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Investigation of health and safety impact from the 'Site BIM' tools in the live construction sites

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ABSTRACT: ***Construction in the UK is the second most dangerous industry in terms of fatal and minor injuries according to the 2014 report of HSE. The use of mobile devices such as iPad, Tablets and Smart phones on the live construction projects is also on the increase in the UK due to the 2016 - Level 2 BIM (Building Information Modelling) implementation target, set by the UK Government. Hence, the use of such devices may become a distraction from work activities on the construction sites and will cause a major risk to the end users. The subject of improving safety of BIM use is widely researched, but there is a gap in knowledge about the actual use of the mobile devices and perception of 'Site BIM', on the construction site activities. The main gap identified in the 'Site BIM' is the health and safety aspect of using such devices on the construction sites. A safer way of working with such devices needs to be identified to avoid any potential site hazards and fatalities before the widespread use of the devices are found on the construction projects. In that context, the paper is aimed to highlight the safety issues that are required to address for the successful implementation of the mobile devices for safer use of the 'Site BIM'. Questionnaire survey was used to collect the site information among construction professionals in the UK. The survey findings suggested that a proactive approach may be helpful to stop potential hazards and risks causing by the use of mobile devices and potential measures need to be identified before any injuries and incidents occur. The paper concludes that training, changing size of mobile devices and ensuring a separate induction training for 'Site BIM' tools will improve the health and safety of the end users of the mobile devices at the live construction sites.***

KEYWORDS: Health and Safety risks, Mobile devices, Site BIM, Construction site, BIM Implementation.

I. INTRODUCTION

In recent times digital information is becoming more familiar on construction projects. Construction is an information-intensive industry, and the success of a project depends upon the availability of accurate data [6]. Site work is generally paper based and due to the adverse weather and conditions it is challenging for site engineers to collect and share site information in real-time [9]. Sites offices can often be a long walk on projects, forgetting necessary documents or a pen all happens down to human error. But often data information may get lost if distracted. A mobile device may improve the reporting processes due to the information getting inputted and stored immediately. A recent research stated that "the main problems associated with manual and labour-intensive processes are delays in obtaining, processing, and accessing information, as well as the inconsistencies and inaccuracies in the information itself due to the manual entry of data [13]." Therefore, an efficient way of inputting data on a construction site is in demand and the possible solution in this direction is effective implementation of new information modelling system such as BIM (Building Information Modelling).

The use of tablets and mobile device on projects is on the increase in the UK, this could be largely due to the 2016 - Level 2 BIM implementation target set by the UK Government (applies to central government funded projects). Contractors will not want to lose competitiveness through the non-implementation of BIM. Research in this area has predominantly been based around the projects benefits in terms of cost, scheduling and system architecture. Davies and Harty [4] introduced the implementation of an innovative site based BIM tool 'Site BIM', which is going to significantly change how day-to-day construction management occurs. This is possible through the use of mobile computing technology that will automate the construction phase for the through the affordable devices, capable of receiving an internet/intranet signal, which will help to send live site information and also receive design information instantly.

This is supported by Chen and Kamara [2] and they suggested that the advancement in the affordable mobile devices, increases in wireless networks and the enhancement in mobile applications have given the potential to improve the process of the construction site management.

However, a factor that seems to lack in research is the health and safety of the end user whilst using a mobile device on a live construction site.

Construction in the UK is the second most dangerous industry, although it only employees 5% of Britain's it accounts for 27% of fatal injuries and 10% of reported major injuries [8]. Use of a mobile device may become a distraction, and with heavy vehicular movement on construction sites this could be a major risk to the end user. Accidents because of being hit by a moving vehicle in 2012/13 accounted to 10% of the total fatalities in the construction industry [7]. The subject of improving safety through BIM use is widely researched, but there is a niche area of the actual use of BIM on a live construction project through the use of a mobile device or 'Site BIM'. This

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phrase was coined by Davies and Harty [4]. Moreover, Sacks et al [10] suggested that the practicality of tablet PCs is questionable due to the security, and site conditions from the health and safety aspects. Hence, the paper is aimed to address the issues by analysing the safety impact of the site BIM tools on end user's perception during the live construction projects, and identifying the practical barriers to implement the site BIM tools such as tablets and mobile devices. The rest of the paper is structured under literature review, research methodology, survey data analysis, presentation of results and discussions followed by conclusions, future recommendations and references.

