TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

KATI KONTIO

MOBILE SAFETY MANAGEMENT TOOLS IN CONSTRUCTION

Master of Science Thesis

Examiner: professor Kalle Kähkönen
Examiner and topic approved by Faculty of Business and Build Environment council on January 4th, 2017

ABSTRACT

KATI KONTIO: Mobile safety management tools in construction
Tampere University of Technology
Master of Science Thesis, 57 pages, 2 Appendix pages
January 2017
Master's Degree Programme in Civil engineering
Major: Construction production
Examiner: Professor Kalle Kähkönen

Keywords: occupational safety, safety observation, construction, mobile application, mobile device

The vast development of mobile technology is driving the development of mobile solutions for construction. The pressure for mobile development and improvement in productivity is leading to different solutions in construction site management. New solutions and software are being released internationally but the problem is to find suitable solutions for Finnish construction site management. Furthermore, the fact that construction is one of the most dangerous fields in the world sets some needs for the development of the technology. This research aims to find suitable mobile solutions for safety management and improvement in Finnish construction sites.

Finnish safety management procedures are considered unique worldwide. Legislation and regulations are guiding the safety management in Finnish construction sites and the amount of paperwork has increased over the years. This study introduces ways to safety improvement and legislative practices in Finnish construction culture. The bases of mobile technology and mobile applications for construction work are evaluated and suitable features, benefits of mobile technology and different solutions for safety purposes available are introduced. The study presents an example of mobile solutions for safety observations in construction. The application is introduced and all of the features and functionalities are evaluated. The application is tested in a real-life construction site and interviews concerning the use and contents of the application are discussed with the construction company and software developer. The goal is to be able to launch this application for safety observations into further use in this company.

The conclusions based on the case study of safety observation application were pointing out that the application itself is ready for use. However, lots of discussions concerning certain features were pointing out some problems with the user interface and further processing of the observations. These defects have been corrected in order to launch the application at the end of year 2016.

TIIVISTELMÄ

KATI KONTIO: Rakennustyömaan työturvallisuuden hallinnan mobiilityökalut
Tampereen teknillinen yliopisto
Diplomityö, 57 sivua, 2 liitesivua
Tammikuu 2017
Rakennustekniikan diplomi-insinöörin tutkinto-ohjelma
Pääaine: Rakennustuotanto
Tarkastaja: professori Kalle Kähkönen

Avainsanat: työturvallisuus, työturvallisuushavainto, rakentaminen, mobiiliapplikaatio, mobiililaite

Mobiiliteknologian nopea yleinen kehittyminen ohjaa teknologian kehittymistä myös rakennusalalla. Paine mobiiliteknologian kehittämiselle ja tuottavuuden parantamiselle tuottaa nykypäivänä paljon erilaisia sovelluksia myös rakennustyömaan hallintaan. Paljon sovelluksia ja erilaisia ratkaisuja lanseerataan kansainvälisille markkinoille, mutta näiden sovellusten sovittaminen suomalaiseen rakennuskulttuuriin on välillä hankalaa. Ongelmana onkin löytää oikeanlaiset sovellukset suomalaisiin käytänteisiin. Tämä tutkimus pyrkii löytämään soveltuvia mobiiliapplikaatioita turvallisuuden hallintaan ja kehittämiseen rakennusalalla.

Suomalainen lainsäädäntö ja säädökset ohjaavat turvallisuuden hallintaa rakennustyömailla ja lainsäädännön kiristyessä myös erilaisten raporttien määrä on noussut. Tässä työssä esitellään lainsäädännön ja työturvallisuuden parantamisen asettamat tavoitteet ja käytännöt rakennusalalla Suomessa. Työssä esitellään lisäksi mobiiliteknologian perusteita ja arvioidaan erilaisten mobiilisovellusten toimintaa rakennusalalla. Soveltuvat ominaisuudet, mobiiliteknologian hyödyt sekä erilaiset sovellukset turvallisuuden hallintaan esitellään työn teoriaosuudessa. Työn tapaustutkimuksessa on keskitytty löytämään mobiilisovellus rakennustyömaan työturvallisuushavaintojen tekemiseen. Havainnointiin valikoitunut sovellus esitellään, ja sen erilaisiin toiminnallisuuksiin tutustutaan sekä niiden arviointi suoritetaan tapaustutkimuksessa. Sovelluksen toimintaa testattiin rakennusliikkeen työmailla Suomessa testijakson aikana, ja käyttäjätietoa kerättiin työmailta haastattelujen avulla. Haastatteluissa keskityttiin pääosin sovelluksen käyttökokemuksiin ja turvallisuushavainnointilomakkeen sisältöön. Testauksen tavoitteena on julkaista havainnointisovellus laajempaan käyttöön rakennustyömailla Suomessa.

Case-tutkimuksen perusteella saadut johtopäätökset osoittavat, että sovellus on valmis käytettäväksi. Tutkimuksessa havaittiin muutamia ongelmia käyttöliittymässä ja havaintojen analysoinnissa, joista on keskusteltu ohjelmistokehittäjän kanssa. Sovellus on tarkoitus ottaa laajempaan käyttöön rakennusyrityksen työmailla vuoden 2016 lopussa.

PREFACE AND ACKNOWLEDGEMENTS

This thesis is written in Tampere University of Technology in the programme of civil engineering. The research is conducted at VTT Technical Research Centre of Finland in the research project called DRUMBEAT, which aims to develop new ICT solutions for distributed publication and utilization of building information models on the web. I would like to thank VTT for this opportunity to put my thesis into practice. Markku Kiviniemi has provided me valuable help and guidance during this project.

Another party in this research project was Skanska Oy, and I got to study their way of safety management very close. I want to thank especially Mari Korpela and all of the staff members with whom I was able to discuss the case study of this project. I furthermore want to thank Insta Audit and Antti Lehtomäki for showing so much interest towards my study of their mobile application.

The process of this thesis was not easy and there have been times when I have doubted if this work will be finished. I want to thank especially Kimmo for all the support he has given during this time and all the proposed settlements that I needed to keep on going with this thesis. My good friend Jenni has provided invaluable help in the final stage of this thesis. I also want to thank my friends from the TUT who have always had enough humor to deal with my “eternal project” of graduation. I am grateful for all of the support I have received during the years. Last thank you goes to my parents who have enabled me to study this far and always believed in my success.

The long process is now over and the future leads to the real challenges.

Tampere, 18.1.2017

Kati Kontio

CONTENTS

LIST OF KEY CONCEPTS AND TERMS

Occupational accident	Accidents occurring at the workplace
Occupational disease	Harmful effects of work that are not due to an accident, such as over-exertion injuries, allergies or hearing complaints
Commuting accident	Accident occurring on the way to or from the workplace
Safety level inspection	Finnish method of measuring safety at site, a legislative operation.
Safety observation	An observation at construction site, that relates safety of the working environment.
ICT-technology	Technology that controls both information and communication
Mobile application	Wireless and with mobile device controllable software
Mobile device	A handheld and compact computer or other electronic device such as a tablet or smartphone that contains a user interface and applications.

1. INTRODUCTION

As the technology is developing and new software solutions are being invented the pressure of ICT development is getting bigger also in the field of construction. For example building information models are used as a tool for structural modeling as they provide more detailed information about the building than 2D layout and other procedures are also transferred into the digital time. Mobile devices and software solutions are a new form of ICT development in construction and the need of their utilization is driving the development of mobile tools for construction sites. This development has brought up mobile devices as a part of construction projects as tools for viewing designs as well as management. The mobile devices are relatively new phenomena in construction sites and the digital development around this field is behind average. More effective new solutions and new software are being tested in many companies through different development plans and digitalization is one of the new trends through the whole industry.

Construction has always been one of the most hazardous industries concerning occupational safety. Laws and regulations for safety have been drastically increased and occupational safety has become one of the most important development fields. Safety issues are being analyzed and new management and information solutions are being invented. Different kind of mobile based solutions are considered to improve productivity in general but many of the features can be used specifically for safety issues. Also, the mobile technology is offering more transparent and effective ways to store and distribute information in construction projects and these features can also improve safety development in construction.

1.1 Objectives

Objective of this thesis is to analyze new possibilities to support safety by using mobile devices. By utilizing mobile devices many of the safety procedures can be more effective and better results can be achieved. The main objective of this thesis is connected to recognizing promising solutions and the features that promote safety, especially by analyzing data. The case study of this research concentrates on finding safety observation application and analyzing suitable features for safety and production effectiveness.

The main idea behind this research is to produce information through mobile observations and to help software development for safety management purposes. The main fo-

cus is to find relevant information for safety observations and future improvement through safety information collection at site. The mobile tools for the safety management and other safety related purposes will be tested and categorized in order to help finding suitable tools for different needs of safety management.

1.2 Research questions

This research aims to answer following questions about utilizing mobile devices for safety management in construction environment:

- What kind of value do mobile devices offer in collecting safety information at construction site?
- What kind of software solutions are used for construction safety purposes?
- What qualities are essential for mobile safety observations and software for safety observations?
- What kinds of safety observations are relevant in case of producing further guidance?

1.3 Research methods

The research methods for this thesis consist of a literature study and a case study. The literature study contains literature search from terms *safety in construction*, s*afety indicators* and *mobile devices in site operations*. The term *safety observation* is described based on a literature study in Finnish construction culture.

The case study is executed on the safety observation software in collaboration with a construction company and a software developer. The safety observation software is tested in construction site environment and interviews concerning the test period are executed in order to collect user feedback and proposals for improvement. The research aims to answer the research questions presented in the sub-chapter 1.2 based on the literature study and discussion. The conclusions are made based on the research data collected in interviews and discussions.

Results of this thesis are based on a literature study and case-study with interviews. The case study is executed in collaboration with construction company Skanska and software developer Insta Audit. New innovative ideas of utilization of building information will be collected and analyzed. The goal is to characterize mobile safety management in construction site.

1.4 Structure of the research

The structure of the research is divided into literature study and case study. The literature study concentrates on safety in construction, mobile devices and safety observations in Finland. The safety in construction part firstly describes the situation in construction compared to other branches and provides statistic about the safety indicators in Finland. This part also explains the Finnish method of dealing with safety in construction and presents the most common indicators that safety is measured with nationally. The second part of the literature study concentrates on mobile devices and software. The section describes what kind of software is available in safety management and related purposes. The third section aims to explain the process of safety observations in Finnish construction culture.

The case study part of this research concentrates on testing the selected software for safety observations. First the software is introduced and test period is described. The findings of the interviews are introduced and possible deductions are made based on the interview information. Finally, the conclusions of the study are introduced and possible deductions and future applications are described. Furthermore, the success of the study is reviewed.

2. SAFETY IN CONSTRUCTION

Safety has become more and more important development area in Finnish construction culture over the last decade. Many of the construction companies have developed safety management systems and practices in order to achieve zero accident rates and to improve conditions at construction sites. The development around the subject of safety management continues with different kind of research around the area. Also, the Finnish legislation strongly controls conditions and safety culture at working places by many laws and regulations. The aim is to avoid inequality between different fields´ safety cultures and to guarantee a certain level of safety for all employees throughout the country. Several studies have established the link between good occupational safety and increased productivity as well as reduced costs. [Landrum et al., 2014] It is stated that safety is an investment that provides real benefits by lengthening careers of employees and preserving resources. Good safety practices and strong safety levels are promoting also company´s reputation.

2.1 General safety practices in Finland

When studying safety in the construction industry it is important to understand safety as a systematic process. The term safety culture can be seen as a multi-layered phenomenon which combines the experiences and visions of employees, social phenomena of the working community and organizational processes. [Reiman et al., 2008] By this description all organizations can maintain a safety culture at some levels. Safety culture however is a more concentrated view of the organizational culture and therefore concentrates to safety related sides of the whole concept. The three main parts of safety culture are: organizational scope, psychological scope and social processes. All of these must be taken into account when evaluating organizations´ safety.

Good safety culture means that personnel have basic qualifications to perform their job well in everyday life and that organization is jointly committed to the same basic values of safety. [Landrum et al., 2014] Safety culture is a company-wide commitment that requires the effort of all employees and possible subcontractors. For this kind of commitment safety development and management must be transparent and traceable. It is also important to understand that the safety culture is not only dependent on the actions of the administration but on those of the whole organization. [Reiman et al., 2008] Organization acts as a whole and all of the functions and elements are in interaction so that every employee can affect on safety. Good safety culture in an organization creates the

conditions for safe working environment and enables employees to take necessary actions.

Construction as a field is very concentrated on the designing processes as well as the production itself. Projects start well before the ground is broken and safety should be a part of the designing phase from the very beginning. [Landrum et al., 2014] In order to establish a safer working place, companies must take risk management into account and set the rules for safety culture in projects. By making safety as a part of everyday life in companies, risk management and organizational practices can be determined in a more precise way. This way of thinking sets the principles on safety culture in a company.

Figure 1 Good safety practices in Finnish construction culture [Tappura et al., 2015]

In Finnish construction sites the useful safety related practices are well in use. Safety is taken into account when handling management at organizational level. Good practices keep safety as a current day-to-day issue and help prevent loss of resources in the future. Some of the current actions illustrated in Figure 1 have been documented to be practical policies in keeping up a good safety culture.

First of the good safety practices in Finnish construction culture is information flow about the safety issues. It is important to address safety related issues in monthly basis in order to keep safety as a current topic. The topic can be incorporated into status meetings for example, which is a common way in Finnish construction projects. It is im-

portant to commit all of the project partners to same jointly agreed goals and safety practices and to inform all of these partners also of the safety issues. Other examples of good practices are the safety inspections and safety information distribution. By maintaining and constantly monitoring the safety levels by measuring different indicators of safety related components, companies can develop practices to ensure certain safety level in the future. The third example of a good practice is: understanding the results of accidents. The loss of resources can be very big for a company especially after severe injuries and the most important thing is to get perspective on the issue and work on preventing all accidents. The fourth and most relevant of the examples is good orientation procedure. New employees must be properly oriented to construction sites and projects. In these meetings, it is important to make ground principles clear especially for subcontractors and to make sure all of the workers understand the hazards on the construction environment. [Tappura et al., 2015]

Assessing safety culture is about understanding the underlying logic that guides the organisation's activities, especially in relation to safety. [Oedewald, 2015] Being able to understand the culture of an organisation is important for the operating company itself and for the regulator because it allows an opportunity to change course before the organisation drifts into failure. It also allows efficient development activities. An in-depth assessment of safety culture often requires external experts, due to the fact that the members of an organisation tend to be at least partially blind to their cultural norms and assumptions. However, the development and continuous improvement of safety culture cannot be completely outsourced. It needs to be integrated in the development of the organisational processes and everyday management actions.

