

Exploitation of BIM based information displays for construction site safety communication

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Abstract:

This paper discusses the potential of disseminating up to date and visualized safety related information to construction workers/site staff of building construction sites. The paper is based on an on-going research project called BIM Safety. This research effort was commenced in April 2009 and will continue until June 2011. As a part of the research, a pilot study was carried out where LCD information displays were placed at construction site premises and were used for presenting weekly updated information relating to safety issues. The presentations took also advantage of 3D- and 4D-model views of the building under construction. Feedback over the content of the display presentations was gathered with a questionnaire from the site staff. This paper presents the findings of the pilot study and the enquiry, such as identified benefits, and discusses the possibilities as well as targets for further development.

More information about the research project <http://www.vtt.fi/sites/bimsafety/>

Keywords: Building information modeling, safety communication, site planning, construction planning, visualization

1. Introduction

The research covered in this paper falls into the category of safety awareness creation. Generally the safety awareness creation can mean different kind of areas of actions including i) Continuous reviews of working conditions and relating potential hazards, ii) Analysis and anticipation of unsafe conditions, iii) Communication and collaboration between different professions and workers, and iv) Sensing and warning technologies. These can be as direct means of safety awareness creation whereas some additional indirect means exists as well that do also contribute to this arena. Education, training, safety regulations, safety planning procedures and safety by design can be understood as such indirect means which all have linkages to safety awareness creation.

In our research the safety awareness creation is addressed by exploring potential advanced communication solutions, this is the use of ICT enabled information display screens. Information display screens are common in industrial and commercial settings, where they are used to disseminate current, easily accessible information to the staff and visitors. Rapid advances in display technology over the past decade, in particular, have driven costs downward and thus even largest size flat displays have realized commoditization of these solutions. They are used very widely for different purposes varying from professional needs to individuals' entertainment.

Digital technologies including building information modeling (BIM) are widely used in the design and construction that provides a natural starting point for the next step that is to take advantage of these technologies also for safety communication. Research suggests that ICT applications can help avoid accidents by collating design and planning data in formats that can be visualized and further explored. BIM technologies are generally seen as means to facilitate communication in relation to safety aspects (Eastman et al, 2008; Suermann & Issa, 2007; Heesom & Mahdjoubi, 2002; Khanzode & Staub-French, 2006). On the other hand some researchers suggest that the ICT applications can also have unintended and negative impacts (Huber, 1990). Overreliance is an example of a situation when individuals ability to observe is biased due to the received messages. This can raise the overall safety risk level in an unwanted manner. The described scenario reveals the high priority and importance of careful information content design for the purpose of safety communication.

A research experiment was designed for gaining an improved understanding of using this media as means for site safety communication. Particularly, rather than embracing general construction site safety information the research addressed the dissemination of safety notifications and guidance that were task specific according to the actual work progress on site. Also, the use of BIM as a way to communicate safety information visually was experimented. The objective of this paper is to present the gained results from an experiment where information display screens were used on building construction site for safety communication.

2. Approaches towards advanced safety communication

Safety communication is an integral part of an organizations safety effort. It provides support to the continuous, every day work on safety promotion and management. It helps to create and maintain prerequisites to safety and health at work, and contributes to promoting the organizations safety culture and atmosphere.

The basic aim of safety communication is to help personnel to make informed decisions regarding safety and adopt an attitude that can improve their health and safety. Communication can act as a means to disseminate company safety norms and beliefs. It can facilitate understanding of safety systems, risks, production pressures and organizational policies on safety. When utilized in an optimal manner it can act as a lubricant between organizations, people and tasks. (Real & Cooper 2009). Examples of important factors in safety communication are i) openness of communication, ii) two way communication and iii) easy access to information. According to Kines et. al. safety communication should be an integrated part of the entire construction process, from planning to construction and operation. (Kines et. al. 2010)

Openness in communication, which means open access to everyone, is a key factor in creating a positive safety climate. Openness in communication helps the personnel feel that they have the organization's support and their thoughts and opinions are valued (DeJoy et. al. 2004). Openness is also important since the events that lead to accidents and injuries are mostly non-routine and unpredictable (Zohar 2002). This is especially true in changing environments such as construction sites. Furthermore, open communication in working conditions also enables two way communication, in which the employees can e.g. raise their concerns on safety issues and suggest solutions to identified problems. This can also facilitate injury and accident reporting, which then provides basis to learn from past accidents.