II. LITERATURE REVIEW

The role of mobile IT in construction has the potential to automate many processes. Bowden et al [1] found through case studies that mobile technology through various forms can reduce; construction time and capital cost, operation and maintenance costs, defects, accidents, waste and increase productivity and predictability. Typically devices of the modern day have various functions that can improve on site construction management. Smartphones are now typically equipped with touch screen, GPS receiver, gyroscope, accelerometer, and wireless communication technology [9]. There is a view that efficient communication systems are important to the improvement of information speed between the site office, headquarters and the supply chain [2]. Having moved forward in the forms of mobile technology it is know the opportunity to embed mobile device use on construction projects. Although the theory of site based mobile technology has been developed by Son et al [13], the key factors that influence a successful application of mobile IT was investigated, they found that user satisfaction was important to the success of implementation.

The whole idea of bringing mobile device to the live construction site is to aid in the provision of key live data so that may be lost using traditional paper based formats. However, site management work is still dominated by paper whether in the form of drawings and other design information or in the use of paper notes and forms for capturing information [4]. It is only know through collaborative IT solutions such as BIM that information flow can be exchanged throughout all stages of a project life-cycle. The need for the use of mobile technology is ever apparent and the benefits of such are widely researched. Although questions remain whether or not the introduction of mobile device for live data capture poses a risk to end user safety? Suzuki and Nagayusu [14] have identified by various types of devices, which have been adopted for field use throughout construction sites in Japan. More commonly in the UK construction industry, electronic devices are used to provide and capture information such as digital cameras. But the adoption of using a device that allows the user to interact with vital construction information in a dangerous site environment may pose significant risks. A drawing is simply a reference tool, but when viewed on a mobile device it can be zoomed, edited etc. This then poses a significant risk of distraction compared to a paper drawing.

In addition, a study by Vanichkachorn [15] highlighted that the mobile devices affected their work and impaired safety, however, he suggested that safety risks are dependent not on frequency, but rather than method of use for the device. The fact remains using traditional paper based methods and other less interactive mobile devices (digital cameras, radio etc.), the additional safety concerns barely exist. In the study, the main work where attention is paid will be inside a site office. Reducing the potential distractions on a mobile device is the key during site instructions. Davies and Harty [4] suggested for the construction site use the device, which was installed with a brief-cased mode. Such mode would then lockdown a device ensuring applications such as social media and cannot be accessed. This then also shows a clear differentiation to the worker because the tool is solely for task purposes. Therefore, mitigating such risk of distraction is necessary, particularly when using mobile dives on construction sites.

A. Introduction of Site BIM

Site BIM is defined as using a means of mobile device to automate site based activities that will record project data and inform the BIM in real time. This reflects the view of Davies and Harty [4] who in their research implemented BIM related tools and tablet computers for use on site during the construction phase - 'Site BIM'. This is in line with the view of Sacks, et al [10] who suggested that most academic research relating to BIM use has been based around design, pre-construction, planning and there has been far less effort to develop BIM based tools to support production management on site. A connection from site to access BIM systems needs to be established in order for the information flow to exist. Davies and Harty [4] found that tablet computers provided the vehicle for making use of BIM model data but also acted as a functional capability. As mobile technology is advancing it has the potential to take the onus off other work flows enhancing the effectiveness of using a tablet. The use of tablet PCs and the development of site BIM systems are seen as building on the existence of the coordinated 3D models [4], which is similar views that site BIM is expanding the usual uses of BIM, and using it practically for construction site use. To enable a collaborative work flow to ensure level 2 BIM is achieved an onsite entity needs to exist to provide the information work flow. Without onsite automation true BIM will not exist as design information may become lost in paper form.