An example of the Finnish good safety culture and continuous development around the subject is a case study conducted by NCC and Skanska for European Agency for Safety and Health at Work in year 2011. The two construction companies formed a consortium and decided to find ways to improve the safety of construction sites by running a safety project at Sello construction site located in Espoo, Finland. The aims of the project were set at the beginning of the project and the documented aims were: "*To have high level of safety performance, which could be measured by indicators, such as lack of serious accidents. The main actions were to identify and use the most appropriate (site specific) good safety management practices, as well as to further develop the safety management process of a large-scale construction site."* During the project the two companies focused on using good safety management practices and safety was included to the project designing from the beginning. Pre-criteria for safety level inspections were set higher than the client had requested and safety demands concerned also the contractors, who were obligated to meet these requirements by contracts. Whole consortium concentrated to improve communication and co-ordination between the designers and site personnel. Workers´ safety was taken into account in every design that was made. The results of the case study were good and consortium achieved an accident

frequency rate that was ten times less than average. The success factors for positive results were the decisions and background work. "*The fact that resources had been reserved for production planning was evident in the successful pre-planning, which preempted potential problems and identified good safety-promoting solutions in advance."* This proves that the Finnish method of safety planning and management can eventually promote safety into the zero-accidents level. [Leino & Suvanto, 2011]

2.2 Safety legislation in Finland

The purpose of Finnish safety legislation is to improve safety and health of working environment. Legislation is laying the ground principles for safety management and planning. The goal is to produce similar safety culture regardless to the field or workplace. [Pihlajamäki, 2015] Equal safety at working place is one of the most important objectives of safety management and legislation. Finnish Legislation has many standards and laws for safety at workplace. Finnish construction follows two main documents in construction work: *National Occupational Safety and Health act* and *Finnish Government decree on the Safety of construction work*. The main principles of the construction as a field are introduced at the *Degree on the Safety of construction work*. The document determines the basic guidelines for safety practices and general parties of construction projects in Finland.

At the first chapter *of Finnish government Decree on the Safety of Construction work* it is stated that: *"In a construction project, the client, the designer, the employer and the self-employed worker must together and each for their part to ensure that no danger arises from the work to those working at the construction site or other persons in the zone affected by the work."* and *"The project supervisor must, through training and guidance, ensure that all those working at the shared construction site are sufficiently familiar with safe working practices and that they are familiar with the hazards and risks of the construction site in question and the measures required for eliminating them."* [Finlex, 2009] This document sets the general rules for safety management and responsibilities in Finnish construction culture. Most of the sections deal with the responsibilities of different parties of the construction projects, also the necessary documents and designs are defined.

On-site inspections are defined in the fourth chapter of the document. This chapter deals with the inspections needed for example machinery, equipment and other tools at the site environment. It provides information about how to take lifting equipment and scaffolds into use and what kind of inspection records are required by the law. Section 16 of the chapter 4 introduces the weekly maintenance inspections and safety follow-up principles*:*

"The following must be checked at the construction site as part of the maintenance inspections carried out at least on a weekly basis: general order of the construction site and workplaces, protection against falls from heights, lighting, electrification during construction work, cranes, equipment for lifting persons as well as other lifting equipment, lifting accessories, construction saws, scaffolds, means of access, and prevention of collapse of ground and excavations. Other matters important to safety must also be checked. When scaffolds are inspected as part of the maintenance inspection the matters referred to in Annex 4 to this Decree must be taken into account." [Finlex, 2009]

"In connection with the inspections, attention must also be paid to the right timing of the construction work coordination measures referred to in section 13." [Finlex, 2009]

"The driver of a crane or other lifting equipment must, daily or whenever necessary before the work begins, test the functioning of the equipment, and, especially during cold and rainy periods, test the brakes and warning equipment to ensure that they function properly. When a vehicle or loading crane is operated, special attention must be given to foundations." [Finlex, 2009]

Section 17 of the chapter 4 sets the guidance for inspection reporting: *"The results of the inspections referred to in sections 15 and 16 above must be entered in a record or other report. The entries must include details of the participants, inspected objects, any remarks, and the dates on when the required corrections were made."* [Finlex, 2009]

Section 18 of the chapter 4 states *"The deficiencies endangering occupational safety and health and noticed during the inspections referred to in sections 14 - 16 above must be corrected immediately and always before the machine, piece of equipment or tool is taken into use."* [Finlex, 2009]

The degree clearly sets the limits on what needs to be inspected on a weekly basis at the site. It gives guidance on what to inspect but the practical implementation is handled at the sites. The Finnish Institute of occupational health has developed TR-safety level inspection forms for construction sites in 1993 [Laitinen & Ruohomäki, 1993], which take into account all of the required aspects. This form is used as a base for all of the inspections conducted in Finnish construction sites. Many companies have used this form to produce their own sheets for TR-safety level inspections, but the inspection rounds are carried out based on same principles everywhere so that the results of the safety level indicators can be compared nationally. The compatibility of the levels is crucial in order to establish some national data of safety in construction sites. Companies can also use these nationally compatible levels as safety standards and objectives in safety management. However, the lack of legislative form has led to a situation where companies can alternate the inspections relatively much. Some companies have carried out regulations to weigh some of the most important aspects of the safety level inspections, which makes national comparison more difficult.

2.3 Comparing construction to other fields by means of safety

The statistics about the severity of construction work can be found globally. Finland, however, is one of the countries where the construction culture is heavily regulated and in Finland there are rapidly fewer severe accidents and injuries compared to worldwide statistics. Statistics are very difficult to document due to vast difference in accident reporting throughout the world, which causes distortion of the statistics. Finland has one of the most precise reporting policies when it comes to accident reporting compared to different fields. Hämäläinen (2010) states that: *"Some international comparisons have been made but these are available only for developed countries, which have data on occupational accidents and diseases."* Most reliable comparisons can be made with countries that share similar construction culture. Scandinavian countries such as Finland and Sweden have many of the same regulations and statistics and are more similar than European average. Spangenberg et. al (2003) have compared the Lost-Time injury rates between Sweden and Denmark for example. The Lost-Time Injury rate (LTI) and The Lost-Time Injury Frequency (LTIF) are basically the indicators that represent injuries compared to actual working hours. Calculating formulas for these indicators are introduced later in this study in Table 4. The two indicators are used to compare injury rates and frequencies globally. The differences are quite small when looking at severe injuries but in the minor injuries a bigger difference was discovered. The LTI rate ratio between Denmark and Sweden was twofold in case of minor injuries. The study states: "*A difference in LTI-rates was also found when national statistics for reported occupational injuries in the building and construction industry in Sweden and Denmark were compared."*," *However differences in reporting procedures and in work tasks, etc. might confound the comparison of lost-time injury rates between countries."* [Hämäläinen, 2010]

Finnish workers´ compensation center (TVK) has conducted a study about reported accidents in Finland in years 2005-2014. The study shows that construction is one of the most dangerous fields in Finland and the rate of accidents is clearly higher than in any other field. [Priha et al., 2009] Also Lost-Time Injury Frequency (LTIF) is higher although decreasing year by year. Table 1 shows the LTIF situation in Finland in year 2012 to 2014. In the comparison construction was followed by Administration and supportive services, Logistics and Industry. The study also shows that fatal injuries are decreasing but still 4 fatalities occurred in year 2013. Number of fatal injuries from year 1990 to 2013 is shown in Figure 2. Many other studies confirm the findings of the TVK´s studies, Finnish institute of Occupational Health has also found that the LTIF is two-fold compared to industry average. [TVK, 2015]

Table 1. Lost-Time Injury Frequency trending in years 2012, 2013 and 2014 in Finland. [TVK, 2015]

Branch	***2012***	***2013***	***2014***
Construction	*65,5*	*63,1*	*62,1*
Administration and supportive services	*53,5*	*51,8*	*51,5*
Logistics	*48,8*	*46,1*	*42,9*
Industry	*36,4*	*33,2*	*33,8*
Wholesale and retail trade	*29,6*	*29,1*	*29,5*
Health services	*28,2*	*30,8*	*30,1*
The municipal sector	*23,7*	*24,2*	*22,8*
All branches	*30,4*	*29,6*	*29,1*

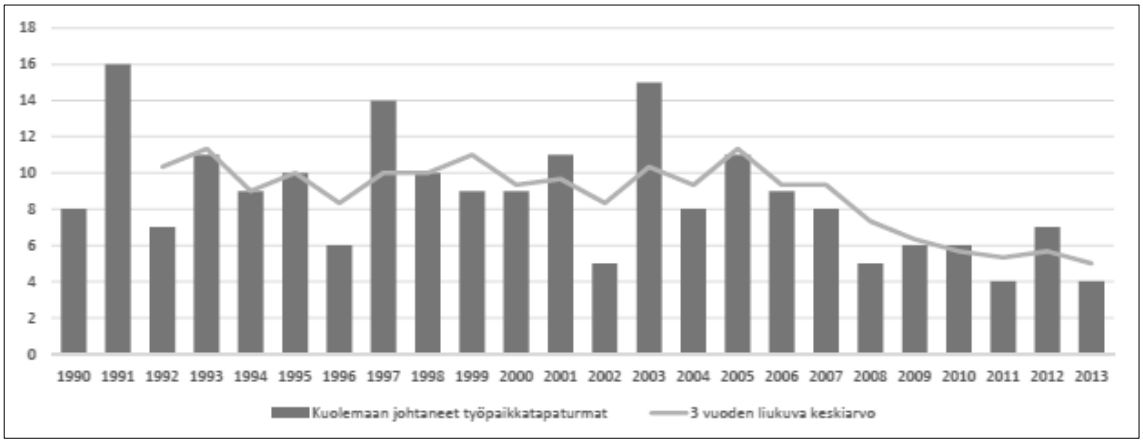


Figure 2 Number of fatal injuries among construction employees in Finland in years 1990-2013. [TVK, 2015]

The accidents in construction industry are divided in five branches by occurrence: building construction, metal and engineering works, electrical works, civil engineering and machinery operators. As seen in Figure 3, building construction had the highest rate of accidents followed by metal and engineering works. Electrical works, civil engineering and machinery caused a minor part of the accidents in construction. Figure 4 shows that most of the accidents in construction resulted from *workers moving around at site* which is the cause of 27,8 % of all accidents. 23,1 % of the accidents are caused by *hand-operated tools* and 21,9 % by *handling of objects*. [TVK, 2015][Kauppinen et al., 2014]

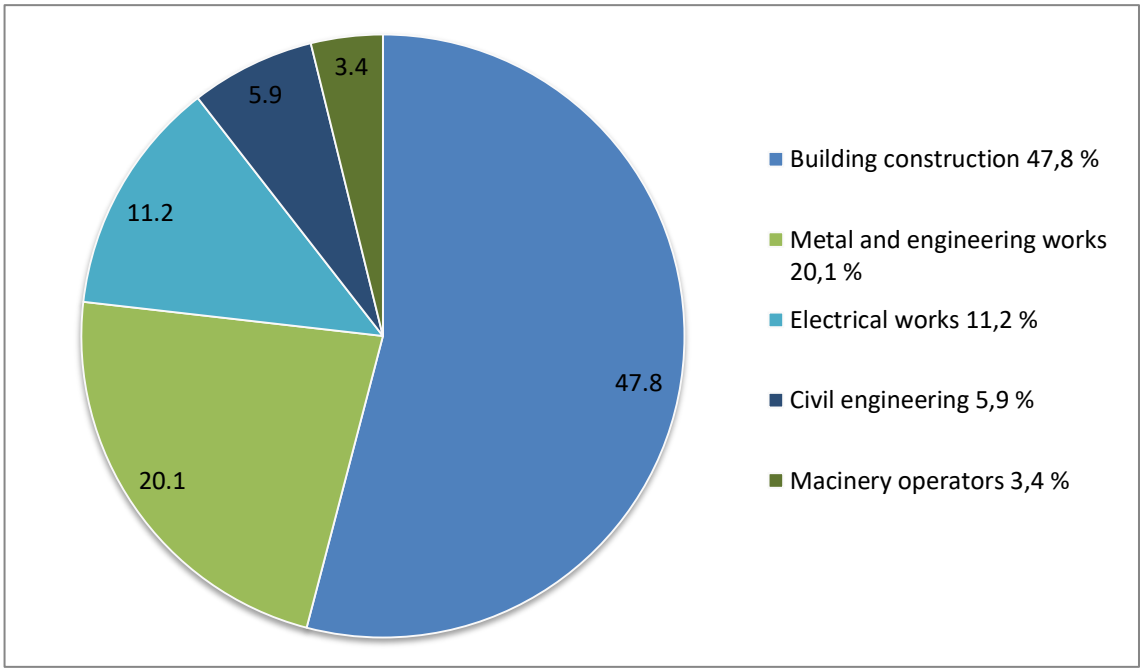


Figure 3 Number of accidents in different branches of Construction industry in year 2014 [TVK, 2015]

