Assessment of BIM for Managing Scheduling Risks in Construction Project Management

Musa Adamu Musa, 14100644@brookes.ac.uk
Department of Real Estate and Construction, Oxford Brookes University, Oxford, OX3 0BP, UK

Henry Abanda, fabanda@brookes.ac.uk
Department of Real Estate and Construction, Oxford Brookes University, Oxford, OX3 0BP, UK

Henry Oti, aoti@brookes.ac.uk
Department of Real Estate and Construction, Oxford Brookes University, Oxford, OX3 0BP, UK

Abstract
Poor risk management is among major challenges facing the construction industry on issues of timely project completion. Although risk factors are numerous, the nature of construction projects being prone to changes during execution makes it difficult to adequately capture risk aspects related to scheduling and timely project completion. Traditional 2D computer-based tools do not adequately utilize digitised computable information, thus limited in capturing construction risk. Hence, the exploitation of emerging BIM to bridge this gap is now being noted in construction project management. This study investigates the application of BIM in managing scheduling risk of construction projects. Being the preliminary part of an ongoing research, the investigation is carried out through a desk-top study. We argue that in order to properly minimize the risk of schedule delay in projects; construction sequencing activities need to be adequately digitised and BIM offers the opportunity to integrate vital aspects of project management that considerably improve scheduling risk management.

Keywords: BIM, construction, risk, scheduling, project management

1 Background to the Construction Industry
In the UK, the construction industry is significant to the economic and social development, having an annual turnover of more than £100 billion and accounts for almost 10% of its GDP (EISC, 2012). It comprises over 280,000 businesses covering some 2.93 million jobs, which is equivalent to about 10% of the entire UK employment (BIS, 2013). Despite this, it is known for inefficiencies. The UK government, together with the industry has set out some strategic objectives to curtail these inefficiencies which have led to the publishing of a report of the Government Construction Strategy by the Cabinet Office (2011). This report sets out the government's ambition of collaborative 3D BIM (with all project and asset information, documentation and data being electronic) on its projects by 2016 (Cabinet Office, 2011). This is geared towards a sector where parties involved in projects will be working on a shared platform with reduced transaction costs and less margin for errors. Furthermore, Sawhney et al. (2014) discussed based on other literature reports that the sector is confronted by many inefficiencies like time and cost overruns, irregularities in procurement and below par performance on development projects amongst its peers. Proverbs et al. (2000) reviewed that the industry has given rise to dissatisfaction due to the level of service it provides as well as the quality of the end product. On the whole, a note of the most frequent problems facing the industry clearly identified some issues which include: fragmentation, poor workmanship and supervision, low productivity, changes of design during construction, over-specification, over reliance on traditional procurement, absenteeism of labour, inexperienced management and so many more.

The problems stated above can be attributed to a number of causes. Proverbs et al. (2000) mentioned that some causes include the labour intensive nature of the processes associated with the industry, its casualness in adopting new technologies, e.g. information technology (IT) as well as the lack of collaborative nature of the industry. Also, poor risk management is an aspect that gives rise to many problems in construction. Typically, the projects change over time during execution due unforeseen and uncontrollable circumstances. The industry is still improvising the best means to adequately manage effects of uncertainties in projects (Taxen and Lillieskold, 2008; Li et al, 2009).

The advent of BIM seems to provide some succor of promise to enhance risk management in projects. Like many other aspects of construction, BIM has been suggested to provide opportunities to manage the different aspects of risk in construction (Matějka and Tomek, 2014). Yet, perhaps partly because of the emerging nature of BIM, literature about how BIM can be used in managing construction risk is sketchy. Although risk factors numerously include adverse weather conditions, natural disaster, site accidents, poor supervision and management, cash flow difficulties etc. the scope of this study is limited to schedule-related risks. This aspect of risk is especially important because it can trigger other types of risks such as cost, quality risks, etc. if not properly managed. Also, there appears to be growing research efforts on incorporating aspects of scheduling in the digitization of the construction project otherwise known as BIM.

