CHALMERS
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Visual Means as a way of improving communication in construction projects

Based on observations from the Swedish construction industry

Master's Thesis in the Master's Programme Design and Construction Project Management

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CHALMERS UNIVERSITY OF TECHNOLOGY
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ABSTRACT

The purpose of this master thesis is to analyze the use of visual tools in construction projects and how these tools influence the communication between various stakeholders within the project.

The investigation and empirical part of the study has been conducted by qualitative research methodology based on interviews, observation, checklists and questionnaires from ten different urban construction sites within a large Swedish construction company.

Construction projects are unique in the sense that they are often consisting of new actors that need to collaborate and involves many uncertainties throughout the project's lifecycle. Thus, a lot of information transfer takes place between various external and internal stakeholders from the initial phase until the project completion. One way to enhance the communication within the construction project is by using of visual tools at workplace. The applicability of using visual tools for making communication flow easier, better and understandable is analyzed within the Swedish construction projects in our study.

From the study, it is evident that there are a number of visual tools being used certainly and uniquely in different construction projects. The visual tools thus help to enhance the information flow and also overcome the language barrier. Improvements can be done persistently to augment the purpose of using the visual tools in the construction projects

Key words: Visualization, Visual tools, Communication, Construction sites, Visual management

Visuella medel som ett sätt att förbättra kommunikation i konstruktions projekt
Baserat på observationen från svensk konstruktion industri

Examensarbete inom masterprogrammet Design and Construction Project Management Design and Construction Project Management

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SAMMANFATTNING

Syftet med detta examensarbete är att analysera användningen av visuella hjälpmedel i byggproduktionsfasen och hur det påverkar kommunikationen mellan de olika parterna i projektet.

Den praktiska delen av undersökningen har genomförts genom intervjuer, observationer, checklistor och frågeformulär på tio västsvenska byggarbetsplatser, alla med samma svenska byggentreprenör.

Byggprojekt är unika så till vida att de oftast innefattar nya aktörer som skall sammarbeta och innehåller många osäkerheter under projektets livslängd. Byggprojekt omfattar informationsutbyte mellan olika interna och externa parter i hög grad, informationsutbyte pågår från startskede fram till överlämnande av färdigt projekt. Användandet av visuella hjälpmedel för att förbättra informationsutbytet syns tydligt i vissa byggprojekt. Tillämligheten av olika visuella hjälpmedel för att förbättra och underlätta förståelse har undersökts i denna studie.

Resultaten visar att olika visuella hjälpmedel, var och ett med sitt specifika användningsområde, har använts i olika byggprojekt. Alla har verkat mot att förbättrar informationsflödet och även att överbrygga språkbarriären som i vissa fall uppträtt. Förbättringar kan ständigt göras för att öka användbarheten av de visuella hjälpmedlen i byggprojekten.

Nyckelord: Visualisering, Visuella hjälpmedel, Kommunikation, Byggarbetsplatser, Visuell hantering

Contents

1 INTRODUCTION 1

1.1 Purpose and aim 2

1.2 Research question 2

1.3 Method 2

1.4 Delimitation 2

1.5 Outline of the report 3

2 THEORETICAL BACKGROUND 4

2.1 Communication within Construction sector 4

2.1.1. Project process and Stakeholders 5

2.2 Lean and Visualisation 7

2.2.1 Use of visualisation highlighted in Health and Safety 9

2.3 Visualisation tools 10

2.3.1 Board and meetings 11

2.3.2 3D and 4D model 11

2.3.3 Monthly and weekly planning 11

2.3.4 Look Ahead Plan board 12

2.3.5 Markings on the walls 13

2.3.6 Construction Board 14

2.3.7 Visual signs 14

2.3.8 Interactive visualisations and animations 14

2.3.9 Augmented Reality 14

3 METHODOLOGY 16

3.1 Research Design 16

3.1.1 Qualitative and Quantitative research method 16

3.2 Initial site visit 16

3.2.1 Data Collection methods 17

3.3 Detailed case study 18

3.3.1 Data collection methods 18

4 CASE STUDIES 20

4.1 Detailed description of cases 21

4.1.1 Site: 1 21

4.1.2 Site: 2 21

4.1.3 Site: 3 22

4.1.4 Site: 4 and 5 22

4.1.5 Site: 6 22

4.1.6 Site: 7 22

4.1.7 Site: 8 23

4.1.8 Site: 9 23

4.1.9 Site: 10 23

5 RESULTS 24
5.1.1 Characteristics of Visualisation 24
5.2 Detailed case study 31
5.2.1 Weekly protocol 33
5.2.2 Information Poster 34
5.2.3 Accident report 35
5.2.4 Videos 36

6 FINDINGS AND DISCUSSION 38
6.1 Visual tools identified from site visit 38
6.1.1 Stakeholder-Visual Means Mapping 41
6.1.2 Theory vs Practice 42
6.2 Identification of success factor and gaps in using Visual tools 43

7 RECOMMENDATIONS 45

8 CONCLUSION 46

9 POSSIBILITIES FOR FURTHER RESEARCH 47

10 REFERENCES 48

11 APPENDIX 51
11.1 Appendix I - Visualization characteristics checklist 51
11.2 Appendix II - Visual tools checklist 52
11.3 Appendix III - Interview questions: Initial Site Visits 53
11.4 Appendix IV – Questionnaire: Detailed case study 54
11.5 Appendix V - Interview questions: Detailed case study 55
11.6 Appendix VI – Questionnaire: Detailed case study 56
11.7 Appendix VII - Characteristics of visualization 57
11.8 Appendix VIII - Characteristics of visualization 58
11.9 Appendix IX - Characteristics of visualization 59

Preface

The work of this master thesis has been accomplished during the spring of 2016 at a Swedish construction company.

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Last but not least, we would also like to thank our family, friends and the university for providing their support all the way for accomplishing our thesis.

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& Morteza Khoshdel Rohani

List of Figures

Figure 1.1 Outline of our report 3
Figure 2.1 Communication within construction projects (Dainty, et al., 2006: 58) 4
Figure 2.2 Project process 5
Figure 2.3 Stakeholders involved in the production phase (Cleland, 1999:282) 6
Figure 2.4 Health and safety poster (Sanderson, 2014) 9
Figure 2.5 Weekly planning meeting 12
Figure 2.6 Project planning outline (Seath, 2014:15) 12
Figure 2.7 Look ahead plan (Viana, et al., 2014:781) 13
Figure 2.8 Marking on the walls (Tezel, et al., 2011:4) 13
Figure 2.9 Construction board (Brady, et al., 2012:5) 14
Figure 2.10 Comparison of 3D model with actual image using Augmented Reality (Fard & Mora, 2007:4) 15
Figure 4.1 Project Mapping 20
Figure 4.2 Categorization of projects based on size 21
Figure 4.3 Construction site 1 and 2 21
Figure 4.4 Construction site 3,4 and 5 22
Figure 4.5 Construction site 6 and 7 23
Figure 4.6 Construction site 8 and 9 23
Figure 4.7 Construction site 10 23
Figure 5.1 Level of information availability- About projects 25
Figure 5.2 Level of information availability - About standards/ quality 25
Figure 5.3 Level of information flow between top management and site managers 27
Figure 5.4 Level of information flow with external stakeholders 28
Figure 5.5 Level of collaboration between top management and site managers 28
Figure 5.6 Weekly protocol 33
Figure 5.7 Weekly protocol- Survey results 34
Figure 5.8 Information poster 34
Figure 5.9 Information poster- Survey results 35
Figure 5.10 Accident report using VDC 36
Figure 5.11 Videos 36
Figure 5.12 Survey results - Videos 37
Figure 6.1 Information Board 38
Figure 6.2 Calendar including major events 39
Figure 6.3 Various types of accident report 39
Figure 6.4 Oculus rift (on top) and Display screens (on bottom) 40
Figure 6.5 APD plan (on left) and Stock control board (on right) 40
Figure 6.6 Markings on wall (on left) and 2D drawings with specification (on right) 41
Figure 6.7 Stakeholder- Visual Means mapping 42

List of Tables

Table 2.1 Categorizing visual means based on Eppler's perspective.....10
Table 5.1 Level of information availability- summary.....26
Table 5.2 Reason for selecting tools.....32

1 Introduction

Construction projects are complex and dynamic in nature relatively leading to plan failures, cost overruns and time delays (Solís, 2008). The construction sector varies from manufacturing industries in many aspects. The manufacturing industry bases its business on mass production, whereas the construction industry is mostly project based. One of the main differences is that in construction projects, manufacturing and especially the assembly takes place on-site, while in the manufacturing sector it takes place in the factories. Characteristics of construction industry can be divided by its features of output, its size, nature of demand for construction output, nature of construction work, variety of construction technology, and structure of industry (Faizal, 2010).

Construction projects are often considered unique, complex in nature and thus requiring continuous monitoring and proper planning throughout its project life cycle. It involves greater level of uncertainties and risks all through the life cycle (Solís, 2008). The activities are highly interdependent as without completion of certain task the other tasks cannot be started (Solís, 2008). Time, cost and scope are the three major constraints that every project faces. These three components are incompatible and interrelated with each other in such a way that change of one component affects the other two.

Communication is considered as the critical elements for all the construction projects by influencing the productivity and quality of the end product (Tezel, et al., 2011). The production phase is the central part of the project life cycle where the actual execution of planned work takes place. Communication during the production phase is much more complex as it involves various stakeholders like contractors, sub-contractors, project management team, suppliers, construction workers, client, local residents and so on throughout.

Visual artefacts convey the information more effective than words. It is the tendency of the people to halt and look at visuals rather than reading lengthy texts. It is a proven fact that attention can be easily captured by a visual artefact rather than a group of words (Carlson, 2009). The applicability and benefits of using visual means for improving communication in the Swedish construction industry is studied in our research.

Visual management helps the project team to be more efficient by making the workflow visible and keeping everyone on the same track (MDes, 2007). Visualization helps employees to understand the organizational value and customer expectation in a better way (Tjell & Bosch-Sijtsema, 2015). Visual tools pave the way to achieve the benefits of visualization and also play an active role in making things happen throughout the project life cycle (Tezel, et al., 2011). Visual aids like pictures, videos multiply the understanding level of the audience and are used to convey the message, clarify points and create excitement.

Visual means can be created either manually or using software. The use of it in real time depends on the nature and complexity of the project. Visualization assists in optimizing onstruction project schedules including workforce, equipment and

resources efficiently (Tezel, et al., 2011). Some reported benefits of using visual means in construction projects are (MDes, 2007):

- Saves time by simplifying the complexity
- Flexible, collaborative, configurable and user friendly
- Reduce waste by improving the communication
- Save costs and avoid delays

The Communication and information flow has to be given importance within the construction projects which in turn causes schedule delays, cost overruns and inadequate quality when it is not managed properly (Dainty, et al., 2006). In the construction project sites, the use of visual means has to be encouraged in order to improve the communication by overcoming all the communicational barriers.

1.1 Purpose and aim

The purpose and aim of our thesis is to find out how construction project execution can be supported through visualization for better communication between various stakeholders involved in order to deliver the projects successfully.

1.2 Research question

The following research questions are formulated to provide a deeper understanding of the concept of visualization in real time practice.

- What types of visual means are being used in the Swedish construction projects and how?
- How do these visual means help to communicate the information between various stakeholders in the production phase effectively?

1.3 Method

The required data for analysis is collected based on direct observation, structured and semi structured-interviews. The deliberate methodology of the work involves:

- Selecting a number of projects based on the location, nature and size that best underpins our research
- Initial site visits of the selected projects to identify how they make use of visualization both on-site and in site office
- Detailed case study on certain identified visual means from different stakeholder's perspective to identify the gaps and success factors relating to our study

1.4 Delimitation

The research identifications are based purely on specific case studies from the Swedish construction industry. The production phase of the construction project cycle is alone considered in this study. As it is difficult to keep track of all the stakeholders involved in the production phase, the focus is mainly given to the primary stakeholders identified during our site visits. The emphasis is predominantly given to

some of the commonly and notably used visual tools in present era of the construction sector. Due to time constraint only certain tools are investigated in the detailed case study. The study gives major focus to communication and information flow leaving behind the other characteristics of visualization.

1.5 Outline of the report

Chapter 1: Introduction- In this chapter the purpose, aim and delimitation of the study is described clearly and the research questions are presented.

Chapter 2: Theoretical background- The theoretical framework includes topic such as importance of communication in construction sector, the visualization concept and discusses certain identified visual tools that are being used in other construction industries.

Chapter 3: Methodology- This chapter describes and explains the methodology involved in our research in detail and also outlines how the data is analyzed.

Chapter 4: Results- The purpose of this chapter is to present the results from analyzed data.

Chapter 5: Findings and Discussion- This chapter presents the findings and discusses in relation to the literature review.

Chapter 6: Conclusion- This chapter includes the concluding remarks of the report.

Chapter 7: Further research- This chapter proposes a vision for future work.

The following figure shows the overall outline of our report,

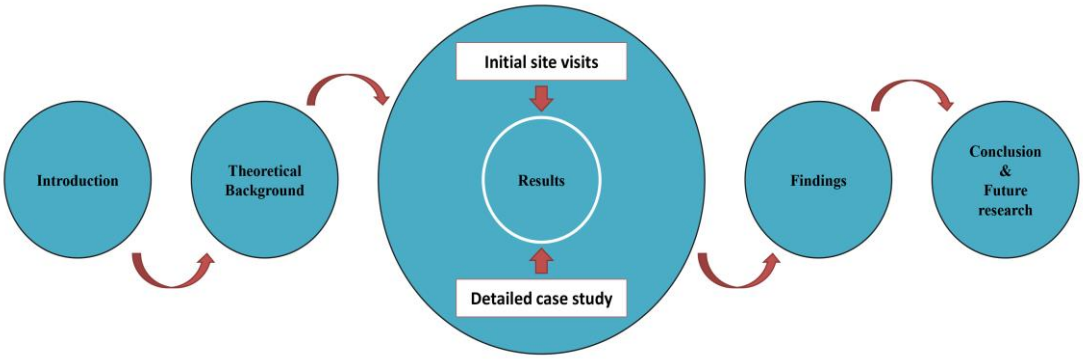


Figure 1.1 Outline of our report

2 Theoretical Background

This part focusses on the concepts and theories that are related directly and considered to have influence on our research.

2.1 Communication within Construction sector

Communication can be defined in many ways. A simple definition is, exchanging information between two parties. Emmitt & Gorse, (2007) also define communication as a sharing of meaning to reach a mutual understanding and to gain response, including some form of interaction between sender and receiver of the message.

There are many different forms of communication and selecting the most appropriate one depends on the nature of the information and receiver (Dainty, et al., 2006). The medium of communication can be divided into many types. They are verbal, non-verbal, written, audio-visual and electronic. Verbal communication is the most direct method of communication which can be either formal, informal, long or short between people. Non-verbal communication is harder for the receiver to understand the conveyed meaning as it is a reflection of one's body language, culture, behaviour etc. Written communication provides a permanent record of communication but involves less interaction. Audio-visual communication is concise and effective as it uses graphs, charts, images to convey the message. Electronic communication such as using email, web-based tools are common nowadays (Dainty, et al., 2006).

Communication is of vital importance in construction industry as it involves a lot of stakeholders from the beginning to end of the project. The figure 2 shows an overall picture of construction communication and its complexity. Many construction problems arise due to communication problems as the stakeholders involved in construction project have various background, culture and professions and they use different terms and methods to communicate (Higgin & Jessop, 1965).

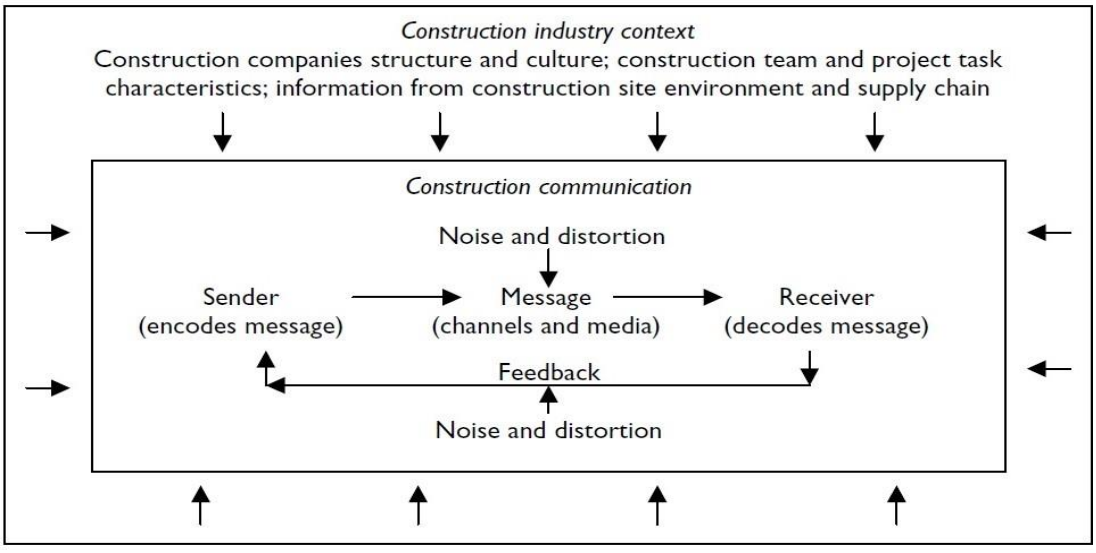


Figure 2.1 Communication within construction projects (Dainty, et al., 2006: 58)

The effectiveness of construction process strongly depends on the communication quality. Poor communication may cause production difficulties and an increase in construction cost (Emmitt & Gorse, 2007).

