Building Information Modelling as an Information Management Tool: A South African Perspective for Contractors Who Take on Design Responsibility

Ursula Eicker, Richard Weeks
Graduate School of Technology Management, University of Pretoria, South Africa

***Abstract*--Measures need to be in place during the construction phase to insure that the final project design adheres to the contract specifications and that the project progress is in line with the contract document and that the resources are managed accordingly. This is where information technology would benefit the project management aspect of construction and provide information integration throughout all facets of construction. Building information modelling is an information technological process that aims to streamline the control of a construction project throughout all the different stages of the project life span. The preliminary investigations suggests that there may be shortcomings on how projects are managed in terms of information, especially with regards to time (scheduling data) and cost, from the initial estimating and budget data. Based on the findings of the investigation, it is explored how implementation of Building Information Modelling, as part of Information Management, can provide more efficient project control within the South African construction industry.**

I. INTRODUCTION

A. Current economic environment of the South African construction industry

The South African construction market slowed down considerably after the big boom of the 2010 FIFA World Cup. This period saw the birth of many small contracting companies, but after the 2010 FIFA World Cup came to an end, so did the liquidity of these companies. Slabbert [27] assessed that, "*With big projects for the 2010 FIFA World Cup behind it and other projects delayed because of funding problems, activity levels are on the decline*." Business Monitor International [8] reported that post activity as preparation for the 2010 FIFA World Cup, the South African construction industry was left with "*a dearth of contracts, a bloated budget and a construction industry that is haemorrhaging jobs*." The reason for this might be the lack of appropriate project management tools and skills within the South African construction industry. Basic performance requirements of a successful construction project are to complete the project on time, within budget and at the right quality [6], [9].

Cremonese and Wissinger [11] claim that: "*Building information modelling software is a powerful tool with enormous potential to streamline the construction process. Architects initially hold the power of BIM, though they must share its capabilities to enhance construction efficiency"*. Business Information Modelling (BIM) entails the entire project management life cycle of a construction project. It starts with the 2D project plan, drawing- and other specifications, progressing to the 3D visual and coordination of the project to be executed. Ensuing 4D and 5D entails the modelling of the schedule and cost estimation of the project and finally the 6D entails the workflow processing of the project. The technology behind BIM is relatively new within the boundaries of South Africa and an investigation is therefore necessary to determine what benefits the implementation of such technology would contribute to the success of a construction project in terms of information management.

In summary, the thin line between success and failure on a project needs to be managed and information technology can assist in the integration of the complex information. BIM is an information technology (IT) based process that is used for the different facets of the construction life span in large projects throughout the world.

B. Research Problem

The preliminary investigation suggests that there may be shortcoming on how projects are managed in terms of information, especially with regards to time (scheduling data) and cost, from the initial estimating data.

The main research problem statement is encapsulated within the ensuing question:

Will the implementation of BIM, as part of Information Management, provide more efficient information and project control within the South African construction industry?

C. Research objectives

The primary objective of this study is to determine to what extent BIM can assist the architectural, engineering and construction (AEC) industry with regards to project performance through extensive information management.

The associated research objectives, within the context of the South African Construction Industry are as follows:

- to determine what benefits, risks and challenges exist in the South African construction industry with regards to the implementation of BIM as a project information management tool;
- to consider what legal implications BIM can possibly lead to with regards to intellectual property, ownership and risk within the South African construction industry;
- to determine what local and international products/packages can be used as part of BIM; and
- to determine what information collaboration is necessary between the employer, architect, consultant and contractor to ensure that the implementation and use of the building information model is a success as well as what conflicts of

interest is created, if any, in the traditional "design in flight" process typical of South African contracts.

II. THEORETICAL

A. Theory and research review

Information management entails the management of information as a resource. Harris and McCaffer [16] state that to be competitive in the construction industry, each resource must be fully exploited and utilised to the benefit of the project. Information exists in each phase of the building life span and needs to be successfully transferred from each phase to the next between members of the project team to ensure successful completion of each phase as information is used for competitive strategic, tactical and operational decision making.

