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HOW TABLETS CAN IMPROVE COMMUNICATION IN CONSTRUCTION PROJECTS

Erle Harstad[1], Ola Lædre[2], Fredrik Svalestuen[3], and Nawras Skhmot[4]

ABSTRACT

Lack of adequate communication tools can cause information losses in construction projects. The most efficient way for construction personnel to manage information on sites is to retrieve information at the point where they are and at the time when they need it. This has been difficult to achieve as information management normally involves paper-based documents. However, the rapid development of mobile information and communication technologies are offering new possibilities for portability and access to information at the construction sites.

This paper aims at exploring the effect tablets have on communication in construction projects, through a literature study, a document study, and an exploratory study with interviews of different key stakeholders in the architecture, engineering and construction (AEC) industry. The result of this study shows that tablets can enrich the communication between design and construction practitioners, and help reduce waste such as unnecessary transportation and rework caused by errors due to old, wrong and irrelevant drawings. However, tablets also entail initial costs of training and equipment, and is highly dependent on internet accessibility. This study can help AEC practitioners and academics to understand the strengths/challenges of using tablets as a communication tool at the construction site.

KEYWORDS

Lean construction, waste, flow, tablets, communication

INTRODUCTION

The construction industry is entirely reliant upon efficient communication between individuals, teams and organizations (Dainty, Moore and Murray, 2006). Due to its specific characteristics, the industry forms a complex communication environment. Furthermore, with the current imperative to improve industry performance by

1 M.Sc., Dept. of Civil and Transport Engineering, NTNU – Norwegian University of Science and Technology, Trondheim, Norway, +47 95011205, erleharstad@gmail.com
2 Associate Professor, Dept. of Civil and Transport Engineering, NTNU – Norwegian University of Science and Technology, Trondheim, Norway, +47 911 89 938, ola.ladre@ntnu.no
3 Ph.D. Candidate, Dept. of Civil and Transport Engineering, NTNU/VeidekkeEntreprenør AS, Norway, +47 986 73 172, fredrik.svalestuen@ntnu.no
4 Project Engineer, VeidekkeEntreprenør AS, Norway, +47 414 09 992, nawskh@blockberge.no

designing and constructing faster, many processes that are reliant upon efficient communication occur concurrently. Dainty, Moore and Murray (2006) state that this increases the probability of problems occurring in the transmission and reception of vital information to the construction effort.

According to Blokpoel (2003), lack of adequate communication tools is considered to be one of the most important factors for information losses in traditional construction projects. Information losses often result in errors due to old, wrong or irrelevant documents (Blokpoel, 2003). Further, this leads to iterations. Iterations in the construction phase is usually called rework and is clearly a type of waste to be avoided. According to Ballard (2000) completing assigned tasks is a central principle of lean construction, both for the reduction in waste involved in making multiple visits to the same work location and for increasing plan reliability. This has further positive impact on efficiency.

An efficient production management system also relies on accurate and timely information availability. According to Koskela (1999) one of the 7 preconditions in the Last Planner process of production planning is that sufficient and correct plans, drafts, and specifications have to be present. The research of Lindhard and Wandal (2012) shows that one of the reasons for non-ready work assignments are outdated drawings. Lack of access to accurate construction information in the site meetings, or when controlling activities out in the field, will increase the share of non-value adding activities.

The most efficient way for construction personnel to manage information on sites is to retrieve or capture information at the point where they are and at the time when they need it (Chen and Kamara, 2008). This has been difficult to achieve with traditional information management methods, which normally involves paper-based documents. Bowden, et al. (2004) indicates that the main type of information that onsite construction personnel receive and transmit is paper-based. This poses a major constraint for communication on site. However, the rapid development of mobile and wireless communication technologies offers new possibilities for portable information systems and communication tools to construction personnel (Lofgren and Rebolj, 2007). The use of mobile devices, like tablets, has entered the construction sites in large parts of the world. However, implementation of tablets requires resources and reorganizing.

This paper aims at exploring the effect tablets have on communication in construction projects, and to present strengths and challenges with the use of tablets as a communication tool at the construction site.The main questions addressed in this paper are:

- How can tablets contribute to communication between design and construction practitioners?
- What are the strengths and challenges of using tablets to communicate between design and construction practitioners?
- What initiatives can lead to tablets providing better communication between design and construction practitioners?

