factors associated with the selection of display media. The moderator, with the central role of directing and focusing the discussion through probing questions, used preplanned questions and slides to excite conversation from the participants (Simon 1999). The questions were timed to correlate with lulls in conversation, rather than to direct the conversation toward specific topics (Goldenkoff, 2004). The discussions are documented in Appendix 6.

There were two main challenges discovered in the development of the focus group discussion. Identifying participants for the discussion proved difficult due to the timing of the study. The flyer used to inform potential participants is included in Appendix 7. Also, the development of material to probe in depth without leading the conversation was exacting. The use of relevant literature from other fields was useful in that it provide discussion material, but was not specific enough to the discussion to strongly influence the direction of discussion.

2.5 Questionnaire

Based on the interview responses, a questionnaire was developed to obtain a more representative sample of the AECO population. The distributed questionnaire can be found in Appendix 8. The interview participants were chosen for their interest and insights associated with their early adoption of IT. In determining the general perceptions of the industry, a pool of respondents was chosen through an opportunity presented by an industry event and questionnaires were distributed to the attendees, mostly consisting of building architectural designers. A questionnaire differs from interviews in that the questions are more thoroughly structured and repeated to all of the respondents in exactly the same format. In this case, the questions offered a specific range of responses to each question, thus allowing for quantitative evaluation of the responses (Oppenheim 1966). The questionnaires were self administered with questions structured through the piloting performed in the interview process.

The main challenge found was gaining a substantial pool of respondents. The use of an electronic questionnaire either posted online or emailed to potential respondents would offer a way of presenting the information to a larger pool of industry members.

2.6 Data analyses

The coding of the discussions in the observational quasi-experiment was performed live using an existing coding scheme. The coding was performed live to expedite the analysis of the results over video-taping and having coding occur by two separate evaluators. The live coding limits the ability to react to unique situations and changes, but provides a richer environment in which the coder has a live and direct link to the occurrences. In the future, a more thorough and repetitive coding of the discussions would be suggested to more rigorously validate the data, but the live coding was a result of the time and resource constraints of this study. The live coding did consist of two observers and allowed for the timing to be validated for accuracy.

When reviewing the interview results, the data was compared with the results from the questionnaires based on the consistency of the questions posed. However, there were challenges with non-responses to questions in the interview process because the interviewees were not given a structured range of answers to choose amongst. They spoke only of the topics that came to mind through the questions and the probes used. Their responses were used to generate the range that questionnaire respondents reflected upon. So the analysis of this data was reviewed with the concept that the interviews offered the insights into the value of the technology and its expectations, while the questionnaires were viewed as a means of verifying if the general industry beliefs reflected those of the early adopters. Neither pool of participants was large enough to draw significant results with the interview pool of $n = 14$, and questionnaire pool of $n = 19$.

In the future, utilizing richer media to record the data from observational experiments, interviews, and focus groups, would offer a means for a more thorough evaluation and the potential to identify visual cues. The live coding and note taking gathers a significant amount of evidence, but richer media would offer more information to review for analysis.

3. Building information models

In the following three sub-sections, the results from the study pertaining to the use of BIM will be presented.

3.1 Literature review findings

Building Information Modeling (BIM) involves designing, analyzing, integrating, and documenting a building's lifecycle by developing an intelligent virtual prototype of the building using a database of information (Leicht and Messner, 2007). Despite limited use, the concept behind BIM has been around for more than 30 years. The concepts were developed in the early 1970's and first used in the building industry in conjunction with the development of Nemetschek's Allplan software (Tse et al., 2005). However, the software was not widely used in industry, which has been mainly attributed to the lack of computing power, but recent improvements in computer capabilities and the development of newer software, such as *Autodesk Revit*, or *Graphisoft's Archicad* have contributed to increased BIM usage (Ibrahim and Krawczyk, 2003).

Besides simply developing the design in these parametric modeling tools, the software offers the ability to imbed information into the design which allows numerous opportunities for analysis of the design, ranging from cost estimates, to energy analysis, and many more (Bazjanac 2003). While the tools offer benefits in terms of 3D visualization and parametric modeling, it is due to the analysis tools that BIM has garnered so much attention. These tools are considered valuable for their ability to allow simpler and easier perform analysis on the building design if it is creating in BIM authoring software (Sawyer, 2005). The ability for exchanging and sharing BIM better enables comparative analyses of design and performance factors (Fox and Hietanen, 2007).

Despite the demonstrated value of utilizing BIM for design and construction, there are still barriers to the implementation of BIM on a large scale. As noted by Kiviniemi et al. (2005) there are notable shortcomings in the use of IFCs for the interoperable sharing of information between disciplines. Even if the information were readily interoperable, there are different manners of defining building systems which make collaboration challenging (Lee et al., 2004), and Haymaker (2005) demonstrates the need for improved management of BIM dependencies between different organizations. Creating a BIM which can serve the diversity of purposes expected on a project requires planning and execution which can overcome the differences between disciplines.

3.2 Field study findings

To try to determine if these beliefs and challenges are being observed in practice, this study incorporated interview and questionnaire questions about experiences with, and perceptions about, the use of BIM. The questions focused on three areas: personal experiences with BIM in industry, changes seen in how BIM has been used over the past few years, and changes expected in the future.

From the interviews, the primary uses found for BIM software were for internal design development and analysis. Almost all of the firms interviewed used BIM software for some aspect of authoring their designs, or for the construction firm in developing project plans, as seen in Figure 1. Most firms, though, were not entirely reliant on BIM software, but used other software in conjunction with it. They tended to use BIM authoring tools if they planned to utilize the analysis tools associated. Since most of the firms responded that they used the analysis tools fairly regularly, it seems likely that they are using the authoring software regularly as well. Figure 2 shows the types of systems the firms design using BIM files. The BIM file created did not necessarily need to be for the firms design expertise. For example, a mechanical systems design firm stated that the most common BIM modeling they perform is to develop a space model defining the building loads, and they often develop their actual design in a separate non-BIM software tool.

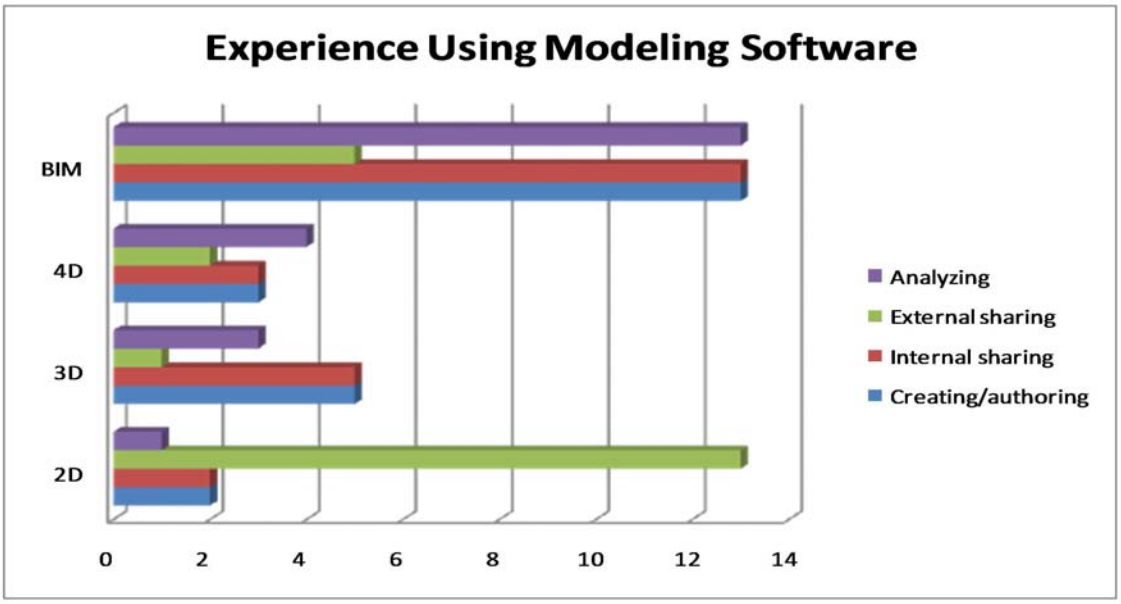


Figure 1. Computer Modeling uses observed over the past three years.

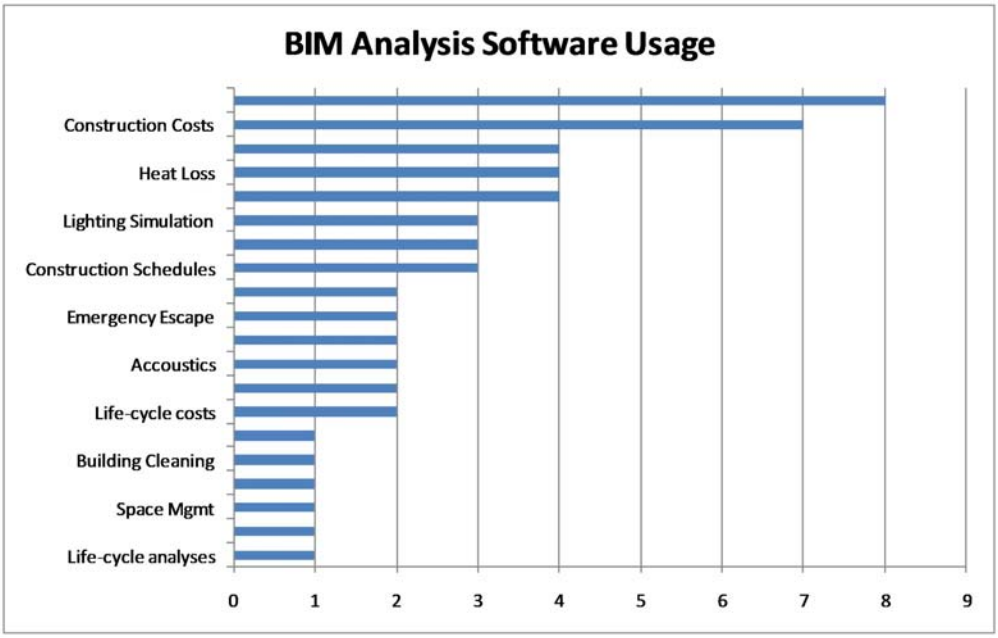


Figure 2. Analyses commonly performed using BIM tools.

In addition to analyzing the files, the software was used for sharing the design information. Overall, the sharing of model files is mainly internal. Indeed, little sharing of BIM files was found between different firms. A few cases were noted where files were shared between companies, but the cases were cited as "unique" or "rare." There were two main reasons cited for the lack of model sharing which occurred in the interviews. The most common reason cited for not sharing files was that there are only a small group of companies using BIM software. As a result, there is little added value in sharing the files if the other companies cannot use them. The second reason commonly cited for not sharing files was the reluctance to share files due to the legal liabilities. Since the legal precedent for AECO is based mainly on 2D paper drawings and specifications, moving into the use of BIM files as legal contract documents could offer unforeseen legal liabilities to the firms who are sharing their model files.

Other, less common, reasons mentioned included not getting paid for the work put into BIM files. The perception stated was that in sharing a model file, the designer needs to put more work into authoring the design so the other design disciplines will be able to use the file. The current practice is for the disciplines to draw the necessary information from the 2D drawings provided to them. One example of where this challenge was seen was by one of the construction firms when using a BIM to develop an estimate for the building. The firm commented that it was usually simpler to create a new BIM of the building architecture than to work from a model provided by the project architect because the BIM would not be broken into the elements the firm needs when developing the estimate. An example is the difference for a concrete floor, in the architectural

model the floor would be created as a single floor object, but in developing the estimate it would be broken up into the separate concrete sequences as it would be constructed.

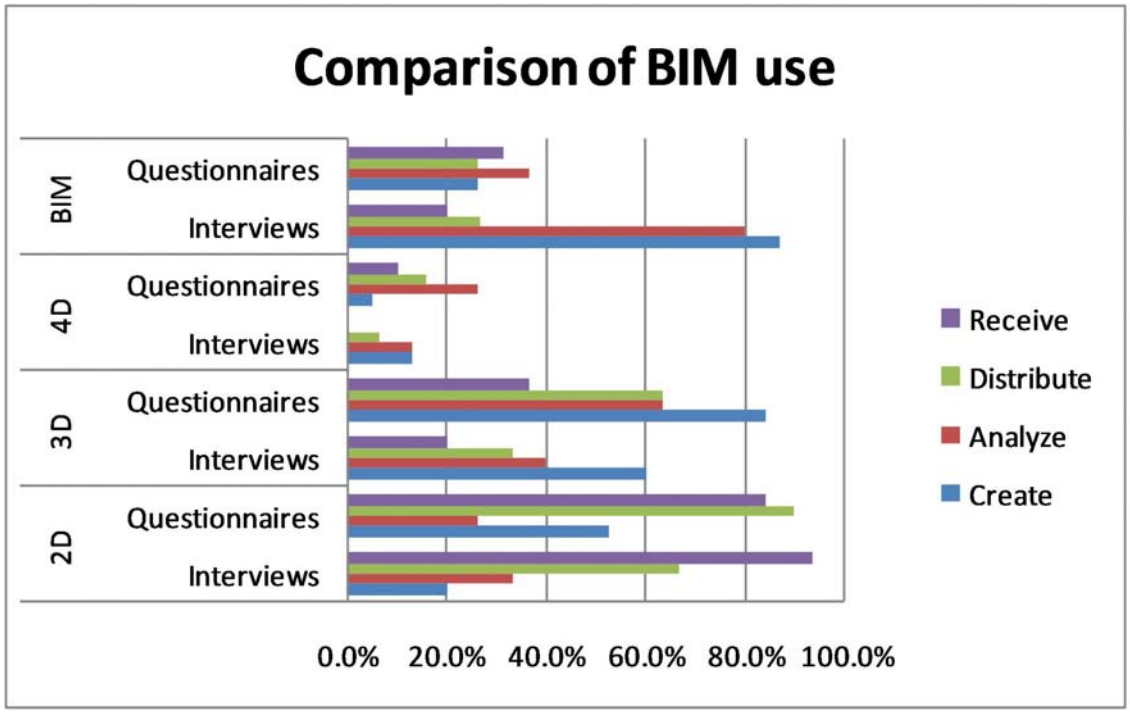


Figure 3. Comparison of modelling uses between interviewees and questionnaire respondents.

One of the unique solutions noted for this was by a consulting firm, in which they would sell their BIM files back to the project team. Thereby, getting compensation for their work and for the additional liability they incur.

To determine how well these responses reflected with the general industry, the results were compared with those of the questionnaire responses, as shown Figure 3. The overall outcomes were fairly close. The interview subjects had shifted to the reliance on BIM more than the questionnaire respondents, but that was not unexpected since it was one of the factors in choosing the interview subjects. Other than the amount of BIM use, the other responses were closely aligned.

Following the questions about personal experience with BIM use, the topic shifted to the changes that have been seen in BIM use since the beginning of 2004. The interviewees all responded that there had been a definite increase in the use of BIM. Figure 4, below, shows their response about what new building systems they had seen developed using BIM software. The largest difference in response is the change noted in architectural systems, whereas the other design fields and construction uses are reasonably well matched. One possible reason for the difference in response to the

architecture BIM use could be the difference in occupation of the questionnaire respondents as compared to the occupations of the interview subjects. The questionnaire responses were made up mainly of architects, while the interviews sought an array of designers, consultants, and construction professionals. When considering that 84% of the questionnaire respondents were architects while 33% of the interviewees were architects, the correlation with the difference in response is a plausible explanation. Also considering this difference, it is interesting to note that the increase in BIM use in the other disciplines is fairly well matched considering the small sample sizes.

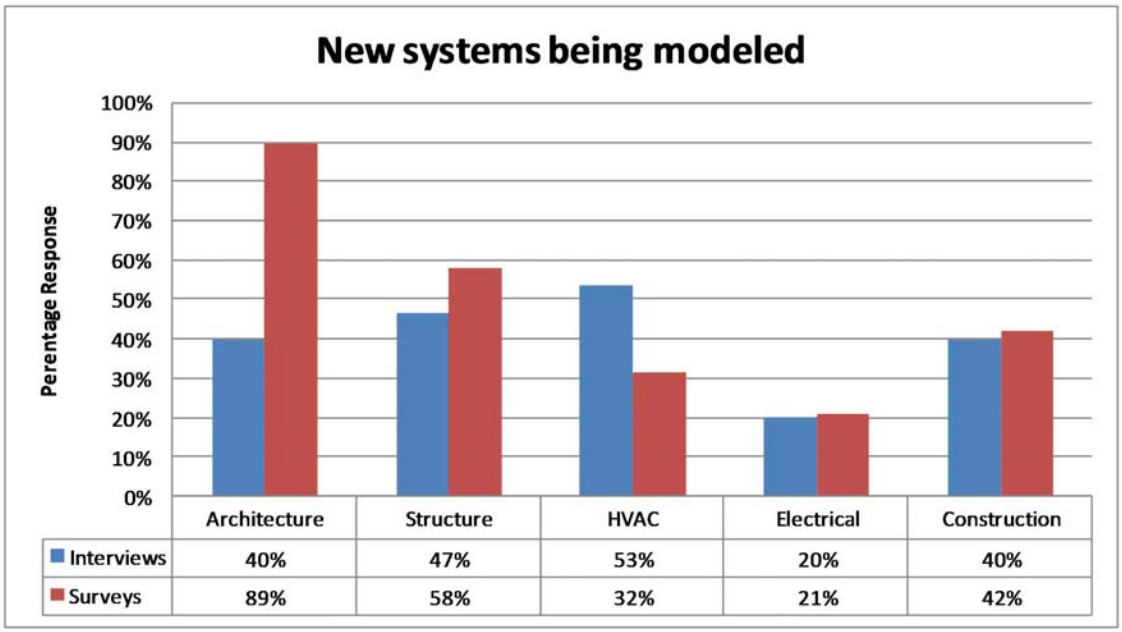


Figure 4. New systems being modelled in BIM in the past three years.