BIM adoption in UK construction is lacking behind other countries, and the UK Government has set a 2016 target for Level 2 BIM adoption on centrally funded projects. BIM will change the future of the UK Construction Industry and in achieving the Government's target, site information to inform the model will be required. This supports the view of Davies and Harty [4], who suggested that mobile devices can be the vehicle to access the BIM model on site with aim of improving site

productivity. This stance is supported by several researchers [1], [2] and [11]. It is inevitable that an increase of devices will occur, due to lower costs of devices and an increase in BIM adoption.

B. Health and Safety impact from Site BIM

From the industry prospect, Costain policy [3] states to ensure accidents and near misses do not occur as a result of inappropriate uses of mobile devices their use is prohibited within the site boundary unless it is carrying out a designated operation where the equipment has been sanctioned by managers and documented in the risk assessment and method statement [3]. To use a device, it could be suggested that use is mandatory in a 'safe sectioned zone', although this may have an adverse effect due to the open collaborative nature the tool is introducing, this theory will be tested later in the study. The policy is the correct direction companies should be taking to mitigate the risk and also bringing clarity to the potential argument of "He's using iPad, why can't use my phone". Huge steps are not needed to ensure end user safety just awareness and training will be needed with slight alterations to company policies to accommodate for the increasing use of mobile devices.

Davies and Harty [4] suggested that use of a smaller device such as an iPad mini for example may improve manoeuvrability. A smaller device may be able to be stored within the users PPE whilst walking around site, thus potentially minimising the risk of slip, trips and falls, therefore challenging the view of Sacks, et al [10]. The study by Kim et al [9] proposed to use mobile computing technology for on-site construction management. But this research is focussed to systems and does not assess any end user information within the study. Davies and Harty [4] use a real world project case study of implementing 'Site BIM', feedback of the end user is within this study which has generally been accepted by the end user. Although the information does not highlight any potential H&S issues with using a device.

Eadie et al [5] conducted a research, which is found the most prominent piece of research since it measures the BIM use throughout a project lifecycle; this confirms that the perception from users is that BIM is most often used at early stages of a project. The construction phase is the third most significant stage where BIM use is identified through the study. This research confirmed the need to further research Site BIM implementation and the subsequent measurement of the impact. Moreover, past study reveals that a mobile system is built from the beginning it can offer a real-time database that can monitor site safety activity, thus having a positive impact toward site safety through using a mobile device. But the question remains what if the user who is inputting the safety information becomes harmed as they are unaware of their surroundings. Protective gloves protect from abrasion, cuts and punctures, skin infection and disease or contamination [7].

Protective gloves are mandatory on major construction projects, due to the nature of using a mobile device this area will be included to investigate further in the study. Siegenthaler et al [12] highlighted in their research that LCD displays received a higher fatigue rating; this may become a hazard to a user's health. This will be contained within the investigation to see if industry professionals feel the same way as the researcher.in this context, this study aimed to investigate the health and safety aspect from industry and user prospective by conducting a structural survey.

III. RESEARCH METHODS

In this study, both quantitative research approach was selected. The web-based questionnaire survey was used to collect the survey data. A total of ten civil/construction organisations (250+ employees), five client organisations (150+ employees) and five supply chain organisations (25+ employees) from the UK were selected for the sample frame as shown in Figure 1 below. The sample size of the population was derived using an online sample size calculator. The respondents are construction professionals which have experience in the construction sites and having some level of knowledge of using mobile devices during the construction operations.

Statistical analysis using SPSS (Statistical Package for the Social Sciences) was used to analyse the collect survey data and present the survey findings from the survey. The results are presented in graphs and table to highlight potential cultural trends and existing practice from the answers. In the survey, a simple-random sampling method was utilised. This method selects a sample or population within a total sample frame. Every participant within the sampling frame has an equal probability of being involved within the final sample.