Communication can be affected by many factors related to the organization of the construction process and the stakeholders themselves (Hoezen, et al., 2006). Torrington & Hall (1998) identified several constraints that hinder efficient communication within the construction industry: the individual's frame of reference, stereotyping, cognitive dissonance, the halo or horns' effect, jargon and not paying attention.

To overcome all these above mentioned issues, it is necessary to have a well-planned and managed communication system. There is always a need to improve communication because it is proven over years that the construction sector can benefit from improved communication (Dainty, et al., 2006). There are mainly four reasons for improving communication.

- An improvement in the communication within and between the stakeholders can decrease failure of construction projects (Higgin & Jessop, 1965)
- More open communication results in innovative ideas and better solutions (Aktin, et al., 2003)
- Communication improvements in initial phases of project life cycle could affect quality of construction projects positively (Emmitt & Gorse, 2003)
- Communication improvement might lead to better decision making during various stages of project process (Salisbury, 1998)

One way to improve communication is by increasing the use of Information and Communication Technology (ICT). ICT includes technologies such as intranets, emails, and 3-D visualization and can be used both within separate phases and between (Dainty, et al., 2006). Visual tools help to convey the information in a clear and simplest way thus avoid misunderstanding between different stakeholders involved in the project by overcoming some of the communication barriers. It can be used throughout the project life cycle and also between various departments to communicate efficiently. Presently, the visual tools are used in different phases of the project to display project information, plan work, maintain standards, regulate health and safety etc.

2.1.1. Project process and Stakeholders

Project process and stakeholders are the two major factors influencing the communication within the construction projects. Project process is an allied outline for the project from the beginning to the end (PMI, 1996). Generally, project process has four major phase: concept, definition, implementation and handover as illustrated in the figure below.

Figure 2.2 Project process

Concept - During this phase the feasibility of the project is evaluated and the decision of whether to implement the project or not is decided.

Definition - In this phase individual stakeholders such as architects and engineers collaborate together to make documents needed for the implementation phase.

Implementation - Throughout this phase the design is finalized and are used to build the final products.

Handover and closeout - The final project deliverables are handed over to end users.

Construction projects involve different stakeholders with diverse background and knowledge within various phases of the project process. Thus, communication becomes critical due to language and cultural barrier posing a challenge to complete the project on time with allocated budget and quality (PMI, 1996). In this study, the focus is given primarily to the implementation or production phase where the actual execution of the project takes place involving various stakeholders.

In general, stakeholders are all those who have an interest or role in the project and or influenced by the project. Stakeholders are categorized into two types: internal and external stakeholders. Internal stakeholders are those who have direct impact on the project and external stakeholders are those who have a strong impact on the project, but they are not involved in the project directly. The figure below shows the different type of stakeholders involved in the production phase of construction projects (Cleland, 1999).

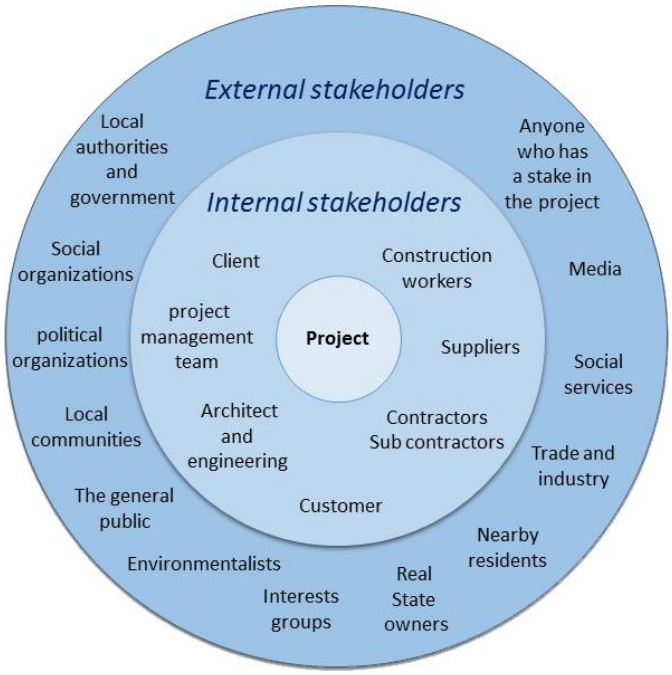


Figure 2.3 Stakeholders involved in the production phase (Cleland, 1999:282)

The client, architect and engineering team, construction project management team, suppliers and contractors are some of the primary stakeholders involved in the implementation phase of the construction project. There are a lot of stakeholders

involved from the beginning to the end of the project (e.g. owner, contractor) and some stakeholders come into the project at varying time period (e.g. plumber) depending on the requirement. Communication becomes more complex in the production phase as the stakeholders involved needs to be tracked and updated continuously about the project and as well their work plan to bring coordination with various stakeholders involved within the project (Cleland, 1999).

2.2 Lean and Visualisation

In Construction industry, the principles of lean are proving perfectly applicable (Worley & Doolen, 2006). The Visualisation ideas has been evolving along with the lean concept over period of years. The history of lean concept originates from the Japanese automaker company Toyota. Initially, they have focused on removing waste to increase customer value in their industry and later on included efficiency by optimizing work flows, and this new philosophy become known as lean manufacturing. The implementation of lean concept not only provide economic benefit to an organization but also noticeable benefits like increased communication (Worley & Doolen, 2006). In manufacturing industry, visual tools supporting communication started with Last Planner System, Kanban, 5S etc and been carried to other industries as well.

Visual Management is one significant approach in the implementation of Lean concept in the construction industry (Viana, et al., 2014). It is the managerial strategy of escalating ubiquitous information availability at close-range communication, enhancing information flow by eliminating obstructions and providing sensory aids for people at work place (Tezel, et al., 2011). Visual management uses simple and easy-to-understand visual tools on workplace elements (e.g. walls, floors, boards etc) for sharing information with various stakeholders involved in the project (Viana, et al., 2014).

The functions of visual management are transparency, discipline, continuous improvement, job facilitation, on-the-job training, creating shared ownership, management by facts, simplification and unification (Tezel, et al., 2011). Some of the functions of visual management are explained below.

Transparency-Transparency is defined as the ability of a tool to communicate with people by making it more visible and comprehensible. A visual tool with higher transparency level helps the worker and manager to understand the conveyed meaning at a glance.

Discipline – In general discipline means following standardized procedures. Everyone including new and inexperienced employees should be able to distinguish between things happening around at a glance without being dependent on another entity.

Continuous Improvement- Visual management functions as a base for continuous improvement and perhaps more significantly encourages employee involvement to manage and improve quality.

Job Facilitation – It helps employees to physically and/or mentally ease their work routine by providing visual aids. Visual management provides platform for people by giving correct, quick and easy understanding of their job requirements.

On-the-job-training- Information provided in the work place using visual means facilitates on the job training and aids the employees to learn by practical experience. It is cost effective, less work disruptive, encouraging and easy to access by everyone.

A visual workplace should be self-ordering, self-explaining, self-regulating, and self-improving work environment (Tezel, et al., 2011). Glassworth describes eight building blocks to a visual workplace. They are,

- Team members should motivate and improve themselves for building an effective visual workplace
- Setting standards to tell people what to do and how to do
- Visual workplace should answer the following six core questions of where? what? when? who? how many? and how?
- Eliminating information deficit for effective visual place
- Reducing unnecessary motion and non-value adding activities
- Work flow has to be flexible and evenly distributed
- Providing information on right time thereby maintaining people's value field
- Making people to track their motion to avoid unnecessary movements (Kattman, et al., 2012)

Visualization aids employees to understand their role and contribution towards the project in a better way by improving transparency and information flow (Tjella & Bosch-Sijtsema, 2015). The human brain is capable of processing pictorial representation easily than texts (Eppler & Burkhard, 2007). Visual tools play a vital role in circulation and communication of the same information to everyone involved in the project having different skill, knowledge, experience and responsibility (Ewenstein & Whyte, 2011). The purpose of a visual tool is to motivate viewers to re-construct the information and to initiate sense making activities. For creating and transferring knowledge effectively through visualization, the following five perspectives should be taken into account.

- Content – What has to be visualised?
- Purpose – Why it has to be visualised?
- Target group – For whom it has to be conveyed?
- Communicative situation – Where and in which context it has to be visualised?
- Method/ Format – How it can be represented to serve the purpose? (Eppler & Burkhard, 2007)

The visual framework formed should answer for what, why, for whom, where and how questions for better visualization of knowledge. The visual means need to be updated, maintained and improved regularly to avoid failures (Eppler & Burkhard, 2007). Though the importance of visual means has been identified in number of theoretical studies, the knowledge embodied in visual framework is generally underrepresented (Ewenstein & Whyte, 2011).

Visual tools help to overcome language barrier (Tezel, et al., 2011). Even too much of information presented using visual tools create confusion and distract attention instead of understanding. Visual tools are simple and financially feasible to use and they

create an easy to understand environment for both management and workforce (Tezel, et al., 2010).

Visualization concept is being used in various areas within the construction project. They are generally used in planning, maintaining healthy and safety, resource allocation, materials handling and so on. Visual tools are used both on-site and as well as in site office. Markings on the walls, facade, floor etc, putting material photo and technical specification on display in front of storage location, transportation routes with directions marks on the surface, color coded waste container are some examples of visual means on site. In site office information board, accident report, time plan, display screens, 2D and 3D drawings, safety boards are some of the notable examples.

2.2.1 Use of visualisation highlighted in Health and Safety

Construction work involves a lot of risks, however these risks can be controlled or mitigated if safety is employed as a vital part of the whole production phase (Gould & Joyce, 2002).

People's actions and site conditions are two main reason for accidents. Visual artefacts can be used as a tool to facilitate health and safety environment in construction site. It is carried out by continually engaging, teaching and reminding the employees about healthy and safe environment with the help of visual tools (Henderson, 2011). Visual tools also aid construction workers to do right things in a right way for a right reason even when no one is supervising. Posters on use of safety equipment's, tables or charts showing record of injuries and other safety signs serve as a tool to maintain health and safety on-site. Posting safety metrics in workplace area is one of the powerful method to enhance health and safety.

Figure 2.4 Health and safety poster (Sanderson, 2014)

Designing to remove or avoid risks before the production phase commence is also vital in terms of health and safety (Gambatese, et al., 2005). Weinstein, et al., (2005) highlighted that addressing safety in design, shows a significant potential for reducing accidents on site. Using software based visualization tools, such as CAD systems, are more suitable for designing a healthy and safety workplace (Rwamamara, et al., 2010). CAD and BIM models can be used for ensuring health and safety on a very

complex site thereby decreasing confusion and enhancing health and safety standards on site.

2.3 Visualisation tools

Visual tools aid all parties who are involved in the project to understand the topic and process easily thus aiming to increase productivity (Rwamamara, et al., 2010). There are a lot of visual tools that are being used all over the world within the construction industry. The tools can be divided in to two main types: conventional (traditional) tools such as 2D drawing, hand sketches and Gantt charts; and software model-based tools like 4D model. Communication is the most important key for planning and designing the project. The use of visual tools to communicate with different stakeholders has become common in construction industry nowadays. (MacKenzie, et al., 1999). Woksepp (2007) highlighted that visual tools helps to reduce the lead time through improving communication and coordination among the actors involved in the project.

During the literature study, the visual tools mentioned below are predominantly used in most of the construction projects especially in Finnish and Brazilian cases. Based on Eppler's perspective, the identified tools are categorized and presented in the table below mentioning how these tools can be related to the context of improving communication within the construction projects.

Table 2.1 Categorizing visual means based on Eppler's perspective

Visual means	**Purpose**	**Target group**	**Communicative situation**
White boards	Used as a communication tool to plan activities and exchange information	Contractors, construction management team, Sub-contractors, architect, client	During meetings
3D and 4D models	Used as a tool to visualize the design to eliminate communication barrier	Construction management team, sub-contractors, clients	During meetings and also in site office (using oculus rift or computers)
Look ahead plan board	To breakdown the activities to be carried out in further coming weeks and thereby increasing coordination	Sub-contractors, Construction management team	Project office
Monthly and weekly planning	Interactive communication platform where the future activities are planned	Contractors, construction management team, Sub-contractors	Project office

Markings on the walls	Used to aid construction workers by providing basic information, plan to avoid mistakes	Construction workers, Supervisors, site managers	Construction site
Construction Board	Communicates information related to daily work package	Construction workers, Supervisor	Planning- Site office Execution- Construction site
Visual Signs	Mainly to convey information relating to health and safety	All internal stakeholders	On-site and site office
Interactive visualizations and animations	Communicate and demonstrate complex issue in the simplest way	Contractors, construction management team, Sub-contractors, architect, client	Project office
Augmented Reality	Identify discrepancy in design	Architect, construction management team	Project office

These visual means will further be described in the following section as they are most likely promising and useful for saving time, enhancing communication, reducing construction cost and supporting scope.

2.3.1 Board and meetings

The white boards and the meetings are considered similarly important to visual planning system. The board is used as a communication tool during meetings, where planning activities and information exchanges happen (Lindlöf & Söderberg, 2011). In addition, the placement of the board is a really important factor.

The meetings are short and normally last between fifteen minutes to one hour and they can be held more often because they are so short and effective. The frequency of meetings depends on the communication needs of the specific team, but two times a week is most common in the organization (Lindlöf & Söderberg, 2011).

2.3.2 3D and 4D model

The 3D model emphasis on the design of the building and its spatial construction. 3D visualization techniques allow spatial concept to be carried in an easily understandable form (Staub-French & Khanzode , 2007). It helps everyone to visualize the design thereby eliminating communication barrier. 4D model involves integration of 3D model with construction scheduling still making it easier to visualize time with the design.

2.3.3 Monthly and weekly planning

These plans continuously remind employees and construction workers about the project's objectives and the results of their daily work. Monthly plan involves sub-processes and activities

Figure 2.5 Weekly planning meeting

for the coming month and it sets up visually in order to have a comprehensive understanding about goals in the near future. In terms of allocating resources efficiently, there is always a weekly plan which may consists of activities that are linked to individuals (Dalman, 2005).

2.3.4 Look Ahead Plan board

Look Ahead Plan (LAP) or Make-Ready Plan is derived out of the master plan involving detailed breakdown of work/activities to be carried out in further coming weeks followed by a weekly plan.

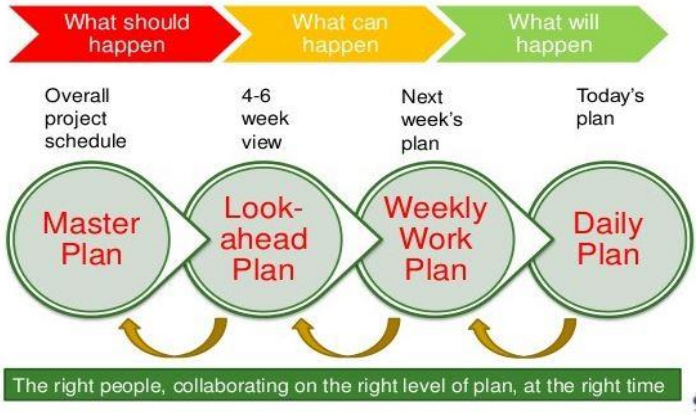


Figure 2.6 Project planning outline (Seath, 2014:15)

It involves active involvement of various participants involved in the project thereby increasing the coordination, control and level of commitment. LAP focuses on what is supposed to happen in upcoming weeks in the project by making short term obligations and ensuring all the necessary resources will be in right time at right place to avoid delays. A typical LAP involves 4-6 week work forecast for improving the success rate of completing the project on time. LAP is updated every week and the performance is measured by calculating Planned Percent Complete (PPC). PPC is defined as the ratio of completed task to the planned task (Ballard, 1997).