In order for project teams to better manage information, reduce costs and save time in the growing multi-disciplinary complexity of construction projects, integrated information technologies can be used as an enabler [16]. Fig. 1 depicts the different elements of a building life span from conceptualisation and needs discovery to post construction facility management.

B. Building Information Modelling

Enshassi and Abushban [12] recalled that for many years, most business processes and operations were executed with great difficulty due to the absence of information technology and management. Automated works did not exist and having to execute the work manually took longer, adding to cost and also increased the risk for human error.

Popov, Migilinksak, Juocevicius and Mikalauskas [23] reported that with the growth of ICT in the construction industry, building information modelling and process and construction simulation is becoming increasingly accepted and utilised as a management tool for the project life span management.

Ernstrom, Hanson, Hill, Jarboe, Kenig, Nies, Russel, Snyder and Webster [13] define building information modelling as the development and utilisation of a computer generated model to simulate the design, construction and operation of a facility.

C. Benefits, risks and challenges of implementing BIM

"*The key benefit of BIM is its accurate geometrical representation of the parts of a building in an integrated data environment.*" CRC Construction Innovation [10].

Benefits of BIM include the ability to identify design clashes before it becomes a reality [13]. An example of a design clashes is when the ductwork of a building does not fit onto the structural framework due to different size tolerances and allocated space or void zones. This reduces potential errors and time spent to do costly corrections on site that could cost the contractor time on the program and rework costs. BIM also provides the ability to all parties' involved as well as non-technical people to visualize the end product in its entirety before construction even commenced.

III. RESEARCH DESIGN AND METHODOLOGY

A. Research strategy

The summary of the research design is briefly alluded to in the ensuing sections. The study commences with a literature study undertaken to gain insight into the underlying theories regarding building information modelling, the benefits, and risks of BIM as well as how information is transferred from one phase of a construction project life span to the next.

An assessment of the company's capability for implementing BIM should first be addressed where after the maturity of the BIM implementation can be determined. Depending on the research participant's company's capability and maturity the researcher can assess to what degree the participant can provide information as to how BIM enables collaboration within the role they play in the execution of a construction project. Primary data collection will take place by means of focus group discussions, interviews, observation, questionnaires and document reviews.

The schedule of data collection is listed as follows:

- Conduct individual semi-structured, open-ended interviews with role players from employers, architects, contractors and engineers, such as business intelligence employees, information technology staff, operational people, quantity surveyors, project managers, architects and engineers.
- Conduct interviews with staff from three or more role player companies.
- Collection of completed questionnaires from three or more selected participants.
- Observation of current practice of information sharing on design and construct projects.

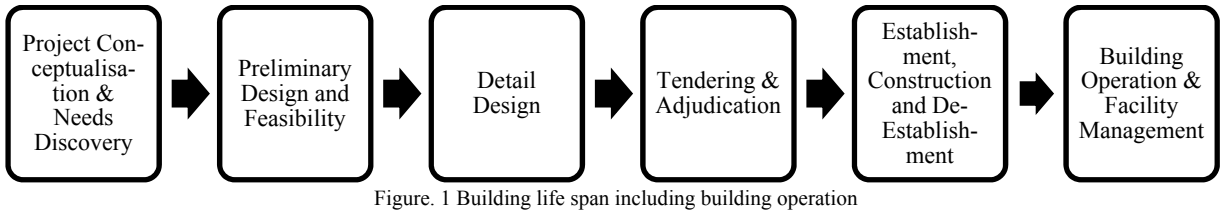

Figure. 1 Building life span including building operation
Source: Own research

- Analysing existing documentation with regards to information management strategies and contract documentation with regards to information sharing.

The theoretical approach for the research study is based on a qualitative approach that is analytically descriptive in nature, with a narrative inquiry as foundation for the research design. Data and information will be collected through formally structured, interviews and questionnaires, document analysis and observations.

Qualitative method

Strauss and Corbin [28] define qualitative research as "*any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification*". It is said to be a tool that is utilised to understand and describe human perception [22]. The particular design of this qualitative, analytical descriptive research study will depend on the purpose of the study. It will also depend on the usefulness of information collected, as well as the validity of this information [17].