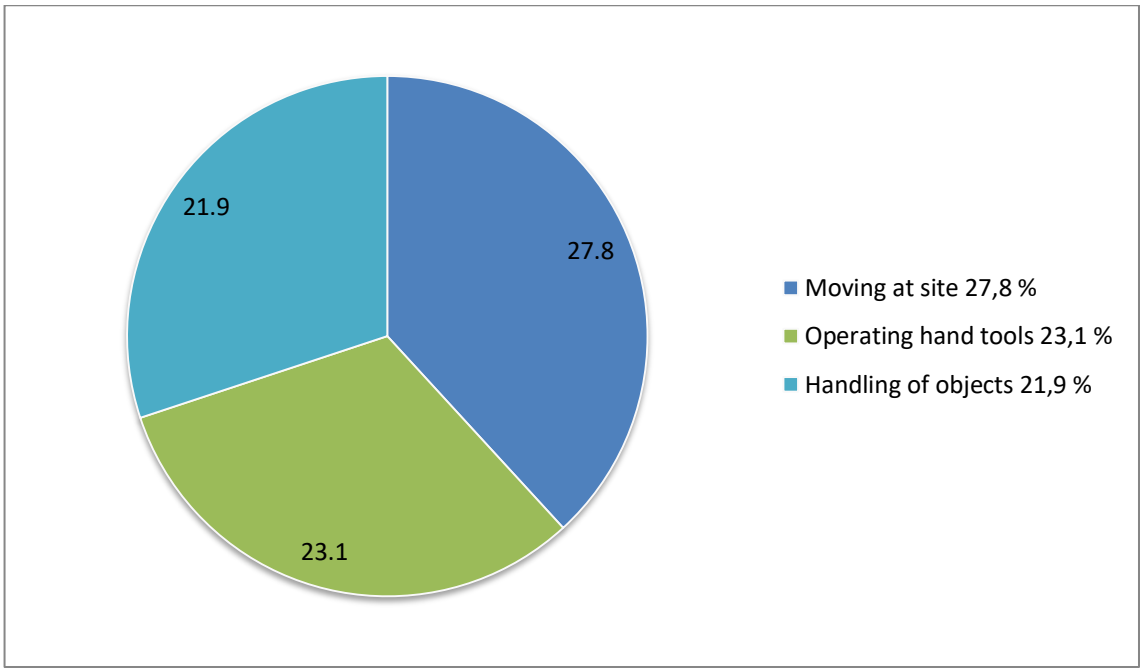


Figure 4 Accidents divided by causes in construction sites in year 2014 [TVK, 2015]

Finnish institute of occupational health has conducted a study about different fields´ health and safety culture in Finland. The statistics also confirm that the construction has the highest LTIF of all branches. For example, agriculture has documented LTI 4- rate

of 50 in year 2010 when Construction LTI 4- rate was 60. Statistics show that occupational diseases occur twice as often in the construction industry than in other industries on average. Most common causes of occupational diseases are asbestos and noise. Even young workers that have started working after year 1994 have been documented to suffer from asbestos related diseases. This is causing some concerns because of the age of diseased persons. The study also stated that 79 % of the respondents felt their health good in comparison to the same aged average. Respondents´ capacity of work was 8,0 on a scale 0-10. The most alarming information of the study, however, was the fact that very rarely (12 %) any actions were made to working conditions after illness or accident occurred. [Kauppinen et al., 2014]

2.4 Safety indicators in construction

In Finland indicators are used to enhance safety and to help safety management. Statistics based on collected indicator data are used to analyze and promote safety development. Different safety related indicators are divided into three different categories presented in Table 2: accident reporting, sick leave reporting and proactive indicators. These indicators can also be divided into proactive and reactive indicators. The reactive indicators are accident and sick leave reporting. Proactive indicators provide information through observations and risk assessment and aim to prevent accidents by systematically reporting information about safety. Reactive indicators are reporting accident rates and sick leaves and are more of a statistical measurement of the safety level and consequences through statistical information.

Most common of the safety indicators are Lost-Time Injury (LTI) and Lost-Time Injury Frequency (LTIF), which describe the rate of incidents compared to real working hours. Table 3 shows all the most used indicators and their calculating methods in Finland.

Table 2. Most important safety indicators in Finland. [Tappura et al., 2010]

Accident reporting	***Sick leave reporting***	***Proactive indicators***
The rate of occupational injuries *(Työtapaturmien määrä)*	*The rate of sick leaves* *(Sairaspoissaolojen määrä)*	*Safety observations* *(Työturvallisuushavainnot)*
Lost-Time Injuries (LTI) and Lost-Time injury frequency (LTIF) *(Tapaturmaesiintyvyys ja tapaturmataajuus)*	*The percentage of sick leaves* *(Sairaspoissaoloprosentti)*	*Risk assessment and hazard identification* *(Riskien arviointi ja vaarojen kartoitus)*
The percentage of absences *(Tapaturmapoissaoloprosentti)*	*The causes of the sick leaves* *(Sairaspoissaolojen syyt)*	*Safety inspections and auditing* *(Työturvallisuustarkastukset ja –auditoinnoit)*
The investigation of accidents and injuries *(Työtapaturmien tutkinta)*	*The costs caused by sick leaves* *(Sairaspoissaolojen kustannukset)*	*Safety related inspections and conversations* *(Työturvallisuuskierrokset ja –keskustelut)*
The severity rate of the injuries *(Työtapaturmien vakavuus)*		*The rate and stage of realization of problem solving procedures* *(Korjaavien toimenpiteiden määrä ja toteutumisaste)*
The costs caused by accidents or injuries *(Työtapaturmien kustannukset)*		*Safety training* *(Työturvallisuuskoulutus)*
		Cleanliness of the working environment *(Järjestys ja siisteys)*
		Ability to work and working atmosphere *(Työkyky ja työilmapiiri)*
		Evaluation of the safety management system and safety level *(Työturvallisuusjohtamisjärjestelmän ja työturvallisuustason arviointi)*

Table 3. Safety indicators and calculating methods [Tappura et al., 2010]

Indicator	***Calculating method***	***Unit***
Lost-Time Injury (LTI)	*LTI 1: Quantity of the injuries that caused at least one day absence. LTI 3: Quantity of the injuries that caused at least 3 days of absence. LTI 4: Quantity of injuries that caused at least 4 days of absence. (EUROSTAT)*	*pcs*
Lost-Time Injury Frequency (LTIF)	*Quantity of injuries that caused at least one day absence per million real working hours. LTIF= 106*(LTI/real working hours)*	*pcs/Mh*
Medical treatment Injury (MTI)	*Minor injury that has required medical treatment and less than one day absence.*	*pcs*
Restricted Work Injury (RWI)	*Injury that causes incapability to perform assigned work. Does not cause absence, substitute work is assigned.*	*pcs*
Fatal accident (FA)	*Quantity of fatal injuries.*	*pcs*
Total Recordable Injury (TRI)	*All documented injuries. TRI=LTI+MTI+RWI*	*pcs*
Quantity of severe injuries	*LTI 30: Quantity of accidents that caused at least 30 days of absence, disability or early retirement, does not include fatal injuries.*	*pcs*
Average seriousness of injuries	*Quantity of absence days per injuries that caused at least one day absence (LTI).*	*d/pcs*
Injury incidence	*Quantity of injuries that caused at least one day absence per 100 workers. LTI*(100/quantity of the workers)*	*pcs/100 person*
Quantity of commute injuries	*Quantity of commute injuries that caused at least one day absence.*	*pcs*
Quantity of occupational diseases	*Quantity of occupational diseases occurred at the considered period.*	*pcs*
Quantity of the occupational injury related absences	*The number of absence days or hours of the injuries that caused at least one day absence.*	*d/h*
Severity rate	*The number of absence days of the injuries, occupational diseases and commute injuries that have caused at least one day absence per million real working hours*	

In a good safety management system, the indicators are simple and concentrated. It is very important that all employees can use and understand the method behind the indicator. [Tappura et al., 2010] Indicators can make a difference by collecting safety related information only if staff is enabling the collection of data. Every-day actions must be monitored constantly in order to be able to immediately step in if needed. However long-term actions can be evaluated less frequently by emphasizing proactive indicators. Every individual worker has to carry out constant monitoring concerning safety. A good quality of safety measuring system is also the balance between short-term and long-term indicators as well as the balance between external and internal indicators. Also, the monitoring and safety improvement should be in line with the company´s strategy and vision. Strategic goals must represent the will of improving and developing safety related practices.

2.4.1 Accident reporting

The most obvious indicator of safety at site is accident rate and the details of occurred accidents. [Tappura et al., 2010] It is very important to document all of the accidents and to report them in order to avoid similar risk in the future. By documenting accident situations and causes the occurrences can be further investigated. Accident reporting can also be analyzed in order to prevent future hazardous situations and to improve working methods. Most important task is to avoid similar working methods that caused accidents and to improve current working methods and conditions in order to find safer solutions. The accident reporting can enhance safety development by producing this valuable information about working methods and statistics behind them.

Most common ways of reporting accidents are the count, frequency and the costs of accidents. [Tappura et al., 2010] This information is relatively easy to calculate and document. Percentage of the absence caused by accidents can also be monitored and documented. This helps the understanding of the results and ramifications of accidents. It may also be helpful to document number of absence days caused by accidents to help predict future situations with accidents. It is also relevant to document the details and the investigation of the accidents occurred.

2.4.2 Sick leave reporting

Safety at construction site can be measured with amount of sick leaves and days of absence. In order to determine the conditions of construction sites it is important to view the consequences of occurred accidents and to develop the practices behind these situations. Sick leaves are the biggest cost in accident results and it is vital to try to minimize

the effects that hazardous situations result in. Sick leave reporting withholds the indicators for amount, percentage and causes of occupational sick leaves. One indicator is also the costs of the sick leaves. [Tappura et al., 2010]

Sick leave reporting can also enhance safety development by producing valuable information about the consequences of different kinds of accidents and illnesses related to construction work. These consequences are important to document and analyze in order to be able to improve and further analyze the accidents or the reasons that lead to sick leaves.

2.4.3 Proactive indicators

Proactive indicators aim to prevent accidents by monitoring and predicting safety levels at site. By indicating safety at the moment, it is possible to predict safety development in the future. Proactive indicators are monitoring compliance with the requirements of safety system and can also measure the effort put into the safety management. The signs of a good safety culture and monitoring are related to recognizing and reporting the hazards. Also, good reporting procedures are important in ensuring the reporting and making sure the number of observations is high. The risk analysis is an important tool in proactively identifying possible hazards and in aiming to prevent them. Most important sign, however, is the constant improvement of the safety related procedures. Safety as a concept is constantly diverting along the other important procedures in construction industry and it is very important to alter the safety procedures as working in construction is changing.

The most important Finnish proactive indicators are:

- safety observations or near miss reporting
- risk assessment and hazard evaluation
- safety level inspections and discussions
- other safety inspections and auditioning
- occupational safety training
- cleanliness of the working environment
- ability to work and well-being at work [Tappura et al., 2010]

Good working conditions are often related to better productivity and other positive effects, such as longer careers and well-being of the employees. Better productivity is a result of fewer absences and distractions to working altogether. With the monitoring of the proactive indicators safety can be measured and predicted. With the help of the indicators it is possible to create a safety system which is determined to minimize accident rate and to create new and improved ways of working. [Tappura et al., 2010]

The most important one of the proactive indicators is the safety observation system. The aim is to collect safety related data from the construction environment and to report all of the observations to the database. The database can be further analyzed and collected in order to recognize accident-prone patterns of working phases. The observations can be positive or negative and the goal is to collect all kinds of data related to safety. Example of a negative observation is a near miss report that describes the circumstances of a near miss situation at construction site. This report can be further analyzed by finding the reasons that lead to this situation and to determine the correct way of handling the situation. Also, the positive observations can be helpful in enhancing safety by introducing good procedures and working methods in local construction sites. These kinds of good examples can be used to create national procedures and guidelines within the organization.

2.5 Safety information and management systems

2.5.1 General

Many industrial fields have studied the performance behind safety management. Safety has been identified as an important area needing further investigation and attention in developing its core functions. Accident prevention has been noticed before and many laws, regulations and standards have been developed throughout the years. Mainly the accident prevention has been based on investigations of documented accident cases and the information needed for occupational safety regulations has been collected cross-disciplinary. The risk management related to occupational safety is based on the same principles than general management: the establishment, implementation and follow-up of the pre-stated standards. [Kjellén, 2000] Nowadays it is noted that the experiences and systematic feedback of documented accidents is an essential step in preventing accidents and to improve safety in general. This is why safety observation and monitoring has been developed and such positive results achieved compared to the old-fashioned method of trial and error.

Model for safety, health and environment (SHE) information system has been explained by Urban Kjellén: "*We are here concerned with the prevention of accidents trough formal systems for experience feedback. In analyzing the necessary processes to accomplish this, we will apply the concept of SHE information system."* The system contains all of the information needed to deal with safety related decisions and management. The decision makers can find much needed information of prevention of accidents or occupational diseases. The system aims to contain also useful information about environmental hazards such as polluting and how to reduce harmful emissions as well as waste handling. The system can also be used to handle physical parameters within accepted

limits such as noise, illumination and concentration of toxins. Also, the psychological working environment can be evaluated by this kind of information system. [Kjellén, 2000]

Model of a safety information system is based on a concern of prevention of accidents through experience feedback. The concept of SHE information system has been applied to accomplish necessary processes of analyzing the hazards at working environment. This system provides all the means necessary to process health and environmental issues. A SHE information system provides occupational safety organization and other decision makers a support in several cases.

- *"Prevention of accidents that may result in injury to personnel, accidental emissions of pollution to the environment and damage to material assets*
- *Prevention of occupational diseases*
- *Reductions in emissions to the air and discharges to the sea of harmful substances and land contamination*
- *Waste handling*
- *Keeping various physical parameters such as noise, illumination and centrations of toxic gases in the working environment within accepted limits*
- *Follow-up of the psychosocial working environment."* [Kjellén, 2000]

The prevention of the accidents trough SHE information systems is a matter of feedback mechanisms. The model for these mechanisms is presented in Figure 5. The underlying assumption is that the accidents can be prevented with systematic feedback system and analyzing. The same assumption is used in safety observations in construction safety management which this research is studying. SHE information system requires resources that include: personnel with authorities, responsibilities, skills, attitudes; organization and procedures for accident reporting, investigation, information distribution; and instruments and tools such as forms, checklists, computer software. Size of the information system depends on company size, its risks and SHE policy. Additionally, there is no single solution how this system can be applied in a company.