In addition to their perspectives about the growth of BIM usage, there were some additional comments directed at changes in how the models are now being used. Several of the interview subjects commented on the shift of the modeling focus towards the incorporation of analyzable information, rather than just visualization and renderings. Also, related to the embedded information, the feeling that the responsibilities associated with the model were growing was raised in several different ways. In one case, the interviewee thought there will be a need to define a new role of the "model manager" or "model engineer." Others had seen where someone on the project naturally began to manage the model, noted because they were a subcontractor or other role where the responsibility was not expected to fall to that individual or company. In other cases, some architects felt that the responsibility naturally belonged to them, and cited Senaatti's new requirement that the lead designer would be responsible for the accuracy of the submitted model when the new BIM requirements are enacted.

Along with the questions about how BIM had and was currently being used, some additional questions were asked to determine impressions of how BIM will change over the next three to four years. When asked about growth in the use of BIM, responses were very strongly expectant of growth. Over 90% of those questioned or interviewed indicated their expectation of more BIM usage in the future. One of the main reasons cited for this was the release of the requirements by Senaatti for BIM use on projects beginning in October of 2007. Accompanying this was a strong belief at 70% that the amount of industry collaboration will also grow. Some of the comments associated with the increased collaboration indicated that to share more accurate and useful information, there needed to be more conversation, partnering and in one case a focus on managing the product value chain.

These views were not universally agreed upon, however, the concept of a "super-designer" with the ability to use the BIM tools and centralize most of the design skill was mentioned. Also, the belief that most clients or owners, in most cases, did not know what they wanted and would be unsure what to do with the information if it was provided indicated that there was still much disagreement about the long term direction of BIM use. Also, nearly 70% of the questionnaire respondents believed there would be a growth in efforts put into modeling systems that are the responsibility of designers in other disciplines. For example, the building mechanical systems designer may need to develop an architectural model to determine the volumes of the spaces for developing the base calculations for their design to begin. This belief seems to relate back to the issue raised earlier with the lack of sharing of BIM files. It was not clear whether the expectation was based on a continued nervousness about sharing files, or from waiting for BIM software to be more commonly used. However, it does indicate that industry is conscious of some of the challenges caused by the expansion of BIM use.

3.3 Principle findings

There are several important items which were identified in the field study.

- According to all of the responses, BIM use has grown.
- Almost all industry members expected that growth willontinue.
- The growth has been evident in all disciplines in AECO projects, and in future growth it is expected to include owners, operations and maintenance personnel, and possibly others.
- There is a substantial challenge to the industry in the sharing of information. Even among the firms working almost exclusively in BIM tools, there was little or no sharing of BIM files between companies. The firms experienced in sharing files still cited the cases of sharing as being unique situations or relationships.

- There was an increased demand for BIM early in projects, and some improvement noted in team coordination. But the improvement was not agreed to be universal, and there was general agreement that more coordination was needed and expected for effective BIM use.
- The industry is still reliant on 2D paper documents as the legal contract documents. Even when companies had experienced the sharing of BIM files, 2D paper documents were still considered the central documents, and the BIM files were seen as supplementary.

4. Media choises

In the following three sub-sections, the results concerning the choices of media will be presented. Results include responses to interviews and a questionnaire, as well as the results of a focus group.

4.1 Literature review findings

As information sharing is the focus of BIM, other theories were explored to identify how to relate BIM to actual process changes and industry impacts. The most relevant literature found was in the field of communications. The literature suggests that the form of the information itself is not the only factor to be considered in process improvements, but that the media used and the tasks being performed also need to be taken into consideration. As Daft and Lengel (1986) suggest in their Media Richness Theory that the media's capability to convey information needs to be matched to the task needs, varying with such traits as the range of cues offered, the personalization of the information, feedback process and the use of natural language. They define two factors which affect the effectiveness of media use, uncertainty and equivocality. Uncertainty is the lack of available information to influence a problem solving task, while equivocality is the lack of direction or multitude of directions in which the problem solving process can develop.

While the basic concepts presented on Media Richness are agreed to be valid, Dennis and Valacich (1999) believe that the richness of media is a relative trait and that there is no "richest" media form to utilize. They suggest that the richness of media to be utilized should be synchronized with the task and message needs. They use five characteristics: symbol variety, immediacy of feedback, parallelism, rehearsability, and reprocessability, to define the appropriate richness for different purposes. The concepts that media richness needs varies with certain underlying factors is supported through other studies, suggesting that media richness is affected by such issues as social definition (Schmitz and Fulk, 1991), culture (Straub, 1994), and personality type (Byron and Baldridge, 2007).

Also, it is suggested that a team's needs for media richness can change with time (Jaffe, 2000). In the early stages of collaboration, teams are unfamiliar with each other and differing styles of communication. As the team becomes more familiar, attuned to the different members' styles and they begin to share experiences about which to communicate, their need for media richness levels change (McGrath, 1993). DeLuca and Valacich (2006) agree with this, and suggest that newly formed teams should employ media with greater immediacy of feedback, higher symbol variety, and lower parallelism in conversation.

Based on these concepts, AECO literature was reviewed to determine to what extent these ideas existed within the industry. There has been extensive research into the growing range of media options available (Madrazo and Weder, 2000) and how different media can be used in the industry ranging from the use of immersive displays (Gopinath and Messner, 2004) to mobile computing devices to improve site communications (Löfgren, 2007). There was a range of media display tools identified, with a few representative samples identified in Figure 5. The literature focused on two main themes: the development of new tools and functionality, and the exploration of tasks on which they could be utilized. Despite the wealth of valuable research in these the AECO areas, little attention has been paid to what factors affect the use of media in industry.

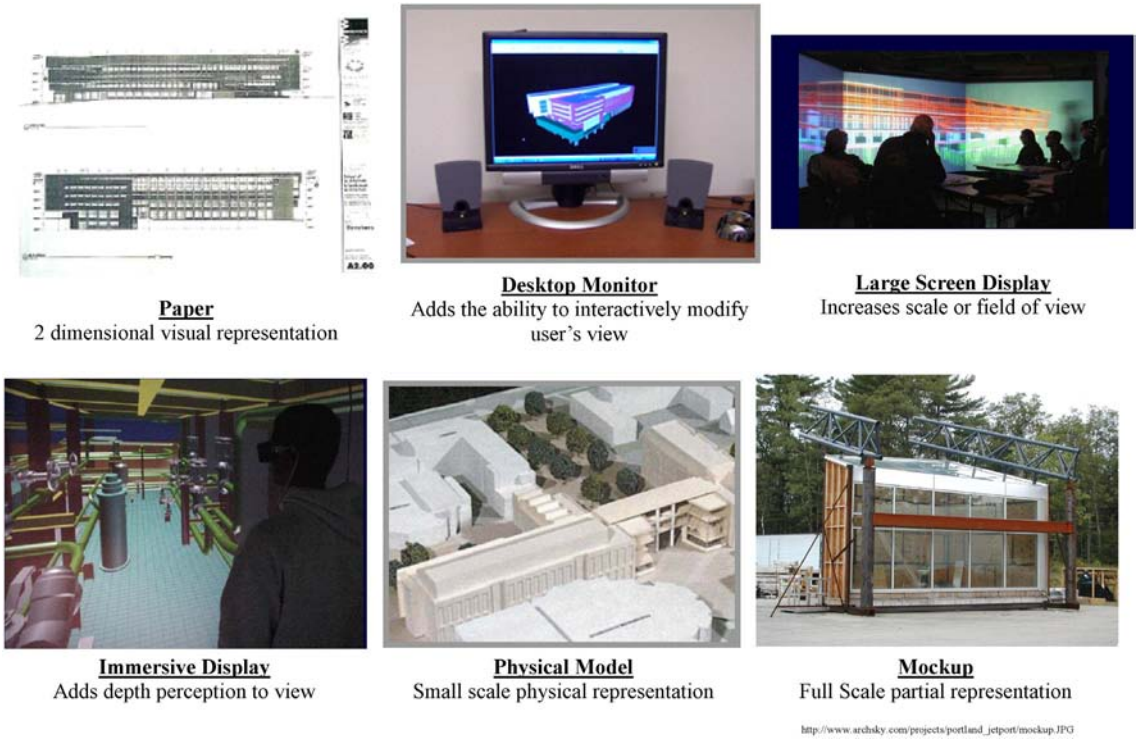


Figure 5. Examples of different media forms.

4.2 Field study findings

To explore if, and how, media usage is changing in the industry, questions were incorporated into the interviews. The questions were similar in nature to those concerning changes in BIM usage: what experiences were had with different media, what changes have been seen in media usage, and what changes were expected in the future. To supplement the responses, a focus group was held to explore the factors affecting media choices in more depth.

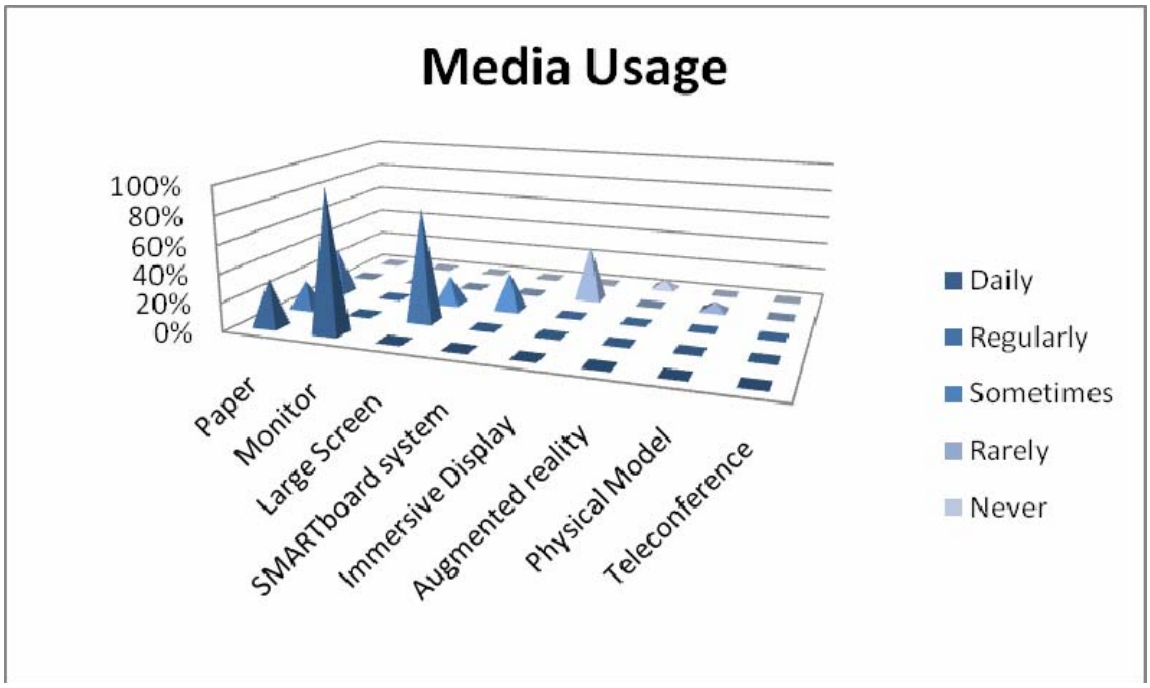


Figure 6. Frequency of different media usage from interview responses.

It can be seen from Figure 6 which media forms were those most commonly used. By far the most common was the computer desktop or laptop display. Following closely behind were both paper and a large projected display. There were some cases where companies used higher end displays, ranging from SMARTboards® within their offices, or in some cases going to a research facility to use a CAVE® or other immersive display. The current uses strongly correlated to the changes which were cited. The responses showed a strong increase in the use of computer desktop displays and larger projected displays. Despite the increase in the use of computers for display purposes, there was still little decrease seen in the use of paper, though there was a notable decrease seen in the use of physical models. One architect said they had not used a physical model in more than five years, and another said they almost never used them and then only in conjunction with design competitions.

Along with the shift to more computer display use, there were some specific display traits that were seen to be of increasing importance. The size of computer screens and the screen resolutions had substantially increased. Many had changed to the use of flat panel or LCD screens. Another common change was adding a second or third screen. Several respondents suggested that though they had not upgraded their display recently, they were expecting to purchase a bigger, or higher resolution screen, or additional screens, in the near future.

The points of view about the newer media varied much more. Some believed strongly in favor of certain display systems capabilities, such as “immersive displays increased

understanding within the project team," or that the industry "must get rid of paper." Others felt differently, saying they could see "little added value" in using such displays or citing challenges, such as a limited field of view and no material feel. It was common for respondents to point out suitability of the higher end displays for marketing or advertising purposes. Those who had used some of the newer media stated, however, that their use of the media was not incorporated as part of a project, but as an experiment or novel activity. Despite mixed reviews about the current status of some of the newer display systems, when asked about the future most responses indicated a growth the use of the newer forms of display media, shown more fully in Figure 7. The media forms that seemed to be the most in question were those currently relied upon, namely paper. While some believed that the onset of newer displays will push paper to the wayside, others expressed sentiments that "…sophisticated presentations will have clients suspicious of how their money is being spent."

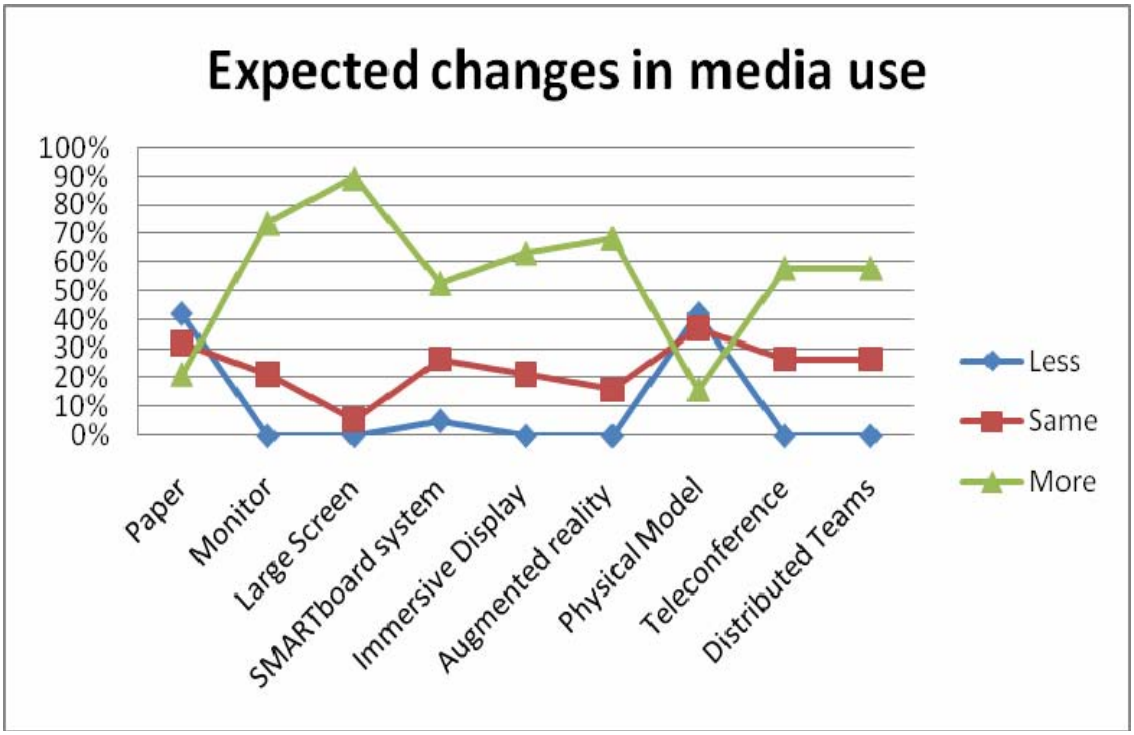


Figure 7. Expectations for the direction of media changes.

Some of the responses were focused on the application of future media development to, such as advancements of mobile displays on cellular telephones or other handheld electronic devices for use on construction sites; the use of bar-coding and RFID tags for logistical tracking; or the use of immersive displays for sales. Some of the other responses were more focused on the exciting aspects of using the newer media, such as being able to "recline in the office while using an immersive virtual reality headset to create the design."

Despite the wide variety of responses in regard to how media will be used in the next few years, the focus was invariably task oriented. Whether the task was performed individually, or in a collaborative manner, the responses showed how they expected the system to enable that task. There was little discussion given, however, to what factors those developments were addressing. To explore the factors presented in theories concerning communications and their applicability to AECO, a focus group was used.