B. Research instruments

1) Narrative enquiry

The narrative inquiry is a research methodology that falls under the qualitative research concept. Hancock and Epston [14] contend that the goal of narrative inquiry is to generate knowledge through collaboration between parties and to gain an understanding of multiple perspectives. This approach is very fitting to the research study, as the researcher aims to document the tacit knowledge of the research subjects and to transform this into explicit knowledge through codification.

The research design that was selected is based on a qualitative approach that is analytically descriptive in nature, with a narrative inquiry as foundation for the research design. The methodology for empirical data collection will now be discussed.

2) Interviews

Interviews were conducted with employees of the different professional role-players in the construction project: engineers, quantity surveyors and contractors. These interviews were conducted in person on the premises of the role players to ensure comfort and security to the interviewee. The interviewee was asked questions for discussion from a pre-determined assessment list which assisted the researcher in determining the capability of the companies being interviewed. The answers received from the interviewees also provided the researcher with more clarity as to how information is shared with regards to a construction project and what role BIM plays in this.

3) Questionnaires

Structured questionnaires were sent to research participants who are not close enough for face to face interviews. Boynton and Greenhalgh [7] state that "*Questionnaires offer an objective means of collecting information about people's knowledge, beliefs, attitudes, and behaviour*." The questionnaire will be presented to those specific research participants in a series of open-ended questions which allows for creative expression and will be formally analysed with qualitative methods.

4) Document analysis

Document analysis was used for the purpose of highlighting current challenges of collaboration and information sharing between the different parties. It also assisted in identifying if BIM models exist in the South African AEC, and where it starts. The types of documents that were used included contract documents, the architecture's policy documents and the service level agreement documents between the employer and consultant.

5) Research sample

Respondents from various companies with the AEC were interviewed or requested to complete the questionnaire in order to gather information as to how they perceive BIM as an information management tool and whether or not BIM can provide improved project delivery. All respondent were kept anonymous.

IV. RESULTS AND DISCUSSION

A. Comparison between literature and empirical research findings

Research Objective A:
What benefits, risks and challenges exist in the South African construction industry with regards to the implementation of BIM as a project management tool?

From Literature

Kaber [18] noted the following problems that many companies in South Africa that are currently using BIM are experiencing. BIM, like all other software follows a learning curve for its implementation and use. Users need extensive training and exposure to become familiar with the method of working with the software package. This could also be due to the limited amount of skills available currently for BIM. The transition period for the change with regards to technology in the construction industry takes generally longer to adapt to than other industries, also different BIM products do not necessarily hold the capability to integrate with one another which would increase the implementation time for new systems with existing systems [18].

To change the processes and procedures within the company with regards to information handling and management requires different policies, guidelines and governances to be developed and enforced to create better

concurrent engineering between different departments, employers and suppliers. This entails an entire different approach on information management and knowledge management within the company.

Azhar, et al. [3] lists the following benefits that may be derived from BIM:

- Faster and more effective processes.
- Better design.
- Controlled whole-life costs and environmental data.
- Better production quality.
- Automated assembly.
- Better customer service.
- Lifecycle data.

Stanford University Centre of Engineering conducted a study on 32 major projects that used BIM during the project life span, and the following results were documented [4]:

- Companies experienced up to 40% elimination of project change orders, which are unbudgeted;
- Estimation of project costs within an accuracy margin of 3%;
- Project cost estimation times were reduced with up to 80%;
- Savings generated of up to 10% on the initial contract value through clash detection.

From Research Participants

Benefits with regards to BIM for the South African contractor who takes on design responsibility includes visualization of the final product in 3D, 2D drawings with quantified values already measured, clash detection and improved information control. BIM also eases the facilitation and collaboration of multi-disciplinary teams on cloud-servers (internet based interoperability) whilst providing real-time cost and schedule estimation and finally a complete facility management tool (post construction) for the employer with all building information in one central, live space.

