Integrating BIM and Planning Software for Health and Safety Site Induction

John, Godfaurd[1] and Ganah, Abdulkadir[1]

[1]School of the Built and Natural Environment,
University of Central Lancashire, Preston, PR1 2HE,
United Kingdom

Email: gajohn@uclan.ac.uk, aganah@uclan.ac.uk

Abstract:
Project management software packages have been around for quite a long time to help managers to run construction projects effectively. Building Information Modelling – also known as Object-orientated Modelling technology was used at the beginning in architectural design which has become more widespread in structural and services engineering. The development of BIM modelling has made the tool more users friendly. As a result, BIM became widely used by most practitioners in their specialist areas. For health and safety practitioners within construction project management, This tool has not been fully explored. BIM technology has the potential to be used in safety planning procedures particularly those related to tasks on construction sites.

The section of the research presented in this paper intend to explore and review health and safety issues on construction site with the sole intension of using better visualisation software to meet the needs of health and safety site practitioners in understanding such H&S problems. A framework needed for better H&S practice on site that may be used actively by all practitioners will be developed. The intension is to find a way forward in addressing 'real' health and safety site issues that may not be easy to be understood by practitioners without the full aid of visualisation.

Keywords: Health, Safety, construction site, BIM, 4D Modelling

1 Introduction

The construction industry has been well known as one of the most dangerous industries in which to work (Gibb et al 2010). Despite the fact that the UK construction sector only accounts for approximately 4% of the UK employees, 27% of all reported occupational fatalities were from the construction industry (HSE, 2010). The nature of the construction process widely contributes to this relatively high occupational fatalities rate. These characteristics include the dynamic work environment, multiplicity of operations, proximity of multiple crews, industry fragmentation and industry culture (Hallowell, 2010). The problems of the nature of the construction process and characteristics brought about in 1998, the commission by the UK government on the construction industry which was led by Sir John Egan.

Most of the recommendations proposed by Sir John Egan in '*Rethinking Construction*' in 1998, has not all been implemented by the construction industry. However, most large construction firms have made tremendous effort to achieve the recommendation of 20 % accident reduction. Although there are still problems with small and medium size construction companies that make up the bulk of the industry (HSC, 2010), the awareness is there among practitioners and academics in finding innovative solutions to address most of what was said in the Egan report. HSE, the government controlling body, has also made progress in the areas, of safety and health regulations, guidelines and approved code of conducts, as well as creating health and safety awareness among construction practitioners. Health and safety management is therefore a most in all construction projects.

Although, health and safety management is widely practiced within all industries of production, , in construction, site conditions cannot be controlled as 'pure' manufacturing industries in terms of production processes as we know it, as such, health and safety becomes *paramount*. planning and management is an essential prerequisite of most construction projects and their practitioners, without a deep understanding of the issues involved in bringing about the realisation of a product safely, lives will be lost or economic failings will be realised due to accidents, and it's after effects on the construction project.

Many researchers also pointed out that there was a lack of integration between construction process and health and safety issues (Sulankivi et al 2010). In order to reduce the frequency and severity of construction accidents, firms implement safety programmes and procedures that include written safety plans and training (Hallowell, 2010). Nevertheless, lack of safety training and practices were identified as key factors behind many construction accidents (Sulankivi et al 2010).

In construction sites, as well known, operatives change over time due to the work requirements. Each construction site has its specific hazards and these differ from one location to another which cannot be generalized. New employees usually come on board without prior knowledge about the possible hazards may face during the work in the construction site. Existing tools may not be adequate for induction to their limitations including lack of providing a wider picture on the site. 4D visualisation approved to be a good tool for demonstrating many design and construction problems due to their ability to show many tasks in 3D over specific period of time

This paper is an outcrop of a project exploring new ways of integrating BIM technology for use during the construction of facilities and construction projects to understand hazards and its perception for inductees. In this paper the following sections will be discussed. The literature review underpinning what constituents the site processes that are viewed as real determinants of health and safety for construction site is investigated. A review of the current application and usage of BIM in construction industry will also be investigated. As such the literature on visualisation is also explored as a rather safe option in opening up new avenues of H&S management, particularly in the area of induction of site personnel and developing better ways for understanding site hazards perceptions.

2 A Kaleidoscope for Construction Site Activities

This section develops and discusses the literature for developing an integrated approach in using BIM and planning software in an optimise way to bring about better health and safety down stream in the construction of projects. Planning literature is first investigated and the relevant literature on health and safety management on construction site is also explored. It also expands on the importance of site induction and tries to put construction site induction in context, which is a must for any site personnel. The section concludes by reviewing the importance of visualisation as a necessary factor that will address some of the gaps that have been identified within the health and safety literature. The section also raises the possibility of using 3D software packages in developing better ways of site induction approach through visualisation of hazards.