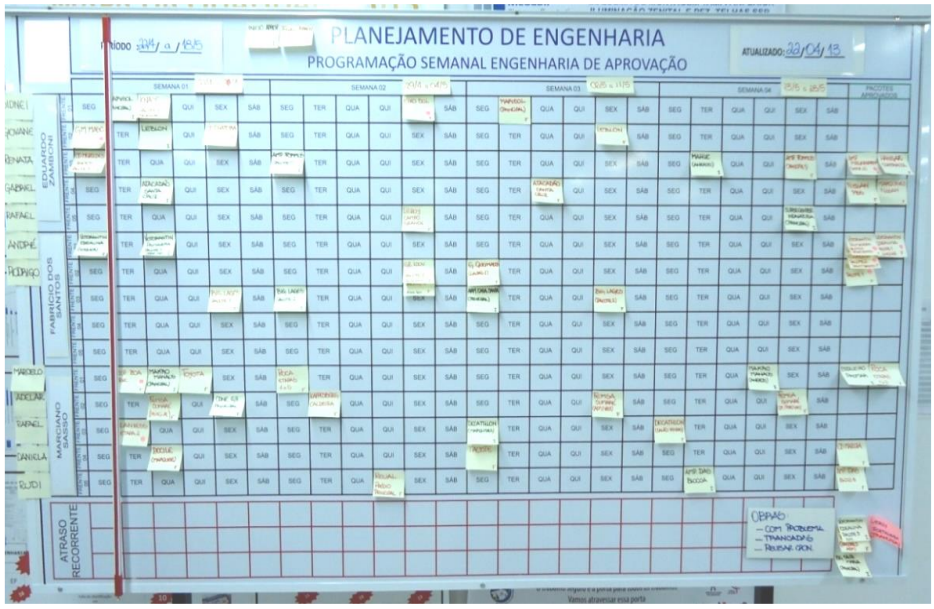


Figure 2.7 Look ahead plan (Viana, et al., 2014:781)

2.3.5 Markings on the walls

The markings on the walls technique is a one of the simplest and most useful visualization tools which provides information for the construction workers and managers working on-site. It can be basic information, a plan or a specification e.g. handwriting on the wall, floor numbers, 2D plan. It is more useful when an apartment has different specification such as floor material, window panel, etc. It also helps to avoid mistakes thus saving time (Tezel, et al., 2011).

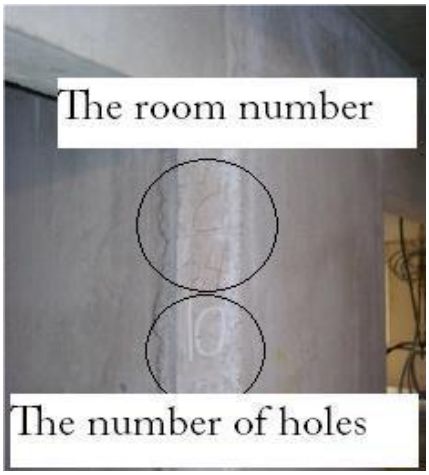


Figure 2.8 Marking on the walls (Tezel, et al., 2011:4)

2.3.6 Construction Board

Construction board consists of color-coded cards containing daily work packages and act as a point of meeting and discussion for the workers involved. The board indicates the worker capacity needed, the material needed and where the work has to be carried

Figure 2.9 Construction board (Brady, et al., 2012:5)

out. The color-coded cards are used as a quality assurance for the completed work. On completion of the work, the worker turns the card to green side.

The foreman checks the quality of the work and puts back the card on the construction board with green side up assuring the quality of the completed work (Brady, et al., 2012). The work goes smooth without interrupting anyone's work with help of these visual cards.

2.3.7 Visual signs

A visual sign is an object which includes visual communication and conveys a meaning. Visual signs that have been used in the construction industry are, for example, posters or a signboard. It is also used to emphasize the company's desired practice, specifically in terms of health and safety (e.g. use your helmets) (Tezel, et al., 2010).

2.3.8 Interactive visualisations and animations

Interactive visualization allows user to demonstrate, explore and discuss complex issues in various perspectives in the simplest and attractive way. The visualization can either be a video or image illustrating how, when and what has to be done. These kind of tools helps the viewer to understand and manipulate the base concept easily thus saving time (Eppler & Burkhard, 2007). Interactive visualizations and animations can be used effectively during the execution phase of the project.

2.3.9 Augmented Reality

Augmented Reality (AR) is one of the emerging technology that could have a greater impact on the construction industry. In this technique, the images obtained from 3D modelling is superimposed with the actual images taken on the construction site. The

inconsistencies between planned and actual work can be clearly identified and visualised. AR helps the project manager to better support the work progress monitoring (Fard & Mora, 2007).

Figure 2.10 Comparison of 3D model with actual image using Augmented Reality (Fard & Mora, 2007:4)

3 Methodology

3.1 Research Design

Research design is the significant aspect of research process as it directs and systematize the research (Currie, 2005). The choice of particular research method is a very important decision in thesis project work as it will affect the study results and determines how to go about collecting the data. There are two main types of research approaches:

- Qualitative research method
- Quantitative research method

3.1.1 Qualitative and Quantitative research method

Data collection can be either qualitative or quantitative (Currie, 2005). In nutshell, qualitative data can be observed but not measured whereas the quantitative approach relies completely on statistical data. The main purpose of quantitative research is to quantify the data. Quantitative research design is an excellent way of concluding results and proving or disproving an assumption. The qualitative data collection method helps in understanding the underlying reasons, opinions and motivations. It provides deeper insight into the problem by disclosing thoughts and opinions collected from various respondents.

Mixed-method approach is a method that uses both qualitative and quantitative research method. The validity and reliability of data evaluation can be increased by following mixed-method approach. In our study, mixed-method approach is used providing a broader aspect for the data collection method and also to strengthen the validity of the result (Ritchie, et al., 2013).

3.2 Initial site visit

From the company of the case studies, a list of the ongoing projects in the west of Sweden was received. Based on the information provided by the company's intranet, the projects were categorized according to size (small, medium and large). The nature and location of the project is also given importance as every project has some unique identity with varying priorities and demand from the client. Based on the uniqueness, nature, location and size of the project, we shortlisted fifteen projects in the beginning of the study, supported by our supervisor. To save time and to make it easier for us to access the sites, most of the projects are selected within the Gothenburg region. E-mail messages were sent to each site manager to obtain permission for the site visit and to make an appointment for the interview. Finally, ten project sites were selected and site visits were scheduled based on acceptance and availability from the site managers.

The initial site visits were conducted based on a prepared set of questionnaires and checklists supported with a few close-ended questions for the site manager. The Likert scale was used to grade the visual tools and find out characteristics of visualization based on their level of usage.

3.2.1 Data Collection methods

In this section, the methods used to collect data during initial case study are described clearly.

3.2.1.1. Observational method

Direct observation allows one to understand more about what goes on in the complex real world situation than interviews and questionnaires (Ritchie, et al., 2013). The interpretation of data varies from people to people as everyone will look into and analyze things differently.

Direct observation is chosen for identifying the visual tools that are used in every project and also to help collecting data using checklist.

Checklists are created prior to the site visits to evaluate or rate the visual tools based on their usage and characteristics. The Likert scale is one of the most commonly used rating scale. The number of statements to be included in the final list is a challenging task for the creator of the checklist. In making this decision, a balance between two main factors has to be taken care: the data collection objectives must come first and also the list should not be too long (Currie, 2005).

Visualness is defined a factor used to measure and judge the extent of utilization of visual tools. The degree of visualness is measured by categorizing it as not implemented, limited extent, more than 50%, more than 75% and fully implemented. If the tool is not at all used in the project, then it is categorized as not implemented. The tool is marked under fully implemented when it is potentially used in the project to greater extent. It is categorized as limited extent, when the tool is being used but not to its full potential. Based on the degree of utilization, the tools are differentiated as more than 50% and more than 75%. They are categorized based on our observation on-site considering the level of information availability and transparency of each tool.

3.2.1.2. Interview method

Interviews are a systematic way of talking and paying attention to people and are another way to collect data from individuals through conversations (Ritchie, et al., 2013). The interview questions can be either open ended or close ended. Open ended questions are answered either short or long and will help to record feelings and opinions of the respondent. Close ended questions can be answered either in a single word or short phrase identifying facts. Close ended questions are easy and quick to answer than open ended questions.

3.2.1.1.1 Semi-structured interviews

A semi-structured interview is one in which the interviewer has a pre-set type and order of questions but at the time of interview, the order of questions can be changed or new question can be added so as to benefit the research objectives (Currie, 2005). The semi-structured interviews aid researcher to analyze and probe deeper into the given situation much better (Ritchie, et al., 2013).

Questionnaires are the most widely used method to collect people's opinion. Questionnaires can be administered in many ways: by post, via e-mails, face-to-face,

or by telephone (Ritchie, et al., 2013). In our work, we interviewed 11 people (including site managers and supervisors) and preferred face-to-face interaction with the interviewee.

The questions for the interview were formulated to gather certain information about the project that were not covered in the checklist. For example, do you use VDC (virtual design and construction)? If yes, how comfortable it is for you to work with? The purpose of the questionnaire is to get an idea about site manager's perspective on usage of visual tools and to find out benefits and barriers in implementing them.

3.2.1.1.2 Structured interviews

A structured interview uses a set of standard questions to all the interviewee's (Currie, 2005). In this case, predefined checklists are used to grade the characteristics of visualization. The gradings are similar to the previous checklist discussed above in the section 1.2.2. The information flow and level of collaboration are evaluated for ten projects with the help of site manager to get accurate and exact result.

3.3 Detailed case study

Once the initial case study had been carried out and the preliminary results analyzed, a detailed case study was carried out for certain selected tools in order to attain deeper knowledge of their uses. The site manager or supervisor are the one who works with the visual tools a lot and responsible for transferring the information to other stakeholders (construction workers, local people, client etc). The data was collected in two ways i.e. survey method and semi-structured interview method.

3.3.1 Data collection methods

In this section, the methods used to collect data during detailed case study are discussed briefly.

3.3.1.1 Semi-structured interviews

The semi-structured interview method with close ended questions are used to collect data from the site manager/supervisor in order to gather opinions, views and ideas about the visual tools. For example: How does this visual tool help to communicate the information in a better way? We interviewed two site mangers, one supervisor and one health and safety coordinator during detailed case study. Each interview time was planned for 5-10 minutes since most of the information about the tool had been collected during the initial site visit.

3.3.1.2 Survey method

The survey method is used to collect data in a large scale (Currie, 2005). In our case, since the receiver of information (i.e. local people, construction workers) are huge in number, arranging separate interview with them is tedious and time consuming. Therefore, the survey method with sets of pre-defined questions was prepared to collect their opinion on working with these visual tools.

Taken into consideration of the language barrier, the questions were prepared both in Swedish and English. The number of surveyors for each tool depended on the

availability and varied between 4-10 persons. In total, we surveyed 25 people during detailed case study.

The data collected from surveys and checklists are interpreted and analyzed. The information gathered from interviews are used as a supportive data for our study. The collected data are then categorized according to the size of project (i.e. small, medium and large projects). The data are represented graphically for easy understanding and comparison. The observed results from the study are compared with the theoretical framework for better validation of results.

4 Case Studies

In total, ten site visits were carried out during the preliminary phase of the site visit. The visited sites are located mostly within the Gothenburg region, except one project. The figure 4.1 below shows the location, name, size and nature of the selected project sites for our visit.

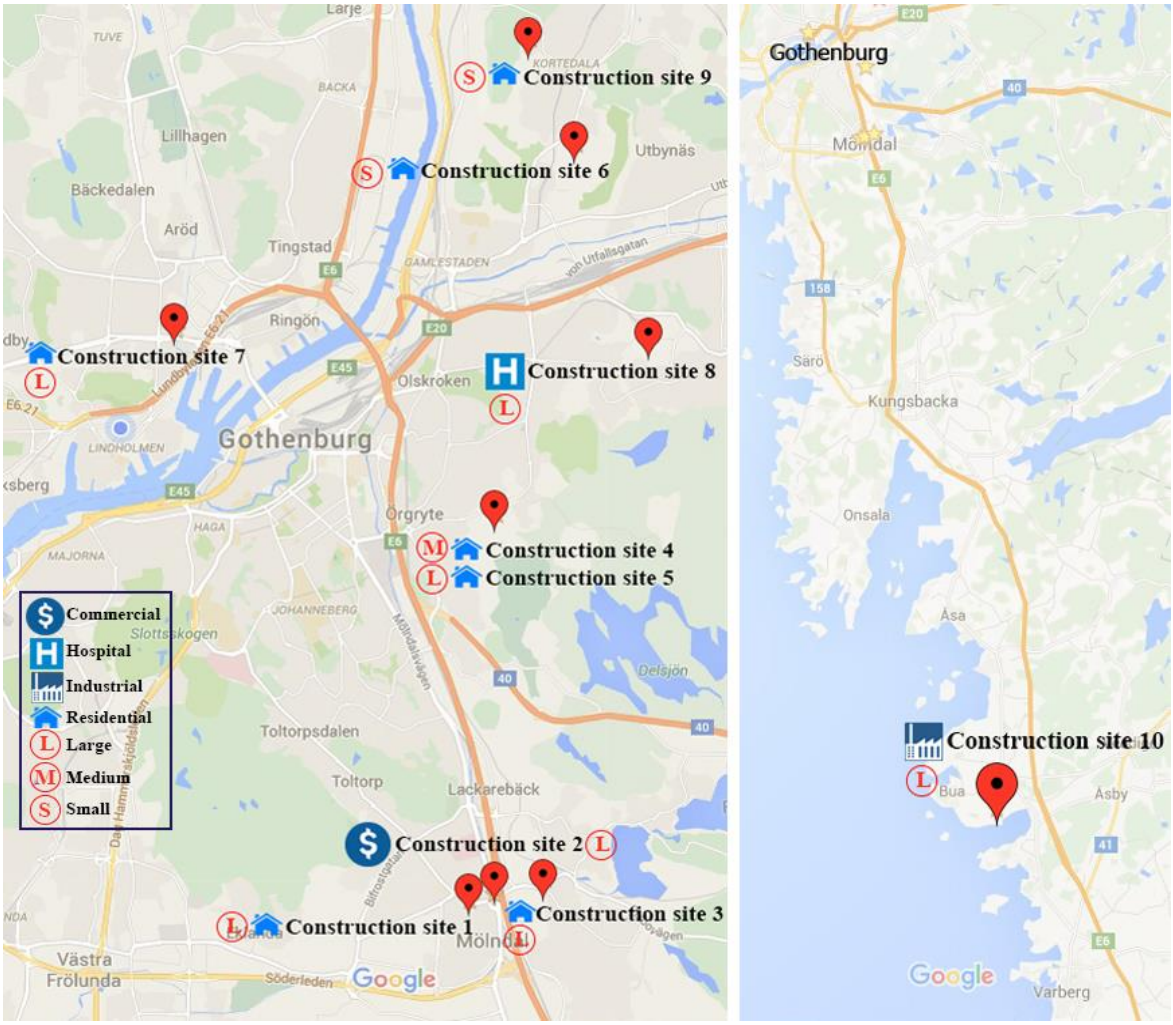


Figure 4.1 Project Mapping

The sites that we visited are mostly residential building construction. We also visited commercial, industrial and hospital projects to have a diverse background and input for our study.

The projects are categorized into small, medium and large based on their budget. The projects with budgets exceeding 100 MSEK are categorized as large projects, budgets between 50 and 100 MSEK as medium projects and budgets less than 50 MSEK as small projects. The figure 13 shows the categorization of projects based on the allotted budget and the number projects that we visited during our initial case study in each category.

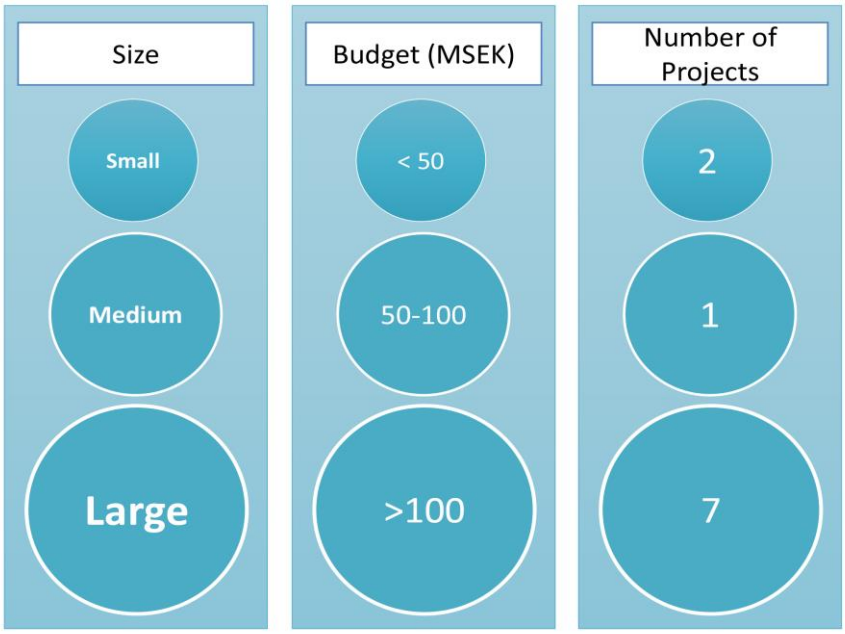


Figure 4.2 Categorization of projects based on size

The case description for all the visited sites are mentioned in short and brief stating the nature and size of the project, estimated budget of the project, time plan for the project and the people whom we interviewed during our visit.

4.1 Detailed description of cases

4.1.1 Site: 1

Project description: Construction site 1 is a large residential construction project near Mölndal city centre. The construction phase started in August 2015 and will be finished by September 2018. The estimated budget for this project exceeds 100 MSEK. We interviewed two site managers, who are responsible for the entire project.