The discussions which took place were quite extensive and lasted for more than two hours. The goal of the focus group discussion was to make some initial determinations of underlying factors affecting choices of media use. To facilitate some of the discussion and rather than starting to create the factors from nothing, concepts from theories concerning communications were presented to help encourage and direct the conversation towards the factors that affected the choices, rather than the specific tasks and media uses. The overall concepts from theories concerning communications, shown in Figure 8, was quickly agreed to be a plausible theory of the relationship between team characteristics, task requirements, and media properties. Once discussion began however, it was quickly noted that though task requirements were considered the overall purpose may not be taken into consideration. The concept behind the theory was that the information was being conveyed to another person. Within the AECO, the media may be applied to help in the development of the information and not used for communicating the information to others. One example cited was sketching; an architect may sketch concepts on paper as a way to help them explore new concepts. The sketching is not intended as a means of communicating the concepts to other people, but as a means to understand and develop the concepts internally.

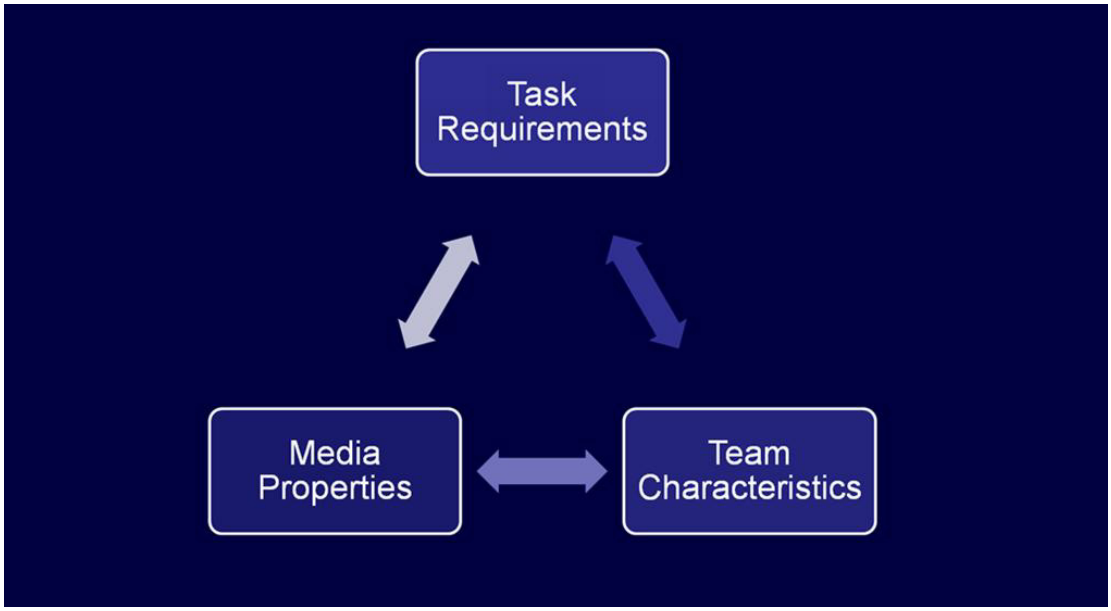


Figure 8. Underlying factors affecting media use.

From looking at the overall concept, the conversation shifted to looking specifically at task requirements. The information presented in theories concerning communications was again found to be useful, but still not believed to be comprehensive for application to AECO. The concepts related to task requirements were associated with conveying information between individuals, and then the individuals would work to converge on a shared meaning of the information. AECO and the design process are built around uncertainty and design process has an iterative nature. With the aspect that information is being created in the process, it was agreed that even if the group shared an understanding of the problem it might not mean they would be able to agree on the direction of the design solution. It was therefore argued that the *creation* of information should be somehow incorporated into the task requirements.

After determining the challenges with the task requirements, the discussion moved to fundamental media capabilities. The information presented from theories concerning communications dealt with the manner in which information was transmitted from one party to another. The issue of synchronous vs. asynchronous teamwork was raised, since the manner in which the team is working will affect the media properties. The psychological aspects were also believed to be neglected. For example, someone watching a video on a handheld display would be classified in the same manner as someone watching an IMAX movie. The capabilities do not consider the experience of the person receiving the information. Also, the granularity of information was raised. A set of print drawings was created at a set granularity, while a computer model would be able to be changed to different levels of granularity.

The discussion moved to the issue of team characteristics as a factor of communication. The factors from theories concerning communications identified factors associated with personal traits of team members, but were found not to include information regarding overall team traits, such as team size. Also, social practices were felt to be noteworthy. An example of software adding chat functionality at customer requests, then not used, was cited. The belief was those who were less comfortable with the technology did not use it at all, while those who were familiar ignored the software's function in favor of the freely available tools.

4.3 Principle findings

Several aspects were identified for the choice of media in the field study:

- The use of display media has changed over the past few years. Most significantly has been the shift to more desktop displays and larger projection systems.

- Along with the shift toward electronic displays have been the use of larger screens, higher resolution displays, and the use of multiple screens.
- Despite disagreement about the added value of new display media currently, there is a belief that the use of these displays will definitely grow in use in the future.
- None of the persons interviewed had shown consideration of the factors affecting the use of the display media to be considered other than task specific considerations.
- When considering the present theories concerning communications as they apply to AECO, the concepts were valid, but they did not consider all of the factors raised by the industry members, including:
    - Overall: Purpose of the media use
    - Task: Creation of information during the process and iterative tasks
    - Media: Synchronous vs. Asynchronous work, display granularity, and psychological impact or the "experience" of display
    - Team: Overall team traits, social practices.

5. Project teamwork

In this section the results from the study pertaining to the use of BIM and media as they affect team performance will be presented. The information includes current literature, the findings from the observational quasi-experiment, the interviews and the questionnaire.

5.1 Literature review findings

The need for improved collaborative processes has been an ongoing pursuit in the AECO Industry. There are many theories on the design process within architecture and engineering. Engineering literature commonly presents a linear design process with well defined stages that focus on a well defined problem, as Cross (1994) and Birmingham (1997) both show in their overviews of design process theories. Whereas architectural design models tend to allow for more iterative cycles of design, they are more descriptive in nature and lattice-like in their structure (Magent, 2005). What is commonly presented, regardless of the focus on Architecture or Engineering, or the process being demonstrated, is that there is not one consistent process commonly used throughout industry, but that the process changes with the teams and the task.

In determining the role that the use of computers and new software play in the process, the field of Human-Computer Interaction was studied. As Kuutti (1995) explains, recent theories have been shifting away from the traditional cognitive psychology view of the human-computer interaction as an information processing loop. The challenge with this traditional view is the lack of context to represent real life uses of computers. More recent trends have been the application of Activity Theory (AT) to interpret human-computer interaction (Bannon, 1997). Bannon explains that AT can be applied to study observations of activities, analysis of interactions, and historical analysis of artefacts, among others. The focus is on the social and developmental context of computer use, through the developmental transformations that take place from between actions and operations. While the theory presented offers tools for analyzing the use of computer based tools, the applications are focused on user centered tasks (Jonassen, 1999). Also, collaborative studies utilizing software such as ConversationBuilder (Kaplan et al, 1991) demonstrate the potential for software as a means for improving team interaction. The applications of these concepts were not found in use in the AECO literature reviewed.

5.2 Field study findings

To these ends the study pursued some exploratory measures to try to identify how these concepts apply to AECO. An observational quasi-experiment was performed to identify if the perceptions can be measured in practice. Some interview questions were incorporated to examine industry perceptions on the value of teamwork and the role it plays in the design and construction process. Then, the developments of BIM were used as a specific prompt to identify the relationship between the two. Following these, participants were asked what impacts they could foresee on teamwork utilizing new media in conjunction with BIM tools.

The observational quasi-experiment was developed to explore relationships. The experiment involved three different media displays being utilized for the same task. The three media treatments were: a single screen immersive display, a single laptop computer display, and a set of printed drawings. The groups were developed as interdisciplinary groups with each consisting of: one architect, one structural engineer, one mechanical engineer, and one construction professional. The groups were observed, and their conversation coded, to identify how they utilized the media in performing the task. In addition, the participants were all given post-experiment questionnaires to gather their perceptions about the usefulness of the media and how their group interacted for the task.

The conversations had during the performance of the given problem were coded under five categories: goal clarification, solution generation, alternative evaluation, solution selection, and other. For the purposes of this study, the definitions used by Wang et al. (2007) were used but with analysis and evaluation combined into a single conversation type. This was due to the nature and limitations of the task. For the purposes of the analysis performed the coding terms used were based on the following definitions:

Goal Clarification – Questions, answers, or statements, which clarify the goals and objectives which the group needs to achieve along with the requirements which they need to fulfil.

Solution Generation – Questions or statements, which propose potential solutions or new ideas that were not proposed previously within the group's discussion. Some solutions could be more detailed solutions of the previous ones. As long as it is not exactly the same as the previous one, it is counted as a new solution generation. These solutions can be related to meeting any of the goals within the project, including activity duration, division of work, resource utilization, or activity sequencing.

Alternative Evaluation - Questions, answers or statements, which clarify, explain, or develop additional information, which provide or seek a value judgment related to a proposed solution, or offer a comparison of multiple solutions.

Solution Selection – Statements related to conclusive decisions for or against a solution. The decision should be a final decision agreed upon by the entire group.

Other – All other communications, which are not included in the previously defined categories, including questions, answers, or statements which focus on the use of the technology tools and applications

In performing the given task, all of the groups were given a time limit of 45 minutes. There was a range of four minutes amongst the groups for the time spent on the task. Due to the slight disparity in times amongst the groups, the time aspects will be considered in terms of percentages, rather than specific units of time.

From the overview information, shown in Figure 9, it can be seen that the groups spent very similar amounts of time on each step. Looking at each category individually, the groups spent a very similar amount of time on goal clarification. This would seem to indicate that, with some small variation, it took a relatively consistent amount of time for the groups and members to read the task requirements and, with brief discussion, reach agreement on what they were expected to deliver. The first requirement of the task was to generate a list of potential design options to limit heat loss, with the concept that the groups would use the model to brainstorm potential solutions. Both the immersive display and the paper drawing groups spent the same amount of time, 16-17%, generating ideas, while the monitor group spent 27% of their time generating ideas. In terms of results, the paper group developed 6 total options, the immersive display group developed 5 options, and the monitor group developed a list of 12 options. However, the level of detail of the options was also greater for the options presented by the monitor group. Surprisingly, when rating the usefulness of the media for each of the tasks the monitor group ranked lowest in usefulness for generation, while the immersive display group ranked it the highest as shown in Figure 10; the exact opposite of the measured outcomes in terms of the number of solutions developed shown in Figure 11. Though if it is considered from the time spent on a task, it took the monitor group longer to develop the list of options than the other two groups.

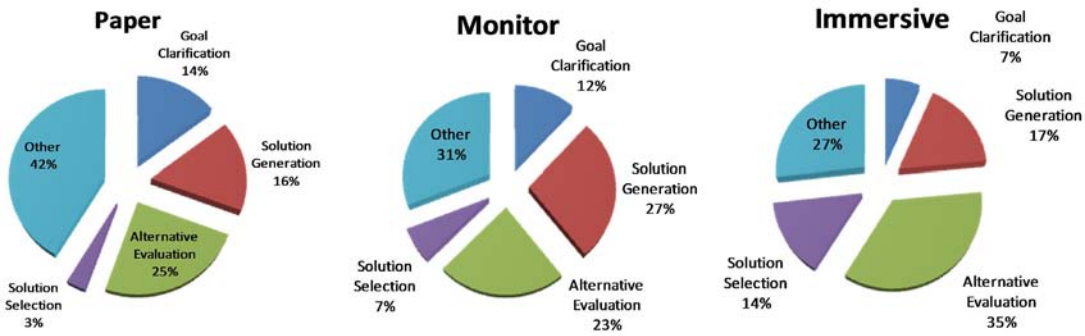


Figure 9. Observed problem solving discussions.

Figure 10. Ranked usefulness of media for problem solving task steps.

For the evaluation of the options presented, both the monitor and paper groups spent an approximately equal amount of time, at 23–25%. The immersive display group spent significantly more time in the evaluation at 35%. The rankings of usefulness this time again seem to correlate inversely with the time spent on the task. The immersive display group spent the most time on evaluation and ranked it the display as the lowest for that task. For the selection, the immersive display group again spent the most time selecting their three preferred solutions at 14%, while the monitor group spent 7% and the paper group spent 3%. Also again, the immersive group indicated the lowest ranking of the media for the solution selection, while the paper and monitor groups ranked it higher.

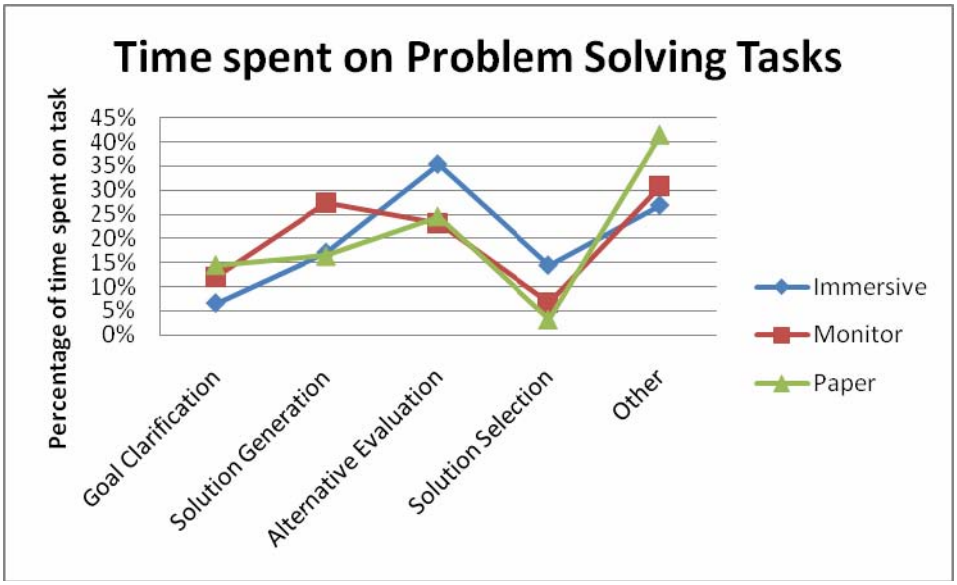


Figure 11. Time spent on each step of the problem solving process.

In trying to determine if the media facilitated the process in any manner, the steps used in the development process by each group were mapped overtime. A sample of the diagramming is shown in Figure 12. While there are identifiable differences between the groups, no group has a clear process where they show consistent discussion at one stage and then shift to the next. Most of the groups jump back and forth between steps, whether generating solutions or evaluating alternatives. Due to this inconsistency within each of the processes, it is not practical with the current data set to draw conclusions about the impact of the media on the development process itself.

In addition to ranking the relative usefulness of the media for the different tasks, the participants were asked how strongly they agreed or disagreed with statements about the media they used for the task. This feedback provides a more absolute scale for determining if the media contributed to the task rather than comparing whether it was useful for different steps in the process. The use of the electronic displays, both the monitor and the immersive display, were found to have a substantial impact on the ability to understand the design. For some reason they had different levels of impact on the team reaching a shared understanding. Both of the electronic displays were also found to have a noticeable improvement over paper in terms of alternative generation and evaluation of alternatives.

One of the items of note is the significant amount of time each of the groups spent in the "Other" category. One of the activities observed in each of the groups was the silent review of the design content before spending time working toward the task objectives.

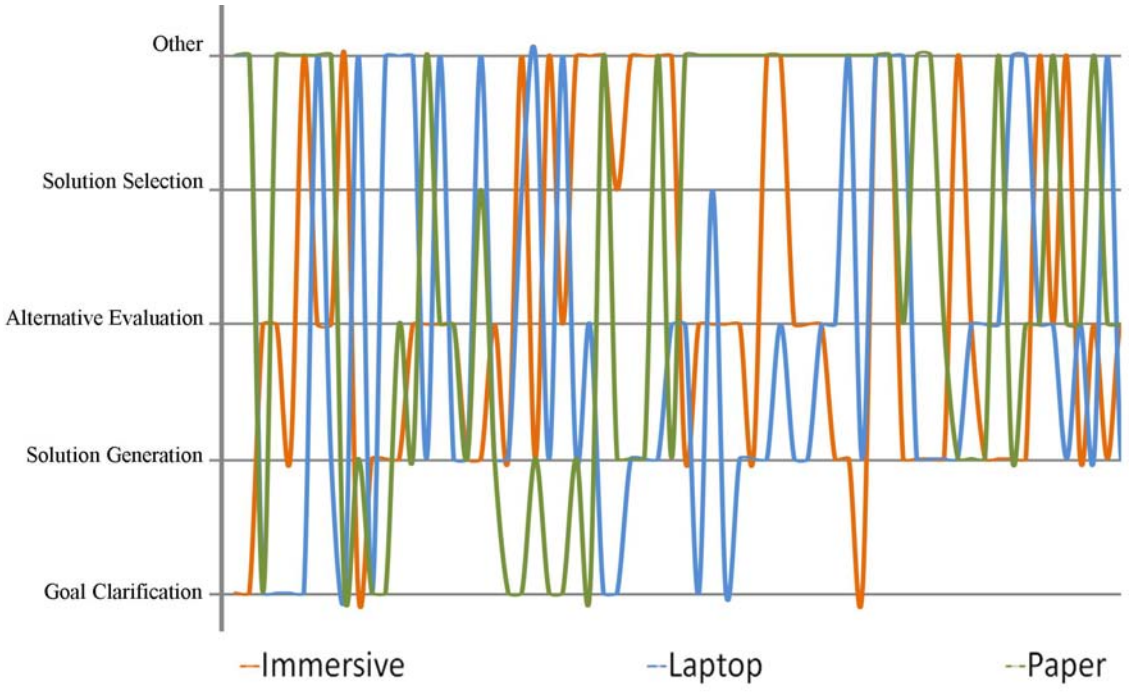


Figure 12. Mapping the transitions between problem solving steps.