2.1 Construction Project Planning

Construction project planning and management is a balancing act of leading and managing people, as well as using and managing resources within given constraints conditions, in an efficient and effective way, to achieve the desired artefact. The constraints include but not limited to time, cost, quality and safety, which are predominant during the realisation of the constructed artefact. Hence construction project management contains both the qualitative aspects as well as the quantitative aspect of management. Most of what is required within the quantitative area has been operationalised through dedicated project management tools (i.e. planning and scheduling software), like programming in the CPM method, resource levelling and the like. Since the advent of computers, most of what is required in programming and the constraints conditions are now safely in the computer environment. In all projects, the act of specifying, visualising and developing the planning schedule for construction has been done using dedicated work breakdown structures (WBS) within the software environment that is now common in projects. Once such plans are developed they are then followed and implemented to bring about the project. However, until recently, most of the information required in using this planning/programming software usually comes from both the CAD drawings and other related sources (Watson, 2010), that are not really related in terms of the WBS and subsystems used in each platform. However, with the development of BIM, and the life cycle realisation of the project in one holistic environment, most of the information can be done directly from what is available in the BIM environment for the project under consideration, which is usually referred to as 4D. The only downside is that we may have to deconstruct the built artefact in BIM to fit with our WBS and scheduling task. The suppose deconstruction of the BIM objects pose a lot of problems, in terms of software integration and inter-operability. Once this problem of software 'talking' to each other has been resolved, we may be able to link BIM in 3D visualisation to programming of the construction schedule of the desired artefact. There are some advantages that this paper intends to explore in relation to the use and application of the integrated approach, which will benefit most site workers.

Construction site planning and operation involves the selection of temporary facilities; equipment and their operations; the selection of competent construction personnel; and the planning, organisation and selection of an effective and efficient site layout design. Construction safety induction involves familiarising construction personnel to site specific safety and health issues that will degrade or impinge on the progress, efficiency and productivity of site personnel during site operations (John, 1999).

2.2 Health and Safety in Construction Industry: Site Induction

The practice of health and safety management in construction can be summarised in the following areas:

- Safety legislation, regulation, standards and guidelines
- Appointment of CDM coordinator by the client
- Designers health and safety considerations upstream in the creation of the artefacts and how it should be implemented during the implementation of the project
- Management of health and safety management during construction for site personnel
- Not forgetting the development of health and safety plan and the creation of the health and safety file right through the life cycle of the project.

Health and safety management is therefore part of the wider planning and management process of the construction project. Soltani and Fernando (2004) suggested that one way to make this industry better in terms of health and safety is to implement effective H & S regulations during the planning of the project. The failure of planning appropriate support infrastructure affects safety, quality, and productivity adversely (Soltani, 2004). Dolores et. al. (2009) using questionnaire methodology to analyse the H&S regulations and requirements in construction industry. The authors determined that there are 10% lower accident rate in general after the *Health and Safety* policies came into force. Some commentators also suggested that within the site organisations themselves, health and safety should be implemented , not in terms of project, by project bases (Ciribini and Galimberti, 2005; Cameron and Hare, 2008), more in a granular level.

Construction presents significant obstacle to repeated hazard analysis. Construction sites undergo dynamic change in ways that fixed industrial facilities do not; works team (i.e. gangs) are transient, the physical structure and spaces change, as well as the environmental conditions (i.e. in weather). Another difference is that in construction, workers of one team are frequently exposed to dangers posed by the workers of other, unrelated teams. Performing risk analysis before any activity at any time is essential but difficult, even if the same activity is performed repeatedly, since the site conditions change through time. This demands more effort than most contractors or workers are willing to invest, and therefore safety management in construction sites commonly suffers from low level of efficiency, with effective risk analysis performed rarely (Tang, 1997; Sacks, 2010). In the absence of an efficient and effective way of predicting peak risk levels, safety management on construction sites is performed at constant level of effort, focusing on provision and use of personal safety equipment, training, accident and near-miss investigations, and taking steps to fulfil regulatory requirements (Sacks, 2010). Given the dynamic nature of construction sites, analysis of construction activities and their related hazards is inadequate for reliable risk assessment if it does not explicitly account for the likelihood of exposure of potential victims to hazardous situations.