Figure 4.3 Construction site 1 and 2

4.1.2 Site: 2

Project description: Construction site 2 is a big commercial construction project situated in the heart of Mölndal, which includes 25000 square meter office area. The

time line for this project is from June 2014 to October 2016. The production cost exceeds 100 MSEK. We interviewed the site manager in this project.

4.1.3 Site: 3

Project description: Construction site 3 is also a large residential project construction located near Mölndal centrum. The project involves a construction of eighty-two apartments. The scheduled construction period is from 2015 to 2020 for the whole project and estimated budget exceeds 100 MSEK.

Figure 4.4 Construction site 3,4 and 5

4.1.4 Site: 4 and 5

Project description: Construction sites 4 and 5 are two parallel, ongoing residential projects near the center of Gothenburg. In site 4, the production phase started in September 2014 and site 5 started one year later in October, and it will be finished in March 2017. Out of these two projects, the estimated budget exceeds 100 MSEK for one of the project and 50 -100 MSEK for the other project. The projects have separate site managers but the same project manager for both the project.

4.1.5 Site: 6

Project description: Construction site 6 is a small scale façade refurbishment residential project at Kviberg, located in north east of Gothenburg. The scheduled refurbishment period is from June 2015 to November 2016. The overall budget is less than 50 MSEK for this project.

4.1.6 Site: 7

Project description: Construction site 7 is a large scale residential building construction project located close to the city center. The project includes eighty-one residential apartments of different types. Its construction phase is scheduled from October 2015 to October 2017 and production costs exceeding 100 MSEK.


Figure 4.5 Construction site 6 and 7

4.1.7 Site: 8

Project description: Construction site 8 is a large scale children hospital project located in the east of Gothenburg. The project started in spring of 2015 and will be finished completely in 2020. The estimated budget for this project is approximately one billion SEK, thus clearly exceeding 100 MSEK.


Figure 4.6 Construction site 8 and 9

4.1.8 Site: 9

Project description: Construction site 9 is a small scale residential construction project located at Decenniumgattan. The production phase last for one year between June 2015 to July 2016 and the project cost is slightly less than 50 MSEK.

4.1.9 Site: 10

Project description: Construction site 10 is a large scale industrial project located away from Gothenburg at Väro, between Varberg and Kungsbacka. The project started in September 2014 and it is scheduled to be finished in June 2016. The project cost is estimated to exceed 100 MSEK.

Figure 4.7 Construction site 10

5 Results

The data collected from checklists, direct observation and interviews are presented below in the following two sections i.e. characteristics of visualisation and detailed case study. The first section covers the result obtained from the preliminary site visits including the type of visual tools that are being used and as well some of the main characteristics of visualisation relating to communication flow within the project. In the second section, the results obtained from the detailed case study of certain noticeable tools are described briefly.

5.1.1 Characteristics of Visualisation

The characteristics of visualisation such as information flow, level of collaboration and information availability are evaluated for every project to identify the gaps in the communication of information between various stakeholders and the use of visual tools in real time practice.

The data collected are represented graphically for better understanding and to bring a comparison between various projects. For presenting data relating to information availability, level of collaboration and information flow, the levels are graded between low and high in the horizontal axis and number of projects in the vertical axis.

The level of information availability is categorized into six sections such as about project, about standards and quality, about work plan, about logistics and material handling and to construction workers on site. The grading is done based on how far the visual tools are used to present information relating to these specific areas. The information availability about project includes drawings, time plan, 3D models, important events in the project like milestones etc. The figure 5.1 shows the level of information availability about project for ten projects. Almost all the large projects have time plan and drawings for display on-site, which is why the grades are higher in the graph. It is clearly evident from the graph that the small and medium projects used less 3D models and had less information than the large projects.

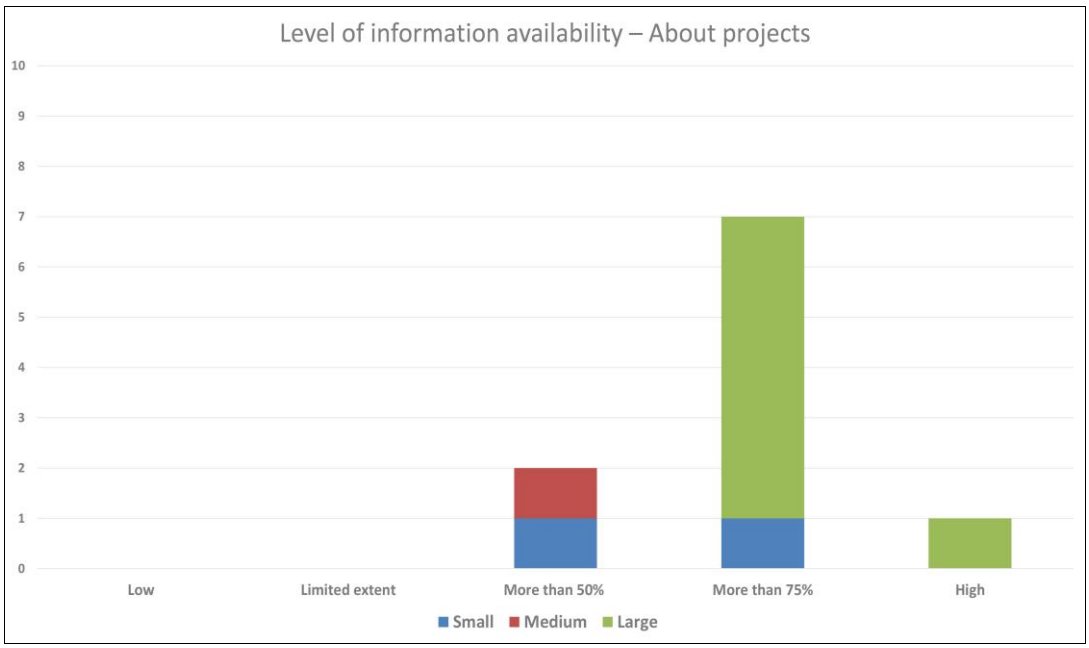


Figure 5.1 Level of information availability- About projects

The information availability about standards/quality includes safety standards for workers, environment standards, quality guidelines etc. In every project the site manager maintains documents for standards and quality. The display of information should be easily accessed by the workers as well. The projects are graded between low and high based on the extent of information displayed relating to standards and quality for workers. For example, the project was graded as high because all the information about standards and quality were displayed in the project studio and safety visual signs was placed in many places (dining room, reception, in front of site office etc), providing an easy accessibility to the information for workers. The figure 5.2 shows the varying grades provided for other projects relating to standards and quality.

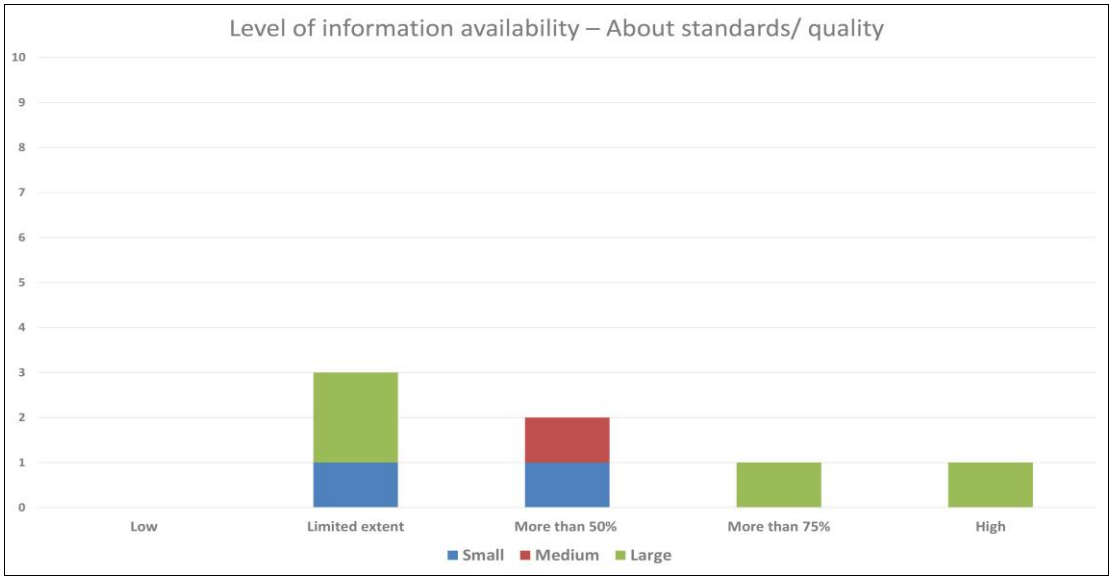


Figure 5.2 Level of information availability - About standards/ quality

The level of information availability about health and safety/risks includes information that are needed to maintain health and safety workplace and also to avoid accidents. For the large projects, grades vary from project to project based on the focus given to present information visually relating to risks and safety. Even small and medium projects have higher grading than certain larger projects. The graph is shown in appendix IX for further reference to the reader.

The level of information availability about work plan encompasses information relating to work package, weekly and monthly work forecast and so on. The grades are varying between various projects irrespective of the size of the project. Form the graph (referring to Appendix IX), most of the large projects give importance to work plan as they display information more than 75% using visual tools. The level of information availability about logistics and material handling includes information relating to material delivery, order and handling of purchased resources. Here, the grades are also fluctuating from project to project regardless of size of the project similar to the previous case (see Appendix IX). The construction projects involving prefabricated materials gives more focus to logistics and material handling than other projects.

The level of information availability to construction workers measures the availability of information to workers on-site. It includes information availability relating to the project, safety, 2D drawings with specification and so on. Almost 75% of the visited sites had necessary information on site to the workers as a sign to improve the information flow by making it visible for everyone (see Appendix IX). The summary of the data collected relating to the level of information availability is presented below in the table below.

Table 5.1 Level of information availability- summary

Level of information availability	**Size of the project**		
	Small	**Medium**	**Large**
About project	Average	Average	High
About standards and quality	Varies from project to project		
About health and safety/risks	Varies from project to project		
About work plan	Varies from project to project		
About logistics and material handling	High for projects involving prefabricated materials		
To construction workers on-site	Depends on the type of project and level of construction on site		

The level of information flow between various stakeholders is measured based on the site manager's opinion about it. Considering, the level of information flow between

top management and site managers most of the projects had satisfactory level of communication expect few projects as shown in the figure 5.3 below.

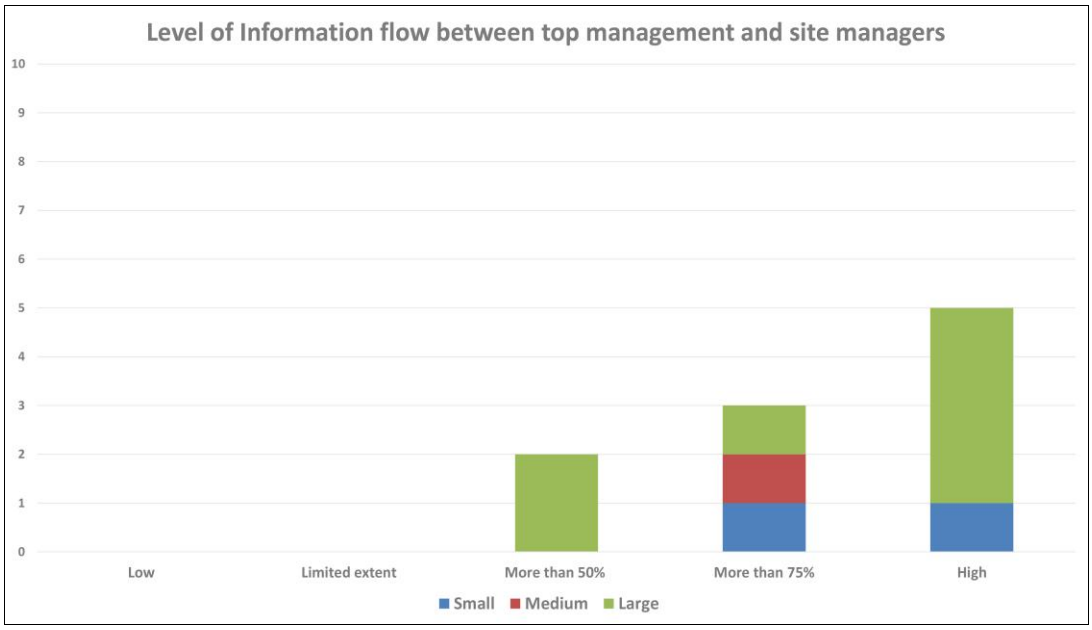


Figure 5.3 Level of information flow between top management and site managers

The level of information flow between site managers and construction workers have higher grades (see Appendix VII) in all the projects. If we consider, the information flow between various sub-contractors almost all the projects have higher grades except few (refer appendix VII). The value is lower as a result of communication barriers due to language and culture.

The level information flow between external stakeholders such as society and local residents are equally important as internal stakeholders. In most of the projects, the site manager gives their best to make information available to external stakeholders as shown below in the figure 5.4. In some large projects, the client takes the responsibility to present information to the external stakeholders due to the involvement of many contractors in the project. The grades are awarded lower in that case since the responsibility lies on the client and not on the contractor.

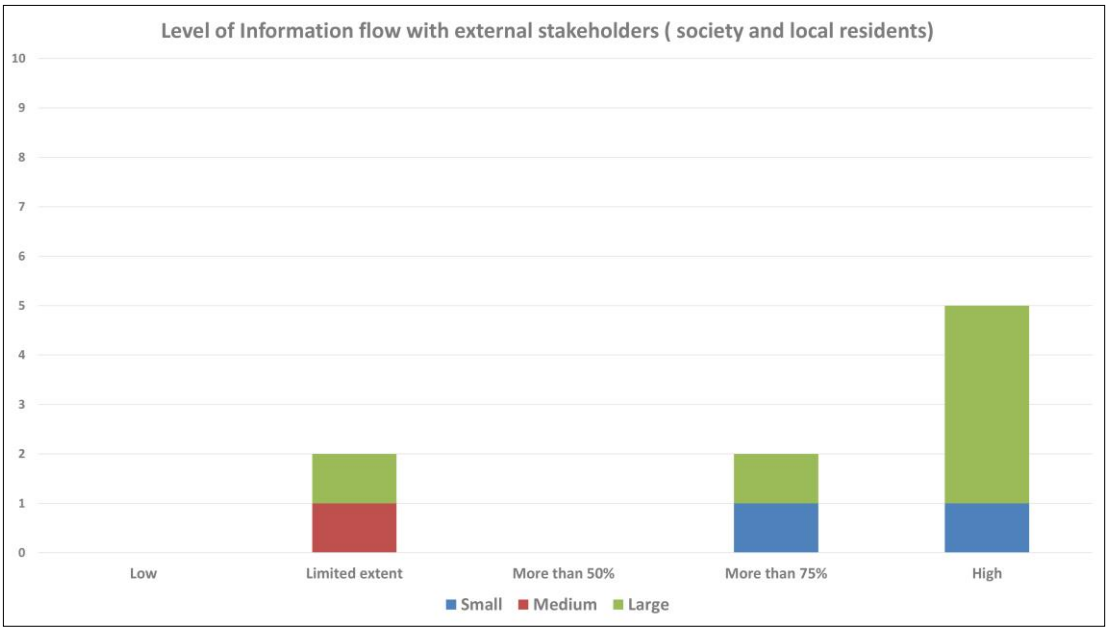


Figure 5.4 Level of information flow with external stakeholders

The level of collaboration between various internal stakeholders is evaluated similar to the level of information flow. The level of collaboration between top management and site manager works better in some cases and considerably low in few cases as shown in the graph 5.5 below. The lesser value is due to restricted face-to-face meetings and less clarity in sharing the information.

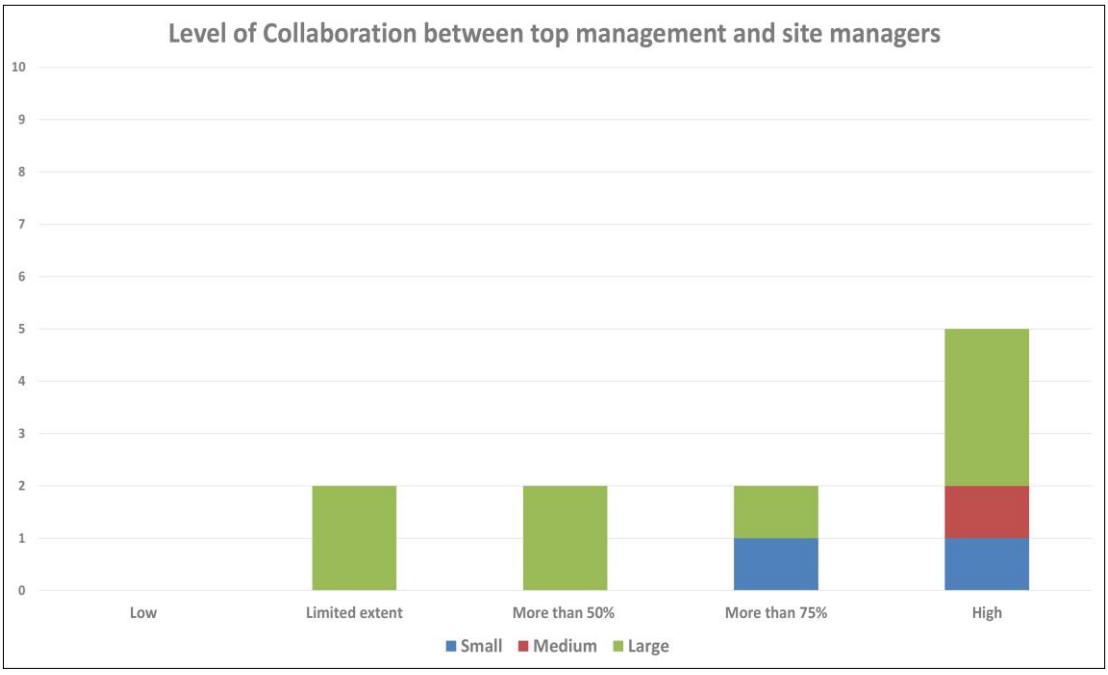


Figure 5.5 Level of collaboration between top management and site managers

The level of collaboration between site manager and construction workers is high in majority of the projects (refer appendix VIII). The level of collaboration between various sub-contractors also have higher value in most of the projects (refer appendix VIII). The smaller and medium level projects have higher level of collaboration than larger projects as there were less people involved and the amount of information to be shared will also be less in some cases.