Easy access to information means that safety information is effortlessly available to everyone. In example target groups, location, form, time and use of messages and media should be taken into account when planning safety communication. Using a multi-channel approach is seen as an effective communication way to reach the personnel in organizations and to improve information availability. This means that more than one communication medium is used in delivering safety messages. It ascertains that everyone has seen, read or heard the message, reinforces messages and increases exposure to information (Real 2008). When designed and planned well, safety information can be provided without detail overload. Safety messages should be kept simple and easy to understand, but also make additional information easily available for those individuals, who want to seek more information. (Real 2008.)

Visual communication

Visual communication is considered to be one of the oldest ways to communicate, the first versions of writing were, after all, pictures. People rely on vision to be the most reliable of their senses and so consider things they see to be true. (Hietala 1993.) Because

of this, visual communication is a very high-impact way of communicating. Visualizations can be used to clarify and extend verbal communication. Visual materials such as plans, sketches, photos, videos and slide shows are used every day in most companies. The visual acts to support the message in a similar way as body language, expressions, intonation and volume does in direct oral communication (Yazdani & Barker 2000).

Still, the relationship between seeing and understanding is problematic. How one understands a thing one sees depends on social background and experience. The practices around visual materials may lead the focus of attention away from the relevant and also make the message more difficult to understand by complicating or concealing information from the viewer. (Weick, 2005.) On the other hand, visualizations can have ample benefits in making information understandable and crossing borders created by i.e. different native languages. Good visual design supports the message by presenting the essential (Brusila, 2000).

Building information modelling and communication

Physical and virtual models are part of the current design, construction and management practices. People usually have a need to visualize the building or environment or simulate different functions. Building Information Modelling (BIM) can be used to visualize the project and methods of construction. Building information model is a three-dimensional description of a building, the surroundings and e.g. temporary site equipment. Beside 3D geometry it may include many kinds of product and construction information, such as identification and property information of building components, as well as construction schedule of the building assemblies. These BIM-models can be used to support communication, for example to help discussions on the construction process between professionals and to disseminate information to project stakeholders. It can also help to make the process more understandable to people with no background in construction.

From the viewpoint of safety, BIM technology can result in improved occupational safety by connecting the safety issues more closely to the construction planning, providing more illustrative site layout and safety plans, providing methods for managing and visualizing up-to date plans and site status information, as well as by supporting safety communication in various situations, such as informing site staff about coming safety arrangements or warning about risks (Sulankivi et al. 2010).

Today, most experience in using BIM for safety purposes is related to BIM based site layout plans, but there is some experience for example of BIM based falling prevention planning also. A three-dimensional site layout model can be used to produce various illustrative views of the site plan, from the desired viewpoints and perspectives. Challenging points or solutions can also be highlighted from the plan. Some modelling software include tools also for producing animations from the same BIM-model. Animations can provide a general understanding of the site quickly, and can be used for example as virtual sightseeing when introducing the project to site staff, or when presenting site arrangements to the client. Visualization opportunities regarding site arrangements and risk zones includes for example visualization of temporary site area or

space reservations, visualization of site walkways and visualization of risk zones related to cranes (Sulankivi et al. 2009).

3. Pilot for advanced safety communication at construction site

As a part of the BIM Safety research project, a pilot study was carried out where LCD information displays were placed at construction site premises and used for presenting weekly updated information relating to the safety issues. The target was to test the usability of LCD information display screens together with novel material, to promote safety communication at construction sites.