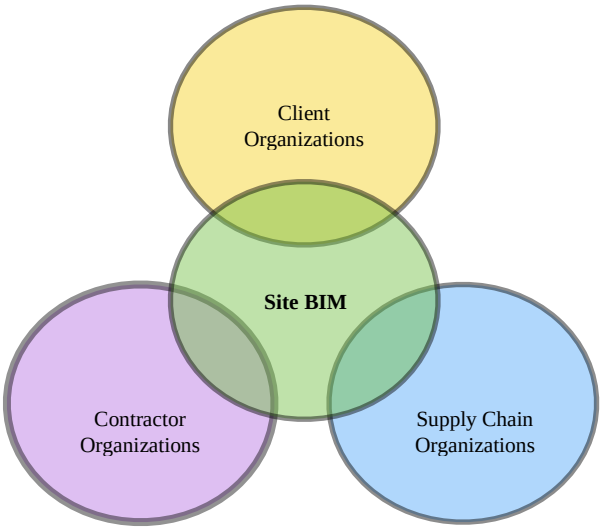

FIGURE I
Type of organization participated in the survey

To analyse the data collected from the survey, a statistical tool called SPSS was utilised. The sample size was calculated using on online sample size calculator to ensure the study is representative of the population. It was

found that 80 samples are enough for the study. The actual achieved response rate (93%) of the investigation was slightly lower than expected and actual responses were 74 collected from the target of 80). The reason for this could be partly due to the holiday period.

The expected response rate was set at a higher number so if it wasn't achieved the study will still have enough responses to validate the credibility of the study, and provide an accurate sample. Wave analysis was the method utilised to check for response bias. The analysis occurred weekly, to ensure maximum responses were achieved within the seven-day period.

IV. RESULTS AND DISCUSSION

The results found from the survey of safety impact of 'Site BIM' to the end users are presented under graphs and tables. At first couple of charts are presented to show the demographical representation, involved in the survey.

The information of participants in terms of years of expertise and age group are shown in Figures 2 and 3 below.

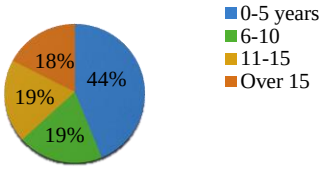

FIGURE IIIII
Years of Experience

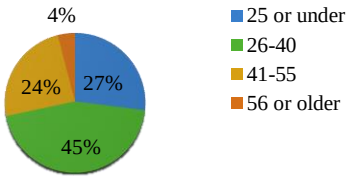

FIGURE IVVVI
Age group

After presenting the demographical information, the site experiment and BIM knowledge of participants in the survey, is presented in Figures 4 and 5 below.

A survey question was utilised to measure whether the "increase in productivity outweighs the potential safety impact of using a mobile device on-site" and the results reveal that 51% respondents agreed with H&S impact have high influence compare to increase in the productivity (49%), which is shown in Figure 6 below. The responses indicated that there is a health and safety hazard when using the mobile devices on live construction site, but these risks could be mitigated by ensuring end user safety. This kind of response is not unusual due to the construction industry being the second most dangerous in the UK [8]. Hence it is confirmed that mobile devices in the live construction sites create more H&S hazards while support to increase the site productivity of construction operations.