The commonly used visual means observed during each site visit along with some remarkable observations noticed in the project sites are mentioned below.

5.1.1.1 Site: 1

Commonly used visual means: Information board, Weekly plan, 2D drawings, 3D and 4D models, Gantt chart, APD plan, Environment poster, Safety poster, Accident report, Logistics plan, Prototyping, Bordering.

Observation: As the project is in the initial phase of construction (i.e. foundation), not many visual tools on site, other than bordering, was noticed. Visual Design and Construction (VDC) is used in the project but the site managers are not used to work with VDC, putting a barrier to implementing it. Communication gap exists between site managers and construction workers due to cultural and language barriers. The site managers are unhappy about the information flow and collaboration from the top management as it sometime involves imposing some methods and regulations that did not go well or work out for the particular site.

5.1.1.2 Site: 2

Commonly used visual means: Information board, 2D drawings, 3D and 4D models, Gantt chart, Team structure, APD plan, Calendar including major events, Logistics plan, marking on floors or walls, Bordering, Stock control board, VDC in health and safety.

Observation: VDC is predominantly used in this project. Display screens and oculus rift are also made available at the site office to access BIM models. On-site safety is given higher priority and a display screen is also kept to convey the information to workers since the location of site office is far from the site. Site manager mentioned that the weekly planning meeting and short meetings with the company team helps to increase the information flow and collaboration level.

5.1.1.3 Site: 3

Commonly used visual means: Information board, 2D drawings, look ahead plan, Gantt chart, colour codes, marking on floors or walls, Bordering, Stock control board, Prototyping.

Observation: The site manager is friendly with the workers and confident about what he is doing. They use colour coded sticky notes over the drawings to decide on future major activities and deliveries during the planning session. The use of 2D drawings with specifications on-site readily provides information to workers, thus avoiding the possibility of errors and re-work. VDC is used only to limited extent in this project.

5.1.1.4 Site: 4 and 5

Commonly used visual means: Information board, 2D drawings, Gantt chart, Pictures/Images, Safety poster, APD plan, marking on floors or walls, Bordering.

Observation: The project manager has good control over the project and ensures whether the information has been communicated effectively. VDC is extensively used in the project for visually presenting the designs and making workers to understand better. Unlike other visual tools, they also use the walls of the dining room to display information related to project. The use of visual means to enhance safety can be improved.

5.1.1.5 Site: 6

Commonly used visual means: Information board, 2D drawings, Gantt chart, Calendar including major events, APD plan.

Observation: As it is a small scale project with less people involved in it, they prefer using basic communication techniques (like phone call and email) and the collaboration between workers also works well in this case. Site manager mentioned that using VDC for smaller projects like this will not be cost and time efficient. Communication with local people is of greater importance in this project as there will be a noise disturbance during the demolition and other works.

5.1.1.6 Site: 7

Commonly used visual means: Information board, 2D drawings, Gantt chart, APD plan, Bordering, Stock control board.

Observation: In this project, color codes are widely used to differentiate between various material deliveries and pasted it in both dining room and also in site office. 3D models and VDC is not used in this project. Visual tools are mostly used to enhance safety and clean environment. The project involves handling of high volume of prefabricated walls hence more importance is given for planning and handling of materials.

5.1.1.7 Site: 8

Commonly used visual means: Information board, 2D drawings, Gantt chart, look ahead plan APD plan, weekly protocol, Accident report, Pictures/Images, Safety poster, Bordering, Stock control board, BIM models and drawings.

Observation: The updated weekly protocol with highlighted new texts is made available to every worker by keeping it on each dining table is a new idea. The images are used to show the project's work progress from initial phase to till now. Markings of storage area, safety boards and 5's are used extensively on-site. The project information along with site managers contact details is pasted outside the site for providing information to local people and is being updated every week. The site office is maintained very clean and display screens are placed in important locations for providing details about the project. Oculus rift is available in site office but not used to a greater extent.

5.1.1.8 Site: 9

Commonly used visual means: Information board, 2D drawings, Gantt chart, Bordering, Stock control board.

Observation: Since it is a small scale project, visual tools are not given more importance. Only they make use of basic visual tools on-site as well as in site office to support healthy progress of the project.

5.1.1.9 Site: 10

Commonly used visual means: Information board, 2D drawings, 3D and 4D models, Gantt chart, Team structure, Safety poster and boards, APD plan, Calendar including major events, Logistics plan, Accident report, Bordering, VDC in health and safety, Videos.

Observation: Other than usual visual tools, they make use of VDC to greater extent for maintaining health and safety environment. Categorizing incidents, accidents and risks with different colors on the layout plan gives clear idea about the risk prone zones and helps workers to be aware of it and also makes them feel committed. Videos created by VDC coordinator (getting inputs from supervisor and others) to demonstrate workers about lifting of heavy elements on-site. This helps everyone to understand the content in a better way thus saving time.

5.2 Detailed case study

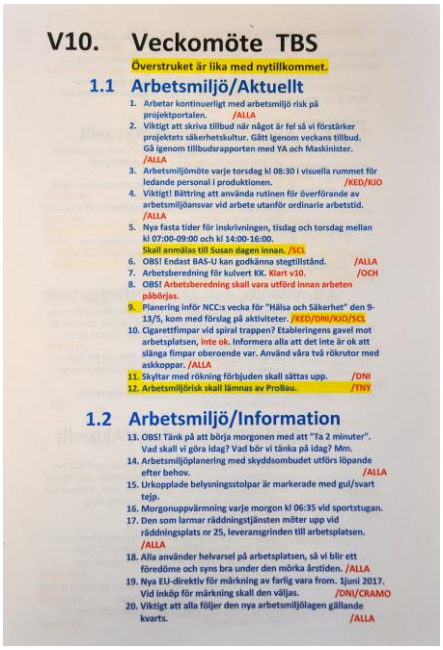
After the initial site visits, information about different kind of visual tools and general characteristics relating to information flow and availability of information had been studied and analyzed. There were many interesting tools which can be studied further in detail but due to the time constraint, we have decided to proceed with four tools that was more remarkable and unique. The selected tools and reasons of choosing these tools are mentioned in the table 5.2 below.

Table 5.2 Reason for selecting tools

Project	Visual tools	Reason	Target group
Construction site 8	Weekly protocol-display	Best way to update the workers about the things discussed during meeting with less effort Highlighted new texts – New and interesting idea More visual	Construction workers Sub-contractors Construction project management team
Construction site 8	Information poster	Image of the project with description Updated weekly Contact details of the site manager	Local residents and society
Construction site 10	Videos	Demonstrates how to carry out lift Easy to make everyone understand New idea!	Construction workers Sub-contractors
Construction site 10	VDC in health and safety	Transparent Includes 3 categories: Incident, accident and risk observation in single plan	Construction workers

5.2.1 Weekly protocol

Weekly protocol is a formal document which is being updated every week by the site manager reporting the standards, quality, risks and important events within the project. Generally, it is updated in the project protocol of the company by making information visible to everyone. In case 8, it was displayed differently than in the other projects. The newly included texts are highlighted every week as shown in the figure 5.6 below and placed on each table in the dining room as well as pasted on the information board by making information available to the construction workers.



V10. Veckomöte TBS

Överstruket är lika med nytillkommet.

1.1 Arbetsmiljö/Aktuellt

1. Arbetar kontinuerligt med arbetsmiljö risk på projektportalen. /ALLA
2. Viktigt att skriva tillbud när något är fel så vi förstärker projektets säkerhetskultur. Gått igenom veckans tillbud. Gå igenom tillbudsrapporten med YA och Maskinister. /ALLA
3. Arbetsmiljömöte varje torsdag kl 08:30 i visuella rummet för ledande personal i produktionen. /KED/KJO
4. Viktigt! Bättring att använda rutinen för överförande av arbetsmiljöansvar vid arbete utanför ordinarie arbetstid. /ALLA
5. Nya fasta tider för inskrivningen, tisdag och torsdag mellan kl 07:00-09:00 och kl 14:00-16:00. Skall anmälas till Susan dagen innan. /SCL
6. OBS! Endast BAS-U kan godkänna stegtillstånd. /ALLA
7. Arbetsberedning för kulvert KK. Klart v10. /OCH
8. OBS! Arbetsberedning skall vara utförd innan arbeten påbörjas.
9. Planering inför NCC:s vecka för "Hälsa och Säkerhet" den 9-13/5, kom med förslag på aktiviteter. /KED/DNI/KJO/SCL
10. Cigarettfimpar vid spiral trappen? Etableringens gavel mot arbetsplatsen, inte ok. Informera alla att det inte är ok att slänga fimpar oberoende var. Använd våra två rökrutor med askkoppar. /ALLA
11. Skyltar med rökning förbjuden skall sättas upp. /DNI
12. Arbetsmiljörisk skall lämnas av ProBau. /TNY

1.2 Arbetsmiljö/Information

13. OBS! Tänk på att börja morgonen med att "Ta 2 minuter". Vad skall vi göra idag? Vad bör vi tänka på idag? Mm.
14. Arbetsmiljöplanering med skyddsombudet utförs löpande efter behov. /ALLA
15. Urkopplade belysningsstolpar är markerade med gul/svart tejp.
16. Morgonuppvärmning varje morgon kl 06:35 vid sportstugan.
17. Den som larmar räddningstjänsten möter upp vid räddningsplats nr 25, leveransgrinden till arbetsplatsen. /ALLA
18. Alla använder helvarsel på arbetsplatsen, så vi blir ett föredöme och syns bra under den mörka årstiden. /ALLA
19. Nya EU-direktiv för märkning av farlig vara from. 1juni 2017. Vid inköp för märkning skall den väljas. /DNI/CRAMO
20. Viktigt att alla följer den nya arbetsmiljölagen gällande kvarts. /ALLA

Figure 5.6 Weekly protocol

The data collected from the construction workers regarding weekly protocol are shown in the figure 5.7. There were totally eleven surveyors participated in this survey. Most of the workers claimed that the weekly protocol is really useful, the information presented by the tool is understandable and feel comfortable to use it. The majority of the construction workers feels that the tool is transparent, easily understandable and advantageous to look into the updates with the aid of highlighted texts and notifies the responsible person for the specific activity. The site manager mentioned that this visual tool helps to make sure whether everybody has the same information about the project. The highlighted texts motivate the reader to read the texts and saves time for workers who follows the information regularly.

It is difficult for the new employers to follow it in the beginning as they do not have the basic overview of the project.

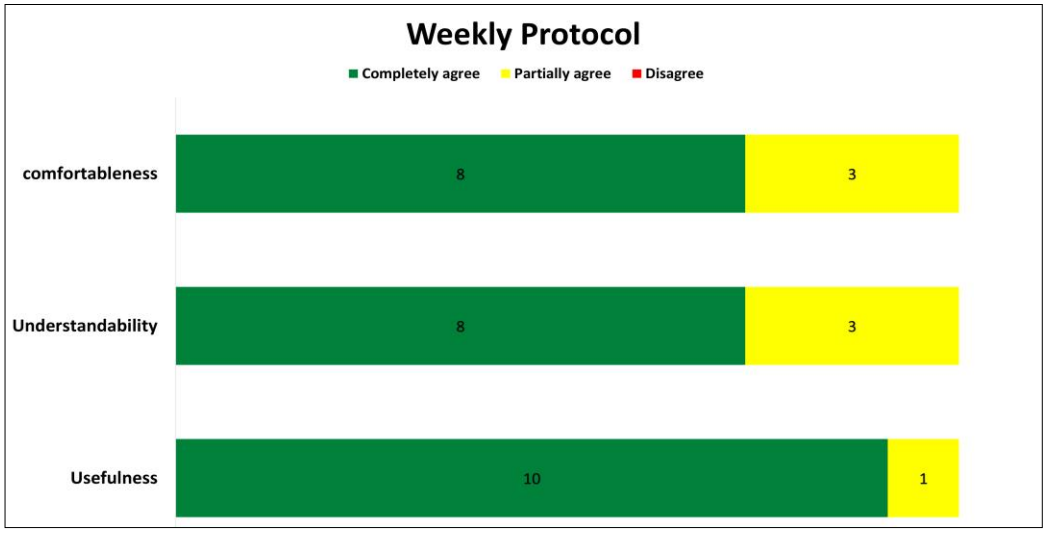


Figure 5.7 Weekly protocol- Survey results

5.2.2 Information Poster

Information poster contains information about the project activities on the right side with the photograph of the site on left side as shown in the figure 5.8 below. It is being updated every week after the weekly meeting and posted in front of the site as well as inside the site office.

Figure 5.8 Information poster

The purpose of the tool is to present the information about the progress of the project to external stakeholders i.e. to the local people and the society. The contact detail of the site manager is also presented in this tool, providing opportunity for the external stakeholders to contact the site responsible in case of emergency and need further clarification. The site manager rarely received complaints from the local residents on seeing the contact details in the information poster.

We had a quick survey with the local people and hospital workers to know their opinion and suggestion about using this kind of visual tool. The data collected is presented in the chart below showing merely three surveyors' answer. The number of people participated in the survey was six, where only 50% of the participants noticed this tool. Some people mentioned that the tool is really useful to get an idea about what is happening in the project. Alike it is sometime hard for them to understand the technical details mentioned about the project.

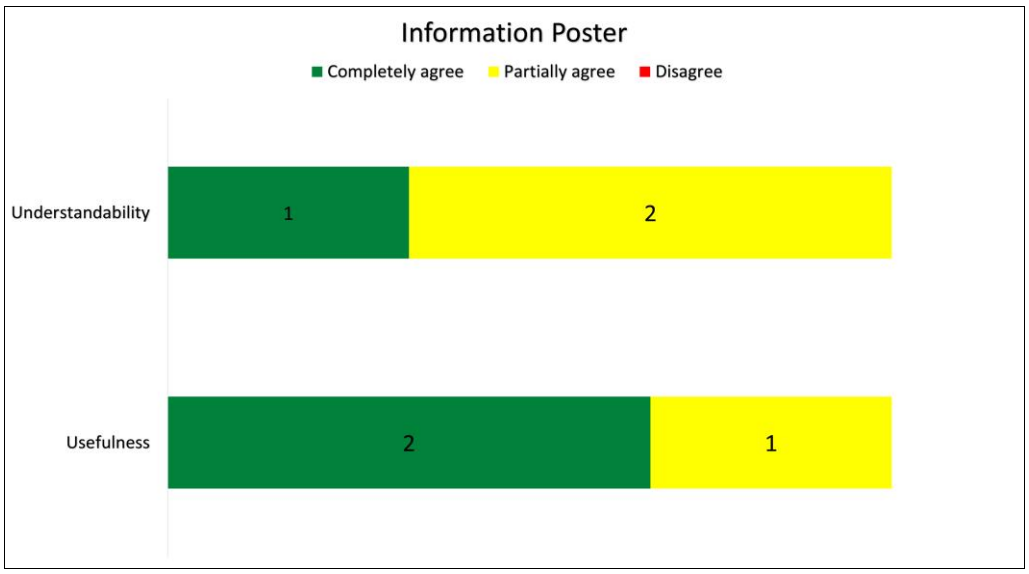


Figure 5.9 Information poster- Survey results

5.2.3 Accident report

Accident report generally keeps track of accidents and risks observed in the project. In case 10, it is reported in a different way through VDC as shown in the figure 5.10 below. The report marks the incident, accident and risk observation zones in the project with three different colors in the sketch up drawings. Health and safety supervisor takes the responsibility to collect the relevant data from various construction workers and incorporate the data in the drawing with the help of VDC coordinator. For example, if too many risks are noted in particular area of the site then the circle for the risk observation will be bigger. This indicates that the zone is risky and needs extra care and attention for maintaining health and safety environment.

The number of people surveyed relating to this tool is comparatively less than the other tools due to less availability workers at the time of visit. The respondents mentioned that the tool is really helpful by making easy for them to understand the accident and risk prone zones on-site. The color helps to understand the conveyed information properly, overcoming the language barrier.