As such, the aim of this study is to investigate the application of BIM in the area of risk associated with the scheduling and planning of construction projects. This study is still in its preliminary stages, so only findings from desk-top study have been discussed. To facilitate understanding, a signpost of the paper will be discussed. Firstly, the domain of project planning is reviewed in section 2. This will facilitate the understanding of the domain and challenges encountered with scheduling. Secondly, an overview of scheduling risk in construction is provided in section 3. Thirdly, section 4 delves into common scheduling software and challenges associated with their uses. Fourthly, in section 5, BIM and 4D modelling applications are examined revealing how challenges associated to scheduling risk can be overcome. Fifthly, the key findings of this review are presented in section 6. The paper concludes with a summary in section 7.

2 Project Planning in Construction

Planning a construction project consists of defining activities and precedence relationships. Scheduling involves determining resources and activity durations, then applying Critical Path Method (CPM) to calculate early and late activity start and finish times as well as floats (Dzeng and Tommelein, 2004). As claimed by Taxen and Lillieskold (2008), the traditional methods for planning projects were developed in the late 1950's and these methods show graphically the sequence of and the relationships between the individual work tasks or activities required for the completion of a project. They include: Gantt, Work Breakdown structure (WBS), Program Evaluation and Review Technique (PERT) and the Critical Path Method and have always played an important role in project management. Nevertheless, Alzraiee et al. (2015) reviewed that although these methods have been useful in the field of project management, the models developed by them often fail to deliver realistic estimates of project duration, cost and productivity. The failure can be attributed to the industry's dealing with accelerating dynamism as well as complexities of construction works which makes construction difficult to manage (Taxen and Lillieskold, 2008; Li et al, 2009;). Also, Alzraiee et al. (2015) depicted that the traditional methods have failed to provide a concise depiction of the project structure and its real behaviour. Additionally, the changing behaviour of a project over time possibly due to uncontrollable situations and organisational policies on productivity affects the project and these are very much neglected by the traditional methods. There is always high uncertainty and requires continuous revisions during project execution. Summing it all up, traditional methods result in models that are discrete in nature and not representative of the system. They can rarely help with decision-making based on analysis of real data (Chen et al, 2012).

3 Scheduling Risk in construction

Serpella et al. (2014) discussed based on the findings of other researchers that risk as a concept has many aspects and is defined as the probability of a damaging event occurring in a project, affecting its objectives. Irimia-Dieguez et al. (2014) defined risk management as the systematic process of identifying, analysing and responding to project risk. Tohidi (2011) defined risk management as the process of identifying and assessing risk, and applying methods to reduce it to an acceptable extent.

Lee et al. (2009) noted that the main purpose of risk management is to identify, evaluate, and control the risk for project success). Simply, risk management involves the process of determining the likely risk to occur, taking necessary steps to examine its effects and fashioning out ways to prevent or lessen the effects, in the event that it ensues. In planning project scheduling, Aziz (2014) suggested that PERT predicts future project performance and problems with regards to time by taking into account three possible assumptions which include: optimistic, pessimistic and most likely (realistic) time estimates. Risks involved in construction projects amongst many, consists of schedule delay (or time overrun) as investigated by Banaitiene and Banaitis (2012). Time overrun is one of the most significant issues being faced by the construction industry today and there are various factors responsible for this which needs attention to understand and address in order to achieve successful completion of projects on time (Memon et al., 2011). Hossen et al. (2015) argued that success in any project is measured by time, cost and quality which show the performance of the construction parties involved and there is built-in uncertainty in the schedule of the construction phase for different projects. Schedule delay can be defined as the time overrun either beyond the completion date specified in a contract or beyond the date that the parties involved agree upon for delivery of a project. Schedule delay can lead to many undesirable effects on the project such as loss of revenue, higher costs due to longer work period, additional material cost and extra labour cost (Hossen et al, 2015).

However, in order to check schedule risk, Aziz (2014) discussed that planning time schedule for project completion should consider: (1) Optimistic time: This the minimum possible time required to accomplish a task, assuming everything proceeds better than what is normally accepted. There is the assumption that there will be less amount of difficulties; (2) Pessimistic time: This is maximum possible time required to accomplish a task, assuming everything goes wrong but excluding major catastrophes. This time assumes maximum potential for difficulties where everything will not go as planned. (3) Most likely time: This is the best estimate of time required to complete a task, assuming everything proceeds as normal. This is the time dimension that will most often transpire in projects.