The pilot study took place on an office building construction site. The pilot project was fully designed using 3D building modeling technologies. The resultant models were used in site meetings for planning construction activities and additionally the models were used as discussion facilitators in meetings participated by main contractors and sub-contractors. In this case, the site managerial personnel was experienced in working with 3D views and relating tools, and was eager to take 3D model usage to the next level in order for improved site-communication. Since creating videos with the BIM tool in use on this project was not possible, a slide presentation with views from the model was utilized. The presentations were up-to-date and visualized taking advantage of 3D and 4D model views of the building under construction.

Two LCD displays were acquired for the pilot. The main contractor's IT department installed the displays and a computer with basic Microsoft Office package to the site according to instructions. The displays were placed at construction site premises, one in the site office hall and the other one in the staff break room, so that as many as possible of the site personnel would have access to the screens (picture 1).

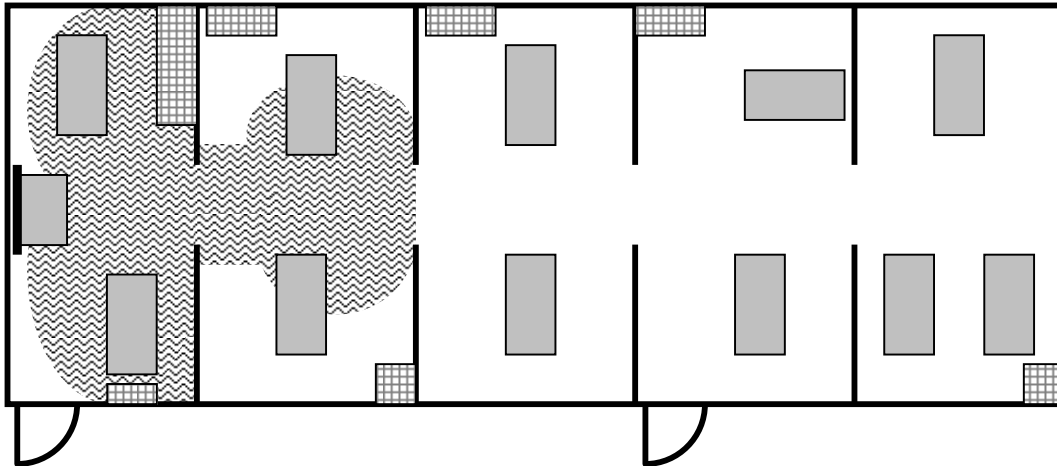


Picture 1: The LCD information display unit placed at the construction site staff break room.

The staff break room is built of five units that are connected via doorways. Personnel can use two doors to the room. The doors are in units one and four. The information display screen was in unit one, up on the end wall, next to a door and in the middle of the information boards (picture 2). The watching area of the display is restricted because of the distance from the display and the walls between units.

The site personnel have daily two coffee breaks, both lasting 12 minutes and a lunch break of 30 minutes. Viewing the information display during the whole length of a break is possible only if a person is in a specific area that is highlighted in picture 2. People who were not actually present in this viewing area could only see the information display in the case of using the front door of that unit. Part of the personnel would have had no visual contact with the display in the case of using merely the other front door and staying outside the specified viewing area.

The display in the staff break room was the main display for site personnel, since they usually were not stopping to watch the other display in the hall while visiting the offices of site management.