Table 1. Results of subjective evaluation of media usefulness.

	Paper	Monitor	Immersive
I feel that the "media" helped the team to understand the task goal	3.50	4.25	4.00
I feel that the "media" helped me understand the building design	3.50	4.50	4.50
I feel that the "media" helped the team develop a shared understanding of the building design	4.00	4.75	4.00
I feel that the "media" helped the team to generate alternative solutions	2.75	3.75	4.25
I feel that the "media" helped the team to evaluate alternative solutions	2.75	4.00	3.50
I feel that the "media" helped the team to select the solution	2.75	3.50	3.00
I enjoyed participating	4.00	4.50	4.25

In addition to reviewing the materials, there was some side conversation related to the colours used in the building model, or commentary on the figures used in the model. Along with this peripheral discussion and silent consideration, there was some potentially relevant discussion which could not be classified into the coding scheme used. For example, one of the tasks was to generate a list of possible changes. Each of the groups, at one point, read back the current list of options which had been developed up to that point. This served as a check for the group of their current status for the task, but did not fit any of the categories for the coding scheme. It is worth noting that a more thorough and flexible coding scheme should be considered in future observational studies. The only potential indication this could make is the ease of conceptualization of the design by the team with lower time spent in the "Other" category, though this cannot be clearly demonstrated from the data sample from this research.

While trying to identify the impact of teamwork on the process, the interviewees all responded that teamwork, in general, was very important to the design and construction process. Responses ranged from statements that early teamwork was crucial to a successful project, to "teamwork is everything." The teamwork was also stated to be "internal, between designers, and among all stakeholders." Many respondents also naturally drew a relationship between the use of BIM and teamwork. Comments included references to the traditional sharing of information and how now "everyone needs to understand the other disciplines' work." It was also stated that teamwork was easier using BIM, citing the ability to show, on the construction site, "here is the problem."

The subjects were also asked to indicate what level of group interaction was appropriate for each stage of the problem solving process. Many of the respondents stated that it depended, very much, on the project and the problem in question. Despite the fact that the

table is generalizing a challenging question, there are some interesting points which can be drawn from the responses. Clearly, as shown in Figure 13, teamwork in small groups is very versatile and works well at all stages in the process, and in many cases appears to be the preferred mode of operation. It is also shown that the step of alternative evaluation may be more effective in slightly larger groups, perhaps to explore more of the issues that may come into play. Also, goal clarification and solution selection appear to be more effective in smaller numbers, or independently. The other item this chart and the question responses show, is there is no clear answer about who should be involved in an absolute sense, but it needs to be decided on a case by case basis.

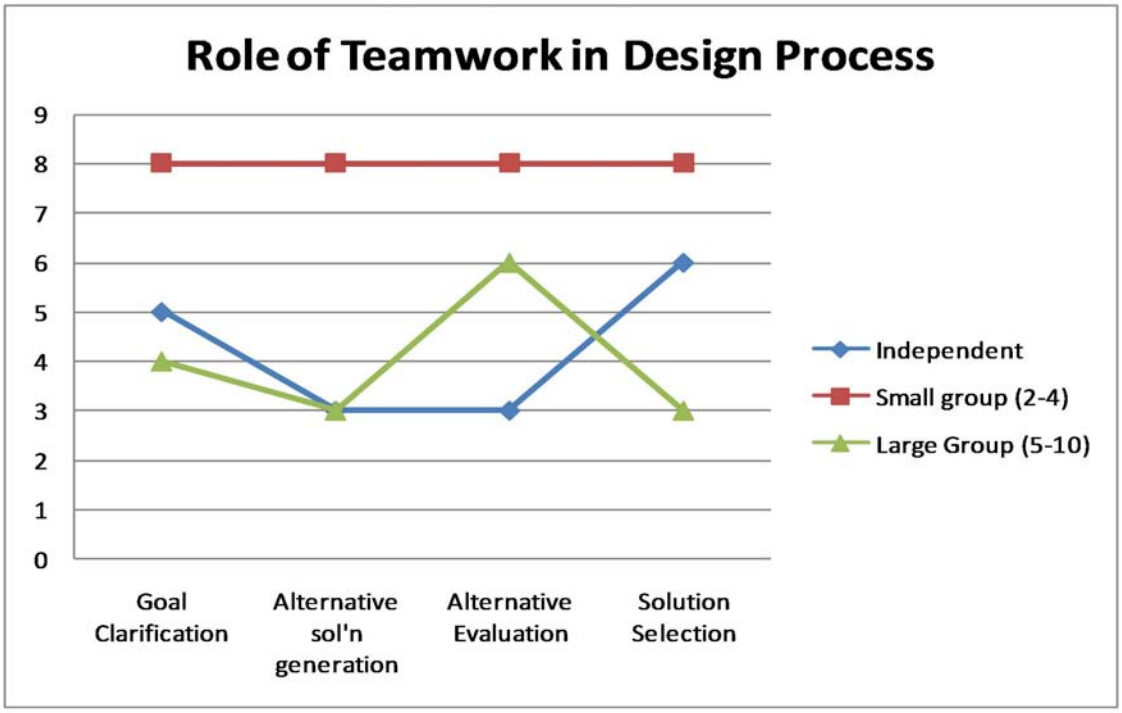


Figure 13. Expectations of team size for stages of design problem solving.

Following these questions on teamwork, and continuing the thread that many of the subjects identified themselves, the subjects were asked more specifically about the impact of BIM on teamwork. It was suggested that teams form earlier in the process and they work more quickly and effectively than in the absence of BIM. Associated with this, it was indicated that the sharing of the BIM files was very important to the teamwork aspect on a BIM project. Several of the responses indicated that teamwork had great potential to be more effective, but there is a clear need for a process of teamwork and someone to manage the process effectively.

There were some mixed feelings about the impact of BIM on project timing, as can be seen in Figure 14. While some believed that it would facilitate an earlier forming of the project team, most believed the team would be formed at the same time as current projects. Also, a larger percentage expected that construction managers would become involved at the same time as they are currently.

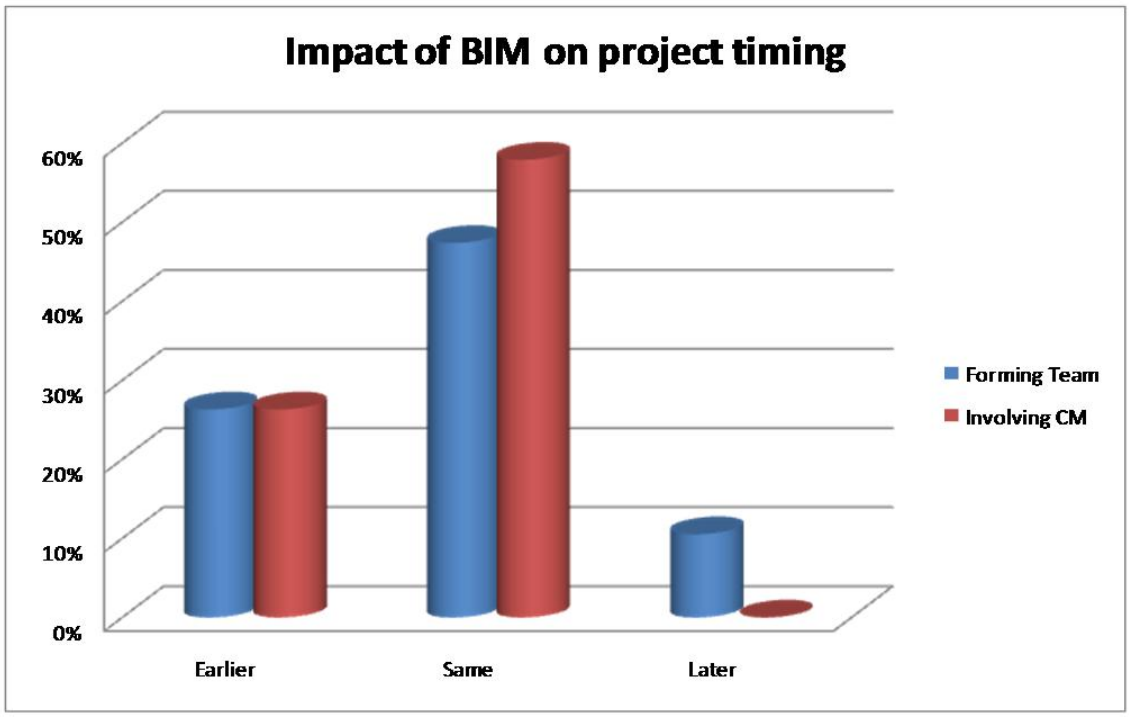


Figure 14. Expected changes to project timing resulting from BIM use.

When asked about the impact that BIM use would have on teamwork in terms of project outcomes, again the views varied. As can be seen in the Figure 14 there was general disagreement about the impact that BIM would have on the time it will take to design a project. While some of the respondents reasoned that the facilitation of information sharing would save time, others offered opinions that excessive information sharing and the need for more thorough collaboration would offset these time savings. It was also pointed out that BIM creates a shift in the roles within design firms, allowing less experienced people to take on more demanding tasks, but this would create challenges in the sense that these less experienced personnel will have less working knowledge and experience to take advantage of the potential offered by BIM. In determining the impact on team interaction and performance, there was agreement that the use of BIM would, at worst, keep the design quality at its current standard, and more than half expected notable improvements in design quality. In trying to discern how these improvements will occur, and based on previous responses to the need for collaboration, respondents were asked about the impact of BIM on the overlapping of different fields of design.

Again, the responses were varied. Despite a few responses indicating a potential decrease in the overlap of design work, most responses indicated either no change or an increase in overlap. In the interviews, the reasoning presented for this was that teams would now have a shared realization of what needs to be done, but still struggle with the challenge of openness.

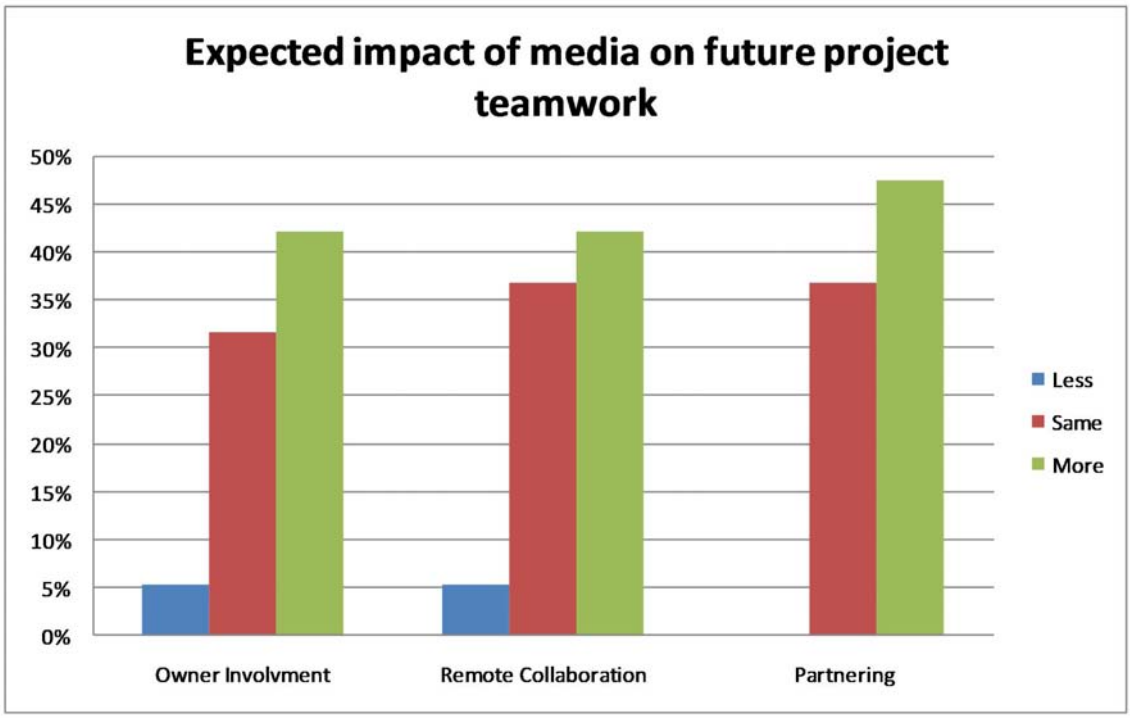


Figure 15. Perceived impacts of BIM on Team interaction and performance.

To carry the concept further, the participants were asked to consider what impact they believed media could have on teamwork. In most of the cases, the responses seized on one of the display systems of interest and offered thoughts on how it could be integrated into a particular task. For example, some respondents suggested the value of being able to use augmented reality systems on a construction site, or the use of multiple SMARTboard displays in a "war room" setting. There were a few common themes among the responses, shown in Figure 16. The common feeling among the respondents was that better utilization of the available media display should increase the clarity of communications. There was slight variation in opinions between communication with the owner rather than within the project team. It is possible that if the question was further refined to indicate the specific lines of communication amongst the team more clearly, there are specific channels of communication that would be improved more than others.

There were other questions asked to determine the impact of media displays on other aspects of project teamwork, with the results displayed in Figure 16. There was a strong theme that the use of different media displays could offer added value in discussions with clients and end users. In several of the interviews, the suggestion was made that the displays could be taken best advantage of early in the process to improve in determining the facility needs, and improving the clients understanding through better visualization. They also felt the display could improve the feedback received from the owner or end user in evaluating the project design.

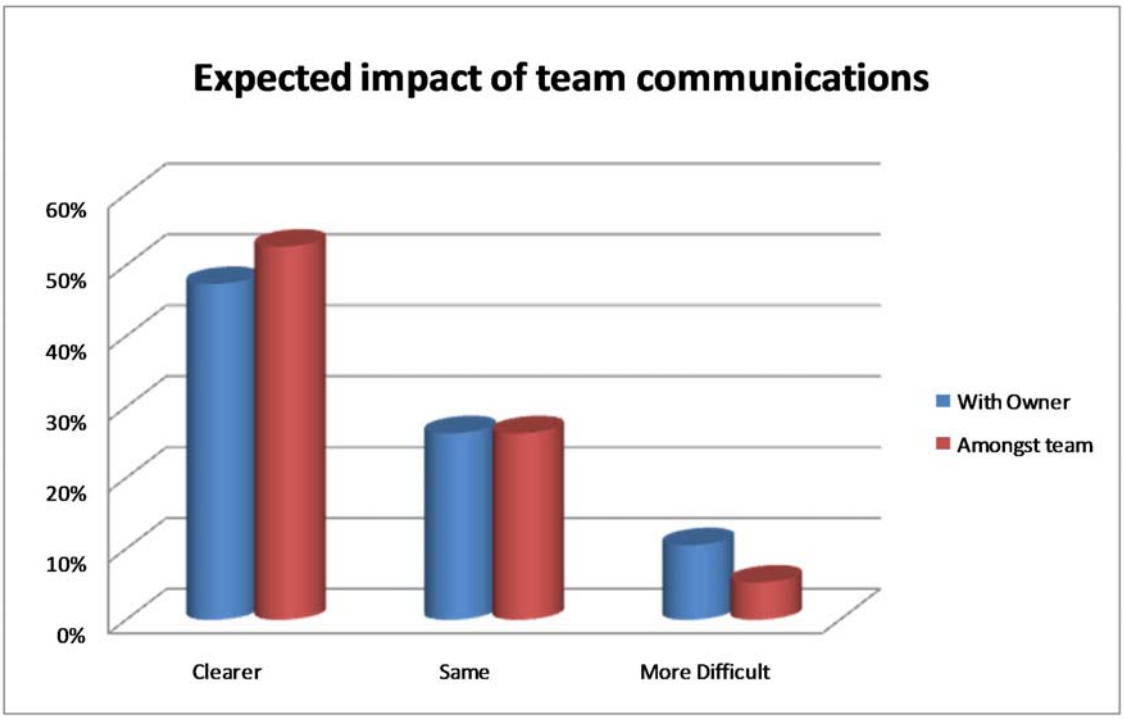


Figure 16. Impact of BIM use on team communications.

Other teamwork considerations which have been noted in the industry are the matters of distributed teamwork and partnering. Respondents were asked what impacts media could have on these, and as shown in Figure 17, again there was a general belief that media offers new opportunity to increase the use of both distributed teams in a more effective manner, and an increased use of partnering and collaboration.

In addition to the responses about specific impacts, there were some interview responses which showed insights into how these tools may fit into the overall process of designing and constructing a building. One response, "models are nice, but do not change the process alone – 'evolution, not revolution'" points out the fact that while modelling is beginning to catch on, it cannot be considered in isolation or as a cure-all for current industry challenges. As another respondent pointed out, "the displays create the

possibility of benefits, but media is just one tool, collaboration is the real goal." Many of the interview subjects were found to have an interest in how media could be utilized to improve collaboration, but there was a common belief expressed that the value of different display traits needed to be more clearly related to aspects of collaboration and roles in the design and construction process.