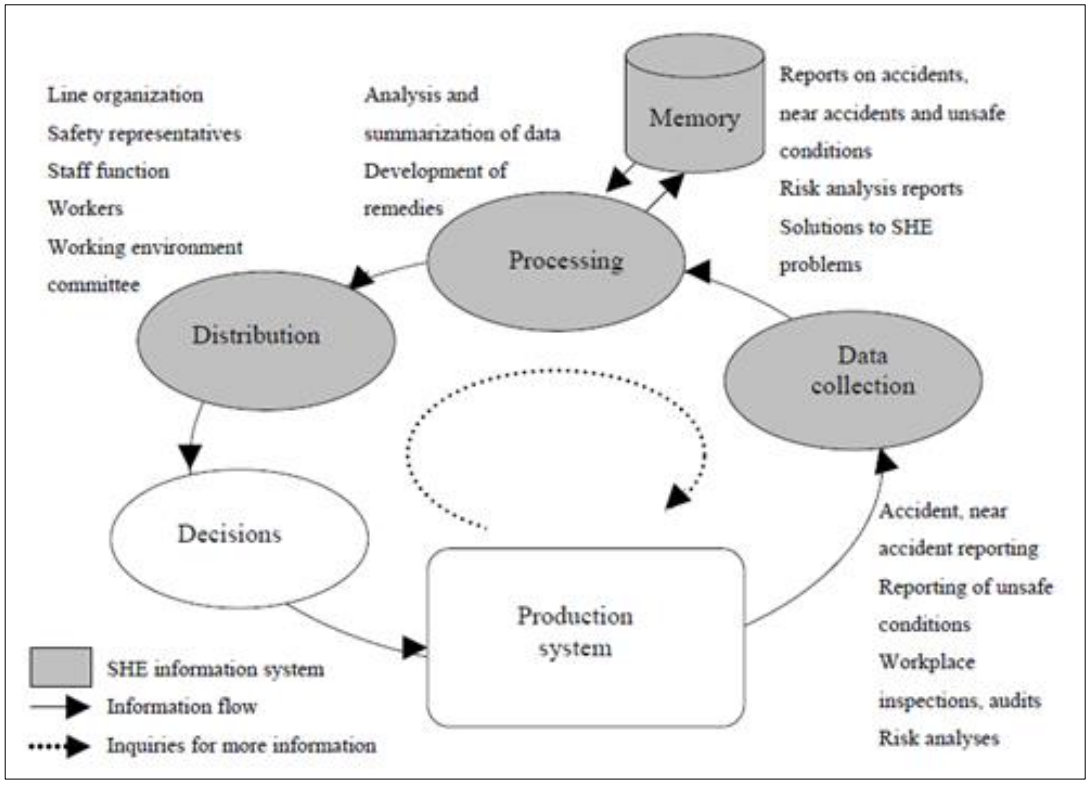


Figure 5 Flow of information in a SHE information system [Kjellén, 2000]

2.5.2 Application of the safety information system in construction

This kind of information system can prevent accidents by data collection and this kind of thinking is used in some companies in Finland. Leino [2008] has conducted a research about Skanska´s safety information system and it´s comparison with SHE information system. In this research he states that: *"Learning from experience should be in place not only at individual or site level."* To ensure this kind of safety performance Skanska started a new procedure for Executive Safety Team in 2008. The idea behind this improvement is shown in Figure 6 and it consists of the same idea as Kjellén [2000] has introduced in SHE information system. The near miss incident reporting is consisted in the safety observation concept and this kind of performance supports the safety observation analyzing and proactive indicator reporting. The goal is to find ideas through the whole organization from the individual and site level to the executive Safety Team level and to turn these findings into work action by creating procedures that support the strategy. To support the safety information system Skanska also developed a new procedure that included a new application for improved data processing and Safety bulletin system for improved Safety information distribution. [Leino, 2008]

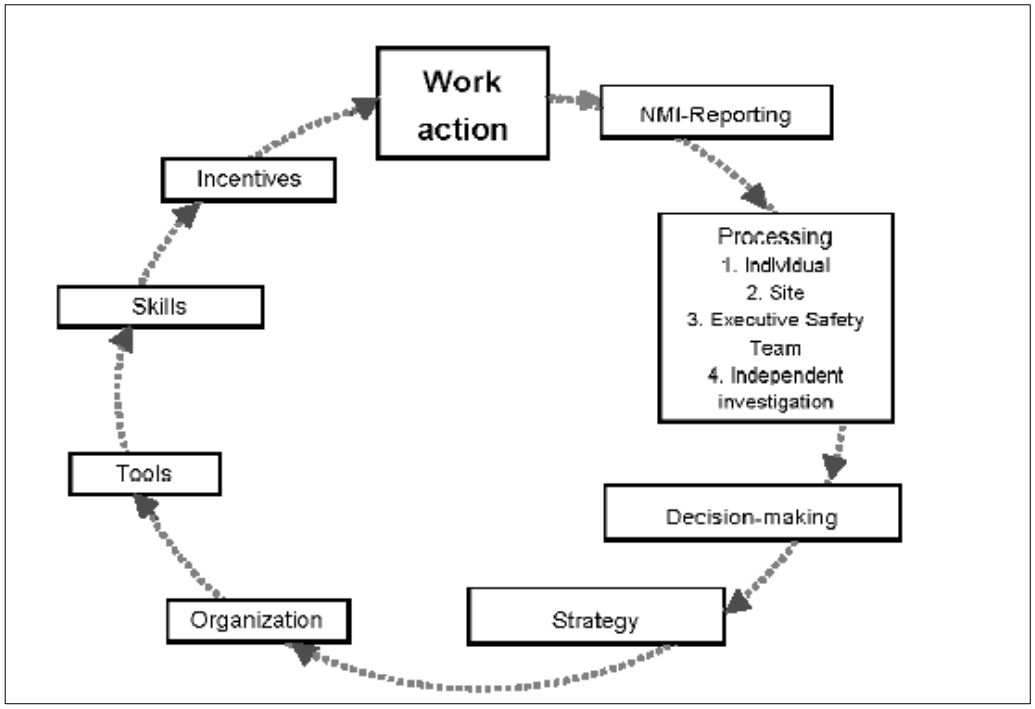


Figure 6 Near miss incident reporting and processing for improved safety performance [Leino, 2008]

2.6 An example of a different safety culture and comparison

Safety at other fields such as nuclear industry or agriculture is very different by nature, although these fields are two of the most dangerous fields in addition to construction. However, the safety culture in nuclear industry is one of the most complex and strict compared to any other field in Finland. As previously stated the construction is the most accident prone field in Finland, the cultural difference is huge compared to for example nuclear industry. The consequences of the defects and accidents can be more severe in nuclear industry than construction. VTT has conducted a study of nuclear power plant safety management and safety in other complex environments: *Safety culture and organisational resilience in the nuclear industry throughout the different lifecycle phases*. [Oedewald et al., 2015]

Viitanen [Oedewald et al., 2015] states that: *"safety culture development in the nuclear industry as well as other is typically approached from a "top down" perspective"*. Safety culture can be seen as something that the management organization is concerned about through management plans and initiatives. It is stated that the management organization and leaders have a key role in defining what type of culture the organisation leads and define how the current state of the organisation is seen, where the organisation wants to be, and how it will get there. "*This leader-centric approach is further reflected in integrating the safety culture and the management system in the nuclear industry*".

The leader-centric approach to safety culture may also contain some flawed information about the safety culture in general. First, it can lead to the assumption that organisational culture can be changed by management, which may not be true in many cases due to cultural features. The leader-centric approach may be a result of relating occupational and nuclear safety together. All of the shop-floor workers may not be able to identify risks related to nuclear safety and therefore the management must be run from top-down perspective. Occupational safety and nuclear safety differ by the consequences. Viitanen states that risks to nuclear safety relate to more systematic failure than occupational risks and therefore do not have same kind of effect on shop-floor workers. [Viitanen, 2015]

Viitanen has introduced different kind of safety culture development methods through assessment and intervention. The tools for assessment can be for example document analysis, field observations and different interviews or workshops. These tools aim to analyze, acquire information and operationalize the organizations safety. The tools for intervention are: behavioral-based safety or human performance programs, safety leadership development and human-resource management processes. While using different kinds of techniques in developing safety culture in organization, the most important key is understanding the relationship between key parties in safety culture management. [Viitanen, 2015]

The construction safety culture is different compared to nuclear industry by nature. The leader-centric approach can be seen also in construction in some ways, but the safety culture aims to concentrate to the production mainly. The safety culture in construction consists of every employee and management personnel. Safety culture can only be planned to have certain objectives in near future but can´t be changed by mainly changing management. The workers have usually good understanding of the hazards at site, whereas occupational safety organization is controlling the safety trough designing. The objective of a safety culture is to maintain certain safety standards in a construction company to guarantee safe and well-balanced working environment. The goal is to point out that safety is joint matter and can only be managed together.

3. MOBILE DEVICES

Term mobile device is used for a handheld and portable computer. Mobile devices are designed to be used with two hands and to be carried along. Most common devices are tablet computers and smartphones but some of the devices are very similar as regular laptops which can be also counted as mobile devices by the determination if they are small enough. Some of the mobile devices can be more powerful allowing almost the same possible features as computers. Majority of the devices include touch screen interfaces and color displays. Operating systems vary but mobile applications are developed for the three of the most common operating systems: Android, iOS and Windows. Most of the variety of mobile applications supports only iOS or Android system, which makes these the most commonly used devices globally.

Mobile devices can be utilized in construction projects by many ways. Mobile applications and web-based tools can be used to implement different kinds of processes in construction projects such as site management or safety reporting. For example, collaborative information management in construction project is currently implemented with cloud-based tools like project document repositories and other web-based services. These kinds of applications can be used locally with the device or with cloud-based services. Most of applications for mobile devices are cloud-based with an intelligent user interface in device but main computing power and data storage are located in a cloud-based service. The benefit of cloud-based services is the increased ability to process data but there are some disadvantages with data security issues. Another way to utilize mobile device for information management is to use web-based applications with mobile web-browser, which allows more flexibility in user interfaces of the devices.

Mobile devices are also an important developing field in construction companies. In year 2015 construction started to focus on developing mobile solutions. In a survey conducted by Sage Software with over 600 construction professionals from small and midsized firms, 33 % feel the need to improve communication and collaboration, 32 % want to streamline processes and over 80 % think that mobile technology is a high or moderate priority. [Sage, 2015] The need for improvement and development has been in air for long and the turning point has finally come. The construction industry is slowly developing mobile management tools with software developers in order to improve management and information flow at construction sites.

3.1 Mobile devices in construction site operations

Mobile devices are used more and more in construction site operations. Most of the mobile devices are used by site managers, but it is believed that in the future companies will provide basic mobile device for selected site workers in Finland. This will promote the cross-organizational communication and possibilities with safety management as well as the information flow. By providing the mobile devices, construction companies can manage information flow through the whole company and try to obtain some benefits through mobile technology.

Construction work is usually located outdoor or at least in cold or moist environment in Finland. The necessary functions for the mobile computing system and its devices are very different than in office environment. *Kimoto et al.* have conducted a study about the application of personal digital assistants as mobile computing system on construction management. The study is made in Japan, where the climate is similar to Finland in places, consisting of the four seasons. The authors interviewed construction professionals in order to determine the necessary functions for mobile devices, which are:

- *"Mobility of Hardware: Construction managers want the pocket size of hardware.*
- *Durability of Hardware: The strength for the physical shock, the rain, the wet and the dust is necessary for hardware.*
- *Compatibility of Hardware and OS: It is suitable that the system can work on any hardware and any Operating System (OS).*
- *Compatibility of Data between the Mobile and PC: Construction managers want to handle the data in PC on the mobile device. The converse is also necessary.*
- *Expressivity of Display: The sufficient expressivity of drawings and pictures on the mobile device both indoor and outdoor is necessary.*
- *Stability of System: Total stability of system including OS, memory card and other devices is necessary.*
- *Operability of User Interface: Construction managers want to input data with gloves. Easy user interface such as pen-touch is suitable.*
- *Processing Speed: Start-up, Shutdown and each process in the mobile system needs quick response. The display speed especially of drawings and pictures is important.*
- *Continuous Computing Environment: The computing environment has recently changed quickly. Construction managers want to continue the use of the system for a long time. The computing environment that assures the long operation of systems is necessary."*

[Kimoto et al., 2005]

The mobile devices need to be durable and easy to operate in outdoor environment, even in cold temperatures. Therefore, waterproof devices are being used or special covers need to be placed to shield more fragile devices. Furthermore, the compatibility is an important factor: the data needs to be compatible with PC´s and other devices so it can be viewed regardless of the device a person is using in field.

The two types of mobile devices in construction sites are smartphones and tablets. Smartphones are often used in tasks that require fast accessibility of the device. However the tablets are used for more detailed work and when the device in use requires more usability, for example viewing layouts or 3D models. The six of the most important features of the mobile devices in construction are: transportability, durability, battery life, stability, performance and input speed. [Knutas, 2012] Smartphones and tablets are the most suitable in construction work for providing the most of these six features. Tablets have the benefit of producing more input speed with bigger screens, but the smartphones are more transportable due to the smaller size.

The construction companies have started to provide mobile devices for the foremen of the construction sites in Finland when mobile technology has become more common and mobile solutions have been rapidly developed. Mobile devices offer many features that can be used to promote effectiveness and precision of construction work. The most important issue is how well these devices are utilized in construction at the moment. *Sage* has conducted a study about *construction technology* in year 2015. This study shows that mobile devices are used in construction sites for reporting, document viewing and scheduling. 76 % of the attendees state that they use mobile devices in daily field reporting and 68 % in customer and job information. Drawings, photos and documents are viewed with mobile devices by 67 % of the attendees. Also, the job costs and project reports are handled with mobile devices by 61 % of the attendees. It was also stated that 47 % of the attendees used mobile devices for scheduling. [Sage, 2016]

3.2 Mobile tools for construction safety

Due to the vast improvement of mobile technology many solutions for mobile safety management have been discovered and the markets offer several applications for safety related information management. Many of the applications at market have different kinds of solutions to safety improvement. There are four different types of safety applications, which are: project management applications that include safety related tools, safety auditing or inspecting applications, applications for specific safety related purpose and applications for specific construction phase. [Sulankivi et al., 2016] Examples of four different types of mobile safety related applications in the markets are presented in Table 4.

The first type: “construction management tools with safety related tools” is the most common application in the market; these kinds of applications can be used more diverse than the other application types. The safety auditing tools seem to be the most appreciated in Finland because of the legislative safety level inspections can be executed with these tools. For example, the InstaAudit application, which is further studied in this research, can be counted as an auditing tool. The applications for a single specific use can be for example guides for occupational safety, instrument for measuring angles or decibel meters. The applications for specific work or construction phase control the single work task and produce safety related information from it, for example the concrete calculators or daily reporting.