To achieve safety and health assurance, it is necessary to have to established sound codes and guides which adequately describe what is good safe practice, how this can be achieved and how it is measured. Without a mention of quality assurance this is nevertheless what we set out to achieve in the field of temporary works (Quinion, 1980). Induction is the first point of contact for the site personnel as well as others that have to come on site. However, within this paper we are limited to the discussion of new site personnel induction.

Most construction site personnel tell you that although health and safety induction should be site specific, but the differences from one site induction to another is marginal. The personnel believed that they know and are familiar with the routine of site safety inductions. However, familiarity breeds contempt, and as such personnel need reminders to make them more safety conscious, especially in terms of site hazard perceptions. One way in which this can be achieved is through visualisation.

2.3 Visualisation

The most recent studies on health and safety have been on the way visualisation can be used to integrate some of the problems encountered in managing by regulations and enforcement alone. Among such key commentators are those who proposed a scenario based SIMCOM+ tool to investigate safety on construction sites. It analysed the structural information including some temporary facilities, equipment, workers and materials in order to identify the collision among different entities on construction sites. Kuen-Chen and Shih-Chung (2009) identified conflicts on static or dynamic construction sites and determined the distance between large dynamic objects in virtual construction sites by different scenarios through VC_COLLIDE algorithm. Sacks et al. (2009) proposed algorithm based methodology CHASTE (Construction Hazard Assessment with Spatial and Temporal Exposure) that calculates the probability of a potential victim during loss-of-control events (Chavada, 2010).

2.3.1 4D CAD

A range of 3D CAD visualisation tools are used in the construction industry to communicate design ideas between all the stakeholders in the design and construction process of a construction project (Ganah et al, 2005). One of 3D CAD techniques limitations is that they do not provide a 3D representation over time whereas 4D CAD does that at any specific time of the project construction process.

4D modelling tools link a project's scope in 3D with the construction schedule to graphically simulate the construction process. Many research efforts have discussed the potential of these tools to significantly improve design coordination and construction execution. Koo & Fischer (2000) argued that 4D models allow reviewing the planned status of a project in the context of a 3D model for any desired time which allows project managers to ensure the integrity of the main schedule, revealing potential time-space conflicts and logistical problems, supporting the communication of product and process knowledge and allowing efficient tracking of the work progress. Furthermore, 4D models facilitate the communication with subcontractors and improve the collaboration between the project team.

The use of 4D models may also help in identifying and eliminating many construction related problems before going to site (Aouad & Tanyer, 2005). It displays the progression of construction overtime and sometimes dramatically improves the quality of construction plans and schedules (Rischmoller et al., 2001)

4D CAD proved to be a useful tool in assisting planners to visualise alternative construction sequences based on alternative decisions made (Koo and Fischer 2000 and Dawood et al. 2000) however, it should not be considered as only planning tool as it relies on available information to provide a graphical simulation of the project schedule and the planner uses these tools as means of visualising and comparing, rather than developing and implementing different decision alternatives (Waly, 2001).

Traditional approaches used for representing construction planning information in an abstract textual description of construction activities may lead to the fact that the planners need visually conceptualise the sequence of construction activities and subcontractors may elaborate the construction plan because it lacks necessary detailing (Rwamamara et al 2010).

2.3.2 BIM

Building Information Modelling (BIM) – also known as Object-orientated Modelling technology was used at the beginning in architectural design it has become more widespread in structural and services engineering. The term BIM is not just referring to a category of leading edge software for designing buildings but it goes beyond that to a process view in which the focus lies on the information over the full lifecycle of a building (Watson, 2010). It directly relates to a project team's ability to visualise, understand, communicate and collaborate. Harty et al (2010) described BIM as a set of practices or activities describes the new ways of working that emerged through the implementation process. Succar (2009) gave a deeper description for BIM as he defined it as a set of interacting polices, process and technologies generating a methodology to manage the key building design information in a digital format throughout the building life-cycle.

Nowadays, each construction project is complex and dynamic system, which makes construction planning, design and site and construction management complex and difficult (Zhang & Li 2010). BIM is widely considered to be an enabling technology with potential for improving communication between stakeholders, improving the quality of information available for decision making, improving the quality of services delivered, reducing time and cost at every stage in the life cycle of a building (Smith & Tardif 2009). One of the key advantages of IBM over 2D and 3D CAD is that IBM represents and manages not just the graphics, but also information- information that allows the automatic generation of drawings and reports, design analysis, schedule simulation, facilities management etc-ultimately enabling the building team to make better-informed decisions. The planned work sequence of work is usually part of BIM which can be used later to produce animations of the construction process of a building over time, therefore showing how the work on site should be carried out according to plans of work and contractual responsibilities. In addition to that, BIM has the potential to be used beyond the design stage to include the construction and operation of a building with the concept of a digital virtual building that parallels the real building (Watson, 2010). Thus the technology can prove crucial to the success of a project by effectively controlling the construction schedule, budget, quality and the reducing risks (Ku & Mills, 2010).