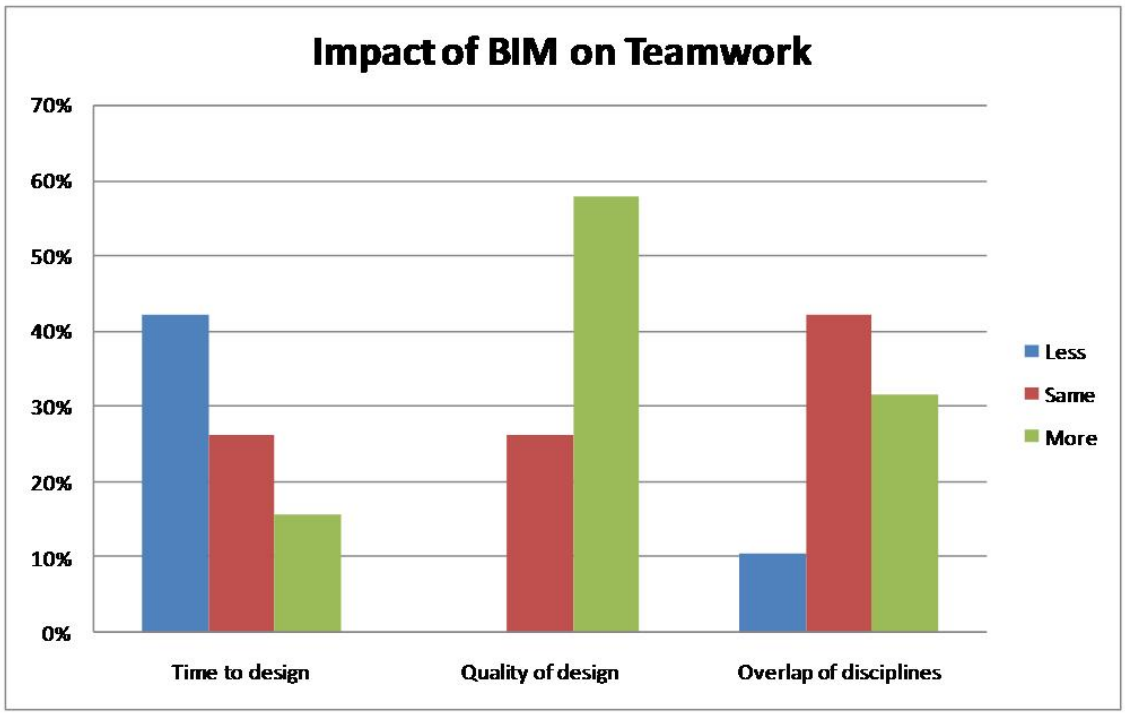


Figure 17. Expected impacts of media on future project teamwork.

5.3 Principle findings

This section on teamwork provided an extensive amount of information from the study about the potential impacts of utilizing media for the improvement of the collaborative process. Several aspects which were identified for the application of BIM and media in the field study are listed below.

- In the experiment, activities where the group spent more time tended to cause lower evaluations of the media for those tasks.
- The coding scheme employed was not flexible and comprehensive enough to demonstrate the effect of the displays on the process and outcomes.
- The use of the monitor and the immersive display were rated as more valuable than paper drawings for understanding of the building design.

- The monitor and immersive displays were rated more valuable than paper drawings for generating and evaluating alternatives.
- Teamwork was found to be very important to the design and construction process by all industry participants.
- Teamwork was expected more in the generation of alternatives and the evaluation of the impacts of alternative solutions.
- BIM was expected to be able to improve team performance if the team could overcome the challenges associated with open information sharing and the increased overlap of design disciplines.
- The use of BIM could shift tasks earlier in the design and construction process.
- Better utilization of display media was expected to contribute to clearer communication amongst project teams and greatly improved communication with the clients and end-users.
- There was a common need identified for determining the display characteristics which contribute to improved collaboration in different settings.

6. Conclusions

In this section, the principal findings from the study are summarized. The results offer some insights into current happenings in the industry, and offer the potential for much future work to be done in defining how these tools and methods can best be employed.

6.1 Principal findings

The principal findings are listed below. Subsequently, possible directions for future research are discussed.

- The development and shift in the use of new media displays strongly correlates with the increased usage of BIM. There were a few specific references directly relating the two, such as:
  - Need for a projection system in conference rooms so the model could be used in meetings
  - Using a second or third screen so information could be displayed on one screen and the model could be displayed on the other
- Information sharing was shown to be a critical issue in the growth of BIM usage and the value of media for utilizing BIM.
- The areas where the monitor and immersive display media were found more valuable coincide with the stages in the design and construction process where more collaboration was expected, namely generating alternative solutions and evaluating the impact of the alternatives.
- The use of richer media displays was expected to greatly facilitate communication with the owner and end-users, allowing them to provide more feedback earlier in the process.

6.2 Future Research

This study was performed as an exploratory step to identify trends and possible causes for the trends observed. There are several aspects of this research which could be carried forward into a more complete study to determine the relationships between the process, model use, and media utilization. Some of these opportunities are suggested here:

- The development of a new coding scheme to track the impact of media use and information exchange on the collaborative process is suggested to more clearly evaluate the impact of the model and media on the process.

- A repeat of this study is suggested in the USA to see if the trends identified are mirrored internationally, or if they are unique to Finland.

- Repetition of the media experiments in the USA to determine which traits are carried over across international borders, and what characteristics differ consistently between the groups in Finland and the USA.

- An in-depth study is needed to more clearly define the media traits and modeling capabilities that should be used throughout the design and construction process. This is an extensive activity and would need to be pursued through a combination of methods:

    - A literature review to relate modeling capabilities to stages of design.

    - A literature review on media and display systems relating them to the factors affecting media use.

    - A theoretical basis correlating team process and structure to the tools they use and the activities they pursue would need to be identified to guide the development of a framework for determining how to use these tools.

    - Longitudinal studies of how teams utilize media throughout the development of a project, offering a variety of tools and training to facilitate their use to test against the framework.

    - A series of experiments to verify the traits of the media and modeling software correlate with the stages of design for which they are suggested.

References

Bannon, L. (1997). Activity theory, *Interaction Design Centre*, Activity Paper September 30, 1997, University of Limerick, Limerick, Ireland.

Bazjanac, V. (2003). Virtual building environments (VBE) – applying information modeling to buildings, In: Dikbas, A. and Scherer, R. (eds.) *ECPPM 2004 – eWork and eBusiness in Architecture, Engineering and Construction*, Istanbul, Turkey.

Birmingham, R., Cleland, G., Driver, R., and Maffin, D. (1997). *Understanding Engineering Design,* Prentice Hall, Europe.

Bowen, D.M. (1995). Work group research: Past strategies and future opportunities, IEEE Transactions on Engineering Management, Vol. 41, No. 1, February 1995.

Byron, K. and Baldridge, D.C. (2007). E-mail recipients' impressions of senders' likability. *Journal of Business Communications*, **44**(2), 137–160.

Campbell, D.T. and Stanley, J.C. (1966). Experimental and quasi-experimental designs for research, Rand Mcnally 1966, Chicago, IL, USA.

CIB w78 (2007). *Proceedings from the 24th International Conference on Information Technology in Construction*, June 26–29, 2007, Maribor, Slovenia.

Cross, (1994). *Engineering Design Methods.* 2nd Edition, John Wiley & Sons. Chichester, UK.

Daft, R.L. and Lengel, R.H. (1986) Organizational information requirements, media richness and structural design. *Management Science*, **32**(5), 554–571.

DeLuca, D. and Valacich, J.S. (2006). Virtual teams in and out of synchronicity. *Information technology & People*, **19**(4), 323–344.

Dennis, A.R. and Valacich, J.S. (1999). Rethinking media richness: towards a theory of media synchroncity, *Proceedings of the 32nd Hawaii International Conference of System Sciences*.

Fox, S. and Hietanen, J. (2007). Interorganizational use of building information models: potential for automational, informational and transformational effects, *Construction Management and Economics*, Vol. 25, Taylor and Francis, UK, pp. 289–96.

Fox, S. (2007). Three original methods for minimizing ambiguities in global project communications, VTT Technical Research Centre of Finland, Working Paper 67, Espoo, Finland.

Goldenkoff, R. (2004). Using focus groups, In: Wholey, J.S., Hatry, H.P. & Newcomer, K.E. (Eds.), *Handbook of practical program evaluation, Second Edition*, Jossey-Bass Publications 2004, San Francisco, CA, USA, pp. 340–362.

Gopinath, R. and Messner, J. I. (2004). "Applying immersive virtual facility prototyping in AECO." *CONVR 2004: 4th Conference of Construction Applications of Virtual Reality,* Lisbon, Portugal, Sept. 14–15, 79–86.

Haymaker, J. (2005). Formalizing and managing the dependencies between models, In: Scherer, R.J., Katranuschkov, P., and Schapke, S.-E. (eds) *22nd Conference on Information Technology in Construction*, Institute for Informatics, Technische Universitat, Dresden, Germany.

Hirvensalo, A. and Kiviniemi, A. (2007). Engineering and construction project information platform, finnish consortium: Project plan. VTT Technical Research Centre of Finland, Espoo, Finland.

Hollway, W. and Jefferson, T. (2000). *Doing qualitative research differently,* Sage Publications 2000, London, UK.

Ibrahim, M. and Krawczyk, R. (2003). The level of knowledge of CAD objects within building information model, *Proceedings from ACADIA22 Conference: Connecting Crossroads of Digital Discourse,* October 23–26, 2003, Muncie, IN, USA.

Jaffe, A.B. (2000). "The U.S. patent system in transition: policy innovation and the innovation process", Research Policy 29, 531–558.

Jonassen, D.H. and Rohrer-Murphy, L. (1999). Activity theory as a framework for designing constructivist learning environment, *Educational Technology, Research and Development;* 1999; 47, 1; Education Module, pp. 61–79.

Kaplan, S.K., Carroll, A.M. and MacGregor, K.J. (1991). Supporting collaborative process with conversation builder, Conference proceedings on Organizational computing systems, p.69–79, November 05-08, 1991, Atlanta, GA, USA.

Kiviniemi, A., Fischer, M., and Bazjanc, V. (2005). Integration of multiple product models: IFC model servers as a potential solution, In: Scherer, R.J., Katranuschkov, P.

and Schapke, S.-E. (eds) *22nd Conference on Information Technology in Construction*, Institute for Informatics, Technische Universitat, Dresden, Germany.

Kreuger, R.A. (1988). *Focus groups: a practical guide for applied research.* Sage Publications 1988, London, UK.

Kuutti, K. (1995). Activity theory as a potential framework for human-computer interaction research, In: Nardi, B. (ed.) *Context and Consciousness: Activity Theory and Human Computer Interaction,* MIT Press, Cambridge, MA, USA.

Lee, A., Aouad, G., Wu, S. and Fu, C. (2004). nD Modeling in construction-buzzword or reality? In: *Proceedings of the International Conference on Construction Information Technology* (INCITE), Malaysia, 18–21 February 2004.

Leicht, R.M. and Messner, J.I. (2007). Comparing traditional schematic design documentation to a schematic building information model, *Proceedings from the 24th International Conference on Information Technology in Construction*, June 26–29, 2007, Maribor, Slovenia.

Löfgren, A. (2007). Tablet computing and lean communication for construction site management, *Proceedings from the 24th International Conference on Information Technology in Construction*, June 26–29, 2007, Maribor, Slovenia.

Madrazo, L. and Weder, A. (2001) Aalto on the Internet: architectural analysis and concept representation with computer media. *Automation in Construction*, **10**, 561–575.

Magent, C. (2005). A process and competency-based approach to high performance building design, Ph.D. Thesis, The Pennsylvania State University, University Park, PA, USA.

Mathers, N., Fox, N. and Hunn, A. (2002). Using interviews in a research project, *Trent Research Group for Research and Development in Primary Health* Care, Institute of General Practice, Sheffield, UK.

McDuffie, T. (2006). BIM: Transforming a traditional practice model into a technology-enabled integrated practice model. *The Cornerstone*, The American Institute of Architects, Fall 2006. http://www.aia.org/nwsltr_pa.cfm? pagename=pa%5Fa%5F200610%5Fbim

McGrath, J.E. "Introduction: the JEMCO workshop: description of a longitudinal study," *Small Group Research*, 24, 1993, 285–306.

Morgan, D.L. (1988). *Focus groups as qualitative research, Second Edition.* Sage Publications 1988, London, UK.

Oppenheim, A.N. (1966). *Questionnaire design and attitude measurement*, Basic Books, Inc. 1966, New York, NY, USA.

Poole, M.S. and DeSanctis, G. (1992) Microlevel structuration in computer-supported group decision making, *Human Communication Research,* Vol. 19, No. 1, pp. 5–49, Oxford University Press, Oxford, UK.

Sawyer, T. (2005). Soaring into the virtual world – build it first digitally, *Engineering News Record,* McGraw Hill Construction, 10 October 2005, New York, NY, USA.

Simon, J.S. (1999). *How to conduct a focus group,* Amherst H. Wilder Foundation, The Grantsmanship Center, Los Angeles, CA, USA.

Schmitz, J. and Fulk, J. (1991) Organizational colleagues, media richness and electronic mail. *Communication Research*, **18**(4), 487–523.

Straub, D.W. (1994) The effect of culture on IT diffusion: email and fax in Japan and the U.S. *Information Systems Research*, 5 (1), 23–47.

Tse, T. et al (2005). The utilization of building information models in nD modelling: A study of data interfacing and adoption barriers, *Journal of Information Technology in Construction* **10**(April): 85–110.

Wang L., Messner J.I., and Leicht R. (2007). Assessement of 4D Modeling For Schedule Visualization In Construction Engineering Education, *Proceedings from the 24th International Conference on Information Technology in Construction*, June 26–29, 2007, Maribor, Slovenia.

Yin, R. (1994). *Case study research: design and methods, Second Edition*, SAGE Publications 1994, Beverly Hills, CA, USA.

Zorn, T. (2005). Designing and conducting semi-structured interviews for research, *Organizational Communication Resources for Teaching*, Waikato Management School, Hamilton, New Zealand. http://wms-soros.mngt.waikato.ac.nz/NR/rdonlyres/em25kkojrnxofpq3j7avsnl46vkmera63kk2s6nd5ey2pypoxs32ne7dykntjde4u2qhffhpol6bzi/Interviewguidelines.pdf. Accessed: 24 July 2007.

Appendix 1: Aurora II Design Activity

Introduction:

The Aurora II project is a newly designed building for the University of Joensuu, in Finland. The Aurora II building will house classrooms, staff offices, laboratory spaces, and the necessary support spaces.

A problem was noticed during the planning authority review of the building as it was nearing 100% designed. The heat loss from the building is approximately 20% greater than is acceptable in the design criteria. The building design needs to be revised so it can fulfill the design criteria, but it is also important to minimize any impacts of these changes on:

1. Building aesthetics
2. Building function
3. Building construction costs
4. Building Lifecycle cost

Your team has been asked to identify design changes that would allow the building to reduce the heat loss, while minimizing the impact to the overall design.

Tasks:

Using the resources provided, your team will have 45 minutes to perform the two following tasks:

Task 1: Develop a comprehensive list of the potential design revisions which could reduce the heat loss from the Aurora II building project.

Task 2: Identify the three (3) design changes that your team believes are the best options for reducing the heat loss to fulfill the design criteria, while minimizing the impact to the overall building aesthetics, function, construction cost, and building lifecycle cost.