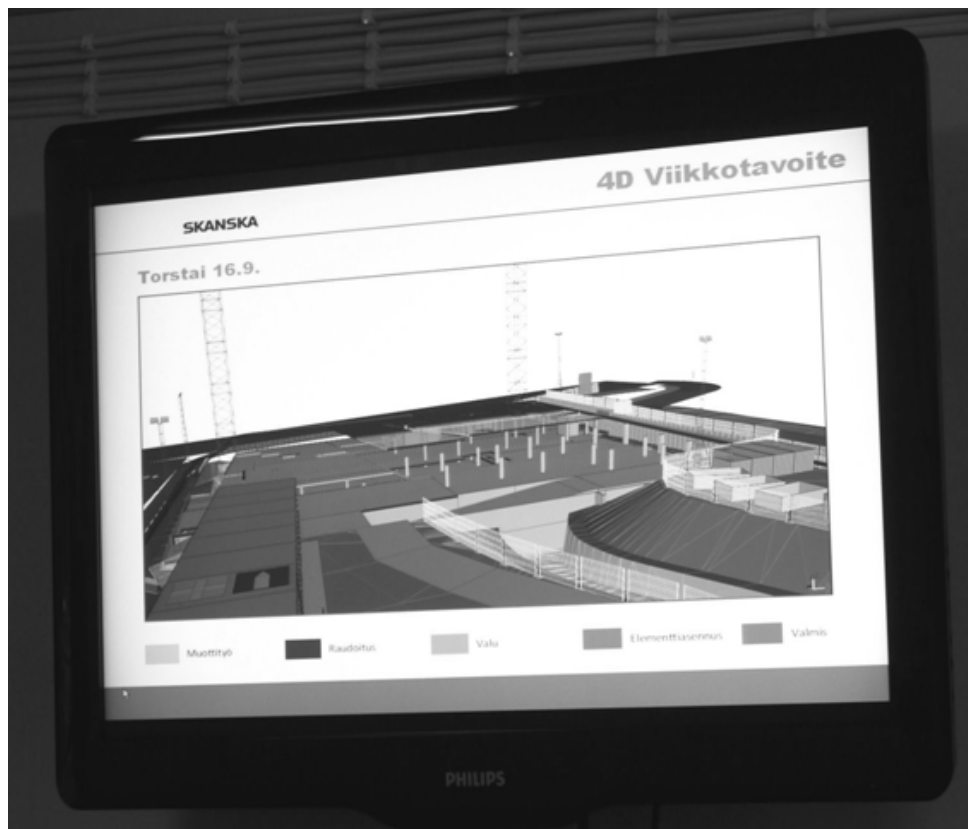
Picture 2. Simple drawing of the staff break room of the site. The information display unit is placed on the left. The space includes 12 tables. There is one main kitchen in the unit one and several microwave ovens and refrigerators, marked with grids. The watching area is marked with wave.

Presentation

The presentation shown on the display screens consisted of in average 25 slides. The actual slide show lasted less than ten minutes and it was run as a continuous loop throughout the day. The research team designed the content of first presentation in co-operation with the contractor's safety personnel and site staff, and it was updated weekly with new information. Contents of the slides were gathered from the company's general site safety instructions and from site-specific plans and models. A member of the site staff used weekly one hour to gather the needed material and update the slides.

The presented slide shows provided information related to the following topics

- current affairs and events
- schedules and more detailed weekly plans
- positive safety notes
- safety observations
- accident or near-miss reports
- safety issues that need improvement
- particularly dangerous places on the site presented with help of 3D site plan
- 3D site plan
- TR Safety observation results
(weekly safety level using TR Safety observation method, where TR is an acronym and stands for the Finnish words "building construction")
- 4D-model views presenting the weekly plans



Picture 3: 3D site plan that is captured from the 4D model of the pilot building construction project. This is an example of part of slide show that run on the information displays.

The pilot trials lasted 4 weeks, after which the site staff have continued updating the presentation and showing it independently.

The idea of this pilot was to experience the use of 3D and 4D model viewing as a part of broader site safety communication. Intention was also to improve site safety communication by providing support to other communication channels. Improving knowledge of site staff about the on-going operations and shortly coming events on the construction site was seen as an important way to increase site safety. The idea was to bring safety issues closer to the site staff by conveying them as a part of standard working environment.