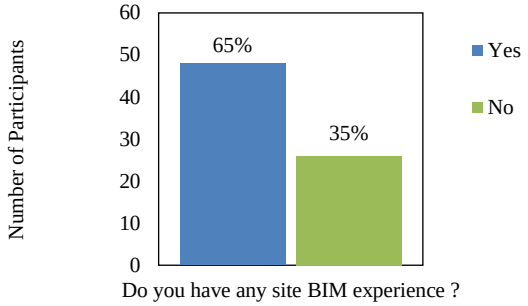

FIGURE VIIV
Site BIM Experience

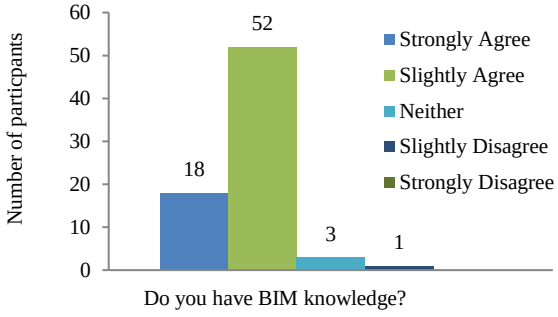

FIGURE V
BIM Knowledge

Q. Do you feel that the increase in productivity from using a mobile device outweighs the potential health and safety impact?

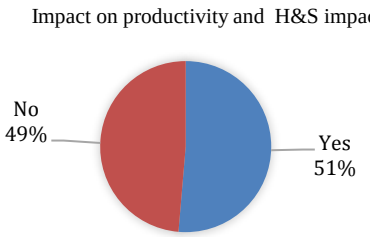

FIGURE VI
Productivity vs. health and safety impact

The paper is aimed to highlight the potential safety and health hazards and its impact on end users whilst using a mobile device on live construction sites. The survey results revealed that 39% of H&S safety hazards occurred due to the slips, trips and falls followed 37% from vehicular movement during the use of mobile devices in live construction projects (Figure 7). The survey also exposed that eye strain to user also contribute to H&S hazard followed by falling objects, neck strain and back strain. The survey findings provide a holistic view of the health and safety impact and future recommendations to the safe uses of the site-based mobile devices/tools, which play major roles for the safe implementation of 'Site BIM'.

Q. What do you feel the main health and safety hazards whilst using mobile device?

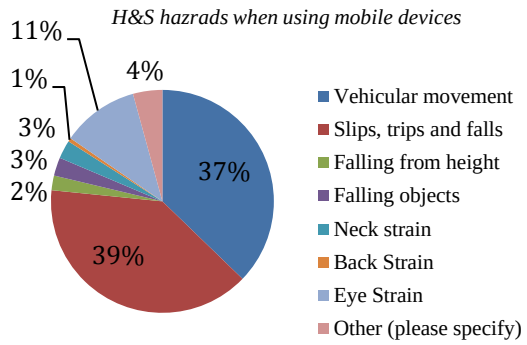

FIGURE VII
Health and safety hazards

In case of safety question regarding selection of mobile devices such as tables or PCs for the implementation of Site BIM tools, it was found that majority around 73% was agreed to use smaller devices to improve the site movement whereas 23% disagree (see Figure 8). The suggestion made from this was that use of a smaller screen device may improve maneuverability. The findings could be a simple solution to the problems found by the previous researchers.

Q. Would using a smaller device improve ease of use and maneuverability for the end user?

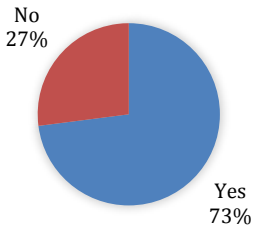

FIGURE VIII
Selection of mobile devices

The case for sectioned areas for device use on a live construction site is ever present. Sites can be dangerous environment without the distraction of an electronic device. Figure 9 illustrates the results made from the further analysis of the primary data. The optional comments left by respondents also held the position that there should not be a sectioned area for mobile device use. One respondent commented, "How can you capture true field data if you don't have full access". This view illustrates the exact point that needs to be addressed in order to ensure level 2 BIM is achieved.