As earlier discussed, in the last few decades, numerous project control methods (PERT, Gantt Bar Chart and CPM) have been developed. Alzraiee et al. (2015) reported that in the afore-mentioned methods, interrelationships among the project variables and surrounding factors are in reality complex and are not linear as portrayed by the traditional methods since interactions amongst project elements as well as with the environment result in challenges that can hinder developing realistic and representative planning models. Further discussion by the authors aimed at the fact that the CPM based schedule baselines always experience high uncertainty in execution and require continuous revisions and enhancements to capture the dynamics generated during the project's execution where in reality, the project is a system of interrelated elements in which each element is unique in nature and interacts with other elements to generate behaviour. Chen et al. (2012) argued that for the PERT method, the approaches do not consider the correlations that exist in the activity durations, activity cost, resources and spaces in a schedule network because the probabilistic models have the duration of each activity entered or evaluated independently of the durations of other activities in the network, and activity cost is calculated accordingly. Chua et al. (2013) reviewed that CPM models do not capture complex temporal constraints containing conjunction and disjunction conditions and dictate only one predefined sequence and therefore, cannot represent complex temporal constraints and all possible sequences resulting from complex functional requirements. Further addition is that the approaches cannot infer temporal constraints from functional requirements. Taxen and Lillieskold (2008) claimed that the traditional methods have drawbacks of the network plan looking intricate and perplexing to first-time users and that even though they have a strong temporal character, most network diagrams do not have a time scale and appear timeless to the untrained eye. Also, there is the underlying assumption of a given functionality of the finished product which may give a delusive impression that only time and resources need to be controlled. For very dynamic projects, updating and maintaining Gantt charts can be cumbersome and if the diagrams are larger than one page, they are not useful for communication or discussions hence, the diagrams are good for static environments, but less useful during continuously changing circumstances (Taxen and Lillieskold 2008). It can be seen that the traditional methods are less effective from different literatures especially for complex projects and can even prove to be worrisome as a result of the dynamism and intricacies associated with constructions both in terms of factors that can be controlled as well as those that cannot be controlled.

Technologies are increasingly being used to support the execution of various aspects of the construction (Ibem and Laryea, 2014), a variety of software packages have become available which are needed to support the application of the traditional methods being used which include Microsoft Project, Asta Power Project, Primvera etc. (Olawale and Sun, 2010). Liu et al (2015) reviewed that with the advances in 3D computer aided design (CAD) and information technology, researchers and construction practitioners have been seeking to develop computer-assisted scheduling tools in order to boost scheduling efficiency and relevance. This is because the traditional construction scheduling is formulated manually in the form of 2D bar charts which has proved to be a laborious and highly error-prone process that challenges construction practitioners. Project management software packages generally facilitate the integration of project data, the interaction with enterprise systems, the interoperability with new Information Technology (IT), optimization of teams' productivity by allowing better decisions to be made in order to maintain a competitive advantage and implementation of an effective project management (Pellerin et al, 2013). The mechanisms of software packages aid operation simulations that are able to consider uncertain durations of work tasks as well as to evaluate various resource allocation strategies in order to create a suitable construction plan (Wang et al, 2014). This facilitates construction management by discovering inappropriate schedule sequences, evaluating issues of constructability and identifying potential time-space conflicts (Wang et al, 2014). Jugdev et al. (2013) reviewed that one of the major tools extensively used amongst others with high intrinsic value to improve project success are software packages for task scheduling such as Microsoft Project. Hence, there is a high correlation between project success and task scheduling. Visualization is enhanced by software packages because they provide graphical views for scheduling activities forwards or backwards temporally during any period of time thereby supporting the project participants in more effectively understanding the sequences of construction work (Wang et al, 2014). Thus, it can be seen that scheduling software packages help in providing information about how construction activities will be carried out sequentially prior to its actual construction on site.

4 An overview project scheduling software systems

Wang et al. (2014) discussed that project scheduling software systems are used to create project schedules from which BIM compliments by using them to create schedule simulations. A variety of software systems can be used to create project schedules which can then be used for this purpose. Table 1 provides an overview of some project scheduling software systems and their relationships with BIM.