The health and safety supervisor mentioned that for handling complex projects involving workers from more than twenty different nationalities, indeed these kind of tools are helpful to enhance health and safety in the work environment. It makes communication easier and motivates workers to come up with the incidents report (a report where the workers mention the date and place of incident happened with short description). It indirectly builds trust within the workers that their complaints are taken into account by the top management. The willingness and knowledge to work with these kind of tools impose a challenge for implementing it effectively.

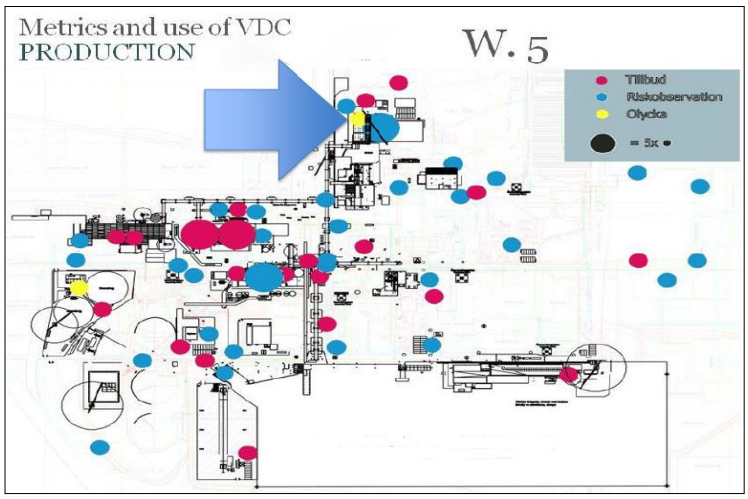


Figure 5.10 Accident report using VDC

5.2.4 Videos

Videos is one of the interesting visual tool that is being used to demonstrate how the lifting has to be done considering the position of crane and other factors. VDC coordinator makes these videos using computer software like Navisworks with the help of project supervisors as shown below.

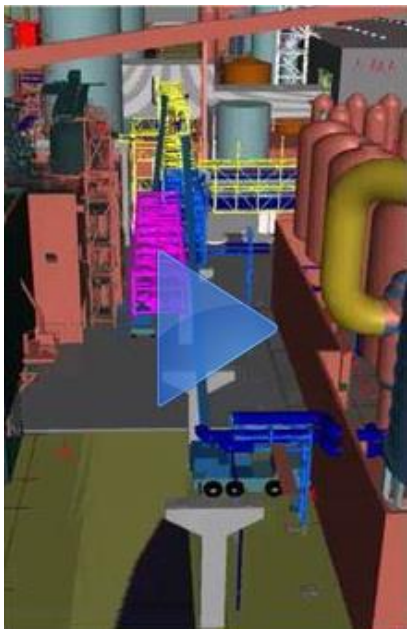


Figure 5.11 Videos

The supervisor mentioned that the use of videos is really important for ensuring whether everybody in the project has the same vision. Videos helps to understand even the complex matter in an easiest and simplest way. It reduces misunderstandings and mistakes within the project. From practical point of view, these kind of tools proved to be useful especially in the big projects in order to overcome language barrier and to effectively manage the complexity involved. During discussion meetings, videos provide opportunity for the co-workers to visualize the actual work and thus helps to identify the mistakes and risks thereby increasing health and safety.

For the survey, there were five participants including the VDC team and co-workers. Most of the participants claimed that the tool is highly useful, understandable and comfortable to work with as shown in the figure 5.12. Sometimes, it is hard to rely on videos 100% as the model cannot be exactly the true representation of the actual work. But videos offer guidance and can be used as a first approach to solve a given problem.

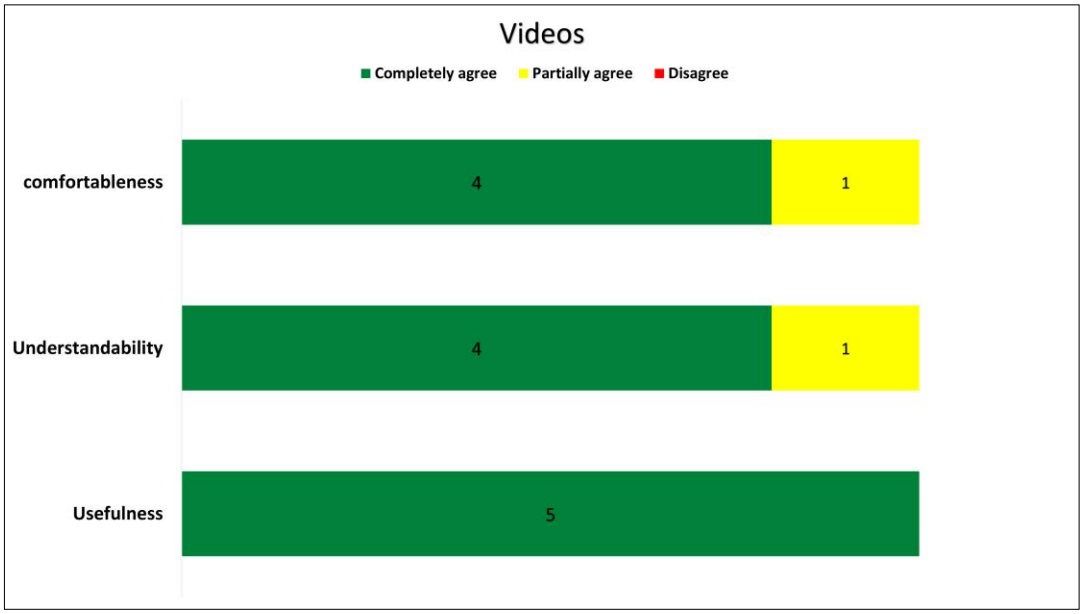


Figure 5.12 Survey results - Videos

6 Findings and Discussion

The results obtained from our study is analysed and compared with the theoretical framework to come up with some findings supporting our research questions.

6.1 Visual tools identified from site visit

The visual tools seem to be used extensively in the Swedish construction projects alike construction industries in other countries. Some tools are predominantly seen in almost all the projects which provides a base to communicate the basic information about the project, standards, regulations and so on. There are visual tools which have been used uniquely or certainly in the projects, serving the purpose to communicate the information to every construction workers and as well as external stakeholders. The percentage of displaying information visually also depends on the size of the project and the attitude of the site manager. Some site managers are eager to work with new tools and rely on 3D models but it is not same with all the cases.

Information board, safety visual signs, Gantt chart representing the time plan, 2D drawings, bordering are found to be used in all the projects irrespective of size of the project. Information board is one of the most typical board which is located in the shared area. Here, the different types of information relating to the project are placed and it is being updated constantly. The following figure, Figure 6.1, shows the image of the information board that was taken during our visit. The location of the board is also plays a vital role. The board has to be placed in such a way that it is easily accessible and seen by each and every one working on the site.

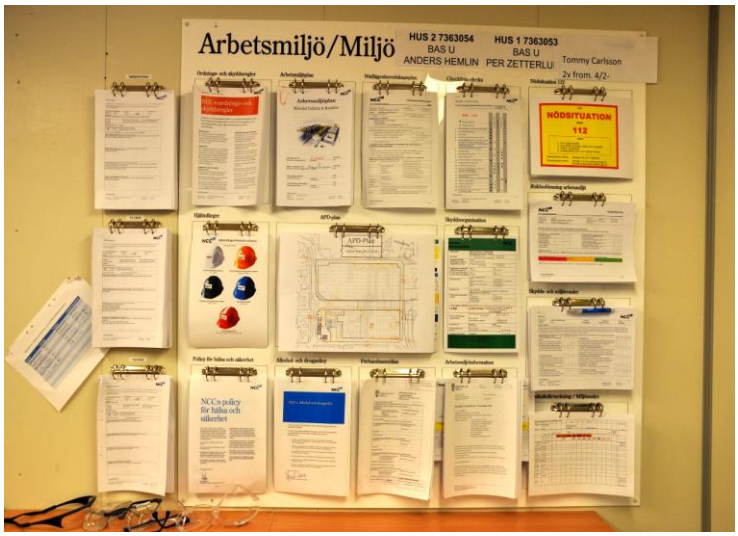


Figure 6.1 Information Board

Gantt charts, 2D drawings are very basic things that are seen in almost all the construction projects. Other than this the construction projects rely on tools like APD plan, Look ahead plan, Calendar including major events, accident report, 3D models, stock control board are used in the site office in most of our case projects. Safety signs, markings on floors or walls, bordering, 2D drawings with specifications are notable visual tools used on-site in the construction projects.

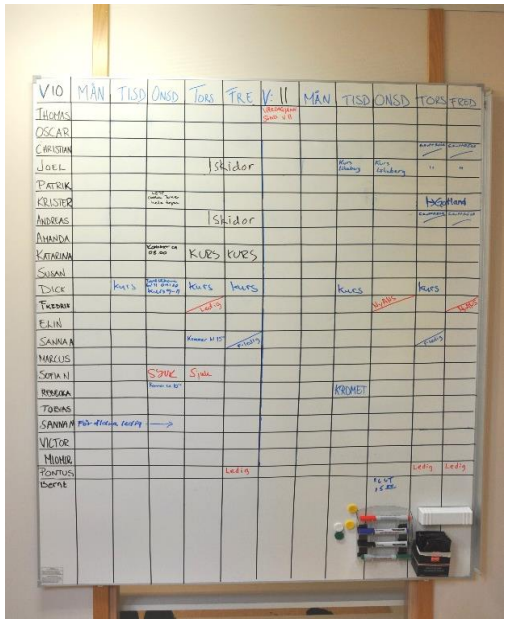


Figure 6.2 Calendar including major events

A monthly or weekly calendar including the important dates, meetings, critical events and milestones would help to increase the transparency and information flow within the project team. The weekly calendar can also be used to notify other co-workers about one's important task or event that happens within that time period. The visual tools such as look ahead plan, 3D models, visual signs that are used in the Swedish construction sector are found to be used in the Finnish and Brazilian cases too as mentioned in the theoretical background.

The importance given for maintaining healthy and safe environment in all the cases are higher, though the way of doing it differs from project to project. Figure 6.3 shows the different visual tools that are used in various projects for tracking accidents. Although the idea behind each tool is simple, they tend to serve their purpose effectively.

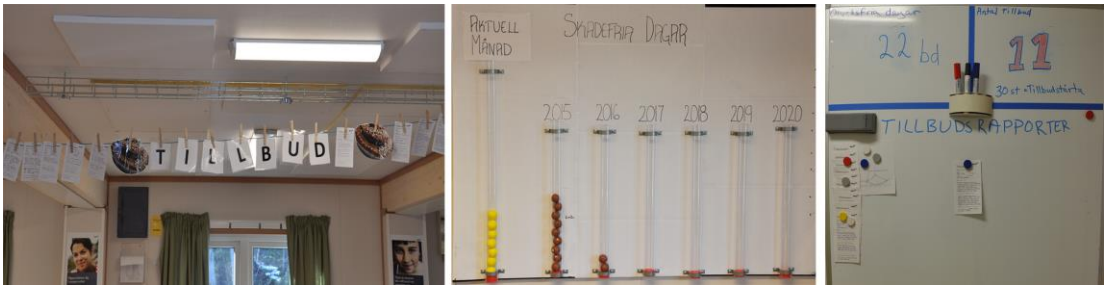


Figure 6.3 Various types of accident report

The display screens are kept in the site office for presenting the information relating to the project. Images and videos tend to grab human's attention and makes easier for them to understand the conveyed information. The use of images to present the progress of the project is an innovative and simple idea. These kind of tools help to realize the work progress on-site by looking at a glance. The use of oculus rift to visualize the model is seen only in the large projects but it can be used fully to its potential.

Figure 6.4 Oculus rift (on top) and Display screens (on bottom)

For logistics and material handling the use of APD plan and stock control board seems promising irrespective of size of the project. The APD plan is the site management plan in which the 2 D drawings are used to show the important things around the site such as storage area, container, waste disposal container, entrance for trucks, logistic route and so on. It is being updated consequently with the progress of the project and it is posted inside the site office, on-site and also in the reception to guide the construction workers and truck drivers. The use of stock control board is prominent in large and medium projects that involves huge quantity of materials handling such as pre-cast elements and other construction materials. It will be even useful in small projects to handle materials effectively. The stock control board also includes the delivery date, order date and who is responsible for the task helping to avoid misunderstandings.

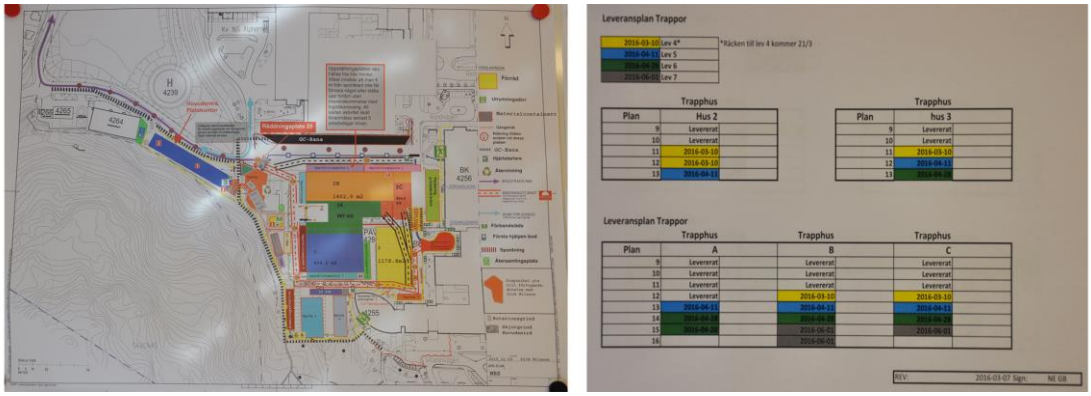


Figure 6.5 APD plan (on left) and Stock control board (on right)

On-site, the markings on the floors and walls act as a guidance to the worker thus avoiding errors and mistakes. 2D drawings with specification are useful when a lot of customization needs to be taken care in the project. For example, the client might have requested for different flooring material for specific area. In that case this kind of visual tools reminds the worker about the change thereby eliminating the need for supervision and reducing the possibility of making errors.

Figure 6.6 Markings on wall (on left) and 2D drawings with specification (on right)

There were some unique visual tools that are found to be used in the Swedish construction sites such as Videos, VDC in health and safety, information board for external stakeholders, using sticky notes over the drawings during meetings and highlighting newly added texts in the weekly protocol.

In our cases, the small projects had comparatively less number of visual tools than the larger and medium projects. The necessity of visual tool increases as the project size and complexity increases. The small projects prefer to follow the basic guidelines set by the company and are not ready to use visual tools much. This is due to the fact that the small projects involve less workers and communication is made easier through direct conversation either face to face or through phone calls. The visual tools in general help to eliminate the language and cultural barriers which is one of the complex issue that needs to be taken care of in most of the large scale construction projects.

6.1.1 Stakeholder-Visual Means Mapping

For supporting the answer for our first research question, the Stakeholder-Visual means mapping is done in order to distinguish the visual means with respect to the target group (Internal and External stakeholders). The mapping is done purely based on the data collected from our study. The main stakeholders noticed during the site visit are only considered in this mapping. They are suppliers, sub-contractors, local residents and society, construction workers and construction project management team (contractor, architect, client).

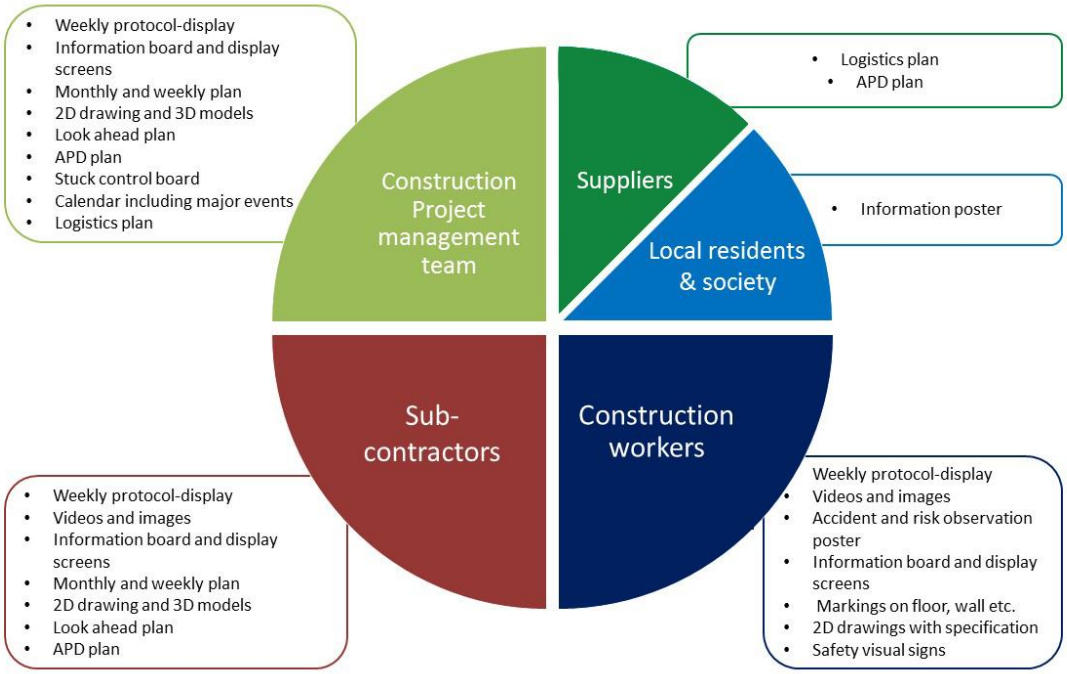


Figure 6.7 Stakeholder- Visual Means mapping

6.1.2 Theory vs Practice

The tools described in the theoretical section are not really the same as used in the Swedish construction projects. There are some identical tools used in real time practice as mentioned in the literature along with some of the remarkable and unique tools discussed in the previous section. The purpose behind using the visual means remains same, though the way of representation differs from project to project.