BIM technology has the potential to be used in safety planning procedures particularly those related to tasks on construction sites. 4D modelling tools can be used to link a project's scope in 3D with the construction schedule to graphically simulate the construction process. Construction tasks on site can be modelled in a 4D CAD production model, in which the model produced by designers used as the starting point. Previous studies have found that certain sets of movement characteristics for construction facilities such as tower crane arm movement, movement of construction vehicles etc. This may enable the system to simulate the construction more realistically. This may enable a system to simulate the construction more realistically (Zhang and Li (2010).

Harty et al (2010) investigated the use of BIM to assess the access adequacy to install new services and perform health and safety assessment –looking for trip hazards. This project did not investigate how health and safety on site during construction can be assessed and addressed. The utilisation of 4D-BIM technology may improve occupational safety by connecting the safety issues more closely.

However, the uptake of this technology within the construction industry is partial and fragmented (Harty et al 2010).

The literature review shows that, as of now BIM usage is confined mostly to the design and planning stages of the project, with very little of it being used in the construction phase of the project. However, the construction phase is where the bulk of accidents, health and safety occurrences are recorded. Also it is in the construction phase where personnel induction is ongoing due to the high churn rate of personnel in the construction industry. Similarly planning software are used in the planning stage, but seldom updated when the actual construction work is ongoing to keep track of progress. New methods are needed to help alleviate some of these problems.

3 Research Methodology

The focus of the paper is the use of Building Information Modelling (BIM) in health and safety on construction sites. The methodology for the project will be more qualitative in approach than quantitative. As such, the first stage of the project is to assimilate all the relevant literature in understanding our study domain. This will entail literature on BIM, visualisation, planning, health, safety and risk on construction projects, as well as other associated works. The research instrument of the data will be an eclectic approach of the literature which will involve both deductive as well as inductive understanding in acquiring the knowledge for future synthesises of the knowledge gained.

The next stage will be using such knowledge to develop a generic modelling approach that will take into consideration, the object oriented modelling understanding that have been used in BIM technology, as well as planning software. This will incorporate developing new classes, frameworks and building blocks that will be replicated when using the integrated scenario for each construction site. However, for this paper, a section of the different stages will be reported to give the reader an understanding of how the research will develop.

4 Integrated BIM approach for Site Induction

Rather than expose the individual to ‘real’ safety and health concerns, the specific site accident ‘hot spot’ can be simulated and the improvement to the personnel’s hazard perception improved considerably, with the aid of BIM and project management software in sync. In Figure 1 the architecture is presented.

The site induction hazard perception toolkit architecture is made up of four parts:

- The BIM software with its library of information
- The project management software with the resources and planning of the desired project
- The algorithms making use of information from both packages
- The user interface

Before the integration can commence the planning software and the BIM should have a way of integrating the information of a particular object that is to be created, such that recognition of such object is the same. Secondly, the different stages of the object in real time should be stored in such a way that a time sequence scenario can be created in the BIM environment. Thirdly the visualisation of the developing project should be such that safety concerns can be visually seen as the project progresses.

As the construction sequence is developed, the integration should be able to monitor critical safety areas and show in time sequence how certain hazards develop on site, through the expert system that is lying behind the 4D scenario.

Each part of this architecture is being developed using object oriented methodology and SSM. As such each part is considered a high level object in its own right, and will be developed independently.

The BIM environment will be used to develop the ‘new’ construction components, that will be directly related to the WBS used within the scheduling software. Critical safety areas will be developed that will show the site inductees what he should be expecting on site.