Table 1 An overview of project scheduling software

Software	Features	BIM integration	Risk integration
Asta powerproject	It links project plans to 3D models within a single application, easily integrates with other scheduling software systems like MS project, Primavera, and Sure track, can protect against litigation caused by delay, It ensures unparalleled control over the presentation of plans, schedules correctly with mixed calendars, it gives logical differentiation between different types of links, user friendly, accurate progress reporting and can be used for small and large projects.	Schedules created can be exported to BIM software for 4D modelling. Asta powerproject BIM uses BIM models to create 4D schedules within the same application.	It enables project risk to be quantified and allows project managers to proactively identify problems that may affect the project.
Primavera	It enhances flexible, web-based, user interfaces that give project team members access anywhere, anytime. With Primavera P6, there is team-based collaboration to improve decision making, streamline co-ordination and improve efficiency due to process automation capabilities. It allows quick and easy forecasting of WBS's activities or projects. It can be used for large and complex projects and can assist in cost and schedule forecast.	Primavera integrates with BIM by using data within 3D model to produce construction schedules and cost estimates. It enables 3D model to become a virtual search engine for building parts and materials that can be accessed after the facility is built.	Primavera P6 reduces the risk of project slippage and cost overruns by conducting what-if analysis and alternative project plans. Its risk analysis provides a comprehensive means of determining confidence levels for project success.
MS Project	This software is part of the Microsoft Office suite and so it integrates cleanly with the various Microsoft applications. It does have advanced features like resource levelling, Critical Path Management and PERT Charting. Although the file format itself is binary, there is a way to do XML export for using the data in other capacities. It helps to work more efficiently with the simple and intuitive Microsoft fluent user interface. One can be able to simplify planning with inactive and active tasks to perform what-if analysis. Allows for identifying unassigned or unscheduled tasks to proactively solve problems. By using the Microsoft Office Backstage view, there is enhanced team collaboration by sharing information more efficiently.	This software integrates with 3D BIM software by linking planned schedules with a 3D model which enables 4D planning and constructability analysis.	MS Project coupled with @Risk software performs risk analysis using Monte Carlo simulation which is a technique used to know risk impact in project management forecasting models. It gives many possible outcomes and the probability of occurrence.

Synchro Scheduler	This software system lets the Synchro CPM engine to calculate start, finish dates and the Critical Path after adding descriptions, durations and logic. Can be imported, exported and synchronized to-and-from other software systems like Primavera, Microsoft Project, Microsoft Excel, PMA Netpoint and Asta Powerproject. During construction, tracking of actual and remaining quantities can be done and the remaining duration can be updated accordingly. The resource utilization graph can be used to determine where a resource may be over or under used and updating the schedule in real time.	Synchro Scheduler is fully compatible with Synchro PRO which provides real-time, 4D functionality to teams enhancing the ability to plan, communicate and manage projects more efficiently and effectively.	Through its calculation of Critical Path, it helps in managing risk associated to projects. Also, the 4D functionality of Synchro Pro helps in risk mitigation.
ProjectLibre software	This software supports social media-like collaboration platform, forums, web conferences, code integration and multiple workflows that can be used for issue tracking. Critical Path is calculated and displayed by default. It has the ability to be exported to PDF. It enables prediction of resources needed to complete a project. It has a feature of allocating resources by skill sets i.e. employees to different tasks based on their skills. Its cycle time analytics help in viewing the completion rate of projects. Its project portfolio management features help in managing several projects at the same time by categorizing them on numerous key characteristics after which results of the whole portfolio can be analyzed.	This software does not integrate with BIM.	It analyzes risk by determining confidence levels of project success
Fast track schedule software	This software ensures that profit improves by staying on schedule and shows the impact of scheduling changes on costs and deadlines. There is ease of exchange of data with spreadsheets, MS Project, iCal, Mindjet, MindManager and other databases. It can also import Microsoft Project MPP and MPT files. There is the possibility for network administrators to establish a global default schedule and templates by capturing preferred settings for dates, data columns, layouts, filters and sorts as well as bar styles and milestones. It can identify and avoid scheduling conflicts. It has integrated cash flow tracking for up-to-date financial reporting. Tracks change orders, punch lists and key milestones.	This software does not integrate with BIM.	This software does not integrate risk analysis and as such doesn't integrate risk management.
Project Commander software	This software allows history of completed tasks to be saved as remaining jobs are prioritised and rescheduled and new tasks incorporated into future plans. It provides reports as jobs are resourced by providing easily understandable graphics. It can show how individuals or groups have been allocated or which ones show availability to handle new working coming in on changing priorities. There is integration with Microsoft Project, Microsoft Access and	This software does not integrate with BIM.	Risk duration allowances can be incorporated into overall task durations. Allied with risk log, the risk time can be linked to particular risks in the log.