RESEARCH METHODOLOGY

The research includes a literature review, a study of internal documents and in depth interviews with different stakeholders in the AEC industry. These methods were conducted in order to obtain an overview of previously written literature on the topics and then study the issue deeper using internal documents and interviews. The literature review focused on information flow at the construction site, and how the use of mobile computing can enhance the information management between stakeholders during the construction phase. The approach was to search for keywords in research databases and library databases. Literatures are also found in reference lists of articles. The study primarily aimed towards academic journals, conference papers and books found at the university library.The study of internal documents aimed at documents from Veidekke Entreprenør AS, a contractor company in Norway. These documents concern the currently available applications for tablets available in today's market.

Nine semi-structured interviews with both design and construction personnel were conducted. The respondents were mainly project managers and foremen from contractors and design consultants working close to the construction site. A representative from an application developer was interviewed in order to reveal new aspects of interest. There are limited projects that utilize tablet potential to the fullest. Therefore, it was necessary to go to three different construction companies to gain experience in several areas.

THEORETICAL FRAMEWORK

INFORMATION FLOW AT THE CONSTRUCTION SITE

A study carried out by Tenah (1986) shows that a manager or supervisor cannot perform his or her functions efficiently without accurate, timely and relevant information on which to base decisions. The flow of information significantly affects all other resource flows, and is therefore important to manage from a lean perspective (Dave, Boddy and Koskela, 2010; Sacks, Radosavljevic and Barak, 2010).

Waste in construction includes delays, quality costs, rework, unnecessary transportation trips, long distances, improper choice of management, methods or equipment, and poor constructability (Koskela, 1992; Alarcon, 1997). Studies show that waste often occur due to poor information management. The research of Love and Li (2000) demonstrates that during construction, rework arises out of incomplete and incorrect information. Their work indicates that rework results in inactivity and inefficient work in several activities at the construction site.

To solve a site problem, production management personnel have to run back and forth between the construction site and their computers inside the site office. According to Lofgren (2007), documentation of building activities, production meetings and various inspections often have to be carried out twice; once when they are actually occurring and then again in a computer document. This leads to inefficient use of managerial resources due to unnecessary transportation, and a production management team that is occupied with their computers a large part of their working hours. Samuelson (2003) claims that the fact that the information needs and communication behaviours at the construction sites are not adequately met, explains the low productivity figures in the construction industry.

According to Lofgren (2007), the quantity of information that is passed to the construction site can be overwhelming, and it often generates poor quality of information in the field. As a result, construction personnel are forced to deal with slow problem solution and construction rework.

Tenah (1986) stated that the information needs of each project team member are linked to their management responsibilities. He divided the construction personnel into five levels, each with different management responsibilities and information needs. The functional management level at the site includes field engineers, the general superintendent, the superintendent and the foreman. The major responsibilities of the managers and supervisors at this level are to organize, supervise and coordinate personnel, equipment, materials and services. The information needs of the foreman consist of drawings, specifications, contract documents, local union activities, safety regulations labour agreements, quality control, progress and field performance reports.

MOBILE COMPUTING AND CONSTRUCTION INFORMATION MANAGEMENT

The rapid development of wireless networks and mobile computing have now enabled new possibilities of portability and on-demand access of information systems and communication tools that the production organization is requesting.

According to Rebolj and Menzel (2004) the concept of mobile computing consists of three components: computers, networks and mobile applications. Computers include laptops, tablets, mobile phones, and wearable computers. Networks include all types of wireless network and satellite networks. Mobile applications are the key factor that responds to specific characteristics of mobile computing and wireless networks and support users' work process by enhancing the efficiency in information communication. Based on Chen and Kamara (2008), there are three types of mobile applications that are used in the construction industry.

- Mobile CAD applications for interacting with drawings at the construction site
- Data capture applications for managing on-site information
- Project management applications for monitoring and controlling the construction process at the construction site.

Lofgren (2006) studied two tablet computer pilot projects initiated in 2005. The projects focused on the management of drawings and specifications used on the construction site from user's perspective. There are, to the author's knowledge, few published studies on use of tablets at construction sites from user's perspective since 2006. The use of tablets and the range of application areas have increased sharply the last 10 years. It is therefore of importance to continue to study the field, to ensure that the development is going in the right direction.