Table 4. Examples of different types of mobile safety related applications [Sulankivi et al, 2016]

Types	***Examples of existing mobile tools***
1: Construction project management applications including safety related tools	*Trimble ProjectSight, Autodesk 360 Field, bim+ Connect, Aconex, Procore construction management software, PlanGrid*
2: Safety auditing or safety level inspection/measurement/rating apps	*iAudit, iOSHA Process Safety Management Auditing, Trimble Inspector, Kotopro TR-mittaus, T3, InstaAudit*
3: Applications for a single specific purpose	*Dakota's EHS Pocket Guide, ChemAlert, iTriange, Clinometer HD, SoundMeter, DMD Panorama, Tekla Field3D, Safety Coach*
4: Applications meant for a specific construction phase or work	*Daily Reports (e.g. for concrete work), Concrete calculator, Fall PtD, Raksamittari PRO*

The first purpose of the mobile devices in construction was to support more efficient access and viewing of the documents and designs at field. This has led to a vast creation of mobile solutions addressing designs and management. Many of these applications also have features that can be used to evaluate safety at construction site. If all of the safety related applications are being studied, the off-line feature is one of the common factors considering construction as a user environment. The off-line feature is important in construction sites, where the internet connection is not guaranteed. The system has to be able to document reports and data while using the device in off-line mode. The data will be then uploaded to the cloud-based database when the connection is stable. [Sulankivi et al., 2016]

The mobile devices can alter the procedures of construction companies significantly and the use of the devices is rapidly becoming more common. Many of the applications on the market have been tested for different kind of safety purposes like document sharing, BIM-model viewing, off-line reporting of safety related data such as safety level inspec-

tions, browsing safety information and guidelines, and various safety measurements and calculations. Table 5 presents more detailed list of safety related use cases and practical examples describing the possible utilization. This table is prepared in a study conducted by Kristiina Sulankivi [2016] titled: *Improving safety at building construction sites by means of BIM and mobile tools,* which was prepared in collaboration with this research.

Table 5. Safety related use cases of mobile applications [Sulankivi et al, 2016]

Use case	***Short description or practical example of possible use***
1. Project and Safety document sharing	*Documents needed at field are carried along digitally in a mobile device or accessed on-line by web.*
2. Viewing BIM-based construction and safety plans	*Reviewing e.g. 3D fall protection plan with help of BIM viewer application.*
3. Safety Notices Management	*Recording notices at field digitally by mobile tools and putting an issue to someone's responsible and following corrective actions. Collecting, filtering and analyzing up-to-date safety data is also possible, helping to decrease specific safety violations and develop safety management procedures.*
4. TR Safety level measurement (weekly observed safety level at the site, a Finnish method)	*Conducting mobile TR-safety level inspection and filing safety observations digitally, as well as calculating the weekly safety level rating automatically by the tool.*
5. Other safety inspections	*Ready-made digital checklists and forms, and filling out those digitally once while the inspection. Inspection forms may be for safety inspection process or checking cranes, for instance. Electronic time stamping registering visit entry and departure may also be included.*
6. Browsing Safety and security regulations and guidelines, and accessing safety and health sites	*Browsing OSHA-regulations, best practices, or fire protection standards at site. Browsing information on personal safety equipment requirements for a specific work*
7. Getting information and help without delay in case of illness, accident, or other H&S related situation	*E.g. iTriange: By entering the symptoms, one gets information about likely causes and a proposal for the treatment/action. By entering name of a drug/medicine, provides basic information and warnings related to the substance, and the location of the nearest first aid centre. (Professional Safety 2014)*
8. Accessing chemical safety data	*Information for chemical safety management by accessing chemicals database by mobile application. E.g. ChemAlert provides access to over 100 000 chemicals, and includes e.g. hazards classifications, recommended personal protective equipment and first aid information.*
9. Photos and Panoramic photos (360 degrees)	*Cameras can be used for documenting worksite conditions and helping safety personnel to identify safety hazards. Panoramic photos can be used for e.g. incident investigations and safety inspections, and created by help of specific applications such as DMD Panorama (Professional Safety 2014).*
10. Measuring safety of the working conditions	*Measuring angles of slopes to evaluate safety (e.g. Clinometer HD), or measuring sound level dB (e.g. SoundMeter) to determine whether a more precise measurement using more accurate device is necessary. Or measuring thermal conditions (e.g. OSHA Heat Safety Tool). (Professional Safety 2014).*
11. H & S related calculations	*E.g. iPad apps available for conventional safety management calculations (ready-made calculation formulas included in apps such as HSE Buddy).*

Most of the mobile tools at the market seem to be designed to safety management purposes but have tools for safety observations also. Mobile tools for safety observations can also be used for many other purposes, because of the simple base of the sheet needed. The main idea of the observations is to make any kind of observation and collet the data needed for other persons to see also and be able to view the situation as it was at the moment.

3.3 Risks related to mobile devices in construction

Risks related to mobile devices can be divided into risks related to people and information. Mobile devices are promoting management systems and supporting safety by providing more information, but can also be counted as risk as such. Most obvious risks concerning mobile devices are related to data security and sharing. In organizational view the biggest problem with mobile devices is that data security must be placed into the hands of every employee using mobile device and gain access to organizational data.

The most common security risk in using mobile devices is the fact that users are responsible of the organization´s data security. This is a result of vast number of mobile devices and lack of sufficient IT support to control every device. Mobile devices also carry a vast variety of different operating systems and software, therefore data security can´t be optimized in order to handle all of the devices in a large organization. The employees have also responsibility over the whole device; the risk of the device going missing or broken must be also taken into account when dealing with security issues. If the goal is to maximize the benefits of mobile devices, big part of the organizational data must be accessible at all times. This brings up the question of whether the organization´s user management system needs to be re-evaluated or could a new system be developed specifically into mobile world. The real question is what kind of software is used to secure the data and who can access this data by using a mobile device. [Cooney, 2012][McKerchar, 2015]

When dealing with the risks that mobile devices bring with in construction environment, the most obvious people related risk is the use of mobile device itself. Mobile tools can result in hazards by occupying worker´s attention at construction sites. All over the world mobile devices have caused more and more accidents by occupying people´s attention and the use of mobile devices has increased rapidly among pedestrians for example. [Sigloch, 2016] The consequences and proper instructions for the use of mobile devices must be prepared before the devices are launched into use at construction sites. Good guideline is not to walk with mobile device and to stay alert during hazardous work phases such as liftings and casting. The more mobile devices are involved in the construction work, the more risks will appear. However, the benefits presented in Table 6 improve the outcome of mobile technology.

3.4 Possibilities and benefits of mobile devices

The benefits of the mobile devices and other mobile technology improvement in the construction industry are diverse. The possibilities of social connectivity and information flow are high with mobile development. The characteristic feature of the construction is that the work is divided into different tasks and working groups and the one project has many contractors and sub-contractors which leads to information losses and the connectivity is not always optimal. The benefit of the mobile technology is that every employee can be connected more easily and the information flows through the organization. The mobile devices can also enable work groups to make contact at the field, which improves social connectivity in construction sites. The benefits of mobile tools in the construction site safety management are listed in Table 6. These benefits have been studied by *Sulankivi et al*. [2016].

Table 6. Benefits of mobile technology in safety management. [Sulankivi et. al, 2016]

Benefit	***Examples***
1. Time savings, and at the individual level easier to deal with issues/work assignments on one's own schedule	*Safety observations and notices are recorded and documented at once while inspection. Mobile application may also automate calculations related to safety auditing. Meeting minutes are made once during the meeting.*
2. Improved productivity	*Beside time savings, faster access to up-to-date project and safety related information improves productivity, as documents needed at field are carried along digitally in a mobile device or accessed on-line by web.*
3. More systematic, transparent and traceable process	*All concerned parties can see who and when created a safety notice or other record, who is responsible for correcting actions, how urgent it is to correct the issue, and a notification of fulfilling the task.*
4. Better information quality	*Easier to manage the project information timeliness with help of a cloud-based system. Easier access to e.g. safety regulations to consider safety more carefully in a specific construction phase or work task. More accurate documentation of safety issues, since information structure/content is standardized by digital forms in app and e.g. photos can be attached to any issue.*
5. Faster resolution of problems and faster access to first aid information	*Faster access to safety information and guidelines e.g. in a case of injury. After an accident, the history data of issue management may help find the reasons at the background of it. Additionally, faster resolution of any occurring issue in a project decreases also safety hazards.*
6. Automated reporting, filtering and summary concerning site status	*A list can be produced e.g. of all safety notices recorded at one building site, or of all which one specific firm is responsible for. Summary of the most common safety violence types at the specific construction site can also be automatically filtered from a cloud-based database, to tell which issues should be addressed and corrected.*

The most obvious benefits are time savings and improved productivity which can be achieved with eliminating manual steps in documentation and reporting procedures at site. The productivity improvement can also be a result of the faster information access at the field. All of the construction project partners have access to updated project information at all times, which improves their own personal productivity. Also, the possible problems and critical construction issues at site can be solved in a much more effective timetable. Previously the site management staff had to move between the field and the office in order to be able to have access to latest designs, leading to inefficient use of the management resources. With the mobile access to all project data these resources can be used more efficiently.

The cloud-based tools enable more systematic, transparent and traceable safety issue management process at site level. All of the project partners can access and inform others about safety related issues and notices. These cloud-based tools can also give notices to the concerned parties via e-mail in order to achieve faster reaction time. This will also inform all parties of how, when and what is done to fix and resolve possible issues concerning safety.

The faster resolution of problems and faster access to first aid information helps the site staff in case of an injury or accident. Various applications provide information about the first aid or procedures in case of an accident. Also, variety of safety information can be downloaded or searched on the Internet. This is one of the most direct benefits of mobile applications when it comes to occupational safety and information. Additionally, mobile devices allow faster resolution to any kind of issue at site.

The automated reporting, filtering and summary concerning site status is one of the indirect benefits of the mobile technology when it comes to safety. If information of safety can be systematically recorded, the database makes it possible to automatically summarize, filter and analyze the current and future safety hazard at site. System can create different notifications for example via e-mail to distribute liability and to distribute important information. The reporting is made more precise and on-time with the mobile technology already but the automated reporting can collect even more information from different places at the same time. The automated reporting is not in larger scale use in construction sites but in the future different automated devices such as wearables become more common.The notices and alarms for safety hazards can be automated in case the safety analyzing system notices something leading to occupational safety risks. [Sulankivi et al., 2016]

4. SAFETY OBSERVATIONS

4.1 Finnish practice and background of safety observations

Safety observations are being used widely in Finnish construction safety culture. The idea of safety observations is to produce continuous information about hazards at site as well as to provide a way for employees to report safety issues at field. Goal is to analyze produced information and regenerate new procedures according selected data to achieve more functional safety culture and to reduce accident rate to minimum. Many of the construction companies have different kind of safety objectives and safety is measured by different indicators.

In Finland, the procedure is to attempt to meet certain standards when it comes to producing safety observations. Observations are collected both from site management and workers. These observations are analyzed and collected into safety information system in order to educate personnel and to prevent future accidents. There can be many kinds of motivational procedures in different companies but one of the most common is to somehow connect the number of observations into rewarding system. However, the most important motivation is to make all employees understand that continuous monitoring and safety information collecting is enhancing safety in every day level.

The background behind safety observations is continuous monitoring. Safety observations are made also in other branches for example industry companies where the concept was originally taken into action. In construction, the observations have been made since 2005, when Skanska started to produce safety observations in constructions sites. [Skanska, 2009] The objective is to improve the personnel's knowledge of safety and make the reporting and improving the safety hazards much easier. When a hazard in construction site is observed, the defect is corrected immediately and the observations are discussed in weekly site meetings. The reporting also allows the hazards to be discussed and utilized further in organization.

Finland has advertised safety management system and safety indicators worldwide. Skanska has won awards for their system at the safety awareness campaigns. [Skanska, 2009] Many of the companies are willing to educate employees and the whole field about the occupational safety. It is a common development area of all companies and many solutions are launched in order to improve safety at construction industry.

4.2 Content of a safety observation

Safety observations contain certain information of the situation and circumstances behind the occasion of the observation. The sheet of safety observations contains the name of the person observing and the place and the date of the occasion. In order to connect the observation to certain organizational quarter and adding the responsible information the sheet contains also information of the adjoining parties. The most important information is the description of the occasion and the ability to add photos to the sheet with a mobile application. Figure 7 demonstrates an example of general safety observation sheet which contains the information needed for safety observation. The sheet has the basic information needed and it is simple to fill, which is an important issue in order to make safety information collection as easy as possible.

The ability to add safety observations directly to safety information system reduces the effort in reporting the observations. The pictures of safety related issues and hazards can be added directly to the observation and the need to describe the circumstances reduces and makes filling of the form much quicker. This can be achieved with the help of mobile applications.

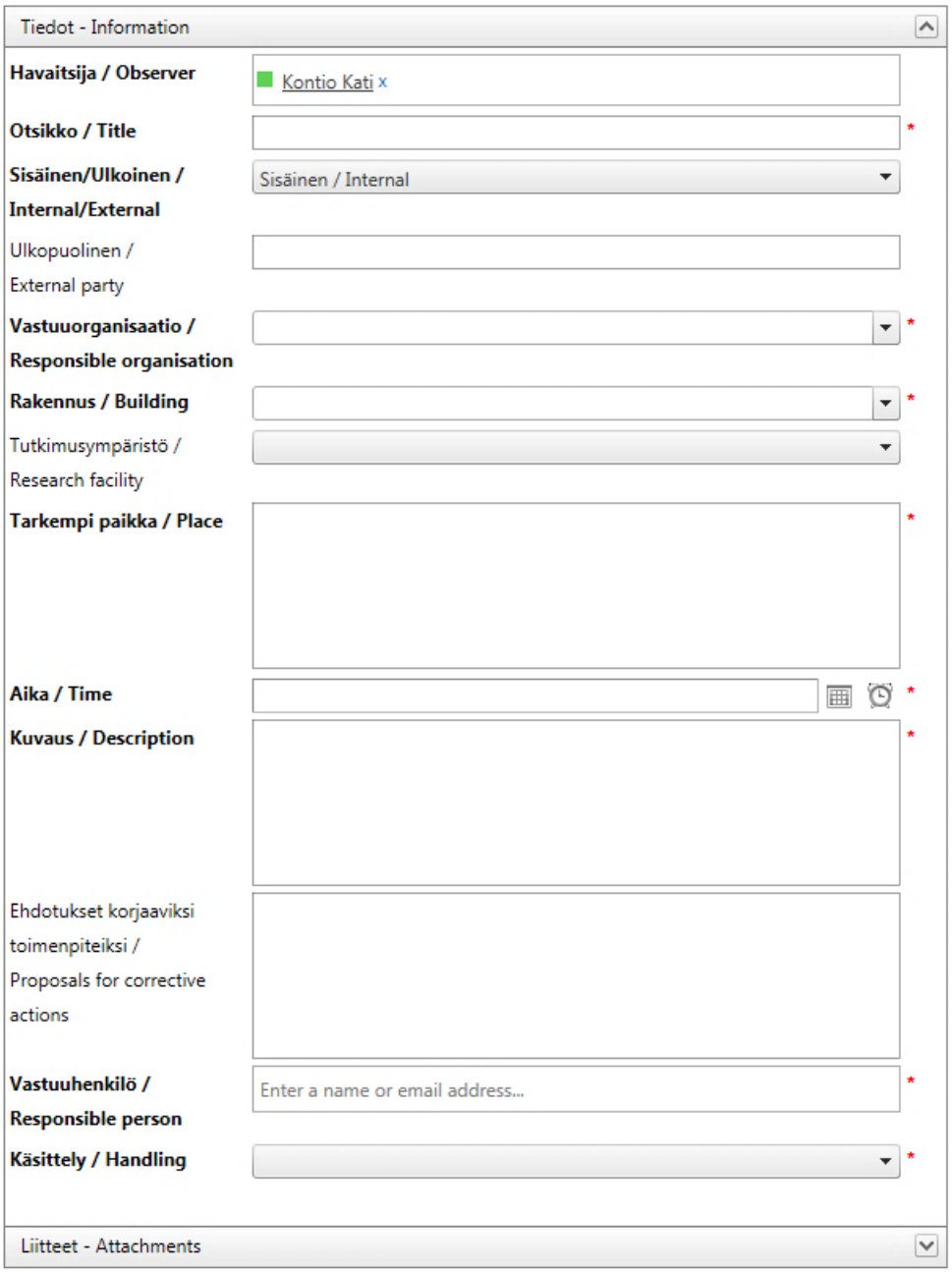


Figure 7 Example of a safety observation sheet from VTT [VTT, 2016]

The safety observation sheet can also contain information of the handling of the sheet and the reporting system allows the observation to be tracked. This allows the observing person to track the handling and further discussion of the observation. The possible feedback can also be appointed to responsible quarters by adding this information.