	Excel and other databases. It can open MPP and MPX files from some versions of Microsoft Project. This software has the ability of calculating the Critical Path of a project. It allows for the copy of records across files by opening up more than one session of the software. This software can be used by non-planners and administrative staff to create short-term plans or update contract programmes.		
Deltek Open Plan software	This software can be used for small, medium and large projects. It consists of multi-project analysis, critical path planning, resource management which caters for the needs of business, resource and project managers. Its tools enhances decision making and optimize program management. It prevents scheduling problems before they occur by defining business rules like every activity with work must have a WBS and any activity in progress must have a valid Actual start. Data can be shared with desktop planning tools like MS project. Some of its features allows for integration of data from systems such as Deltek Costpoint or Oracle Projects. It accommodates cost and earned value management. It also supports Microsoft Access, Microsoft SQLServer and Oracle databases. An application of it enhances team members' collaboration. It facilitates fast and realistic planning through rapid data entry and analysis and powerful reporting on project status and progress.	This software does not integrate with BIM.	It carries out Monte Carlo simulation of project schedules for risk analysis.

In the UK, BIM is defined by the Construction Project Information Commitee, supported by the Royal Institute of British Architects as 'the digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition'. Rather than a software, it is a systems approach to the design, construction, ownership, management, operation, maintenance, use and demolition or reuse of buildings (Smith and Tardif, 2009 cited in Hammad et al, 2012). As noted (Mills, 2001; Ramkumar and Gopalakrishnan, 2014), the industry is unique in its services and products and as a result, it is dynamic and characterized by countless varying risks. Brydeet al. (2013) indicated that BIM is an appropriate tool for managing projects and should be considered by project managers. BIM can be used to update schedule and costs and this can go a long way in managing risks associated to construction projects.

5 4D Building Information Modelling

Many studies have evaluated the effectiveness of BIM, have acknowledged the potential benefits of this new technology and has been accepted as a process and corresponding technology to improve the efficiency and effectiveness of delivering a project from inception to operation/maintenance (Ding et al., 2014). Project planners face many uncertain and complex tasks during construction due to design errors and mismatch of what is planned and actually needed and these errors and mistakes in the construction planning schedule occur frequently. Due to the complexity and the large number of factors involved, computers can be an efficient tool to help project planners. A type of digital model for construction is a detailed building component model, which is related directly to construction activities. This can check design and is closely associated with the construction planning schedule (Li et al, 2009). BIM application can be classified into 4D based applications which is the integration of 3D models with schedule (Ding et al., 2014). Wang et al. (2014) reviewed that combining a BIM-based 3D model and a project schedule represents the fourth dimension which has been highlighted as a great merit of using BIM and by so doing, further facilitates construction management by discovering inappropriate schedule sequences, issues of constructability and potential time-space conflicts. In doing this, a 3D model using Autodesk-for example- and a project schedule using MS Poject, Asta Powerproject or Primavera software are developed separately, after which a schedule simulator such as Navisworks or Synchro software is utilized to link the 3D components with the related scheduling activities. This results into the 4D model which displays construction sequence by showing consecutive 3D components as a progression over the time-span of the project. Li et al. (2009) claimed that construction simulation assists project planners to better understand construction process, predict possible mistakes, validate proposed construction planning schedule as well as analysing resource allocation thereby preventing allocating problems.

Mahalingam et al. (2010) indicated that 4D CAD models integrate 3D elements with time as the fourth dimension and this time attribute indicates the start and finish time of the construction. Hence a 4D model of a structure can therefore be used to graphically simulate the sequence of construction operations, therefore providing the operator with virtual, visual understanding of the construction process. It has been noted to add value to the process and saves time as well as money (Allen and Smallwood, 2008). According to the study of Song et al. (2012), 4D simulation depicts the dynamic status of the building under construction over the course of time. The simulation is based on schedule data where 3D geometry appears at the start time, and is highlighted in colour during the work time until the end of the simulation. In this manner, the progress of construction is simulated. Through 4D simulation, the user can view the construction process in a dynamic visualization and confirm that there are no problems with the construction process. Notwithstanding, Mahalingam et al. (2010) further reviewed based on other findings that there are benefits but 4D technology has not been widely embraced by the construction industry worldwide because it is a complicated process when used on an actual process that requires coordinated effort. Also, another issue is the fragmented nature of the industry which makes it difficult for new technologies to be widely accepted. But overall, 4D models have been shown to enable a diverse team of participants to collectively make decisions on a project and improve the constructability and execution strategies, so as to realize gains in site productivity. A problem worth noting is that building up full details of a 3D model needs a lot of resources such as time and labour. Case studies have indicated that 4D models help identify design conflicts prior to construction, help bridge gaps in skill and knowledge among workers, increase cost control, detect time-space conflicts and ensure lower rework rates and requests for information during the course of the project (Allen and Smallwood, 2008; Mahalingam et al, 2009; Li et al, 2009; Wang et al., 2014).