Research Objective B:
Legal implications of BIM

From Literature

Who pays for the model?

- It is implied that to determine who should pay for the model, one should look at who will receive the most benefit from the model, and that this party should therefore bear the cost of model development [13].
- A global consensus is that all parties will benefit from the model and therefore each party should contribute to some of the cost [13].

Who makes the changes?

- This question relates to who controls the entry of data into the model, who takes responsibility of the inaccuracies that are entered, and who manages the audit trail of changes made.
- Thompson and Miner [31] state that traditionally designers would request disclaimers of liability to indemnify them of any design errors during the life span of the construction project and facility. Additional design changes by the designers would also include extra costs.
- Badenhorst [5] recalls that the King III report is a report on information, technology governance in South Africa that was released in 2009. All organisations within South Africa, including those within the AEC should adhere to the principles of the codes stated in this report.
- The legal implications regarding BIM include, but are not limited to, the ownership of the BIM models and associated information and how these should be protected by copyright and other supporting laws [31].
- Kymmell [19] notes that "*it is common for the design consultants, the general contractor, or subcontractors to implement BIM at their own cost and risk*" which means that the contractor would be held liable for any design related problems that might occur during and post construction.

Reddy [24] notes that the construction industry is more focused on the putting forth standardised methodologies and processes with regards interoperability and collaboration of the modelling side of BIM with less focus on the these functionalities from an information perspective. Thus standardised guidance and governing bodies are highly sought after to give contractors, employers, consultants and engineers a framework of conduct and standard operating procedures with regards to the use of a collaborated BIM model on a construction project.

From Research Participants

Who pays for the model?

The employer or the contractor can pay for the model. In other instances whoever requires the use of such a model would be the party responsible for payment thereof.

Who owns the model?

In normal cases, whoever produced (responsible party for the design and development of the models) or paid for the model would retain final ownership thereof. The legal issues regarding copyright or protection of the models must be documented in the contract document of the construction project. If any party to the project team do not abide by the law as stated in the signed contract document, they can be held liable. The issue of ownership of the BIM model can be solved and incorporated in the contract document.

With regards to ownership of the information including copyright, parties who contribute knowledge to the BIM model are to retain ownership of such works and copyright thereof. Use of such information by other parties must be stipulated in the contract document and this should also

include standard operating procedures with regards to electronic data transfer of such information.

Who makes the changes?

Answers to the above question included some of the following statements from research participants:

- This would depend on the type of change as well as who requested the change.
- The employer, who is still by contract the legal authority figure with regards to the project will independently engage an entity to undertake these changes.
- The contractor is responsible for making the changes.
- The allocated party, as per the contract document. Audit trails exist within the BIM framework to identify who made what changes.
- The legal issues regarding copyright or protection of the models must be documented in the contract document of the construction project. If any party to the project team do not abide by the law as stated in the signed contract document, they can be held liable by law.

What happens to the models post construction?

Answers to the above question included some of the following statements from research participants:

- The models should be archived and kept for future reference, continuous improvement and lessons learnt. Also for commercial use in the case of claims.
- The models, when fully populated are utilized as information repositories by the employer for specialist maintenance and remedial repairs were required.
- The models on conclusion of the construction project should be handed over to the employer to become the facilities model to be utilised by the building owners. Complete information regarding building specifications, "manual" and other details where now available in one repository for use as part of facilities management.

In summary it can be stated that two respondents recalled that the models were paid for by the employer. In these instances the employer retained the ownership thereof during and after conclusion of the construction project. In the two instances where the contractor paid for the models, they kept ownership thereof. Here, the models were not transferred to the facility owner post construction as part of facility management. Thus information regarding the building (such as geometrical, logistical and facility operational manuals, including those for equipment installed in the building), remain archived by the contractor and is not utilised as part of the complete BIM lifecycle, concluding in facility management. As the legal owners of the models, they are entitled to dispose or archive the models as they please.

Research Objective C:
Are there any products, local and international, that can be used as part of the BIM model?