4.3 Process of managing the safety observations

The process of safety observations management is shown in Figure 8. The process of the observations is quite simple: the processing starts from the site organization and moves up in organization as the process continues. First the observation of a hazard is made at the site conditions where it is also reported into the system. The processing starts at the site organization where the observation is acknowledged and needed corrections are made at the field. The observation is usually discussed at weekly site meetings with all of the responsible parties and possible proposals of improvement are also evaluated. This phase is important in order to improve the conditions locally.

The next step in observation process is the occupational safety organization. The occupational safety organization also acknowledges the observation and the corrections made in the site organization. Then the proposals of improvement are also discussed. Next the observation is categorized and the consequences are analyzed. The analyzing of the safety data allows the occupational organization to produce statistical data of the general safety information through the whole organization. This information is then distributed back to the sites in a form of guidelines and safety information packages. The site organization then takes care of the implementation of the information.

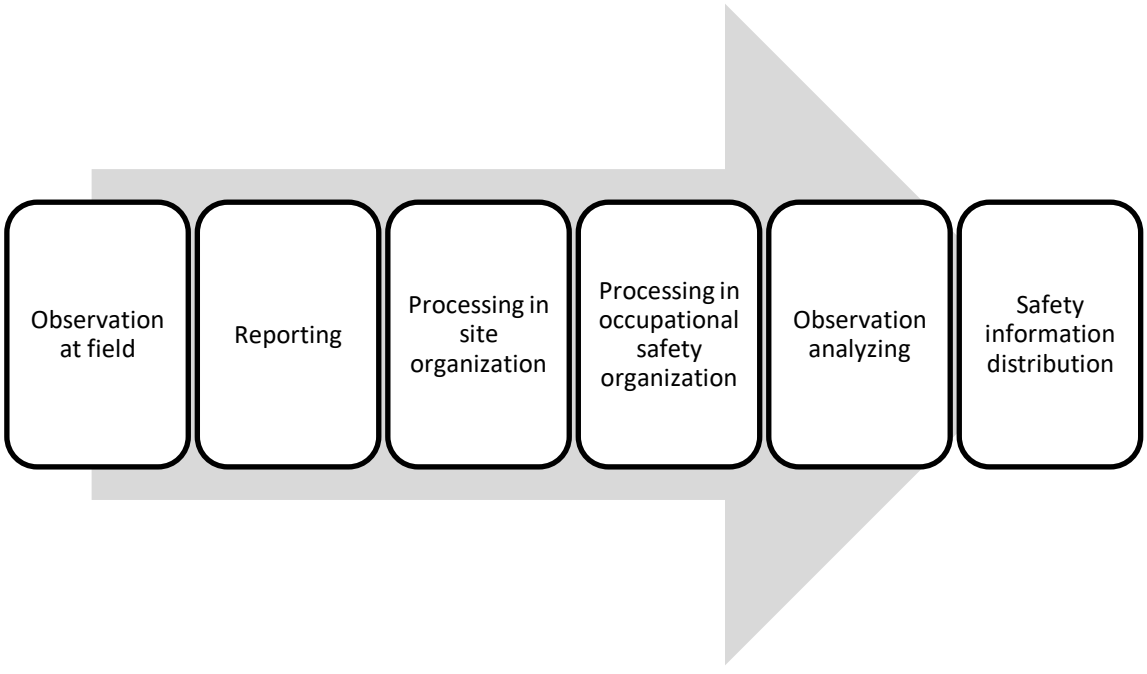


Figure 8 The process of safety observations management.

4.4 Motivation of employees

In construction, the motivation of employees is probably the biggest issue in concerning mobile observations and safety data collection at site as well as the safety in general. Workers make observations about the safety at site in every day basis but most of the corrections and issue management is handled without reporting these issues to the safety system. If a worker notices for example missing fall protection element, the issue is corrected immediately without reporting. The question is how workers can be motivated to report all of the observations they make. Motivating can be arranged in different terms and many of the companies may have different methods in case of employee motivation.

The underlying point in employee motivation is also the motivation of employees to safe work. If the employees are not motivated to work in safe methods, they are most likely not motivated to report safety hazards. Most of the safety hazards are concentrated in specific work actions and the workers may even underestimate the hazards in their own work. [Helander, 1991] The motivation towards safer workplace becomes more difficult when workers are not aware of the risks and even try to avoid direct safety standards. However, the motivational work has paid dividends and safety is more noticeable in construction sites.

There are many different ways to try to motivate employees to safety improvement in everyday life. The most common of these ways seems to be the rewarding system. Companies have started to reward employees for meeting certain safety indicator standards and arranging competitions among the sites by safety indicators. Good method is to tie the whole construction site staff to work towards the same goal and try to raise some group spirit in achieving safety improvement. These motivational procedures have accomplished to produce safety guidelines and state of safety awareness, which promotes the work put into enhancing safety culture in companies. The motivational procedures are becoming more common and for example almost all of the construction sites in Finland celebrate certain milestones of no injuries by offering coffee or lunch. These kinds of motivational rewards are proven to be effective among construction sites. Motivation can be also raised by tying safety as a part of other production goals and as a part of the bonus system. As stated, there are many different ways to motivate employees but the results in collecting safety information are always better if the awareness of safety hazards is also in good level.

5. MOBILE APPLICATION FOR SAFETY OBSERVATIONS - CASE STUDY

One of the objectives of this project is to find suitable software features to producing information through mobile observations and to help software development for safety management purposes. Software for mobile observations has been studied and a test for user experiences was executed related to this research. A set of interviews was held in order to get comprehensive picture of application´s use, quality and features.

Client for this mobile application was construction company Skanska in Finland. The test and application development were mainly designed for Finnish construction culture and the target was to examine Finnish safety methods for safety observations only. The software developer accompanying this study is called Insta Audit. The objective for all parties was to find the best features to actually improve safety rather than to replicate the old paper forms into mobile application. The project started in December 2015 and the software was immediately taken into test after the co-operation was announced.

5.1 Tested mobile software

Mobile application for safety observations contains features for easy reporting and data analyzing at construction site. The application for the observation purposes was modified in this case study according to Skanska´s requirements and needs, which helped the development process by offering concrete ideas and fast resolution to problems. The software was chosen by Skanska among different kinds of safety related software and developers. Most of the software available have a feature for safety level inspections, but other features seem to separate them from another. The tested software has different user interfaces and versions for application and web-based service. The application can therefore be used with either interface and the data inserted can be further processed with computer and workstation. Application version is available in application store for iOS and Android. The web-based service can be used with any web-browser available.

The tested software comprises a set of elementary features concerning safety. Figure 9 shows the six elementary features of the application: auditing, risk assessment, forms, action management analytics and admin feature. These features were developed to enhance safety at construction sites and to improve information flow as well as reporting techniques. This case study concentrates on the safety observation functionalities for Skanska´s purposes.

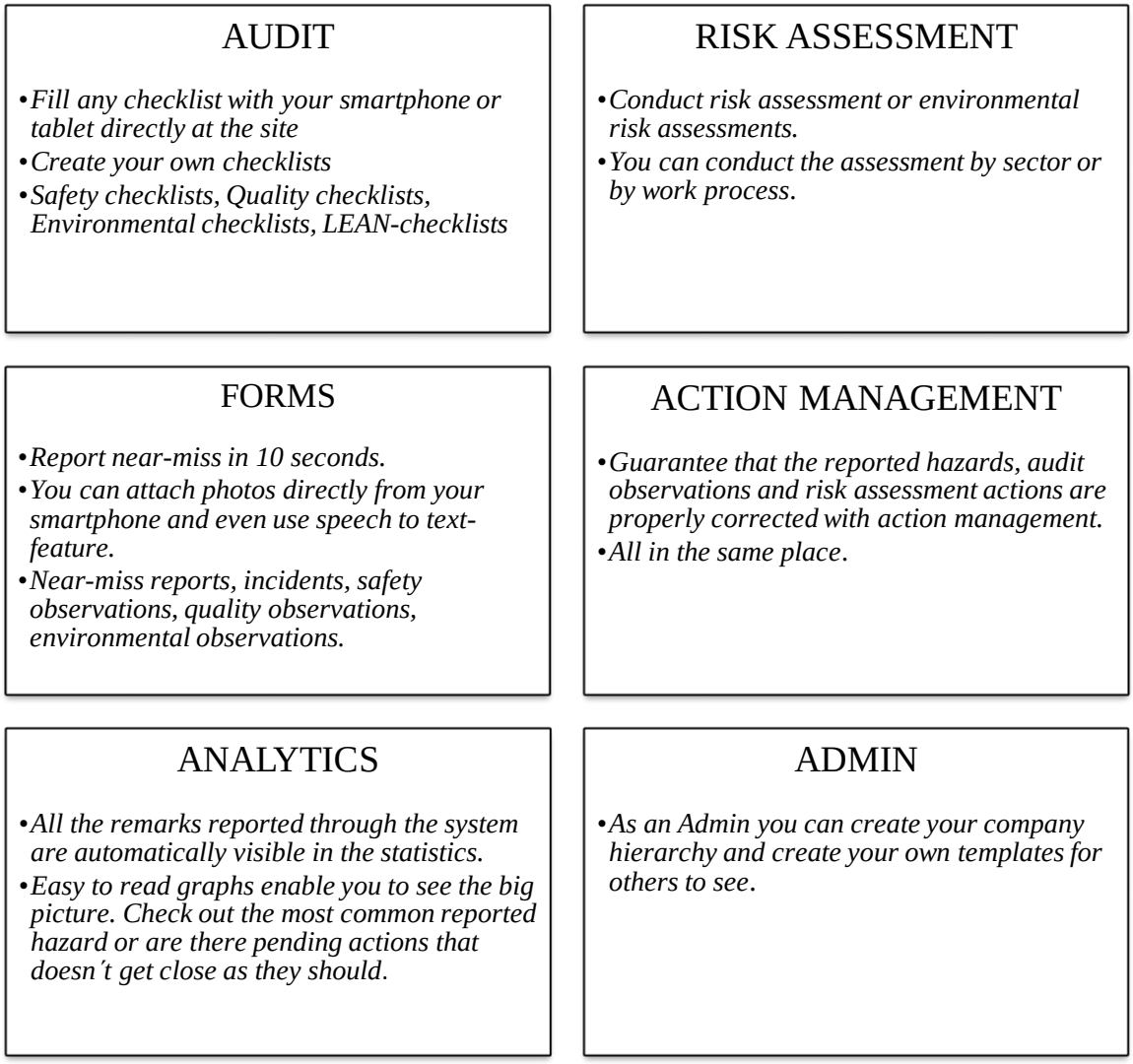


Figure 9 The six elementary features of the case software. [IA, 2016]

The tested application is created for safety management purposes. It has different kinds of forms and auditing tools, all designed to improve safety in construction. Skanska is currently using the application mainly for safety level inspection purposes and the new mobile observation feature will be launched into further use by the end of the year 2016. This case study is determined to find suitable features for the observation analysis and reporting in order to help launching and starting the application.

The tested application contains two types of features for reporting: forms and audits. The user interface is created to meet the requirements of the companies using the application. The view presented in Appendix 1 is presenting the Skanska´s view of the application. In the form side, personalized forms can be created based on a need for them. The audits contain legislative inspection forms for construction work and other kinds of

short “right or wrong” forms. The forms and audits can be created rather easily, which definitely improves the effectiveness of the software. Safety observation form was created by collecting Skanska´s development ideas and wishes in this case study.