6 Key literature findings, discussions

Traditional methods of scheduling such as the CPM, PERT and Gantt charts are great; however due to the dynamism and complex nature construction activities, these methods have proved inadequate to be able to manage the risk associated to project scheduling. This is because they are not flexible enough to tune to the changing nature of projects resulting in uncertainties, giving rise to the need for continuous adjustments thereby failing to show how a project really behaves. This consequently results in schedule delay and as such putting the project at risk. Scheduling risk results in project beyond completion date which can in turn lead to higher materials and labour cost which are undesirable. Based on Table 1, software packages for scheduling needed to support the traditional methods can be classified into two categories-one that is BIM compliant and the other is not. It is important to understand the connection between BIM compliant and non-BIM compliant scheduling software systems.

7 Conclusions

The construction industry has been known for its poor project delivery by exceeding completion time. This can be attributed to so many reasons one of which is poor project planning or scheduling. In order to properly minimize the risk of schedule delay, proper project management is required. BIM, which is an emerging tool in the industry, can offer the opportunity to properly manage the risk of schedule delay. In this manuscript, challenges associated with scheduling have been reviewed. This led to the identification of common scheduling tools and whether they contain risk management components as well as whether they can be incorporated into BIM. As part of future study, the connection between risk, scheduling and BIM will be investigated through practical case studies.

References

Allen, C. & Smallwood, J. (2008) Improving construction planning through 4D planning. *Journal of Engineering, Design and Technology*, 6(1), pp. 7 – 20.

Alzraiee, H., Zayed, T. & Moselhi, O. (2015) Dynamic planning of construction activities, using hybrid simulation. *Automation in Construction*, 49 (Part B), pp. 176-1920.

Aziz, R.F. (2015) RPERT: Repetitive-projects evaluation and review technique. *Alexandria Engineering Journal*, 53(1), pp. 81-93.

Banaitiene, N. & Banaitis, A. (2012) Risk management in construction projects. Available at: http://dx.doi.org/10.5772/51460 (Accessed on: 26 May, 2015).

BIS (2013) UK Construction: An economic analysis of the sector of the', Department of Business Innovation and Skills. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/210060/bis-13-958-uk-construction-an-economic-analysis-of-sector.pdf (Accessed on: 09 May 2015).

Bryde, D., Broquetas, M. & Volm, J. M. (2013) The Project benefits of Building Information Modelling. *International Journal of Project Management*, 31(7), pp. 971-980.

Cabinet Office (2011), Government Construction Strategy, Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/61152/Government-Construction-Strategy_0.pdf (Accessed on 09 June 2015).

Chen, S., Griffis, F. H., Chen, P. & Chang, L. (2012) Simulation and analytical techniques for construction resource planning and scheduling. *Automation in Construction*, 21, pp. 99-113.

Chua, D. K. H., Nguyen, T. Q. & Yeoh, K. W. (2013) Automated construction sequencing and scheduling from functional requirements. *Automation in Construction*, 35, pp. 79-88.

Ding, L., Zhou, Y. & Akinci, B. (2014) Building Information Modelling (BIM) application framework: The process of expanding from 3D to computable nD. *Automation in Construction,* 46, pp. 82-93.

Dzeng, R. & Tommelein, I. D. (2004) Product modelling to support case-based construction planning and scheduling. *Automation in Construction*, 13(3), pp. 341-360.

EISC (2012) Construction sector overview in the UK. European Information Service Centre. Available at: http://www.prismenvironment.eu/reports_prism/UK_PRISM_Environment_Report_EN.pdf (Accessed on: 09 May 2015).