COMMUNICATION WITH TABLETS

Figure 1 illustrates the richness and effectiveness of communication channel. The figure shows that a rich communication channel is the most effective one. Non-verbal communication, artifacts and latency are important factors affecting the richness of the communication channels. Whiteboards provides the ability to draw and illustrate while talking, and a face-to-face conversation with a whiteboard is therefore high on the scale. A tablet can provide the same ability, while also adding an extra dimension in the form of 3D models. A tablet can therefore provide a rich and effective

communication, and it is possible to take it in the field.Conversations through tablet can also take place using email, live chat and video chat without the need to be collocated.

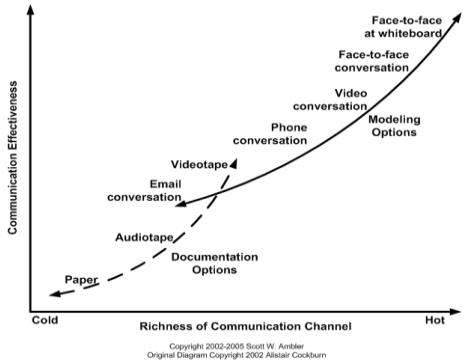

Figure 1: Richness of communication channels(Ambler, 2002)

FINDINGS AND DISCUSSIONS

Tablets are used by people with typical control responsibilities, like project managers, construction managers, superintendents and foremen. Design consultants and client representatives also use them. The majority of the respondents primarily use tablets as a tool to obtain information in design meetings, cite meetings and out in the field. However, there is a number of other applications related to the use of tablets. Based on interviews and internal documents, it is discovered nine different areas of application:

- Access to blueprints in portable document format (PDF)/drawings (DWG) file format and building information models (BIM) everywhere
- Delegating and monitoring of tasks and responsibilities
- Measurement and monitoring of the progress
- Documentation work on site
- Quality assurance work and safety inspections
- Obtaining direct measurements from the blueprints and BIM on site.
- Communication and request for information (RFI) between design consultants and construction practitioners
- Live communication through video chat between site and office
- Operation and maintenance management

STRENGTHS OF USING TABLETS

Tablets provide an easy access to up-to-date PDF/DWG drawings and BIM at meetings, in the office and out in the field. This reduce the risk of errors and rework due to old drawings. It is less time consuming to obtain necessary information like heights and measurements in the field through drawings and BIM at the tablet, instead of walking back to the site office and search through stacks of paper to find the required information in the office. Tablets also provide access to information about the progression of tasks and distribution of responsibilities. Much time is spent on delegate, follow up and ensure that things have been done. Through tablets, the

workers at the site will receive personal tasks and responsibilities which they mark as finished when the task is done. This is an easy way to keep track of the progress of the project and reduce time spent on monitoring tasks and responsibilities.

A tablet contains hundreds of drawings and is easy to carry around compared to stacks of paper. It also reduces the stacks of paper stored at the site office, and time spent on printing and distributing hundreds of drawings. A reduction of paper consumption will also provide environmental gains. Large and heavy laptops have been used on construction sites to access the BIM out in the field. These laptops are dependent on a mouse to navigate in the model, which reduce the mobility of the user even more.Tablets are small, light and it is easy to navigate without using a mouse.

When tablets are used at site meetings, they provide easy access to a huge amount of up-to-date information and lead to faster decision making. Another strength is that tablets provide easy access to email and the ability to share screenshots of drawings in real-time at the construction site. The camera function also allows for taking photos of issues in the field for instantly sharing with a supervisor or consultant. An interviewee was especially pleased with that ability:*"Before, when I called the consultants, it took me five minutes just to explain where the problem was. Now I can take a picture, link it to a specific drawing and send it to the consultants, before calling him up. So much easier."*This enables faster decision-making processes, and facilitates decision making in the field.

With a BIM application it is possible to combine 2D drawings and 3D models. This is of great value. Through 3D models, it is possible to see a realistic environment with how things are connected, and then study details with 2D drawings. This increases the understanding of what to build.