Appendix 2: Post Experiment Questionnaire

Field of Experience/Discipline: Architect/Structural/HVAC/Construction

Years of Experience:

1. Have you had the time, before now, to consider the affects of media choices on project team performance/results?
2. Have you had the time, before now, to consider the affects of media choices on project team interaction?
3. Please write on the lines below, in order of least to most useful, how useful the computer monitor media was for each of the following tasks:

Tasks:	***Clarification of Goal***	***Evaluation of Alternative Solutions***
	Generation of Alternative Solutions	***Selection of Solution***

Least Useful _____ Media Not Used for the

_____ _____

_____ _____

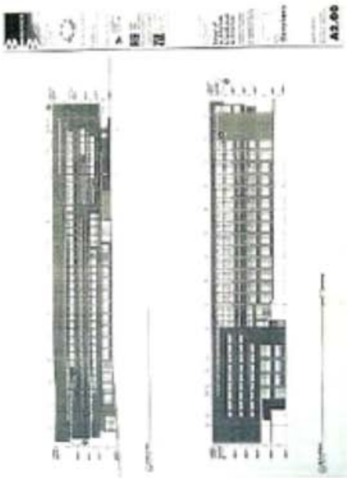
Most Useful _____

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I feel that the “media”helped the team to understand the task goal	1	2	3	4	5
I feel that the “media”helped me understand the building design	1	2	3	4	5
I feel that the “media”helped the team develop a shared understanding of the building design	1	2	3	4	5
I feel that the “media”helped the team to generate alternative solutions	1	2	3	4	5
I feel the “media” helped the team to evaluate alternative solutions	1	2	3	4	5
I feel that the “media” helped the team select the solution	1	2	3	4	5
I enjoyed participating	1	2	3	4	5

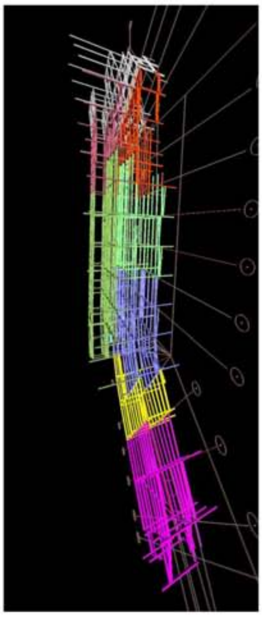
Appendix 3: Interview Question Schedule with identified prompts and probes

Question	Prompt(s)	Probe(s)
Q 1: What have been your experiences with 3D and/or Building Information Modeling (BIM) since 1.1.2004?	1. Model images 2. Types of models 3. Types of analysis	1. Are they used in a productive way? 2. Are they used at the right stage or phase in the process? 3. Are the right project team members involved in the development or use of 3D/BIM?
Q2: In your experience, how has the use of modeling changed since 1.1.2004?		1. Is 3D/BIM used more/less often? 2. New software? 3. Changed peoples' roles during projects? 4. Changed the process for developing the design? 5. Changed building design quality?
Q 3: Do you expect the use of models to change by 2010?		If Yes: What impacts do you foresee for the industry? If No: Why not?
Q 4: Have you had the time before now to consider the affects of media choices on team…	4. Media images	4.1)...Interaction? 4.2)… Results? If Yes: What thoughts have you had?
Q5: What have been your experiences with different media in the design and construction process?		1. Are they used productively? 2. Are they used at the right stage in the process? 3. Are the right project team members involved in their development/use?
Q6: In your experience, has the use of media changed since 1.1.2004?		If Yes: How?
Q7: Do you expect the use of media to change by 2010?		If Yes: What impacts do you foresee for the industry? If No: Why not?
Q8: What role do you feel project teamwork plays in the design and construction process?		1. What tasks are best solo/independently performed? 2. What tasks are small best for small groups (2-4 people)? 3. What tasks are best for large groups (5 or more)?
Q9: In your experience, how has project teamwork changed since 1.1.2004?		1. More/less teamwork 2. Quicker/Slower decision process 3. More/less time spent modeling 4. More/less time coordinating with other disciplines?
Q10: Considering the changes in modeling and teamwork that you have talked about; what impacts do you think media could have on teamwork?		1. What types of projects would it impact most? 2. What types of projects would it impact least? 3. More likely during Design or construction? 4. Early or late Stage/Phase of process?

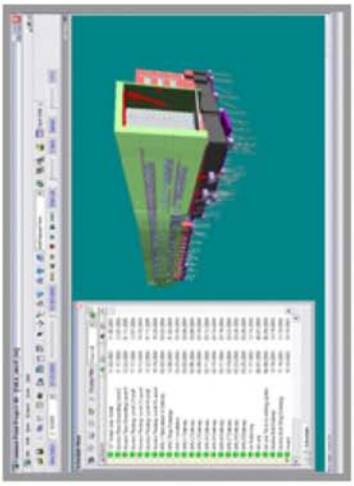
Appendix 4: Prompt 1 – Model Images



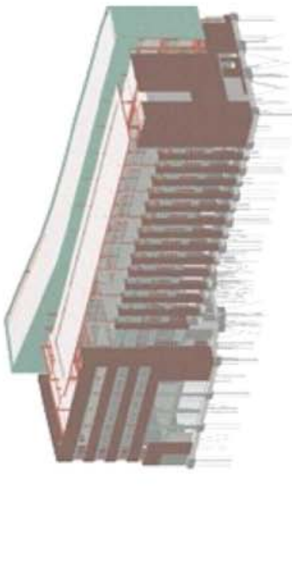
2D Model
Diagrammatic representation of facility design



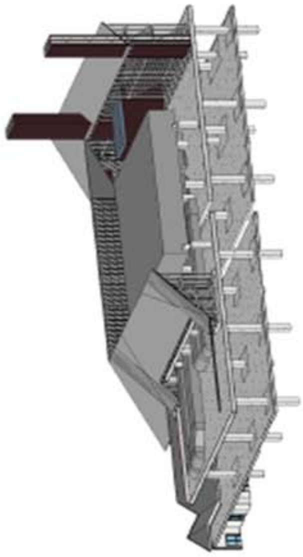
3D CAD Model
Adds depth to the design providing perspective of physical components



4D CAD Model
Adds time dimension to for process visualization



nD Model/BIM
Adds attribute or resource information for design/planning analysis



Interdisciplinary BIM
Adds multiple systems for cross-disciplinary analysis and coordination

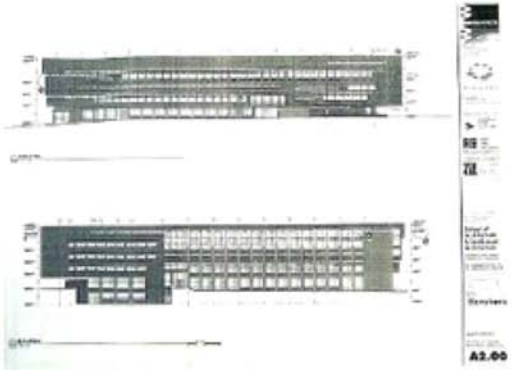
Prompt 2 – Model types and uses

Modeling Uses	2D	3D	4D	Arch BIM	Struct BIM	Mech BIM	Elec BIM	Interdisciplinary BIM
Creating/ Authoring Design								
Sharing/ Communicating Design								
Analyzing Design								

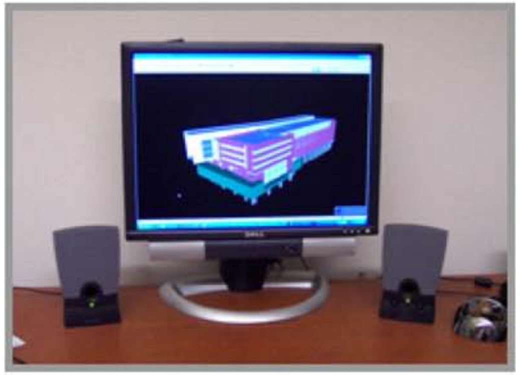
Prompt 3 – Types of analyses

Building Quantities	Heat Loss	Internal Environment	Space Management
Construction Costs	Energy Consumption	Lighting Simulation	Rental Management
Construction Schedules	Life-cycle costs	Acoustics	Building Cleaning
Production Schedules	Life-cycle analyses	Fire & Smoke	Building Maintenance
Clash Detection	Computational Fluid Dynamics	Emergency Escape	

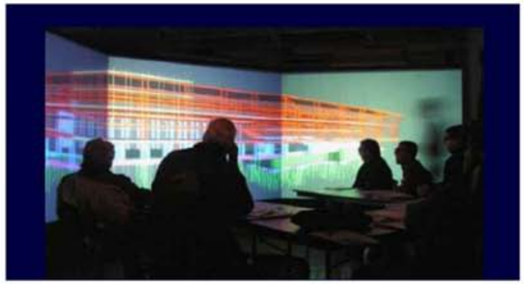
Prompt 4 – Media Images



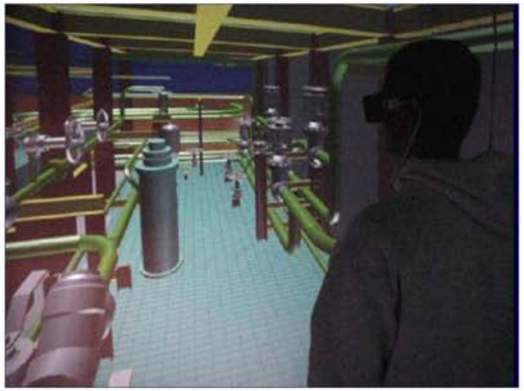
Paper
2 dimensional visual representation



Desktop Monitor
Adds the ability to interactively modify user's view



Large Screen Display
Increases scale or field of view



Immersive Display
Adds depth perception to view

Physical Model
Small scale physical representation

Mockup
Full Scale partial representation

http://www.archsky.com/projects/portland_jetport/mockup.JPG

Tasks:	Independent	Small group, (2-4)	Large group (5+)
Clarification of Goal			
Generation of Alternative Solutions			
Evaluation of Alternative Solutions			
Selection of Solution			

Clarification of Goal:
Questions, answers, statements, and/or discussions that clarify the goal and the criteria which it must fulfill.

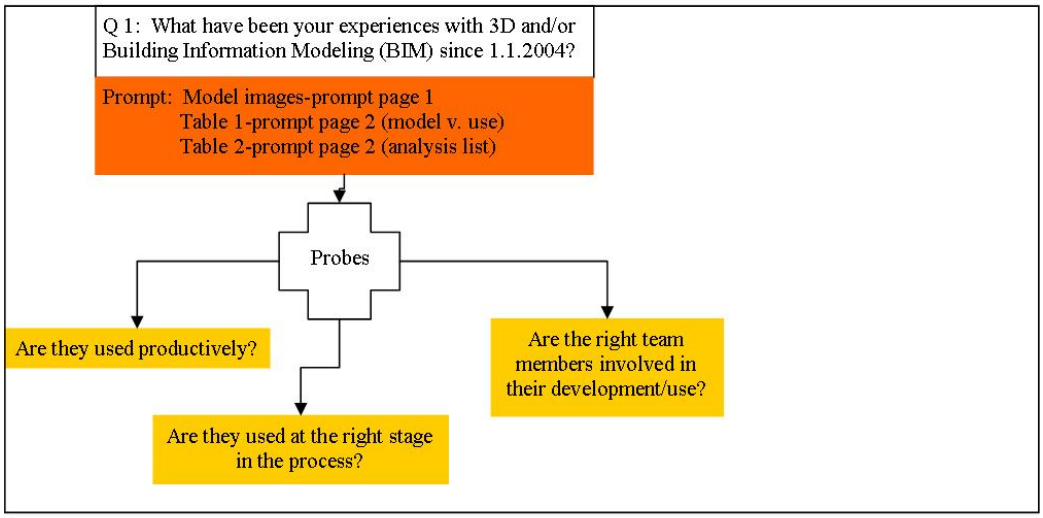
Generation of Alternative Solutions:
Questions, answers, statements, and/or discussions that generate a list of potential solutions which could fulfill the goal.

Evaluation of Alternative Solutions:
Questions, answers, statements, and/or discussions that evaluate the potential solutions.

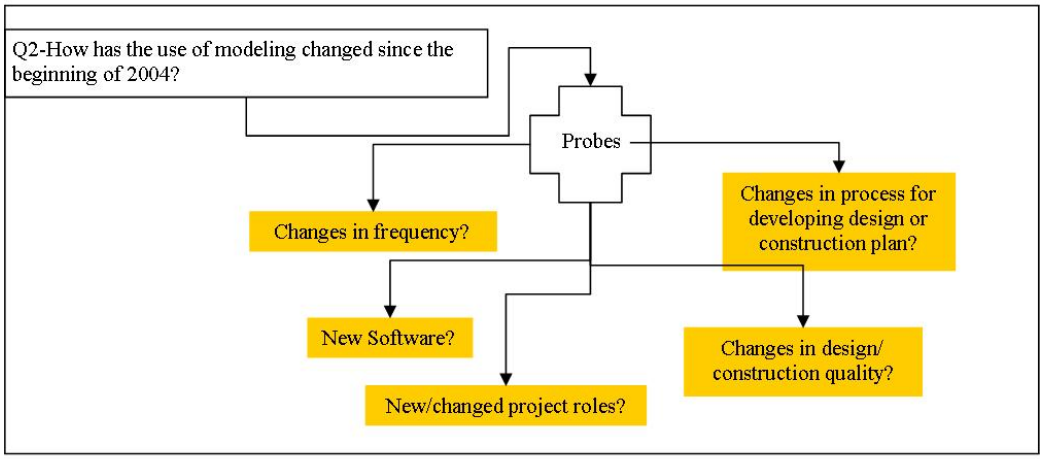
Selection of Solution:
Questions, answers, statements, and/or discussions which lead to the rejection or the selection of a solution.