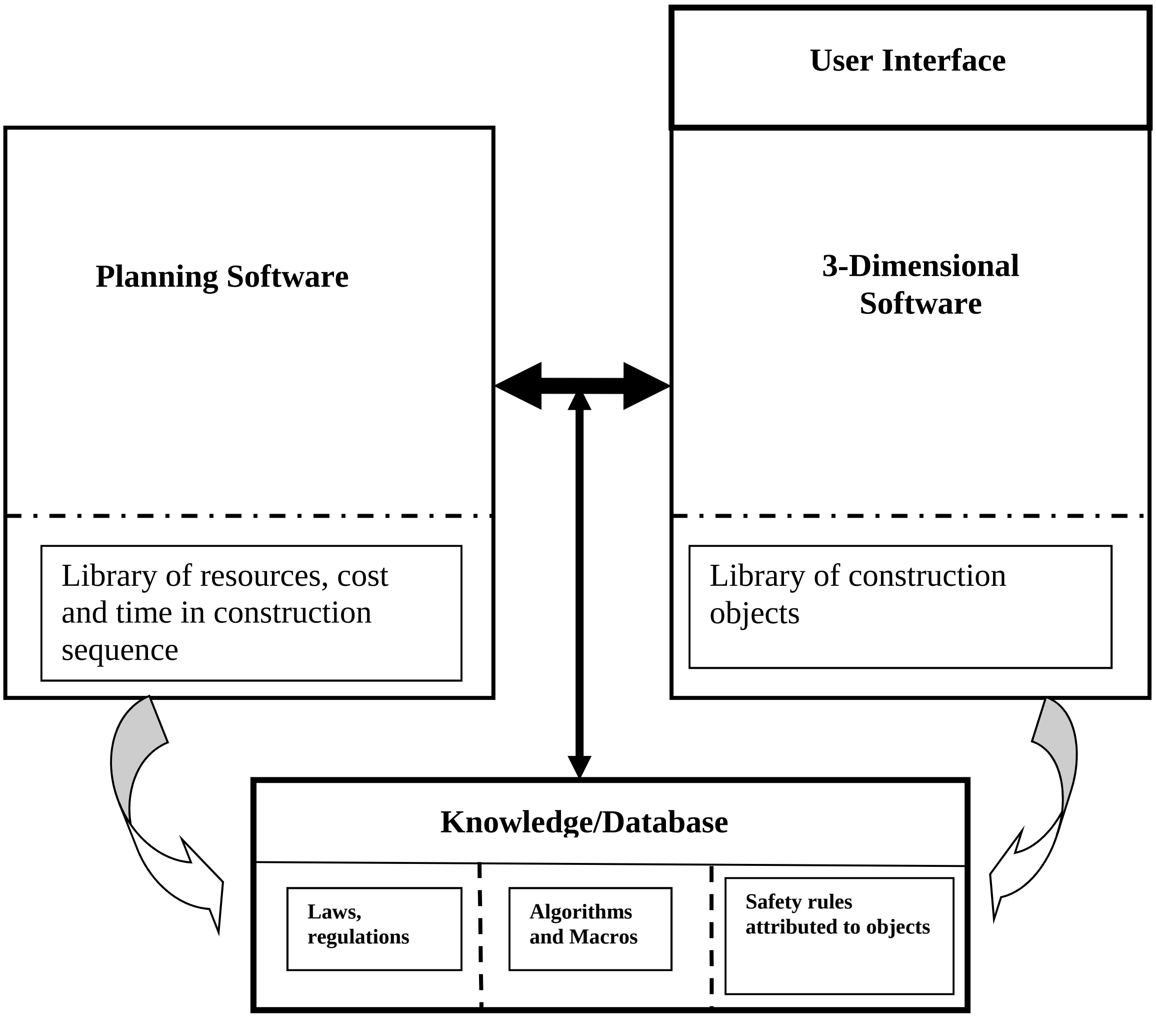

Figure 1: Top Level Site Safety Induction Framework

The algorithms will be used to control the different construction scenarios that will typify site perceptions in a realistic environment. The new recruit hazard awareness will be tested in the past stages of the project, ongoing work and future realistic phases of the project. This will all be made possible by algorithms augmenting the health and safety regulations, codes and guidelines at each stage of the project.

5 Conclusion

Health and safety on construction site can either make or break a contractor, if not properly managed. As such, all personnel need to be properly inducted in managing their health and safety concerns, which are usually done by the conventional means.

Construction personnel are always inducted when they are new to specific site, through prescribed induction manual and training that have been developed through industrial institutions or in-house induction materials. Over time the personnel moving from site to site become familiar with the induction material, and take them for granted. However, accidents are still occurring on sites and hence more proactive methods are required.

BIM is now prevalent within the construction industry, especially in design and planning of construction projects. The usage of BIM in this research on construction execution, have the potential to help augment practitioners understanding of their sites, by so doing reduce their probability of accidents. The BICHS project tried to develop a new way for enhancing the personnel understanding of site hazards, especially in real time as site inductions can happen as the project progresses.

6 Future Works

The development of the intelligent algorithms for identifying site hazards will be the next stage of this research project. The system will enable new site operative to identify potential hazards they may face during their work on construction sites as part of their induction training on health and safety. The system will be tested and validated through real life case studies

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