Hammad, D. B., Rishi, A. G.& Yahaya, M. B. (2012) Mitigating construction project risk using Building Information Modelling (BIM) *In*: Laryea, S, Agyepong, S. A, Leiringer, R, Hughes, W, (Eds) Procs 4th West Africa Built Environment Research (WABER) Conference, July 2012, Abuja, Nigeria, pp. 643-652.

Hossen, M. M., Kang, S. & Kim, J. (2015) Construction schedule delay risk assessment by using combined AHP-RII methodology for an international NPP project. *Nuclear Engineering and Technology*, 47(3), pp. 362-379.

Ibem, E. O. & Laryea, S. (2014) Survey of digital technologies in procurement of construction projects. *Automation in Construction*, 46, pp. 11-21.

Irimia-Dieguez, A. I., Sanchez-Cazorla, A. & Alfalla-Luque R. (2014) Risk management in megaprojects. *Procedia-Social and Behavioural Sciences*, 119, pp. 407-416.

Jugdev, K., Perkins, D., Fortune, J., White, D., & Walker, D. (2013) An exploratory study of project success with tools, software and methods. *International Journal of Managing Projects in Business*, 6(3), pp. 534 – 551.

Lee, E., Park, Y. & Shin, J. G. (2009) Large engineering project risk management using a Bayesian belief network. *Expert Systems with Applications,* 36(3), pp. 5880-5887.

Li, H., Chan, N., Huang, T., Guo, H. L., Lu, W. & Skitmore, M. (2009) Optimizing construction planning schedules by virtual prototyping enabled resource analysis. *Automation in Construction*, 18(7), pp. 912-918.

Liu, H., Al-Hussein, M. & Lu, M. (2015) BIM-based integrated approach for detailed construction scheduling under resource constraints. *Automation in Construction*, 53, pp. 29-43.

Mahalingam, A., Kashyap, R. & Mahajan, C. (2010) An evaluation of the applicability of 4D CAD on construction projects. *Automation in Construction*, 19(2), pp. 148-159.

Matějka P. & Tomek A. (2014) The impact of BIM on risk management as an argument for its implementation in a construction company. Creative Construction Conference 2014.

Memon, A. H, Rahman, I. A, Abdullah, M. R. & Aziz, A. A. A. (2011) Time overrun in construction projects from the perspective of project management consultant (PMC). *Journal of Surveying, Construction and Property*, 2(1), pp. 54-66.

Mills, A. (2001) A systematic approach to risk management for construction. *Structural Survey*, 19 (5) pp. 245 – 252.

Olawale, Y. & Sun, M. (2010) Cost and time control of construction projects: Inhibiting factors and mitigating measures in practice. *Construction Management and Economics*, 28 (5), pp. 509 – 526.

Pellerin, R., Perrier, N., Guillot, X. & Leger, P. (2013) Project management software utilization and project performance. *Procedia Technology*, 9, pp. 857-866.

Proverbs, D. G., Holt, G. D.& Cheok, H. Y. (2000) Construction industry problems: The views of UK construction directors. In: Akintoye, A (Ed.), 16th Annual ARCOM Conference, September 2000, Glasgow Caledonian University. Association of Researchers in Construction Management, 1, pp. 73- 81.

Ramkumar, A. & Gopalakrishnan, S. (2014) Root cause analysis of issues in construction industry. *International Journal of Innovative Research in Science, Engineering and Technology*, 3(1), pp. 1-10.

Sawhney, A., Agnihotri, R. & Paul, V.K. (2014) Grand challenges for the Indian construction industry. *Built Environment Project and Asset Management*, 4(4), pp.317 – 334.

Serpella, A. F., Ferrada, X., Howard, R. & Rubio, L. (2014) Risk management in construction projects: A knowledge-based approach. *Procedia-Social and Behavioural Sciences*, 119, pp. 653-662.

Song, S., Yang, J. & Kim, N. (2012) Development of BIM-based structural framework optimization and simulation system for building construction. *Computers in Industry*, 63(9), pp. 895-912.

Taxen, L. & Lillieskold, J. (2008) Images as action instruments in complex projects. *International Journal of Project Management*, 26(5), pp. 527-536.

Tohidi, H. (2011) The role of risk management in IT systems of organizations. *Procedia - Computer Science Journal*, 3, pp. 881-887.