From Literature & Research Respondents

From literature and the research respondents it is evident that there are numerous packages available that can address different areas of the BIM platform. Such packages include:

- **Autodesk Revit** is BIM specific software that was specifically developed to empower designing and construction professionals to manage project through all the phases of the construction life span as with a coordinated and model-based approach. Revit is a packaged software application that includes features for architectural design, structural engineering and construction [1].
- **NavisWorks**, as part of the Autodesk family of products is a viewer of 3D models. It is not a model authoring tool, but provides a platform for team members who do not necessarily need to make design changes to view the model in a virtual environment whilst still assuring interoperability and collaboration between the different project team members [21].
- **Tekla** is capable of creating and management of models throughout the entire life span of the building. Tekla is supported in South Africa by Cadex Systems [29], [30].
- **SkyBIM** Projects is a South African company, registered in 2011 which provides real-time cost estimating from state-of the art BIM authoring tools such as Autodesk Revit models from which quick automatic quantity take-off calculations can be performed, construction assemblies between different disciplines can be created and costs can be estimated and adjusted much sooner in the design phase of a building through their cloud based system, SkyBIM. This would assist in minimising the risks, reduce project delivery schedules and save costs. The company also provides consultancy with regards to BIM to larger projects [26].

Research Objective D:
What information collaboration and steps are necessary between the employer, architect, consultant and contractor to ensure that the implementation and use of the building information model is a success?

From Literature

To achieve the most benefits from BIM, close collaboration is required between the stakeholders. This includes the architect, employer, general contractor, suppliers and engineer. This collaboration will fundamentally impact the roles and responsibilities of the different parties as well as the process by which information will be shared [20].

The full participation and contribution from all parties involved in a construction project is crucial to the successful implementation of BIM for a project [25]. This involvement does not only pertain to certain phases of the project life span, but from the start of conceptualisation to completion of the construction as well as post construction facilities management.

From Research Participants

Information sharing during a construction project is a basic process. BIM aims to simplify, improve and speed up the way in which information is shared among team members. One respondent indicated that by showing the employer what the use of BIM would enable them to do with regards to information sharing it ensured them to be the successful tenderer for the special project. Another respondent states that information moved through a single entity or platform and managed by a single gate keeper which in this case would be the BIM manager who is responsible for all information and data integrity of the system. This would ensure that all project team members use the latest, accurate and complete project information available. Emails should not be used for data or information transportation as information might be already outdated and would not be integrated with information from other team members. Files might also be very large and be undelivered.

The following collaborative steps were identified for the use of BIM as an information management tool:

- Team members should share IP addresses, ensure transparency of all information and share the same end goal for the project. All collaborative requirements should be stipulated in the contract documents to ensure appropriate governance and protocol for the use of BIM in construction.
- On the preliminary design and feasibility stage of the project life span the rules of engagement (roles and responsibilities) and overall requirements for the use of the BIM models should be agreed and documented.
- Common operational platforms should be used to feed information between team members.

A central person for the project, a BIM manager should be part of the project team to ensure data integrity and accessibility of models at all times during the project life span. This person should also ensure that all parties conduct themselves as required in the contract documents with regards to the BIM models.

The Main Research Problem Statement is as follows:
Will the implementation of BIM as part of Information Management provide more efficient information and project control within the South African construction industry?

From Literature

- Harris [15] states that *"BIM will greatly increase our ability to analyse the life-cycle value of many more design alternatives and options, far better manage costs, and virtually eliminate much of the waste, error, and inefficiency inherent in today's facility delivery."*
- Autodesk [2] describes BIM as *"an integrated workflow built on coordinated, reliable information about a project from design through construction and into operations. By adopting BIM, architects, engineers, contractors and clients can easily create coordinated, digital design information and documentation; use that information to accurately predict performance, appearance and cost; and reliably deliver the project faster, more economically and with reduced environmental impact."*

From Research Participants

All research participants are in agreement with literature, but expressed concern that for BIM to be a successful information management tool within the South African construction industry, appropriate governances and protocols should be documented and managed by a higher governing body. Concern was also noted with regards to the size of the projects that BIM would be appropriate for. Larger, more complex projects are more ideal for the use of BIM, due to the costs and efforts associated with such a collaborative venture.