Method

The pilot construction site employed 50 people at that time. Feedback over the display screens and presentations was gathered with a questionnaire which was distributed to all of the site's personnel by a member of the site managerial staff. It consisted of 12 questions divided into three categories: i) watching habits, ii) display placement, iii) perceived necessity and content of the info screens. Both dichotomous and multiple choice variable questions were used and complemented with open questions. The questionnaire was responded anonymously, and 36 employees returned the questionnaire,

resulting in a 72 % response rate. 20 of the respondents were the main contractor's employees and 16 were subcontractors' employees.

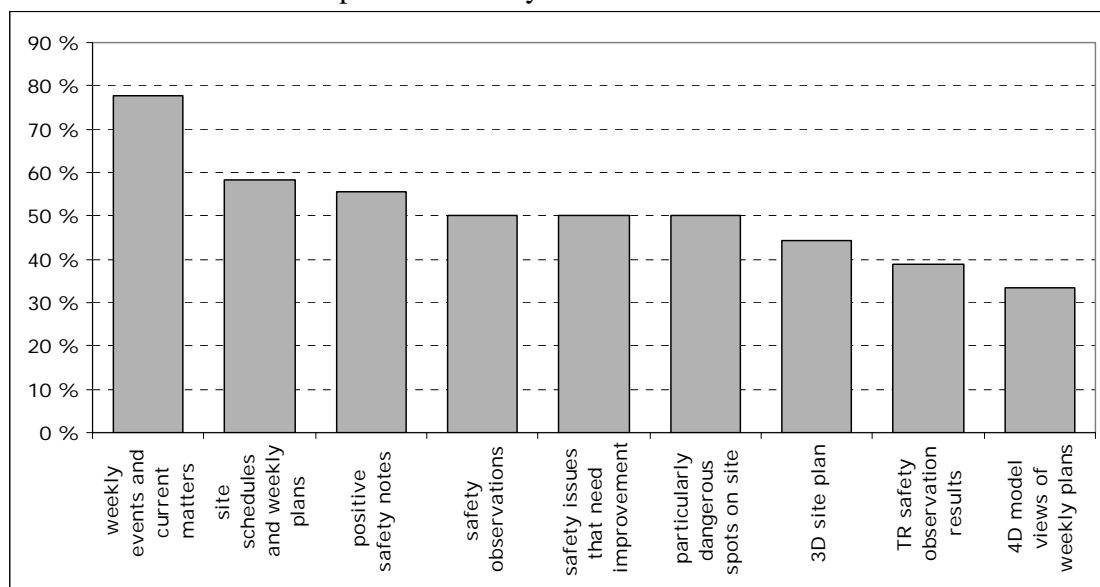
4. Results

The results propose that the display screens are mostly viewed on a weekly basis (37%), which means that viewers watch the entire slide show once in short portions during the week. Watching time is mainly short; more than half of the respondents watch the information display half a minute at a time. 20 per cent of respondents did not watch the display at all.

The information display screens and their contents as used in the study were seen as useful for site operations and their safety. Respondents have received information about current site events (83%), safety issues (82%) and timetables (77%). Weekly updating is considered sufficient, only 9 per cent of respondents replied that updates were not often enough.

All contents of the display screen presentations were considered somewhat useful at a minimum (table 1). Over 50 per cent of respondents considered weekly events, current matters, site timetables, weekly plans and positive safety notes to be important. The least important were weekly 4D target plans, TR Safety observation results (weekly observed safety level at the site) and 3D site plan.

Table 1: The usefulness of presented safety information.



The information display was generally considered as a good source of knowledge on site affairs. For example, the site staff reported that they had gotten useful information particularly concerning dangerous spots on site and also the shown material have improved their overall understanding what is happening on site. Weekly timetable and

accident reports were mentioned as good examples of useful information. Only three of the respondents from the total 36 had had no benefits of the display screens.