Appendix 5: Question Mapping

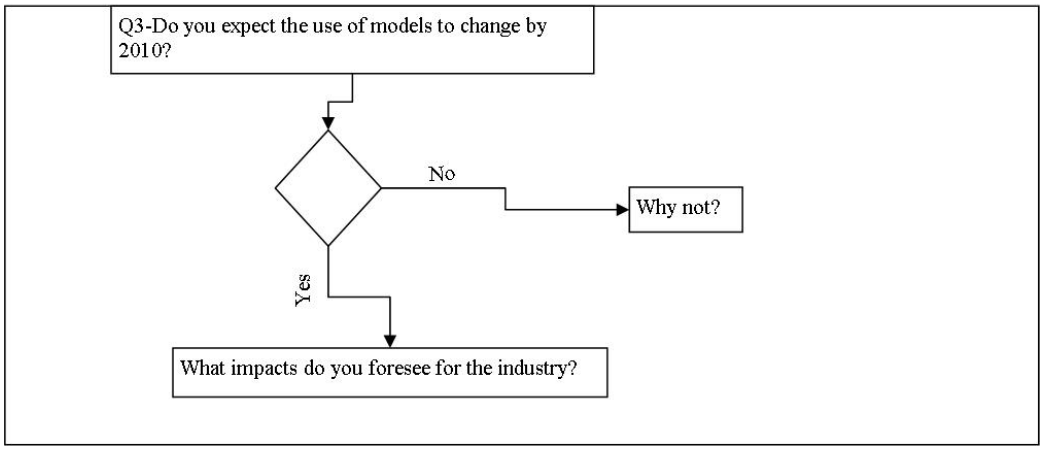
Modeling - Question 1



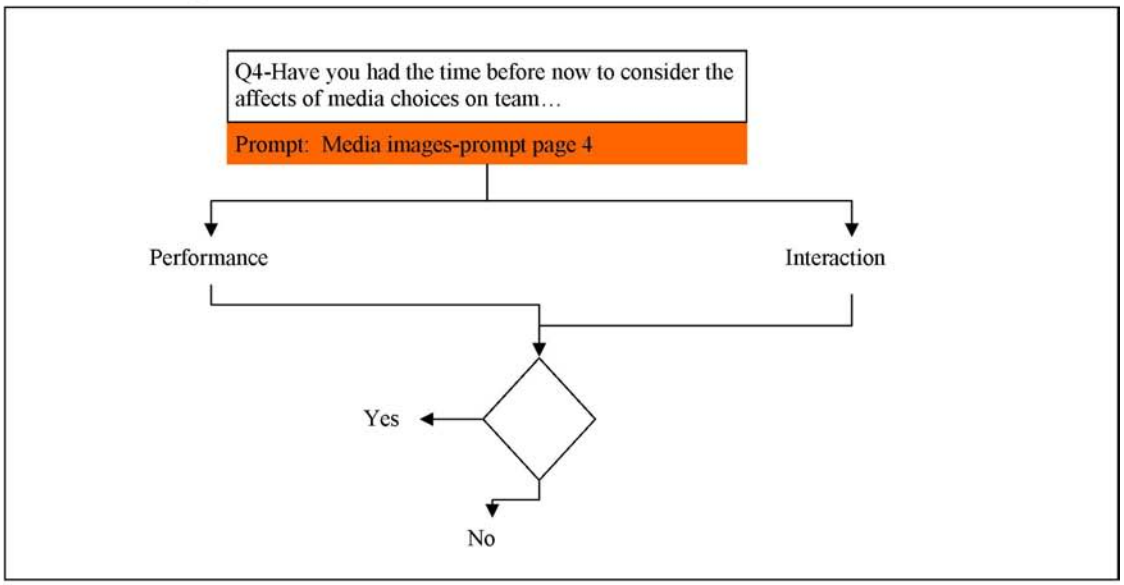
Modeling - Question 2



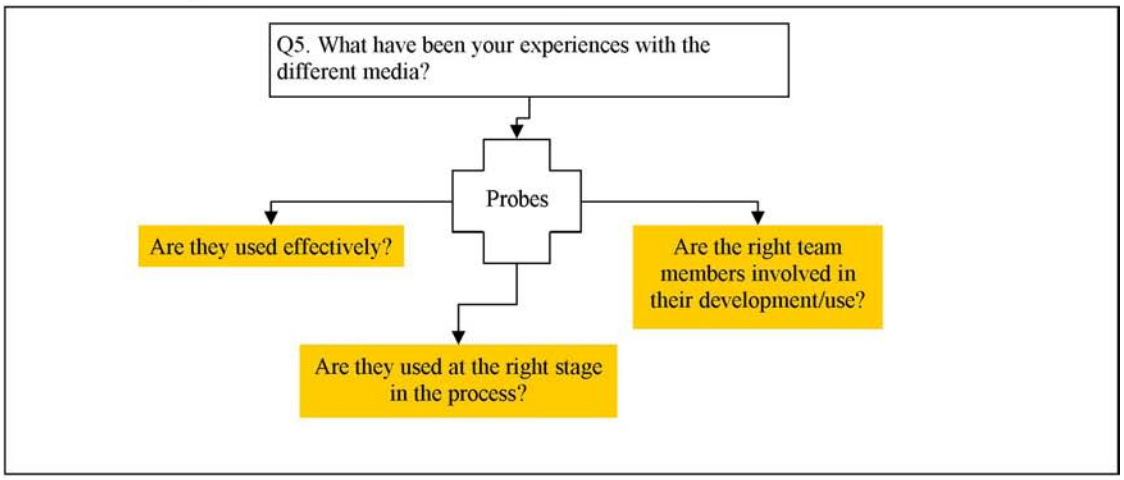
Modeling - Question 3



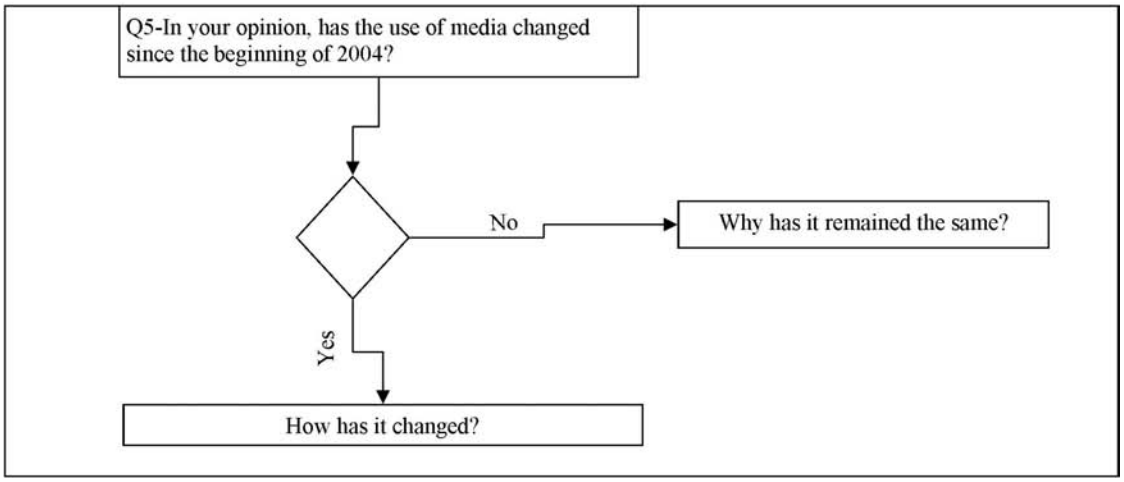
Media - Question 4



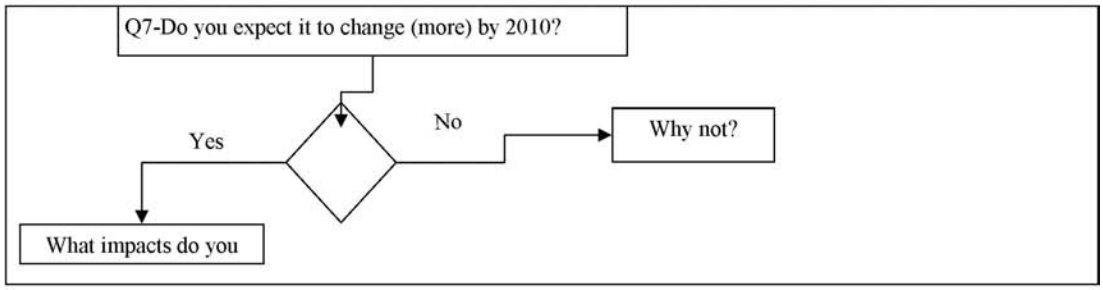
Media - Question 5



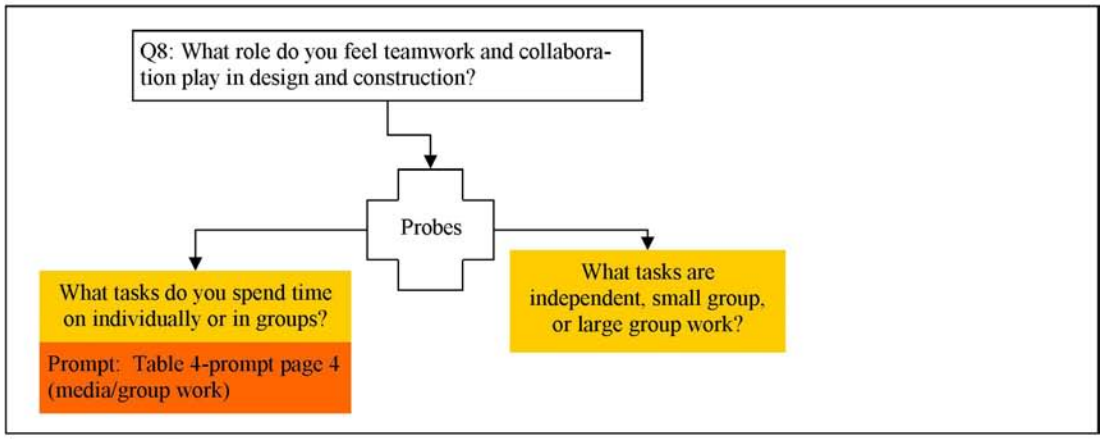
Media - Question 6



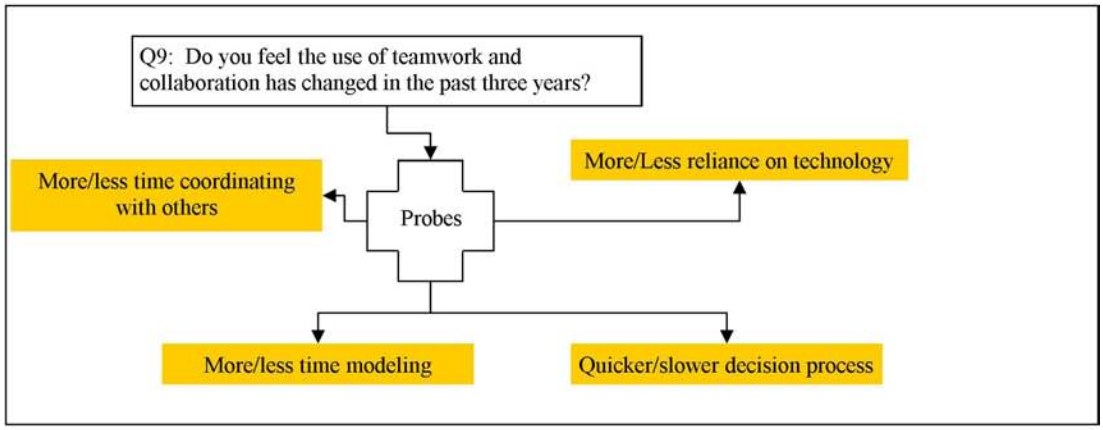
Media - Question 7



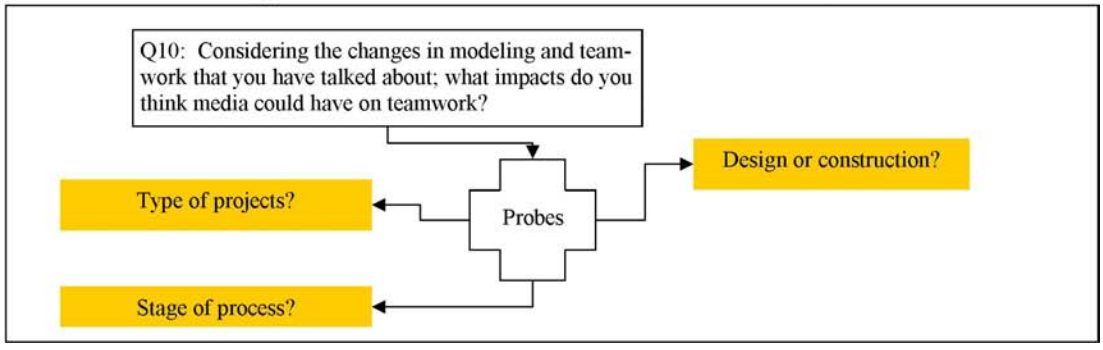
Teamwork - Question 8



Teamwork - Question 9

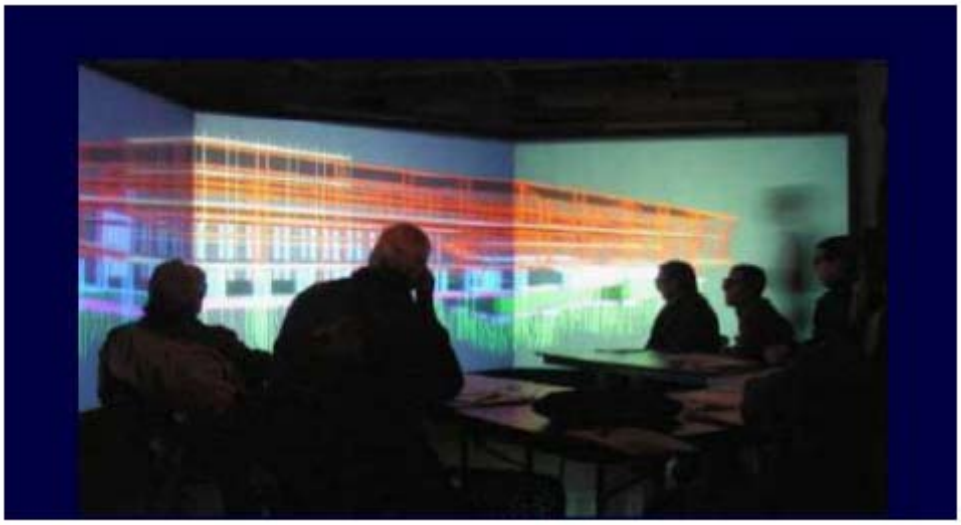


Teamwork - Question 10



Appendix 6: Participate in International Research

Strategic affects of media choices on team performance



ROUNDTABLE DISCUSSION

Discssion Topic
What can be the strategic affects of media choices on team behavior and team performance?

Discussion Format
Round table (exploratory discussion among experts facilitated by a moderator)

Discussion Participants
Finnish AECO companies, plus Rob Leicht and John Messner from Pennsylvania State University, USA.

Discussion Content
Following a brief presentation by industry experts introducing the topic, participants will be invited to discuss strategic opportunities and threats created through the introduction of new media.

Time and Place
The round table discussion will be on Tuesday June 19th at room *Majakka Betonimiehenkuja 3, VTT, Otaniemi. From 1.00 pm to 3.30 pm.*

For more information, please contact:

Stephen Fox: stephen.fox@vtt.fi
Tarja Mäkeläinen: tarja.makelainen@vtt.fi

Appendix 7: Summary of PSU/VTT Roundtable of the Strategic Impacts of media choices on team performance

Intro & questions:

The Roundtable discussion, held on Tuesday 19 June, 2007 was held at VTT in Espoo, Finland. The Roundtable was attended by industry professionals from Finland representing Architecture, structural design, HVAC design, and BIM related Software. The discussion started with an introduction to the topic of the use of media in AECO by a presentation of the uses being employed at Penn State in the US and the resulting interest in the topic from US companies.

Following the presentation there were some questions pertaining to the value of Stereo visualization in terms of added value to the display. The perspectives presented included the use of the visualization for task capability, but the value varies with the task being performed and the need for stereo visualization to the given task. The option of force feedback was suggested for certain applications, specifically ergonomic studies where the spaces are quite small, such as the support spaces on aircraft carriers.

The perspective of using the media in a design environment was also briefly discussed with the comment that the typical practice currently is to design to specific viewpoints of the building, but when using a model with stereo visualization the movement within the model is almost unavoidable so the designer will need to verify the impacts of the geometry in 3D.

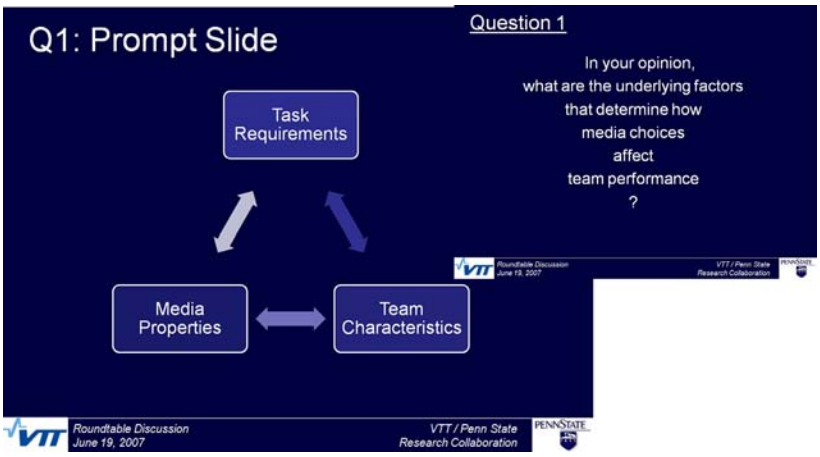
Question 1:

From there the discussion shifted to a more structured progression focusing on the underlying factors which affect team performance. The discussion started at the use of physical models and mockups, with the comment that physical models allow the visualization of the geometry, but do not allow the visualization of the accompanying information or the ability for the audience to interact with the information, whereas with digital models, the users can visualize the information. The discussion then shifted to the fact that there were two variables being discussed, the software and the hardware, in other words the interface of the audience, and the information with which they are interacting.

From this point, it was determined that there were two fundamental purposes to the use of media, which are: **Using the media to understand yourself – so the extension of**

the media as a way of developing ideas through means such as sketching; and the use of media as a means of communicating with others whether to present them with information or to try to reach a shared understanding.

The point proceeded to the concept that the task being performed and its purpose was fundamental in the choice of media, and that the purpose of almost all tasks was to facilitate decision making (John). The way the media was used to support that process could vary however, it could be used to reach shared understanding or it could be used as a persuasive or coercive tool to convince others of the value of a particular solution. In addition, the people in the team should affect the choice of media as well as the "thing" being represented or visualized. The variables associated with those decisions could be the information being worked with, the importance of the accuracy or detail of the information, as well as the location of the team – are they in the same location or working in a distributed manner.



Q2 Task Requirements -

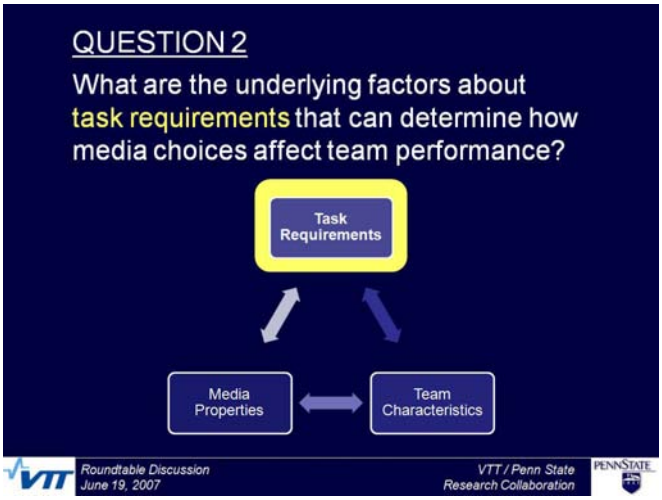
The discussion moved at that point to the discussion of the specific factors which underlie the meeting of task requirements on team performance. The first question raised was, what is meant by "team performance" since there are many ways to measure performance, whether it is speed, efficiency, quality or quantity of results, as a few examples. The answer, for the purpose of the discussion, was that team performance was meeting the objectives agreed upon, or imposed upon, the team.

From there, the identification of the requirements began with the fact that there are many different tasks which are performed and that they vary with who amongst the team is involved and how many people are involved. Also, it was pointed out that the media used will vary based on the needs of the individuals involved, with the quote "my boss has different needs than I do" and therefore his requirements for his computer

capabilities are different. The goal the team is trying to achieve arose as an important aspect, whether the team/individual is trying to understand a concept, convince someone, and the audience they are appealing to will affect the outcome as well. The fact that the process involved was an important characteristic of task fulfillment was also pointed out (John). For example, in performing a virtual mockup of a courtroom, the factors which were identified as being imporatnt included:

- The use of 3D
- Scale of the display
- Sightlines
- Security
- Perception of depth

But the process used for the review of the mockup lacked consistency in its original form. So the use of the virtual mockup changed the variable that the entire team was not able to "wander around" the mock up and then compare notes. The team needed to work through the model one point of view at a time. The change in that variable created a re-definition of the purpose of the review, and **the resulting process was changed**.



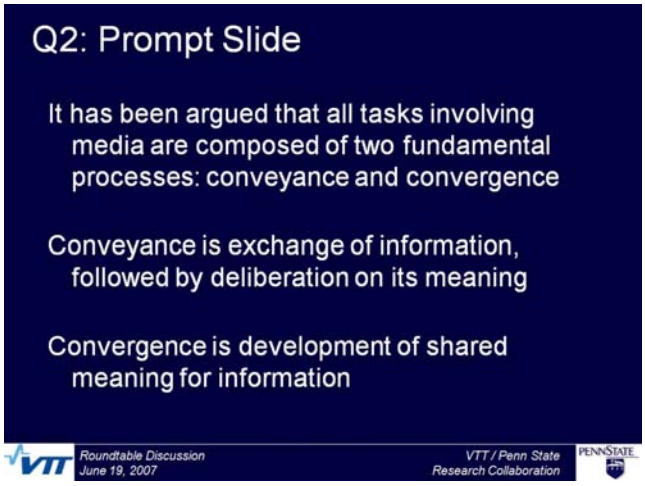
Q2 Prompt – Conveyance & Convergence

The introduction of the information researched from other fields of study, in particular communications, was presented to offer some terms which would enable the conversation and focus on how the information translates into AECO. The first comment from the industry members was an example to discuss the relationship of terms to AECO. The example was the emailing of a construction schedule out to the project team in PDF format, no one from the team reads the schedule, then a meeting is held to go over the schedule at which point a 4D animation of the schedule is displayed and the understanding of the group is quickly reached.