B. Conclusion

It was noted that all respondents stated that change management is a key barrier or challenge when it comes to implementing new systems. A lack of skills necessary to operate such models to the extent of it being beneficial from an information management point of view is also noted as a potential risk for companies within the AEC in South Africa. BIM models and software packages prove to be very costly, depending on the level of implementation.

BIM can provide numerous benefits to the AEC industry:

- clash detection;
- facilitating the collaboration of multi-disciplinary teams on cloud-servers (internet based interoperability);
- real time cost and schedule estimation where 3D models that can be automatically quantified and valued;
- reduction of on project variations, change orders and RFIs, which are unbudgeted;
- quicker more accurate cost estimations and re-estimations;
- a complete facility management tool (post construction) with all building information in one central, live space for potential use by the employer.

To implement Building Information Modeling within the South African construction environment it will be beneficial to a certain extent as long as the benefits of the system outweigh the costs and potential risks in association with the use of such technologies.

If BIM is the direction that the South African AEC is moving towards, from a technological paradigm shift perspective, it would be beneficial if a contracting structure and norm can be developed that combines the traditional disparate contracts and operating methodology of the project team (architect, consultant engineer, contractor and employer) into one collaborative agreement where benefits and risks are shared between team members.

With regards to products that can operate as BIM packages, there are numerous international developed

products listed by the interviewees that are available that can satisfy all or some of the modules in the BIM environment and provide local (South African) support for users on different facets on BIM. Tekla seems to be the BIM package that was mentioned most by research participants.

Sharing of IP addresses, ensuring transparency of all information and share the same end goal for the project are some of the steps that need to be adhered to by all project team members to ensure a fully functional collaborative BIM environment. All collaborative requirements should be stipulated in the contract documents to ensure appropriate governance and protocol for the use of BIM in construction.

C. Contributions to practice and further work

The literature appears to be limited in the South African construction environment regarding building information modelling. This can be due to the fact that building information modeling as an information management tool within the AEC in South Africa is still emerging and due to the fact that most contracts for projects are let on provisional bills of quantities, subject to re-measurement. Further investigations into building information modelling from a South African perspective may prove beneficial to contractors, employers, consultants and quantity surveyors.

REFERENCES

[1] Autodesk Inc., "Autodesk Revit Overview", Retrieved 08/23/2013 World Wide Web, http://www.autodesk.com/products/autodesk-revit-family/overview

[2] Autodesk Inc., "Autodesk launches new solutions for building information modelling", Retrieved 03/23/2013 World Wide Web, http://usa.autodesk.com/adsk/servlet/item?siteID=123112&id=11681863&linkID=1427159

[3] Azhar, S., M. Hein and B. Sketo, "Building information modelling (BIM): benefits, risks and challenges", *McWorter School of Business Science, Auburn University, Alabama*, 2010.

[4] Azhar, S., A. Nadeem, J. Mok and B. Leung, "Building information modelling (BIM): a new paradigm for visual interactive modelling and simulation for construction projects", *in Papers presented at the First International Conference on Construction in Developing Countries*, Karachi, Pakistan, 2008.

[5] Badenhorst, M.; "Making sense of IT governance: the implications of King III", *Paper for CIS Corporate Governance Conference*, September 2009.

[6] Bowen, P., K. A. Hall, P. J. Edwards, R. G. Pearl and K. S. Cattell, "Perceptions of time, cost and quality management on building projects", *The Australian Journal of Construction Economics and Building*, vol. 2(2), pp. 48-56, 2012.

[7] Boynton, P. M. and T. Greenhalgh, "Hands-on guide to questionnaire research: selecting, designing and developing your questionnaire", *British Medical Journal*, vol. 328(7451), pp. 1312-1315, 2004.

[8] Business Monitor International, "South African infrastructure report", London: Business Monitor International Ltd., 2011.

[9] Chan, A. P. and A. P. Chan, "Key performance indicators for measuring construction success", *Benchmarking: An International Journal*, vol. 11(2), pp. 203-221, 2004.