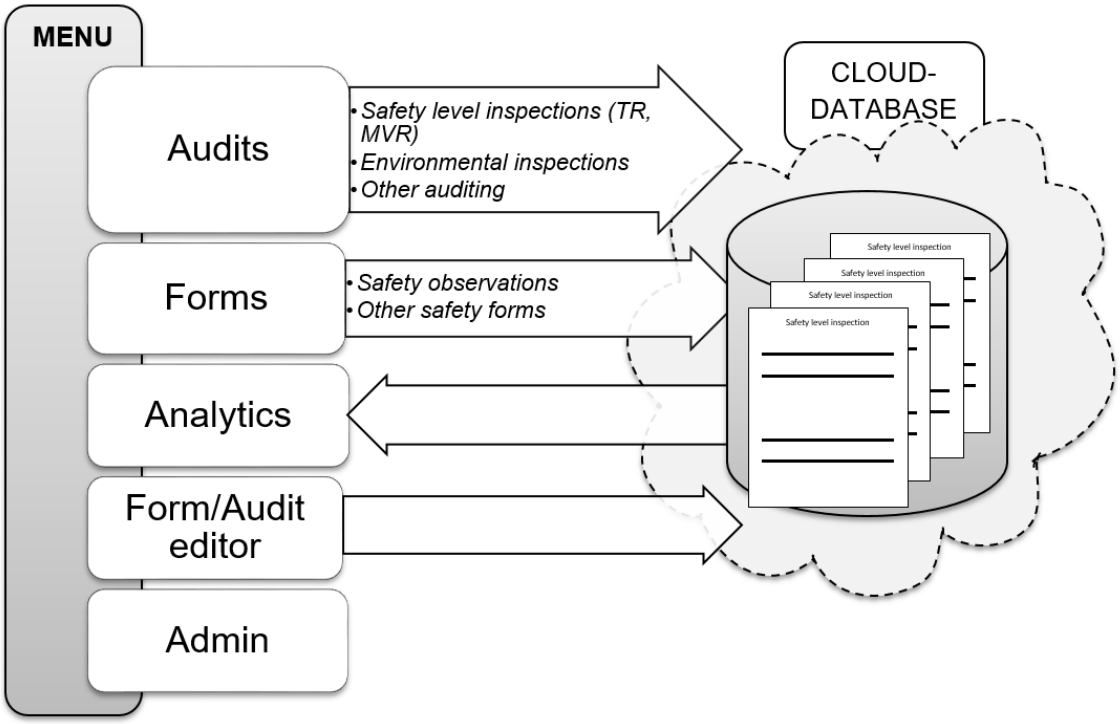


Figure 10 The functionalities of the tested software.

Figure 10 presents the functionalities of the tested software. All of the functionalities can be found in the menu bar and the main functionalities are: Audits, Forms and Analytics. The Audits contain legislative auditing forms, which are mainly lists or forms that have running counters for counting hazards for example. The Forms can be more diverse and contain also filled out questions. By using these four tools, safety information and management can be maintained. The Form and Audit editor is a tool for creating personalized forms and Admin feature allows site staff to add and manage users in their connection network such as construction site. It is important to maintain the user list up to date in order to collect real time information and use all of the features that the software provides. All of the information provided with the software is collected in the cloud-based database, where users can search information by using the Analytics function. Different kinds of filters are used to sort the vast amount of information collected in the database. Also, the most often used filters can be saved for further use in the future.

The software has two different user interfaces: *the web-based application* and *mobile application*. Both of these applications can be used with mobile devices, the web-based application is used with the web-browser and the mobile application can be downloaded from the application store. Both have very similar views and outlines, but the only difference between the two interfaces is that the web-based has more functionality. At the moment, the mobile application can be used only for reporting and information filling whereas the web-based application contains all of the functionalities that are used with computer. This means that the Analytics is only available with the web-based application. When filling out forms with a computer, the web-based application allows also selecting a used picture from the file rather than using the device camera itself.

5.1.1 Admin and different users

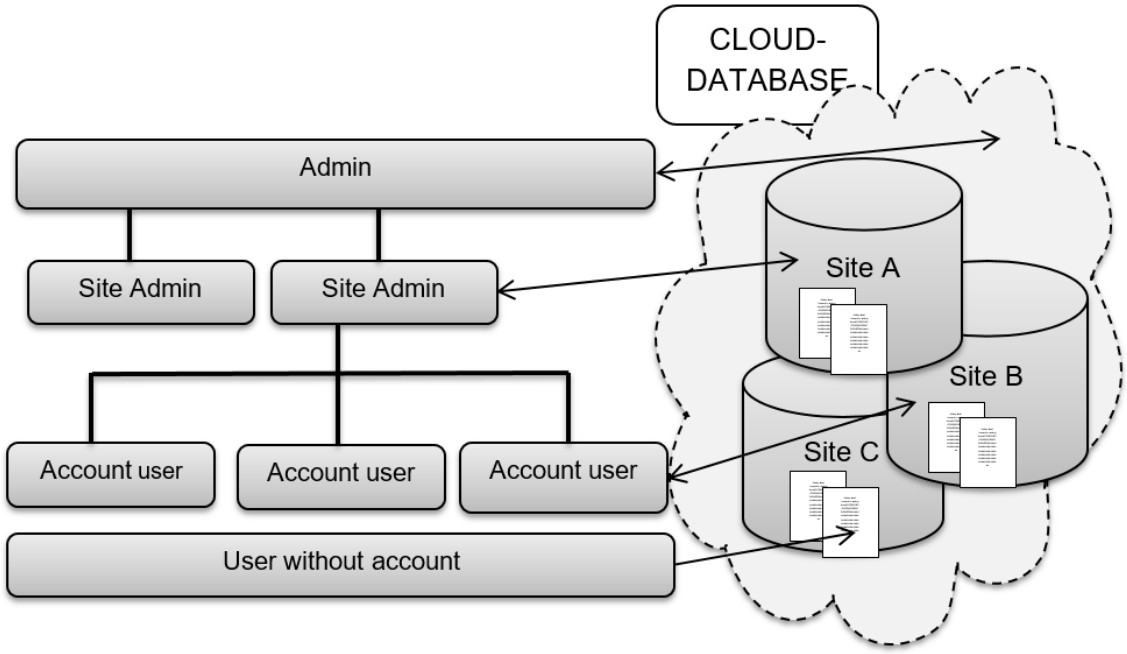


Figure 11 The different user types and their access to the database and safety information in the software.

The tested software has four types of users. The software allows however three of these users to collect information from the database. The main user types are: Admin, Site Admin, Account user and User without an account. The different user types and their access to database are presented in Figure 11. The Admin has access to all of the information collected in the database, and is usually someone in the occupational safety organization or someone else in charge of the safety matters at organizational level. The Admin can also manage all of the other users and share licenses to other users. Admin

user is able to create and modify all of the Forms and Audits and is in charge of the whole software changes concerning the company´s software.

The Site Admin is in charge of construction sites and manages all of the users in this particular site. Site admin can also add sub-constructors to the database and allow access to this constructions site´s information. The Account user can also view information in the database but has no privileges to distribute or allow access to sub-contractors or other users. Account user is usually a site foreman or working group leader among the construction workers. Site Admin and Account user are often concerned for one site at a time.

The User without an account can be anybody owning a mobile device. The User without an account does not have access in any of the information in the database but this kind of user can fill out Forms by using link or tag in the site location. Every site can create an individual link for the site observation form, which is distributed to every worker during the orientation. The link directs the device browser straight into the observation form and sends the filled form into the database. The sub-contractors can comment and discuss observations with direct links. The User without an account can´t be located or identified at the moment, so every entry made by this kind of user must be processed by one of the other users. The User without an account can be, for example, a worker, a sub-contractor´s worker or even a by-passer near the construction site.

5.1.2 Audits

The tested software covers the safety related inspections that are made at construction sites. These audits are mostly legislative and the forms for the audits are collected in the Audit-mode of the application. The audits can be, for example, safety level inspections for building and civil construction sites. Appendix 2 presents the safety level inspection form in the web-based view of Skanska´s software. The form is based on the Finnish safety inspection form originally created by Finnish Institute of occupational health. [Laitinen, 1993] The form is modified to meet the needs and practices of Skanska. The safety level inspection aims to determine a weekly safety level by going through the same checklist weekly. The inspection is referred in Finland by the name “TR-mittaus” and it is used widely in Finnish construction culture. Legislation determines the content of these weekly inspections so the form itself has remained mainly unchanged since 1993.

Auditing forms differ from the other forms by functionalities. Audits are mostly forms that include counters or yes/no questions. The basic functionality is that Audits are made easy to use and contain buttons for different functionalities. The audits can also be modified by the Admin user in the software. Skanska has collected their own list of au-

diting forms in the software. There are for example environmental auditions and safety inspection reporting forms in addition to Finnish safety level inspections.

5.1.3 Forms

The tested software contains a Form feature in which users can moderate and create own inspection or safety related forms. This feature allows the user to create the forms to meet the standards and objectives of the company in question. Skanska has created its own safety observation form which is presented in Figure 12. The form is very similar to the general safety observation form; however, some changes have been made due to user-friendliness of the form.

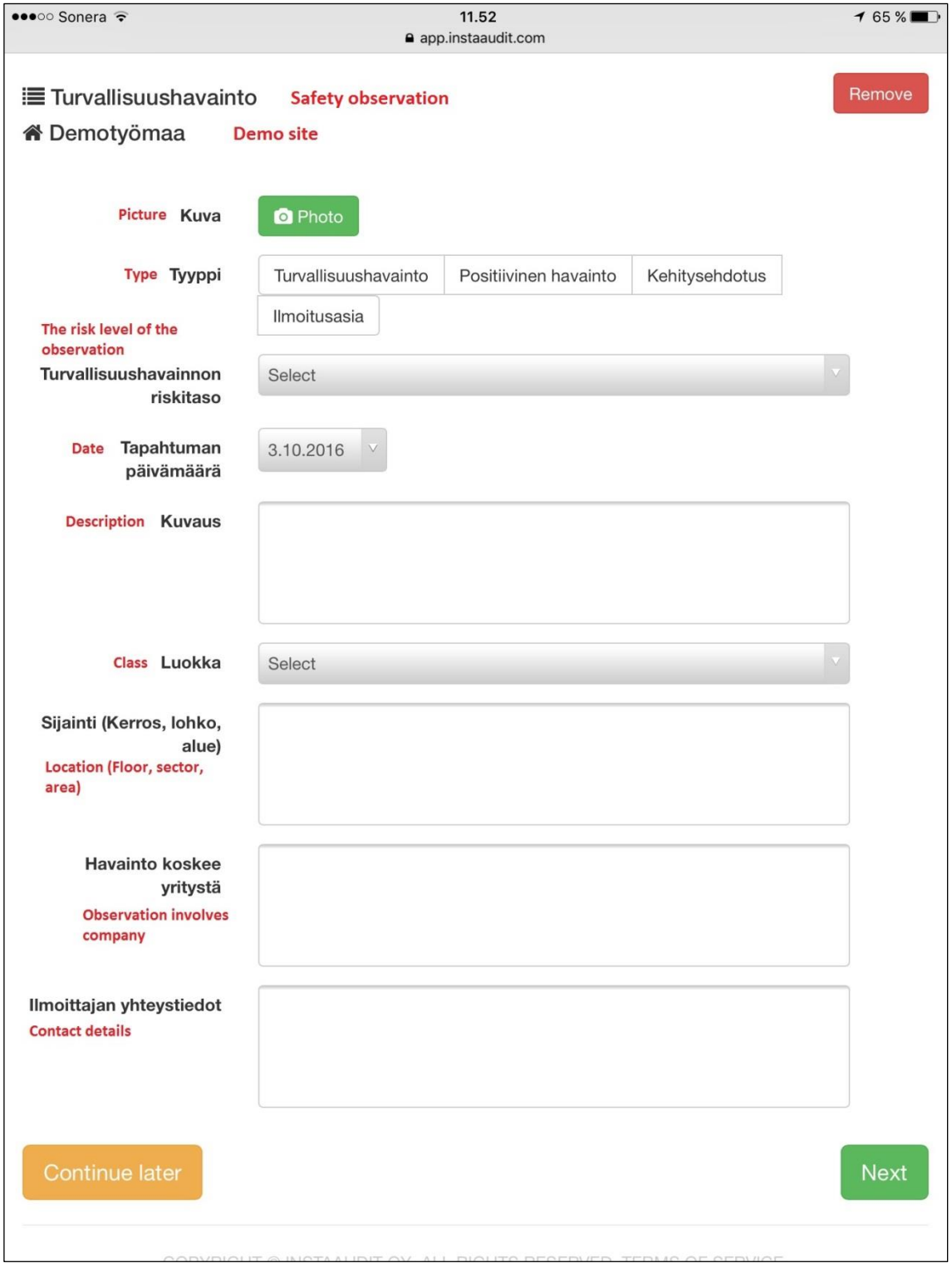


Figure 12 The safety observation form in web-based software [IA]

The form contains sections to fill in safety observation information about the situation in question. Form contains a direct possibility to add pictures of the situation with the camera of the mobile device used. The type of observation can be chosen from the op-

tions that are: safety observation, positive observation, proposal for improvement and notice. After these, the risk level of the observation can be chosen from three different alternatives*: minor, moderate and high risk levels*. The *minor risk* level is chosen if the observation or hazard is not affecting other than the site staff or conditions. This can be for example occupational equipment defect or other minor hazard in construction site. The *moderate risk* level is a bit weightier and should be discussed in local organization. An example of a moderate risk can be a defect in fall protection. The third type of risk level is *high risk* level and this kind of observation usually involves the whole organization because it can result in a severe accident. After choosing the risk level the date of the occurrence is filled in the form.

The most important information is filled in the description box of the form. This section contains the information of what was observed. The picture can usually describe the circumstances more effectively but description can also describe the background of the situation. After filling in the description, the class of the observation is chosen from the alternatives to make further analyzing easier and to address certain work phases or ensemble to the observation. These alternatives are:

- paths/ways, site roads, ladders
- machinery, equipment, staging
- railings, fall protection, excavations
- electricity, lighting
- order of the site, waste management
- chemicals, harmful matter
- working techniques, working positions
- liftings, lifting equipment
- risk-taking, personal safety equipment
- excavation work and
- environment

After these steps the exact location and the responsible company are filled in. Also, the person can leave their contact details in order to receive tracking data and further feedback of the observation.

The handling of safety observations in the tested application is following the same procedure of reporting the information as there were with previous paper forms. However some improvements are added to application. The mobile technology allows responsibilities to be assigned and follow-up is much easier with the application. When the most obvious benefit of mobile device in this practise is the effectiveness and time savings, the information chain follow-up is the next best thing. The responsibilities can be assigned and site managers can see all of the corrections. This process is demonstrated in Figure 13.

As stated, all of the users are able to make observations and add information to the system, but the difference is that how and by whom the observations are processed after the reporting. When an observation is filed into the system, the follow- up is handled by the site managers. If the observation contains a hazard that involves some sub-contractor or other party, the site manager can add responsibility to the observation. When the responsibility is assigned, the person responsible gets an e-mail notice. Based on this notice corrections are made and the processing proceeds to the follow-up. When all of the corrrections and discussions at site are made, the observation is closed. After this the occupational safety organization can analyze all of the finished observations and process the information in order to create new guidelines and good working methods. Last step is the information distribution, when all of this new safety information is put into use in construction sites.