For creating and transferring knowledge effectively through visualisation the five perspectives has to be taken into account: content, purpose, target group, communicative situation, method (Eppler & Burkhard, 2007). The visual tools that are designed according to Eppler's perspective meet the necessity of using the particular visual tool. If any of the five perspectives is not satisfied, then the visual tool will not serve the purpose that has been meant for. For example, in the case of information poster, though the tool was useful and informative, it was not noticed by all the local residents and hospital workers. The purpose of the visual tool is not met since the tool fails to address the respective target group due to improper method chosen for presenting the information.

The functions of visual management are: transparency, discipline, continuous improvement, job facilitation, on-the-job training, creating shared ownership, management by facts, simplification and unification (Tezel, et al., 2011). The tools identified in this thesis work are transparent which is evident from the results obtained from the detailed case study (i.e. comfortamble, understandable). Though the other charecteristics of visual means are not directly measured, it indirectly emphasis the nature of discipline, continuous improvement, simplification, unification and so on by adressing the benefits mentioned in the theoretical part.

Communication in the implementation phase has to be monitored critically as it involves large number of stakeholders throughout the process (Dainty, et al., 2006). In our cases, the small projects had comparatively less number of visual tools than the larger and medium projects. The necessity of visual tool increases as the project size

and complexity increases. The small projects prefer to follow the basic guidelines set by the company and are not ready to use visual tools much. This is due to the fact that the small projects involve less workers and communication is made easier through direct conversation either face to face or through phone calls. The visual tools in general help to eliminate the language and cultural barriers which is one of the complex issue that needs to be taken care of in most of the large scale construction projects.
Additionally, during our study we identified that the attitude of site managers also really matters when considering the level of usage of visual tools from project to project. This is clearly evident from the result (refer table 1) obtained from the level of information availability. Some project managers will be ready to explore new techniques to improve information flow within the project whereas others will try to work within their comfort zone tending to avoid exploring new techniques.

6.2 Identification of success factor and gaps in using Visual tools

The tools studied in the detailed case study gave a deeper understanding about the tool from the perspective of end users (i.e. construction workers, local people, society) and as well as site manager's perspective. Most of the identified success factor matches with the benefits of using visual means that are being mentioned in the theoretical part of the study. Some of the success factors for using the visual tools are mentioned below.

- Overcomes language and cultural barriers
- Easy to understand the conveyed meaning and reduce misunderstandings
- Makes communication easier, clear and motivates the reader to read the presented information
- Visual tools help to increase the collaboration
- Everybody involved in the project will have same information and vision
- Tools such as videos, BIM models helps to identify and avoid the risks before it happens in the project
- Getting more benefit with the use of simple techniques
- It helps to handle the complex projects effectively
- The use of visual tools saves time thereby saving money

Always there exist challenges and gaps while working with any tools and techniques. Some of the gaps identified in our work is listed below,

- Lack of training and knowledge about using 3D models and software's
- Lack of willingness and trying to work in their comfort zone due to generation gaps
- Difference in usage of visual tools from project to project
- Attitude of site manger influences the usage of visual tools in each project. For instance, some site manger prefers to work with traditional systems, some feels comfortable to work with 3D models and so on
- Less focus given to usage of visual tools in smaller projects
- Sometimes fails to check whether the purpose of the tool is up to the mark. For example: dislocation of tool, over or less information

- The type of usage of tools varies from country to country i.e. the tools used in the Finnish and Brazilian cases are not same in the Swedish construction industry

7 Recommendations

The following recommendations can be used a mean to overcome the gaps described in the previous section,

- Training programs on how to work with VDC and other software based tools provides a platform for employees to learn and would help to overcome the knowledge gap
- Teaming experienced employee with newly graduated employees would create a win-win situation by knowledge transfer. For instance, the youngsters will have good computer knowledge and aware of new technologies whereas the experienced employees will have good and sound command over the practical and technical knowledge. By combining them together in a team helps to balance and overcome the generation and knowledge gap
- The location of the tool and size of the visual poster should be checked properly for serving the best purpose of using Visual tools
- Standardizing the use of visual tools irrespective of size and nature of the construction projects i.e. the list of visual tools and their benefits can be included in the company's guideline for creating awareness among site managers regarding the use of visual tools

8 Conclusion

This study highlights and presents the various types of visual means that are being used in the Swedish construction projects. It is identified that some tools are commonly used in almost all the projects and there are also certain unique tools that are being used in some projects. The factors such as size of the project, type of the project, attitude of managers, lack of knowledge etc influences the extent of using visual tools in the construction projects. The success factors and gaps in working with these tools are also mentioned in this study, complementing our research questions. Considering the success factors of visual tools, it is evident that the visual tools support in enhancing the information flow between various stakeholders by overcoming communicational barriers. It provides a positive answer for our second research question. The gaps and challenges has to be monitored and improved further for making more benefit out of using visual tools to improve communication within construction projects. Improvements can be done by considering the recommendations mentioned below to augment the purpose of using visual tools in the construction projects.

9 Possibilities for further research

This thesis focuses on the type of visual tools that are being used in the Swedish construction industry and primarily focuses on how these tools can be used in enhancing the information flow between various stakeholders. The study can be extended by looking into more construction projects and also studying other characteristics of visual tools like collaboration, transparency level etc.

Other visual tools that are highlighted in the study can be studied in detail to identify the success factor and barriers of using it in the construction projects.

A project can be set as a prototype utilizing the visual tools to greater extent in all the disciples within the project throughout the project lifecycle. The recommendation from the study can be tested practically. The characteristics of visual tools can be tracked throughout and improvements can be made instantly till the purpose of using the visual tool reaches its full potential. This project can be further used as a benchmark for the upcoming projects to attain maximum benefit of using visual tools.

The use of visual tools like VDC in the large versus small projects can be studied as there is always a misperception that VDC is best suited for larger complex projects.

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11 Appendix

11.1 Appendix I - Visualization characteristics checklist

	Checklist -Evaluation of the Visualisation Characteristics						
S.No		Low	Limited extent	More than 50%	More than 75%	High	Comments
1	**Transparency level**						
	In site office						
	On site						
2	**Information flow(Right informtation to right people)**						
	Between top management and Site managers						
	Between site managers and construction workers						
	Between various sub-contractors						
	With external stakeholders (society and local residents)						
3	**Level of colloboration**						
	Between top management and Site managers						
	Between site managers and construction workers						
	Between various sub-contractors						
4	**Level of information availability**						
	About project						
	About standards/quality						
	About health and safety/risks						
	About Work plan						
	About logistics and material handling						
	To construction workers on site						
5	**Information availability on changes and updates (Schedule, drawings, APD etc)**						
6	**Location of Visual tools/boards (notable/accessible)**						

11.2 Appendix II - Visual tools checklist

Checklist - Measure of Visualness in Construction site							
S.No	Tools/Items to be noted visually	Not implemente	Limited extent	More than 50%	More than 75%	Fully implemented	Comments
	Site office:						
1	3D Models and 4D models						
2	2D Drawings and printing						
3	Information Board						
4	Look ahead plan/ colloborative board						
5	Weekly work Plan						
6	Time plan						
7	Gantt chart						
8	Pictures/ Images						
9	Team structure						
10	Change order list						
11	Saftey posters/boards						
12	APD plan						
13	Decision list						
14	To and from matrix / Boards for raising questions/(Knäckfrågor)						
15	Calender (including major events)						
16	Logistics plan						
17	Colour codes/sticky notes						
18	Quality standards posters						
19	Enviromental standards poster						
20	Accidents Report						
21							
22							
	On site:						
23	Markings on floors/wall						
24	Bordering						
25	Safety signs (mobile signs/ boards)						
26	3D Models and 4D models						
27	Change order list						
28							
	Materials storage/ delivery:						
29	Material tags/technical specification stickers						
30	Colour codes						
31	Prototyping						
32	Just-in time						
33	Stock level/contrrol board						
34							
	Virtual design and construction						
35	Oculus rift						
36	BIM models and drawings						
37	VDC in health and safety						
38	Videos (for handling materials,equipments and so on)						
39	**Entrance (Check point for trucks etc)**						
40	**Standardisation of workplace elements**						

11.3 Appendix III - Interview questions: Initial Site Visits

For Site Managers/ Supervisors

1. What is your role/task in this project?
2. What method (type) of construction do you use in this project?
3. What kind of visual tools are you using for enhancing better communication and collaboration on site?
4. Do you use VDC (virtual design and construction)? If yes, how comfortable it is for you to work with?
5. How the directives/codes/ standards set by the top management have been communicated to the employees working on site?
6. Do you use any Visual means for communicating with sub-contractors? If yes, what type of tools you are using?
7. How often are the meetings conducted and how long does the meeting generally last?
8. What are the things you discuss during the meeting?
9. How do you document the information/issues discussed during the meeting?
10. Do you have any language barrier for communicating with construction worker?
11. What are the parameters that help in successful implementation of visual management in the construction environment?

11.4 Appendix IV – Questionnaire: Detailed case study

For Construction Workers

1. Name and division/ Namn och avdelning :
2. Do you think this tool is useful? / Tycker du detta verktyg är användbart?
   - □ Disagree/ Håller inte med
   - □ Partially agree/ Håller med delvis
   - □ Completely agree/ Håller med fullständigt
3. Does the information provided is clear and understandable? / Är informationen som föreskrivs tydlig och förståelig?
   - □ Disagree/ Håller inte med
   - □ Partially agree/ Håller med delvis
   - □ Completely agree/ Håller med fullständigt
4. Are you comfortable in working with this tool? / Är du bekväm I att jobba med detta verktyg?
   - □ Disagree/ Håller inte med
   - □ Partially agree/ Håller med delvis
   - □ Completely agree/ Håller med fullständigt
5. What is your opinion about the tool (advantages, disadvantages or some suggestions for improvement? / Vad är din åsikt om verktyget (fördelar, nackdelar eller några förslag på förbättring)?

11.5 Appendix V - Interview questions: Detailed case study

For Site Managers/ Supervisors

Videos/ weekly protocol/ VDC in health and safety

1. How does this visual tool help to communicate the information in a better way?
2. What are the advantages and/ or disadvantages of using this tool?
3. In general, what is your opinion about using visual tools in the construction projects?

Information Board for External stakeholders

1. How does this visual tool help to communicate the information in a better way?
2. Does anyone have contacted you before? If yes, Can you explain the discussion?
3. What are the advantages and/ or disadvantages of using this tool?

11.6 Appendix VI – Questionnaire: Detailed case study

For External Stakeholders

1. Have you ever noticed this poster before? / Har du noterat denna affisch forut?

Yes / Ja

No / Nej

2. Do you think this tool is useful? / Tycker du detta verktyg är användbart?

Disagree/ Håller inte med

Partially agree/ Håller med delvis

Completely agree/ Håller med fullständigt

3. Does the information provided is clear and understandable? / Är informationen som föreskrivs tydlig och förståelig?

Disagree/ Håller inte med

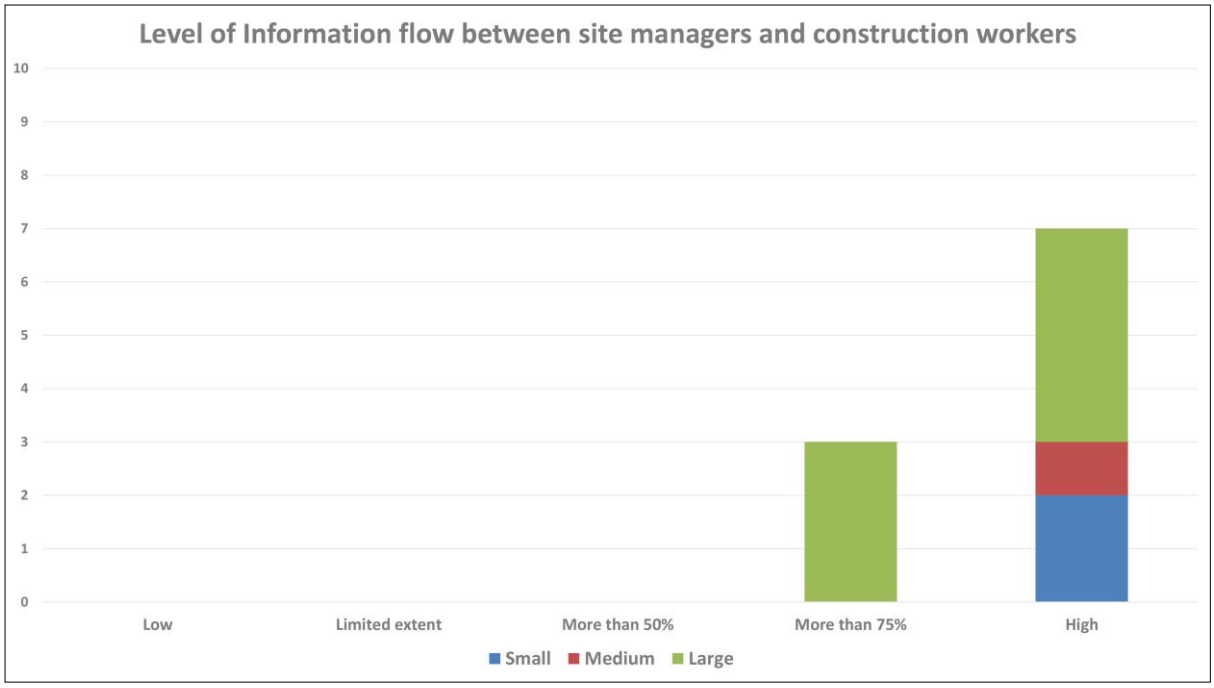
Partially agree/ Håller med delvis

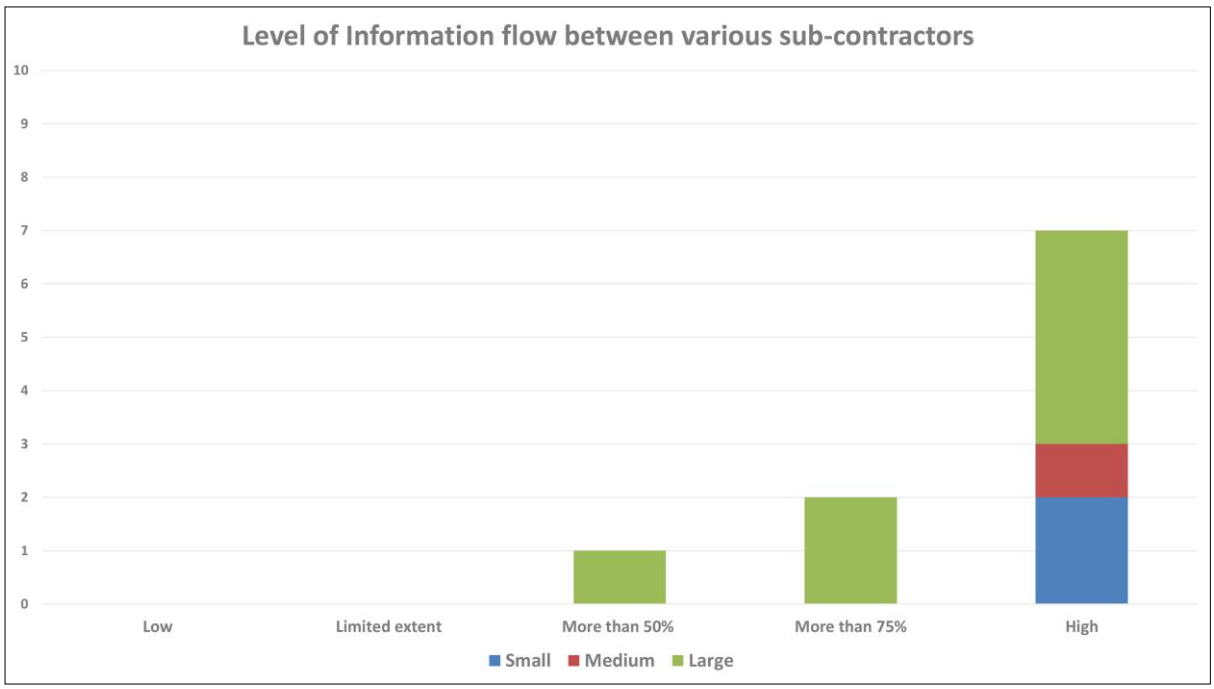
Completely agree/ Håller med fullständigt

4. What is your opinion about the tool (advantages, disadvantages or some suggestions for improvement? / Vad är din åsikt om verktyget (fördelar, nackdelar eller några förslag på förbättring)?