By use of tablets, less time is spent on routine and administrative work. In quality assurance work and safety inspections tablets particularly facilitates preparations and complementary work. Based on interviews, it is created a table to compare a traditional process to a process using tablets.

Table 1: Traditional vs. tablet process of safety inspections

Where	Traditional process	Tablet process
Site office	Gather updated list of documents and plans Find current lists of issue Print documents and lists	Sync the software and get all updated documents and lists of issues on the tablet
Field	Mark issues one-by-one on the paper plan Take photos Handwrite notes on paper	Create multiple issues Make notes on the tablet Attach photos directly to the issue
Site office	Scan the marked up plan Type field notes into the computer Paste digital photos Manually pull together all lists Print or email report for others	Sync the software to pull together all lists Print or email report

As exemplified above, use of tablets simplifies the documentation process. This leads to a higher quality of the documentation, due to a standardization of the process. All communication through tablets is traceable and it is therefore easy to prove that things have been done in a transparent way.

When a worker in the field has a request for information, the traditional process is to walk to the site office, mark the problem area at the paper drawing, scan the drawing, send an email to the consultant, and walk back. According to internal

documents from the contractor Veidekke, this process takes in average 20 minutes. Using a tablet, the worker can mark the problem area directly on the tablet and send the email, without leaving the workplace. New revisions of the drawings can also be received directly in the field instead of walking back to the site office and printing out new copies. Hence, tablets reduce the amount of unnecessary movements. Another strength is that tablets provide an easier access to direct communication between foremen and design consultants, as the exchange of the information don't have to go through the construction manager or the project manager. This provides a more efficient line of communication. It is however very important that such communication is visible to the supervisors.

CHALLENGES OF USING TABLETS

It is a challenge to defend the cost / benefit ratio of the tablets in the initial introduction. This is because it may take years before documented benefits exceeds the cons, as there are many complex connections to take into consideration. In addition to the cost of the tablets, BIM applications also incur costs. It is a spread in how user-friendly the applications are, and they often require guidance and training in the initial phase. In the initial introduction, it is also a challenge that experienced craftsmen have poor motivation to learn a new tool and change the way they work. In addition to the challenge of learning a new tool, some craftsmen get the feeling that the BIM is only developed for design purposes. It is often incomplete and not usable at the construction site. An interviewee explained that many craftsmen also find it difficult to trust the correctness of measurements in the BIM.: *"Objects where often placed a few cm wrong, and it is a lot harder to spot these small errors in a 3D model, than in 2D drawings. When this happen several times, you find it hard to trust the BIM."*

It is necessary to have network access to synchronize the tablets. Without network in the field, the craftsmen have to walk back to the site office to update the drawings and send emails. This can be a challenge on construction sites outside the city and in basements below ground, where there is usually limited access to 3G or 4G.

The tablets are easy to carry around, but they are also easy to lose or misplace. Without a secure password or a remote erase program, this can lead to reduced data security and that outsiders can get access to sensitive project information.

Tablets works poorly when there is precipitation or dust. Without protection, the tablet is thereforedifficultto use during the concrete work and before the building is tight, because of weather, concrete dust and moisture.

Some applications often support only one operating system. This is a challenge when stakeholders often have deals and agreements with different operation systems, which can prevent them from using the system required.

INITIATIVES WHICH CAN LEAD TO A BETTER UTILIZATION OF TABLETS

Several initiatives can reinforce the benefits and reduce the challenges of using tablets as a mean to communicate between design and construction practitioners.

To be able to defend the cost/benefit ratio in the initial introduction, it is important to promote success stories. Ambassadors should show the construction industry what potential benefits the initial costs can provide. It is also possible to start with a small scale pilot project to test the effect, and spread experiences to the rest of the company

once the benefits are proven. Some craftsmen have poor motivation to learn new tools and change the way they work, and it is important to change their attitude. This can be handled by involving craftsmen in decisions during the initial introduction. It is also important to give sufficient guidance and training in this phase to enhance their confidence in using tablets.The BIM should be more trustworthy and useful in the field. This requires that the BIM is modelled for its purpose, and that the right level of detail, constructability and usability of the model is assessed. This may increase the craftsmen's trust in the model.