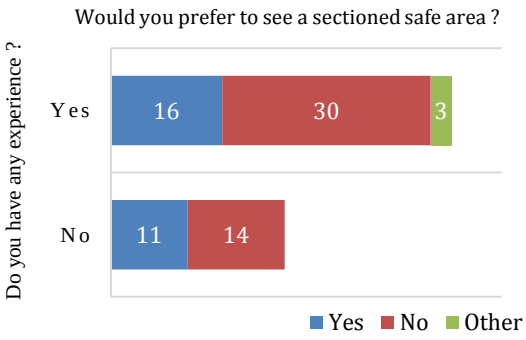

FIGURE IX
Industry experience vs safe area

Construction sites differ from project to project and can be very hazardous if the correct precautions and training are not taken. This is why site inductions are a compulsory element before beginning site work. The survey results shown in Figure 10 exposed that 54% of respondents agreed that users of a mobile device "should be subject to a separate induction" whereas 46% disagree with the induction. Training operatives at the induction stage and approving them to use a device may be a solution. This would ensure all parties are aware of the risks associated with the use of mobile devices and end users will not hamper the productive time for training throughout the project lifecycle.

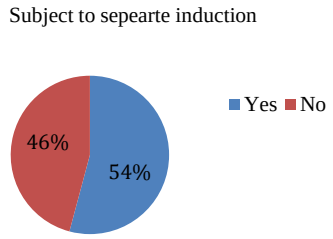

FIGURE X
Responses of separate induction amongst site expert

In the case of perception toward mobile device use, the outcomes from the survey data provided an overall perception toward the use of 'Site BIM' or mobile device use on live construction sites based upon the sample population. Respondents were invited to leave a personal opinion; the main themes are highlighted in Table 1 below in the ranking level of the perception. In result, users are aware that use of mobile devices helps to improve the productivity, easy in training and awareness but at same time they also highlighted that these devices also create a greater hazard and sometimes affects works due to software and systems issues on these devices. These results only reflected the perceptions of mobile devices users from the developed countries like the UK, where more Government is targeted for the BIM implementation by 2016. Hence, the results will be entirely different.

TABLE I

Main themes of overall perception question

Rank	Theme
1	Acceptance of mobile device use
2	Productivity increase
3	Training and awareness
4	Increased amounts of devices may potentially become a greater hazard
5	Software and systems issues may affect the usefulness of the mobile device uses

V. CONCLUSIONS

It is concluded that the use of mobile devices for site management in the construction projects is evolving like a valuable tool. However, these devices can create health and safety risks to the end users. A questionnaire survey was conducted in the UK from the participant having knowledge about BIM. A total of 74 responses were received and used those responses for statistical analysis. The study found that the construction professional agreed that there is possibility of creating health and safety hazards from the insensitive use of the mobile devices to the end users.

Moreover, the survey results also highlighted that the health and safety anxieties to the end user of the mobile devices were slips, trips and falls followed by vehicular movement. Eye strain was another safety concern amongst respondents. To reaffirm participant's knowledge of BIM was above average with 99 percent of respondents having a level of awareness. During the study, respondents were agreed that using a smaller device may improve ease of use and maneuverability for the end users of the mobile devices.

The survey results reveals that the end users of mobile devices are aware that the use of the mobile devices can help to improve the productivity, easy in training and awareness however these devices also can create a greater health and safety hazards at same time. From the site investigation combined with the comprehensive literature review, suggested that necessary measures need to be taken in advance to mitigate the health and safety risks when using mobile devices for 'Site BIM'. A proactive approach to safer use of 'site BIM' may stop any harm and hazard.

The paper concludes from the study that Health & Safety hazards and potential impacts need to be acknowledged before occurring any unwanted incidents. The outcomes from the study will provide to the construction professionals about the potential health and safety hazards and assist them in taking a practice action to overcome such hazards while improve construction site productivity without compromising the health & safety of the end users of mobile devices, particularly at the live construction sites.

VI. RECOMMENDATIONS

Based on the findings from the study, there are several potential areas where further research studies are necessary to improve site BIM safety. These include:

- There is potential to implement a system that encompasses a social media aspect to inform device users of hazardous areas;
- In-depth case study analysis of the implementation of 'Site BIM' but concentrating on the safety impact;
- Further research is necessary into training of mobile device users to measure effectiveness on health & safety aspects of users and;
- Fully analyse the cultural shift required for the workforce. The further research may aid in the safe implementation of devices and ensure no end-user is harmed directly caused by the device.

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