Considering development possibilities, clearer information about different site manager's responsibilities and the location of first-aid supplies on site were requested. Also, many of the respondents thought that the changing of the slides was too quick.

Administrative prerequisites

During the testing resource requirements of the maintenance were discussed. Although the time usage is not a significant factor, some basic IT knowledge is required to update the presentation. On the test site, an IT-capable project secretary took care of the weekly updating of the display materials. She was engaged and sought to further develop the weekly content. However, not necessarily each site has a person that has required capabilities. This may lead to a need for an off-site support for up-dating the weekly presentations.

Also, the content of the presentation was discussed. The more site-specific the content is, the more valuable the site personnel consider the displays. However, if off-site updating of presentation is required, the information gathering and transfer becomes more cumbersome and more generic company-specific information may reduce the value of the site experiences.

5. Conclusions

The usage of information display screens on construction sites has promising possibilities. Such displays provide support to other means of communication and disseminate messages to a wider audience. The target audience of construction site communication is wide – examples of those are permanent site staff, subcontractors, cooperation partners, and authorities. Information displays can provide equal information packages to all those involved. Keeping safety issues visible at all times can help to build and reinforce the openness for site safety communication.

Benefits

Site staff, subcontractors and cooperation partners are on a construction site for various times and durations. The benefit of the screens in such conditions is providing current, updated information that is available regardless of date or time of the day. This information acts to increase safety by making the people on site more aware of what is going on there. Also, as can be seen from the survey results, one does not have to have a lot of time to get information from the screen, which makes a functional medium for job sites with only limited time to disseminate and assimilate information. It can be used to reinforce safety regulations and values of the site.

The display screens also contribute clearly towards openness in communication by providing equal information to everyone being present. This and the nature of visual communication as crossing language and other communication boundaries make it a very democratic medium that has great potential.

As the use of BIM is rapidly increasing in the whole supply chain, it has great potential to develop into an easy-to-use method for supporting the supply chain and spreading up to date information about construction activities on site and related safety hazards. This is why it is important to develop and trial new ways for planning and communicating safety related issues to all stakeholders in an easily understandable virtual 3D environment.

Further development

Based on the pilot study, chances for further developments were also identified. Firstly, placement of the information display screen in the staff break room was such that it was not seen from all over the room. This possibly explains the 20 per cent of respondents who did not watch the display at all. Solutions to this problem could be i.e. providing a second screen or making the current screen movable so that it could be in a different place in different times of the day or week, or placing display screens in places where people are waiting or queuing and so have free time to pay attention to them. Another solution would be to design the staff premises with communication in mind, creating places for effortless receiving and exchanging of information and open spaces where the displays are seen by a larger number of people at a time.

Secondly, the possibilities of using 4D and 3D visualizations are also somewhat limited at the moment. Currently there are only limited possibilities to create moving videos of models without special software. Using still visualizations from 3D and 4D models is not as impressive and eye-catching as moving picture would be. There are also some issues with the understandability of the colors used in the visualizations that are based on structural BIM-models. Different colors have their structural meanings in the model, but may not be understandable to a viewer who is not accustomed to it. Converting model colors from their structural meaning to more realistic ones should be made possible and easy to use in the future, so that more photorealistic images can be created and the pictures are more interesting and easier to understand.

Thirdly, a passive medium such as the information display screen has a risk of becoming background noise over time. People become uninterested if the information is not catching enough and also if changes in the content are not clear enough. The manner of representation should be changed from time to time to keep up interest and viewer's opinions of what information is needed should be heard and taken into account.

For the information displays to stay in use, the content should be easy to create and update. Existing, site specific information, such as timetables, current safety information and BIM visualizations or videos should be easily adapted to use on displays. Participation from i.e. contractors' communication department and safety specialists would also be beneficial, as they could support the site specific information with more general content that could be used in all of the company's work sites.

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