Table 2: Strengths and challenges

Strengths	Challenges
Easy access to information	Cost/benefit ratio
Reduce the risk of errors due to old drawings	Poor motivation amongst craftsmen
Less printing and distributing drawings	Poor usability of the BIM
Environmental gains	Lack of trust in the BIM
Easy to carry around	Dependent on network
Reduce time on monitoring and reporting	Reduced data security
Increases the understanding of what to build	Vulnerable to moisture and dust
Faster decision-making processes	Lack of support of operating systems
Improved documentation and reports	
Reducing unnecessary movements	
Creates a new line of communication	

The applications should support all operating systems, to make sure that all stakeholders can use it. There should also be several functions integrated into one application, to enhance the efficiency of the tablets and reduce the number of applications. Having only a single platform will reduce time spent on looking for information, and improve the construction information management

To meet the dependency of network at the site, it is suggested to install a dedicated network at the construction site. This will guarantee accessto up-to-date information throughout the site without having to walk to the office to synchronize the tablet. It is also possible to reduce the dependency of network at the site with an offline mode in the applications. This allows for obtaining information without access to network. However, this will not be up-to-date information.

There should be used waterproof tablets or protection against moist, sand, vibrations and concrete dust to reduce the chance of tablets being destroyed due to precipitation or moisture at the construction site. This will increase the possibility of using the tablet throughout the construction phase, including the concrete period. When a tablet is misplaced or stolen, there should be a routine to remote erase all content on the tablet. This is to prevent outsiders from gaining access to sensitive information.

Table 3: Initiatives

Initiatives which can lead to a better utilization of tablets
Promote success stories
Pilot projects
Guidance and training
Assess usability throughout the development of BIM
Install network at the construction site
Offline mode
Remote erase routine
Several functions integrated in one application
Develop applications which support all operating systems
Waterproof tablets and other protection

CONCLUSION

This study can potentially give practitioners and researchers new knowledge of the strengths/challenges of using tablets on a construction site. Initiatives to reinforce the strengths and reduce the challenges have also been proposed. These initiatives require cooperation between designers, construction practitioners and system developers. Installation of a dedicated network at construction sitesoutside the city is an important initiative because many of the features are entirely dependent on updated information. However, this leads to higher costs and can be especially difficult on major road constructions where the site covers several kilometres. Guidance and training to enhance craftsmen's confidence in using tablets will also incur costs. It is therefore crucial to have ambassadors promoting success stories, and show the construction industry what potential benefits these initial costs can provide. In order to exploit the benefits BIM can bring to the construction site, it is important to assess usability and constructability throughout the development of the model. Tables 4 and 5 sum up what initiatives that can reinforce the strengths and what initiatives can reduce challenges of using tablets.

Table 4: Strengths and initiatives to reinforce them (not prioritized)

Strengths	Initiatives to reinforce the strengths
Easy access to information	Install network, offline mode, several functions integrated into one application
Reduce errors due to old drawings	Install network to ensure updated information
Less printing and distributing paper	
Environmental gains	
Easy to carry around	Waterproof tablets and other protection
Reduce time spent on monitoring tasks	Several functions in the applications
Increases the understanding	Assess usability in the development of BIM
Faster decision-making processes	Install network at the construction site
Reduce time spent on reporting	Several functions in the applications
Improves documentation and reports	
Reduce unnecessary movements	Install network at the construction site
Creates a new line of communication	

Table 5: Challenges and initiatives to reduce them

Challenges	Initiatives to reduce the challenges
Cost/benefit ratio	Promoting success stories, pilot projects
Poor motivation amongst craftsmen	Guidance and training
Poor usability of the BIM	Assess usability in the development of BIM
Lack of trust in the BIM	Assess usability in the development of BIM
Dependent on network	Install network, offline mode
Reduce data security	Remote erase routine
Vulnerable to moisture and dust	Waterproof tablets and other protection
Applications does not support all operating systems	Extend the application's support for all operating systems

To conclude, it can be said that application of tablets will improve information management in construction projects. At the same time, the proposed initiatives will help to improve the benefit/cost ratio of an initial introduction of tablets. The research is based on a limited number of respondents and it is conducted in a Norwegian context. This may not make the results 100 % applicable to all projects. In the future there should be conducted experiments to get a more systematic view of the net benefits of using tablets. A cost benefit analysis of tablets compared to a manual approach should also be conducted.

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