11.7 Appendix VII - Characteristics of visualization

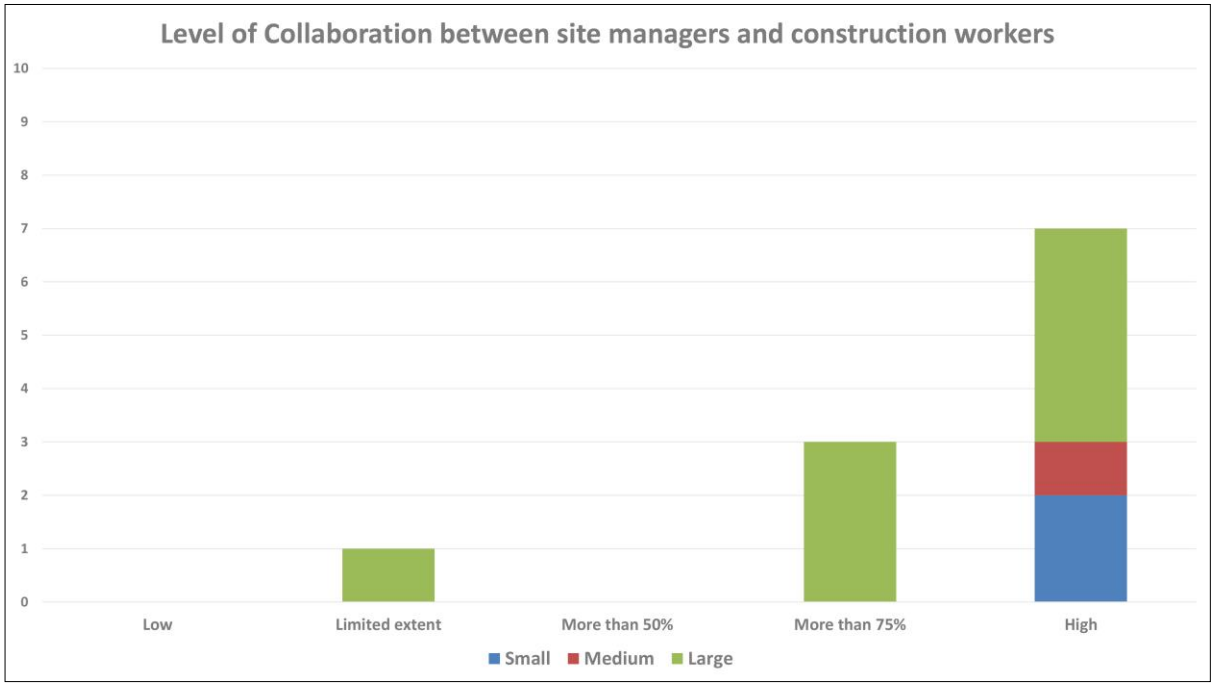
Level of information flow- Graphs

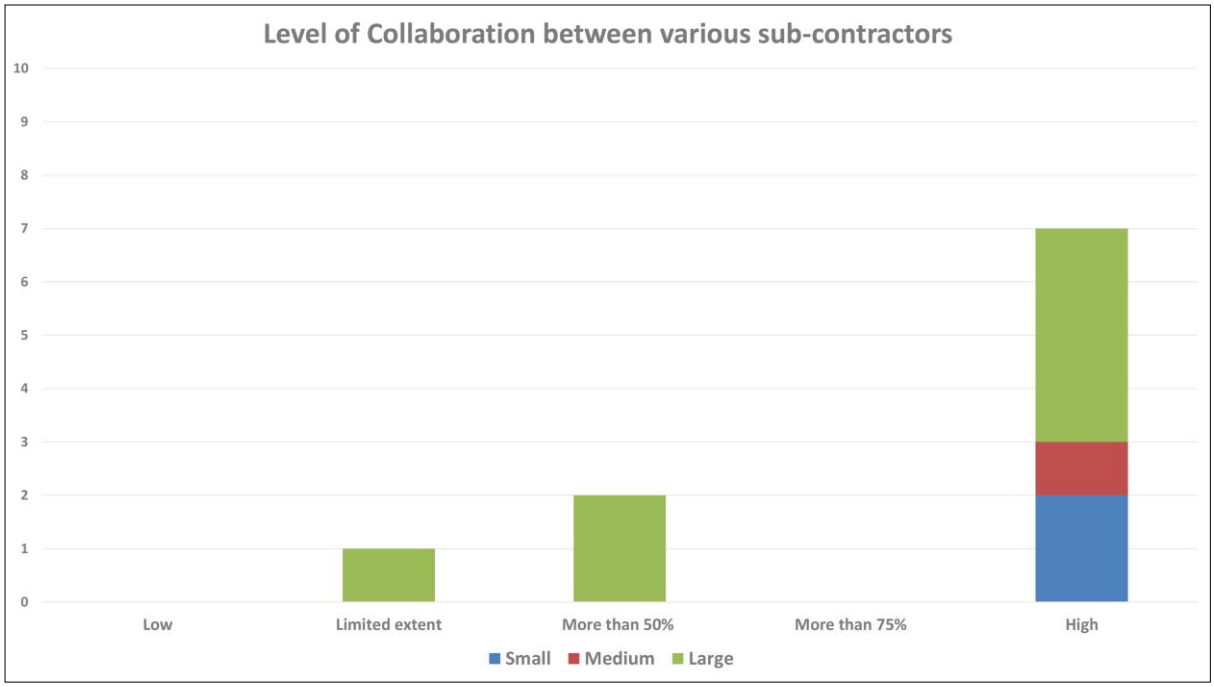




11.8 Appendix VIII - Characteristics of visualization

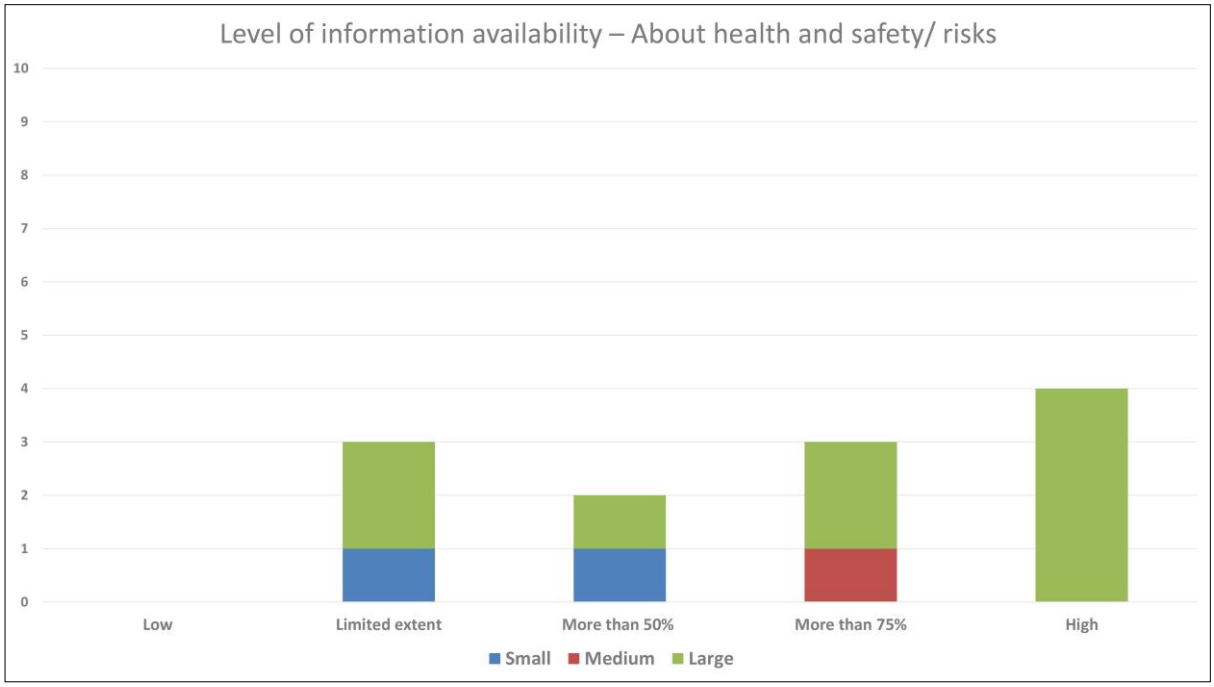
Level of Collaboration- Graphs

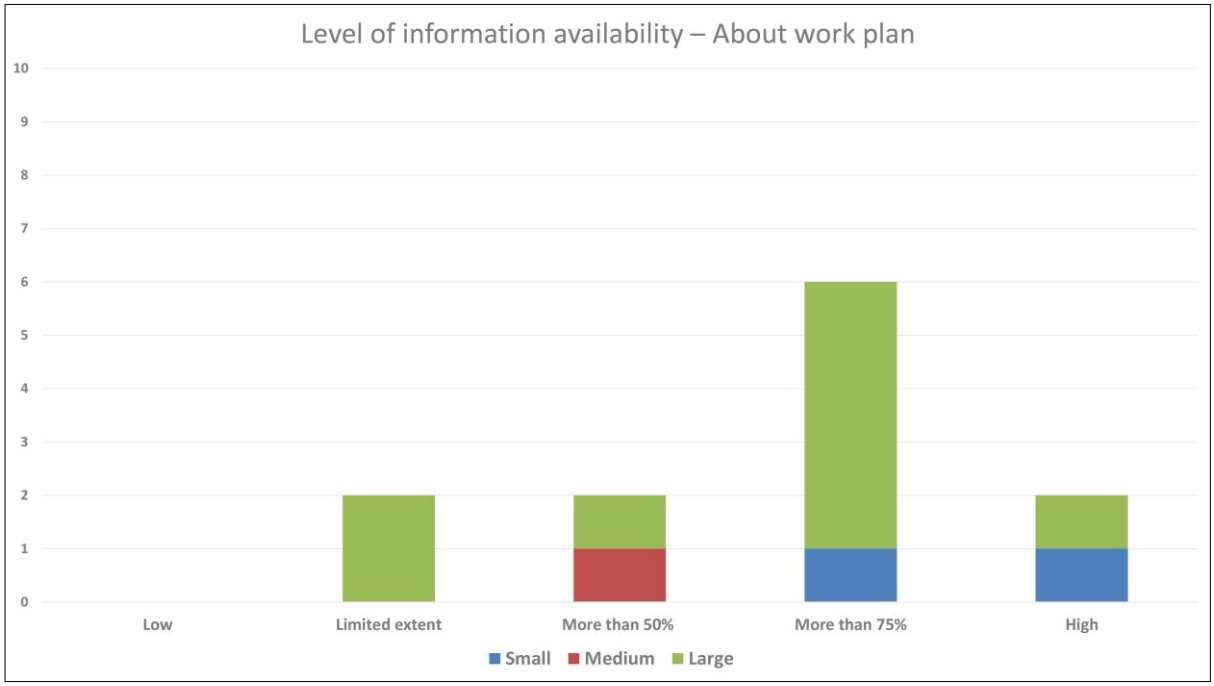


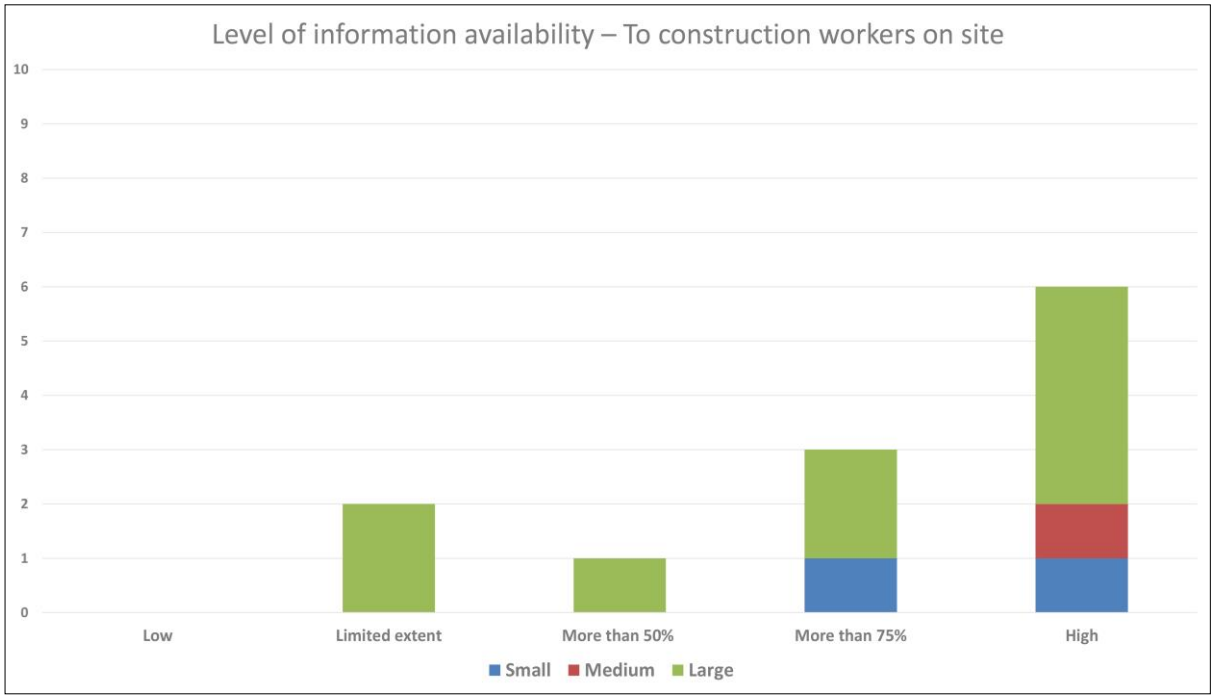


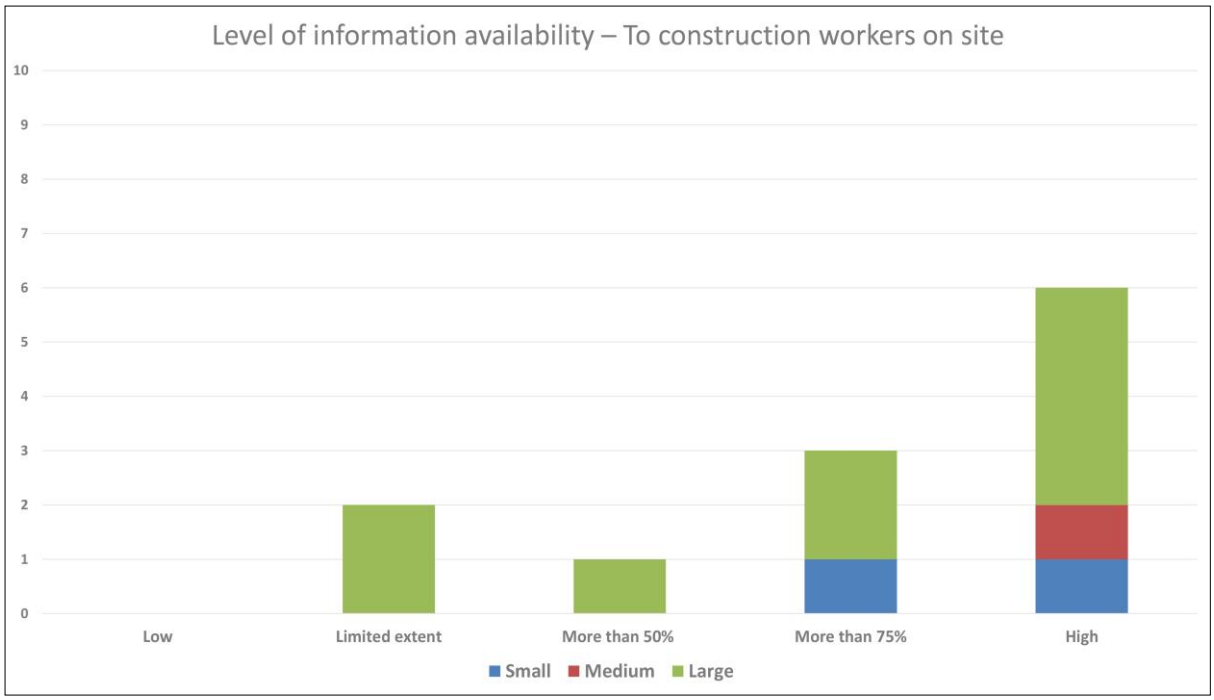
11.9 Appendix IX - Characteristics of visualization

Level of Information Availability- Graphs






Level of information availability – To construction workers on site
10
9
8
7
6
5
4
3
2
1
0
Low
Limited extent
More than 50%
More than 75%
High
Small
Medium
Large


Level of information availability – To construction workers on site
10
9
8
7
6
5
4
3
2
1
0
Low
Limited extent
More than 50%
More than 75%
High
Small
Medium
Large