[10] CRC Construction Innovation, "Adopting BIM for facilities management: solutions for managing the Sydney Opera House", Retrieved 03/23/2013 World Wide Web, www.construction-innovation.info/indexab4d.html?id=991

[11] Cremonese, M. J. and C.A. Wissinger, "Building information modelling: risks and rewards", Retrieved 10/12/2012 World Wide Web, www.law.com/jsp/article.jsp?id=1202464217869&slreturn=20130119031302

[12] Enshassi, A. and S. Abushaban, "Examination of usage and effectiveness of information technology management within construction organizations", *The Islamic University Journal*, vol. 18(1), pp. 121-138, 2011.

[13] Ernstrom B., D. Hanson, D. Hill, J. Jarboe, M. Kenig, D. Nies, D. Russel, L. Snyder and T. Webster, *The contractors guide to BIM*, 1st Ed, The Associated General Contractors of America, 2006.

[14] Hancock, F. and D. Epston, "The craft and art of narrative inquiry in organisations", in *The Sage Handbook of New Approaches to Organization Studies,* Newbury Park: Sage Publications, Inc., 2008.

[15] Harris, D.; "BIM without boundaries", *Journal of Building Information Modelling*, 7, 2008.

[16] Harris, F. and R. McCaffer, *Modern construction management*, 5th Ed, Victoria: Blackwell, 2006.

[17] Hoepfl M.; "Choosing qualitative research: a primer for technology education researchers", *Journal of Technology Education*, vol. 9(1), 1997.

[18] Kaber, R.; "Will the implementation of building information modelling be advantageous to the South African construction industry", *University of Pretoria*, 2010.

[19] Kymmell, W.; "Building information modelling: planning and managing construction projects with 4D CAD and simulations", Retrieved 08/03/2013 World Wide Web, http://0-accessengineeringlibrary.com.innopac.up.ac.za/browse/building-information-modeling-planning-and-managing-construction-projects-with-4d-cad-and-simulations-mcgraw-hill-construction-series

[20] Ku, K. and M. Taiebat, "BIM experiences and expectations: the constructor's perspective", *International Journal of Construction Education and Research*, vol. 7, pp. 175-197, 2011.

[21] Navisworks. Retrieved 08/01/2013 World Wide Web, www.autodesk.com/products/autodesk-navisworks-family/overview

[22] Myers, M.; "Qualitative research and the generalizability question: standing firm with Proteus", *The Qualitative Report*, vol. 4(1), 2000.

[23] Popov, V., D. Migilinskas, V. Juocevivius and S. Mikalauskas, "Application of building information modelling and construction process simulation ensuring virtual project development concept in 5D environment", Retrieved 01/31/2013 World Wide Web, http://dspace.vgtu.lt/handle/1/440

[24] Reddy, K.; "*BIM for building owners and developers: making a business case for using BIM on projects*", New Jersey: John Wiley and Sons, 2012.

[25] Singh V., N. Gu and X. Wang, "A theoretical framework form BIM-based multi-disciplinary collaboration platform", *Automation in Construction*, vol. 20, pp. 134-144, 2011.

[26] SkyBIM, Retrieved 1 August 2013 World Wide Web 08/01/2013

[27] Slabbert, A.; "Grim outlook for construction firms", Retrieved 10/12/2012 World Wide Web www.fin24.com/Business/Grim-outlook-for-construction-firms-20100630

[28] Strauss, A. and J. Corbin, *Basics of qualitative research: grounded theory procedures and techniques*. Newbury Park: Sage Publications, Inc., 1990.

[29] Tekla. Retrieved 08/01/2013 World Wide Web, www.tekla.com

[30] TeklaBimSight. Retrieved 08/01/2013 World Wide Web, www.teklabimsight.com

[31] Thomson, D. and R. Miner, "Building information modelling: contractual risks are changing with technology", Retrieved 01/31/2013 World Wide Web http://www.academia.edu/1216743/building_information_modelling_bim_contractual_risk_are_changing_with_technology