The response was that there were interdependencies of the tasks performed by teams in the AECO projects. The **importance of the dependencies between systems/disciplines** causes a great need for the convergence/shared meaning when performing almost any task on the project. The need for both conveyance of information and the convergence on shared meaning was stated to be important, but the industry has conventions for how information is shared amongst the project team. The introduction of new media allows for increased understanding of the information in new, innovative ways. Another factor of increasing importance in the industry is the time taken to convey the information.

Also, the issue was raised that there can never be a truly "perfect understanding" because each individual in a project has separate experience and knowledge, as well as personal goals/objectives. The focus on the common goals of the project is very important to focus upon for the shared understanding. The value may not necessarily be in reaching a shared understanding using the media, but in facilitating the decisions made through the shared understanding. The understanding is a desired aspect to ensure successful decisions in the process.

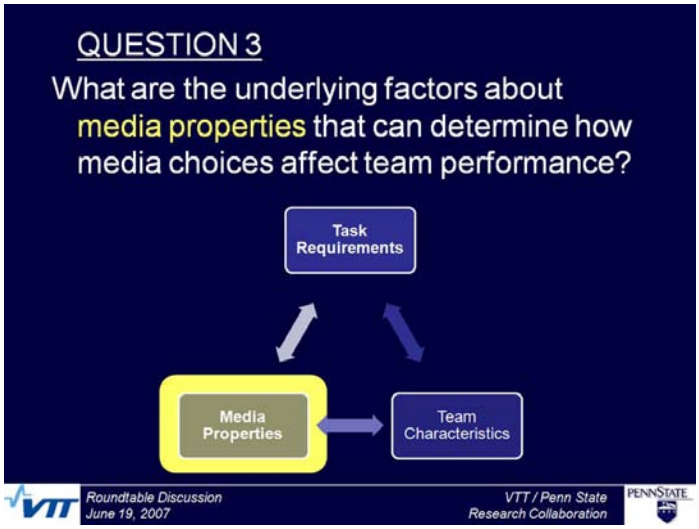
One of the challenges to the terminology brought in from Communications is that it focuses on sharing information between people, but its consideration of how that information is created may not encompass the complexity of the role it plays in AECO. The iterative nature of the design process helps show the need to make "good" decisions as early as possible. The change in the media used may cause challenges, because the brain becomes comfortable with a particular medium and can interact with it with minimal conscious effort, but when switching to new media the effort involved in interacting can complicate the process and the full efforts of individuals may not be focused on the task but being used to learn the interaction while trying to perform the task.



The statement was made that BIM needs to be separated from Media for the discussion; one is focused on the creation of information, while the other is the sharing of information. The technology (media) should be used to ensure the convergence of understanding for the information.

Question 3 – Media Properties

Following well on the last comments from the comment that the model and media need to be treated as separate entities, the conversation shifted to the underlying properties of media. The comments were raised that media needs to present something, the information is therefore important. Also, the meaning needs to be clear to the audience, and the targeting of the audience should fit the media and how best to convey that information.



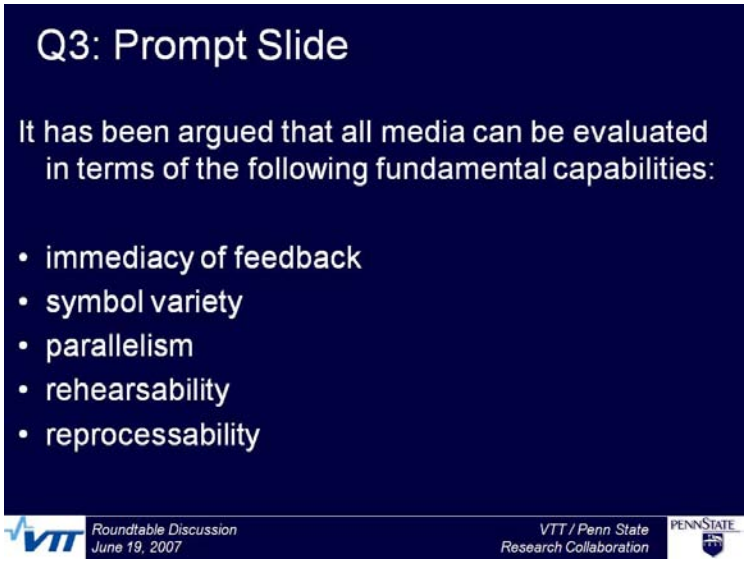
Q3 Prompt – Fundamental Media Capabilities

With the introduction of the prompt of media properties from theories concerning communications, the discussion shifted to the point of factors affecting the team vs the outcome of a team effort. The point was then raised that there are factors unique to the industry which will affect the outcome, such as delivery method, and project constraints such as deadlines. Another person raised the issue of synchronous vs asynchronous teamwork (collaboration vs cooperation). The choice of media will be different if the team is working on the project together at the same time, as compared to if they team is working on the same project but not necessarily in a combined effort.

The issue was then raised of listening in parallel, and seeing vs understanding the information being conveyed. Also, the ability to live modify a model and whether that's

simultaneous amongst the team, or if only one person can access and change the model content. The idea of parallelism was found to be important for the industry because of the number of people trying to concurrently access information and develop new information. It was commented then that the list lacked a component to cover the resolution or granularity of the information. For example, someone trying to view information on a mobile phone in comparison to using an immersive display will have different capabilities and constraints in the detail which can be represented and understood.

Additionally, the comment that even if you can classify the media factors, the psychological aspects of teamwork would still be neglected and are very important in AECO projects. Also, the way the information is "experienced" can be different. The example cited was watching a movie on a mobile phone or IPod vs being in an IMAX theater – the greater the impression the greater the experience. But the tools can be twisted to hide the information that you need in an effort to sell an idea or concept through the experience.



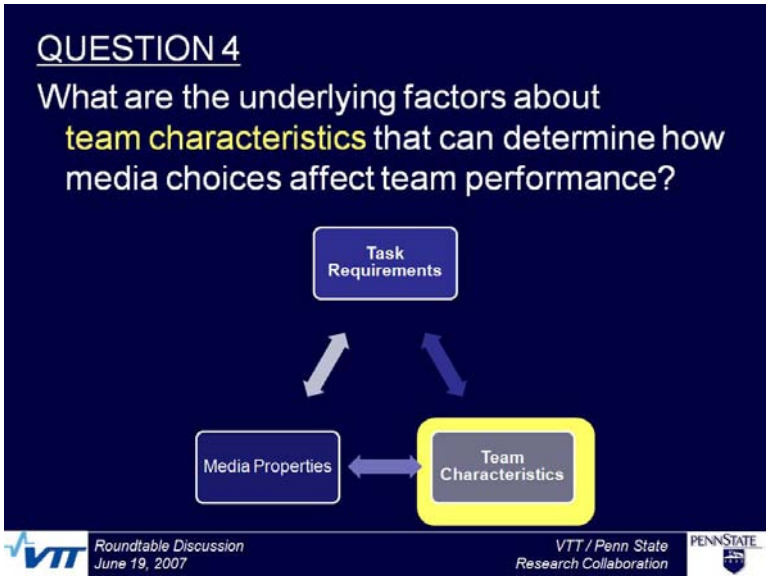
The factor of immediacy was raised in another form using the term latency of feedback (CIFE). The scale and granularity was again raised with the fact that digital information allows a variety of representation and the ability to reprocess or change the information.

Question 4 – Team Characteristics

The discussion was again moved forward to discuss the aspect of team characteristics and how they relate to project communications. The early examples raised were different team makeup, nationality and perceptions of media. The converstion quickly moved to BIM and media with the aspect of experience with 3D and the ability of

immersive displays to supplement understanding, but that the displays shift where your attention is focused.

The fact that extra information can be incorporated into the model, and whether or not all of the information is necessary for the user was raised. The trait that the personnel involved need to be able to "read" the media being used was important. Inexperience and overburdening of information can mislead the user, sometimes intentionally to allow the user to think they are influencing the design when the designer purposefully drew the attention to aspects for that purpose.



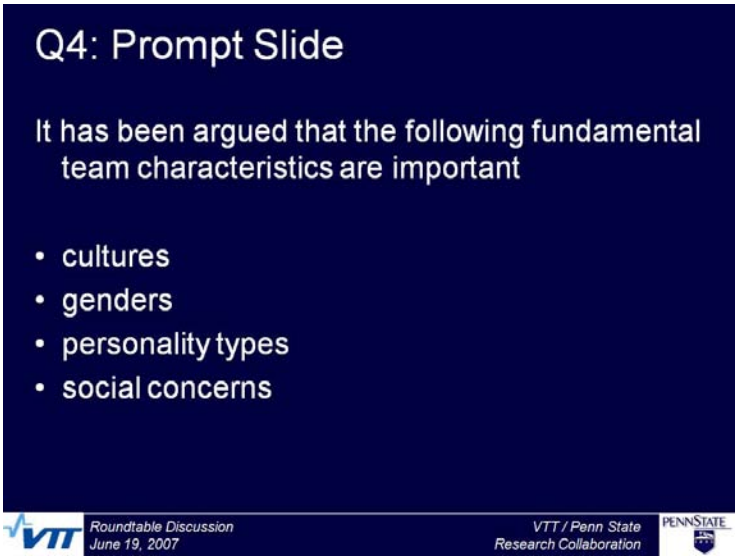
The homogeneity of the team members was considered to be a factor. Also, the matching of the media to the need, and the ergonomics of the situation. For example, is the person in a cave with some type of force feedback to provide sensory information, or simply navigating from a desktop.

Q4 Prompt – Fundamental Team Characteristics

Again a prompt of predefined team characteristics was introduced to focus the attention on the factors affecting team behavior. The issue of team knowledge was raised, as well as the familiarity with the information in question. Also, the use of media outside of professional life was considered to be a factor, people will have different levels of comfort with different technologies. The more conventional the display, the more comfortable people will tend to be with using it.

Other factors raised included the team size, how they were related to the information being reviewed, and their level of influence on the outcome. An example was raised of

a software which added a chat capability for teams sharing information, which had been added on request. The capability was found to be little to no use in practice. The opinion was that the personnel who were not comfortable with "chat" tools did not use it at all, and those who were comfortable tended to still use the freely available tools, such as AOL Instant Messenger, MSN Messenger, etc. The opinion was stated that social practices could be a factor in how technology is used.



The conversation shifted to the discussion that even if a team could define the appropriate media for a specific use, they are still limited to the available media. The general agreement amongst the group was that the emphasis placed within the industry was mainly in marketing of services. The feeling that the goal should be on effectively using information was raised. First, information does not always reach the person(s) who need it. Second, there is information which is created and shared, but not used. The belief was that the need was for a better process to use the information. An example was cited of how information is created and used for steel, the manner a designer creates and uses information, is developed differently than the fabricator, and still differently from the erector.

Final discussion

There was some agreement that people are still comfortable/"used to" using paper documents to identify the necessary information, and they are not ready for receiving information in a new manner. Also, the separation of the content from the representation (model from media) is challenging because they are strongly tied together. The fact that the impacts are very challenging to measure was also agreed upon due to dependence on team and project characteristics. It was suggested that the research could present

the information as Pro's and Con's and allow companies to develop their own strategies based on their business model and team needs.

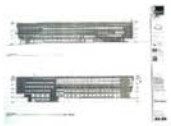
The idea was presented for discussion that the industry should be moving towards a first time correct design. However, the iterative nature of design and knowledge management aspects of projects was agreed to prohibit this as a practical outcome. The use of collaboration and its timing was suggested as a means to limit iterations of the design cycle, with the phrase "fail often, early" but that it was still a part of the process.

The issue was then raised that technology could encourage team members to be less thorough in performance of their design, but was rebutted by the idea that feedback from the tools and the ability to collaborate through different media would discourage this in turn. The challenge was agreed as how to put the "best" media into place, especially with how it continuously is evolving into new forms and resources.

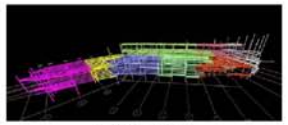
MEDIA USE QUESTIONNAIRE

Profession: Architect Structural HVAC Electrical Construction Owner

1. Please indicate which type of models you have experience with, and how those models were used



2D Model
Diagrammatic representation of facility design



3D CAD Model
Adds depth to the design providing perspective of physical components

4D CAD Model
Adds time dimension to for process visualization

nD Model/BIM
Adds attribute or resource information for design/planning analysis

Interdisciplinary BIM
Adds multiple systems for cross-disciplinary analysis and coordination

Use	2D	3D	4D	nD/BIM	Interdisciplinary BIM
Create Design					
Analysis of Design					
Communicate design to others					
Received from other designers/consultants					

2. Please indicate if you have seen any of the following changes in the uses of modeling over the past three (3) years:

Number of projects using models	decrease	same	increase		
Change in design or construction process	yes	no			
Systems now modeled that were only 2D before	Architecture	Structure	HVAC	Electrical	Construction
Coordination amongst team	worse	same	better		
Necessity of Early planning for models	Less	same	more		

6.1 What aspects of displays do you expect to change by **2010**?

Screen size	smaller	same	larger
Screen resolution	lower	same	higher
Number of screens/monitors	fewer	same	more
Interaction with model	easier	same	harder
Immersive ability	less	same	more
Distributed teamwork	less	same	more

7. For each of the following please indicate how important teamwork is:

Goal setting	Not	Somewhat	Very
Developing options & alternatives	Not	Somewhat	Very
Analyzing & Evaluation options	Not	Somewhat	Very
Making project decisions	Not	Somewhat	Very

8. How has BIM impacted project teamwork?

Forming project team	Earlier	Same	Later
Time to create design	Less time	Same	More time
Quality of design	Lower	Same	Higher
Overlap of design fields	Less	Same	More
Involvement of Contractor	Earlier	Same	Later

9. Considering the impacts you have seen to modeling and teamwork, what impacts do you think media could have on teamwork?

Owner involvement	Less	Same	More
Communication with owner	Clearer	Same	More difficult
Communication with other designers	Clearer	Same	More difficult
Remote Collaboration on projects	Less	Same	More
Partnering between companies	Less	Same	More

3. Which of impacts do you expect in the next 3 or 4 years?

Use of BIM	less	same	more
Collaboration	less	same	more
Create models of other designers' work	less	same	more
Focus of project on Model	less	same	more
Use in other stages (construction, operations)	less	same	more

4. What have media have you had experience in using?


Paper


Desktop Display


Large scale display


SMARTboard


Immersive


Augmented Reality


Physical Model

Use	Daily	Every few days	Rarely	1 or 2 times	Never used
Paper					
Desktop Display					
Projection/Large scale					
SMARTboard (I-Room)					
Immersive Display (CAVE)					
Augmented Reality					
Physical Model					
Teleconferencing					

5. What changes have you seen in media usage since **1.1.2004**?

Paper	less	same	more
Desktop display	less	same	more
Projection Systems display	less	same	more
Physical Models	less	same	more
SMARTboard system	less	same	more
Immerrsive Display	less	same	more
Augmented reality	less	same	more
Remote Collaboration/Teleconferencing	less	same	more

5.1 What aspects of displays have you seen change?

Screen size	smaller	same	larger
Screen resolution	lower	same	higher
Number of screens/monitors	fewer	same	more
Interaction with model	easier	same	harder
Immersive ability	less	same	more
Distributed teamwork	less	same	more

6. What changes do you expect to see in media usage by **2010**?

Paper Usage	less	same	more
Desktop design	less	same	more
Projection Systems	less	same	more
Physical Models	less	same	more
SMARTboard use	less	same	more
Immerrsive Display use	less	same	more
Augmented reality use	less	same	more
Remote Collaboration	less	same	more

VTT Working papers

70 Hemilä, Jukka, Happonen, Ari & Jansson, Kim. Vendor Managed Inventory models in Sweden. Industrial benchmarking experiences from autumn 2006. 2007. 26 p.

71 Hietaniemi, Jukka & Rinne, Tuomo. Historiallisesti arvokkaan kohteen toiminnallinen paloturvalli-suussuunnittelu. Esimerkkitapauksena Porvoon museo. 2007. 136 s. + liitt. 44 s.

72 Sippula, Olli, Hokkinen, Jouni, Puustinen, Harri, Yli-Pirilä, Pasi & Jokiniemi, Jorma. Fine Particle Emissions from Biomass and Heavy Fuel Oil Combustion without Effective Filtration (BIOPOR). 2007. 37 p. + app. 4 p.

73 Helin, Kaj, Evilä, Teemu, Viitaniemi, Juhani, Aromaa, Susanna, Kujala, Tuomo, Patel, Harshada, Pakkanen, Toni, Raisamo, Roope, Salmenperä, Pekka, Miettinen, Juha, Kilpeläinen, Pekka, Rannanjärvi, Leila & Vähä, Pentti. HumanICT. New Human-Centred Design Method and Virtual Environments in the Design of Vehicular Working Machine Interfaces. 2007. 85 p. + app. 1 p.

75 Sääski, Juha, Salonen, Tapio & Paro, Jukka. STEP-NC:n hyödyntämisen vaikutukset verkostomaiseen tuotantoon. Loppuraportti. 2007. 32 s. + liitt. 3 s.

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83 Helin, Kaj, Viitaniemi, Juhani, Aromaa, Susanna, Montonen, Jari, Evilä, Teemu, Leino, Simo-Pekka & Määttä, Timo. OSKU. Digital Human Model in the Participatory Design Approach. A New Tool to Improve Work Tasks and Workplaces. 2007. 37 p. + app. 1 p.

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