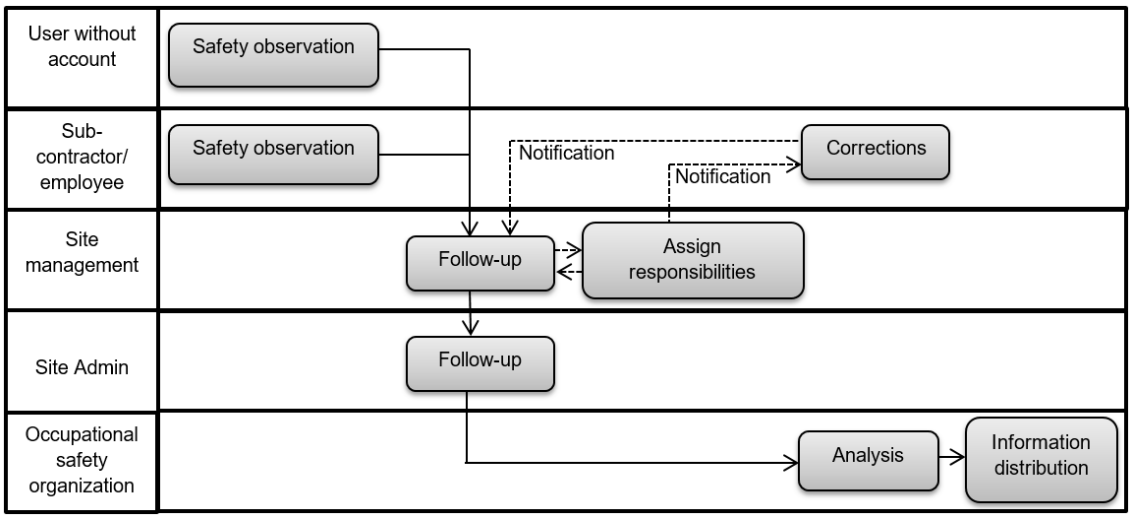


Figure 13 The process of a safety observation in the software.

5.1.4 Analyzing tools

The most important analyzing tools of the application are the diagrams and the sorting tool which manage all of the observations inserted into the system. The analyzing tool contains diagrams and statistics of all of the safety data reported to the database. With the filters the parameters can be modified in order to get the needed information out of the vast amount of safety related information. In order to observe certain site´s safety information the filters can be set to present all of the site´s safety information at a certain time range. This allows all of the users to observe relevant information concentrated to the nearest organization quarter. Filters in the application can be chosen from the alternatives that are: organizational level, templates, descriptions, values, contractors

and time range. By altering these options, different kinds of statistics can be drawn from the database to meet the needs of all parties in the organization.

The software is also presenting some diagrams automatically. The Analytics shows a pie chart presenting the situation of finished tasks. This kind of information is helping site managers to keep track on the follow-up and corrections. Other diagrams are the safety level index and a pie chart demonstrating the documents added to the system. When using the filters the software is producing a list according to the set parameters. This list can be printed, copied, saved or sent to Microsoft Excel. This helps users to prepare presentations of the observations and other safety related data.

5.2 Test period and background of the case study

The application was tested during a six-month period in two different Skanska construction sites in Finland. One of the test sites was an infrastructure construction site in Luumäki and the other one was a commercial building site at Tampere. Both sites were committed to the test period and included personnel that were interested in developing useful mobile tool for construction site management.

The test was started with these two construction sites because of the interest they had towards the application. Both of these test sites had studied the application for safety level inspections, but the safety observations were a new feature. Site managers got familiarized with the application on their own and this implementation process was studied also. The goal was to determine whether the application was indeed suitable and as user-friendly to use as was expected. Occupational safety expert offered both sites technical support during this test period and problems concerning the application were discussed with the software developer also. The office building site had been using older version of the application before this research, however the latest version of the software was updated and brought into use as the test period started. The infrastructure construction site was able to explore the application in its current form. Both sites used the application in a way their working methods allowed and there was no pressure to achieve certain types of opinion during the test period.

The goal of the test period was to determine the best features and to detect flaws in the application. Testing included a procedure where the two construction site managements brought the application into use and started utilizing the application for safety observations in weekly tasks. This was explained to the management personnel in both construction sites at the beginning of the test period. The interviews were set up to determine the opinions of the site´s management personnel, workers and occupational staff in organizational level. The essence of the testing procedure was to use the application as a tool for the safety observations as a part of the existing system and report the results.

6. RELEVANT SAFETY INFORMATION AND ANALYZING TOOLS FOR SAFETY OBSERVATION SOFTWARE – BASED ON THE INTERVIEWS

As a part of the test period and this case study of the mobile safety observation application interviews were performed to determine the results of the testing. The interviews covered the whole test period and both the occupational staff and site management were interviewed. The first interviews and conversations were performed with the occupational staff and the software developer in order to determine the starting point and objectives for the safety observation application and this research. The occupational staff member in this research was the safety coordinator and expert, who also coordinated the two of the test construction sites and oversaw the implementation of the application in Skanska.

The interviews with the occupational staff and software developer continued during the test period and additional conversations were held when defects and possible improvements were detected in sites. The interviews of the site members and management were held in four different sessions in addition to information gotten during the test period in real time. The interviews of the site staff and workers involved site management personnel from the both test sites and health and safety representative of the Skanska´s construction sites in Tampere region. The interviews were held in conversational form and lot of the issues were discussed more freely around the main questions for the application. The main questions for these interviews were:

- Does the application work properly and what kind of benefits does it offer?
- Is the application easy to use?
- Does the application meet the legislative standards?
- Does the application provide all the needed information for site management purposes?
- Solutions for improvement?

6.1 Findings of the interviews

The interviews were performed during the test period in Skanska construction sites. Also the occupational safety organization was interviewed in order to collect information on both sides of the observation process: the data collection and reporting as

well as the further analyzation and processing. The main findings were positive and most of the interviews concentrated on the functionality of the application.

6.1.1 Occupational safety organization interviews

Figure 14 Important aspects of the tested software according to occupational safety organization.

The main findings of the interviews are presented in Figure 14. The goal of this interview was to determine what kind of information is relevant to collect with the safety observation form. The data that can be documented with the application can´t be determined beforehand but the application form can be edited in a way that it collects certain information and this information can be further analyzed. It is important to evaluate if the questions in the form are essential.

In an occupational view is to find certain information from the application easily. Number of the observations is one of the measurements that are monitored from the organizational perspective, but other indicators are also available. The knowledge of the number of the observations doesn´t necessarily promote safety itself but the aim is to improve the awareness and documentation rate at the construction sites in general. It is stated that the general awareness improves safety at site significantly. During the test period some concerns about the number of the observations arose because of the two

aligned systems and database, but this problem will be fixed when the application is launched and all of the data is collected into the same database. The filing and tracking of the observations is essential in order to be able to manage all of the data in the system when more and more information is filed into the system. The user and technical support is very important also to achieve active use of the application. The occupational safety organization in Skanska is handling the support of the application. Technical support is offered if the problem is about the mobile device in question.

The occupational safety organization is mainly concerned about the number of the observations when it comes to measuring the activeness of the safety matters at site. The methods in order to get a number of observations must be determined and suitable software features have been discussed in the interviews. The motivation of employees is the main issue in incenting employees to report their observations. How to get all of the employees motivated without connecting safety information producing to outcome? This issue needs further investigation and research in the future. It was stated that at this time, employees are required to have their own mobile devices in order to make mobile observations at site. The intention is however to provide mobile devices to every employee, including workers, in the future.

6.1.2 Interviews of site staff and workers

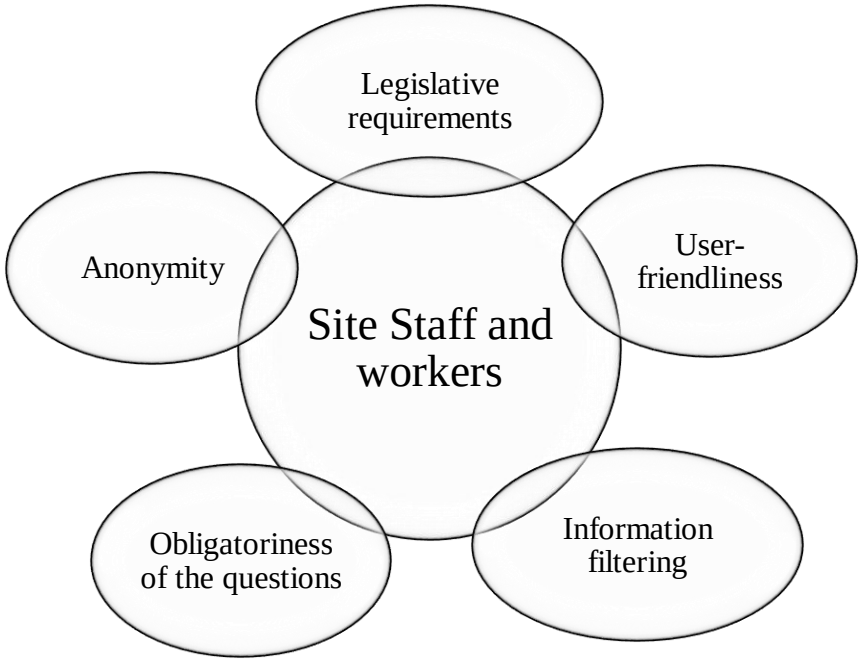


Figure 15 Important aspects of the tested software according to site staff and workers.

Site staff and workers were also interviewed about the application and safety related information collection. Most of the construction site staff had used the application before the interviews. The meetings with staff that were non-familiar with the application were more of a conversation about the functions of the application rather than formal interviews. The main aspects based on these interviews are presented in Figure 15.

In these interviews the regulatory aspect came up and legislation of safety was discussed in case of safety inspections and safety observations. Legislation states that inspections must be made weekly and these inspections must be documented and dates and signatures of the people responsible must be available for inspection. The application clearly meets the requirements for inspection documenting but the responsibilities and correction dates must be clearly documented. A list of the correcting actions with names and dates of the person responsible must be accessible.

The main concern in safety observation feature of the software was the user- friendliness of the form. Workers and sub-contractors must be able to fill out the form easily in order to promote the number of observations. At this point the form was stated to be too complicated and filling of the form too difficult for some of the employees. This concern was taken into consideration in order to improve user friendliness of the software. The goal is to minimize excessive clicks and to elaborate the questions of the form. Also, the obligatoriness of the questions and answers of the original form was analyzed and re-examined. By re-examining the obligatory questions and answers in the form, it was stated that many of the questions could be optional but more obligatory fields and therefore more answers make the tracking of the observations easier. Tracking of the observations is essential in order to establish a feedback system. The tracing is especially relevant when it comes to the credibility of the observations. The origin of the observation can determine the credibility of the observation in question; if the author is unknown the validity of the observation must be examined.

The anonymity of the observations came up in the interviews. The anonymity can bring up difficulties when anyone can fill up the safety observation sheet. It was stated that the guidelines for the content of the observations must be clear, so the form can´t be exploited by making gratuitous observations. This is also why the relevant and wanted data must be determined in order to avoid counterproductive information. The concern for too much information was also relevant and the information filtering rose up in a discussion about the follow-up and analysis of the observations. If more and more information is filed in to the system, how it is possible to manage all of this information in the future? The responsibility is at the moment assigned to site foremen and management to follow all of the observation, but if the amount is rapidly increasing in the future, who will be in charge of the management of the system. This is definitely something to think about if the safety observation system and the number of observations keep increasing. However, at the moment, the number of observations is manageable.

6.2 Deductions of the interviews and future of the mobile application for safety observations

The interviews indicated that the application is ready to use, however few functionalities must be changed before launching the application for larger scale use. The interviews showed that the application will indeed help safety information collection in construction sites. Most of the test users were convinced that the application would help their work in the future and they would be likely to use it on a weekly basis. The needed modifications are connected to user-friendliness and analyzing tools of the application so they are not affecting the reporting features of the application. Some of the functionalities need to be modified in order to simplify the user interface and the ease of use. The Analytics for example needs some modifications to make the filtering function more usable. The goal is to produce software that needs minimum induction to use. The modifications have been discussed with the software developer and are due to be put into practice before launching the software into further use.

6.2.1 Relevant safety related information for safety observations

It is important to recognize relevant data in order to produce safety promoting guidance. Relevant information will help future analyzing and categorizing safety related data collected from the indicators. During the interviews the fact that irrelevant data disturbs the analyzation phase came up and this issue was discussed further. The risk in accessible forms is that everyone can make observations and not all of these observations are relevant to the construction site itself. Some of the empty data can even be malicious due to differences in opinion and business rivalries. The idea of a filter is to be able to sort the observations from different sources. The empty data can interfere with relevant data, but it is not practical to let anyone delete filed observations either. The safety observation system relies on the fact that the safety information is transparent and nobody should have interests to hide anything. The conclusion of the discussions was that the empty data is a possible disadvantage but the transparency of the safety system is more important.

According to the interviews and conversations it is clear that the relevant observation related data is not the minor defects of safety in construction sites such as single lack of a helmet. These minor defects do not affect the safety culture of the company but are such things that need to be reported. The relevant observations to the company´s safety culture are such observations that can be further analyzed and turned into new ways of working. The most challenging part is to find the useful information from the database. This means that there must be ways to control the contents of the observations. Guide-

lines and guidance on what kinds of things should be reported can be a part of this controlling. The guidelines are easy to go through at the same time a new user is introduced with the software by few points. If a person has a clear vision of how the observations are processed and for what reason they are collected, they can better understand what kind of information is relevant when it comes to safety management.

When it comes to enhancing safety, the most important observations are the positive observations. These can be examples of good working methods, new innovations or clever methods at construction sites. The common factor is that every positive observation can help other sites to improve their methods and working conditions. The motivation for reporting is the main issue in collecting more positive observations. Finnish culture is often reluctant to point out positive things, and the problem is that workers don´t see the benefit in a larger scale. Positive observations can help safety improvement in general if the information can be distributed. Another reason for the reasonable amount of the positive observations is that the positive observations are not as urgent to deal with as the defects.

6.2.2 Further processing of the observations

As the safety data is collected into the database the next step is analyzing and further information distributing. This research was able to characterize the further process of safety observation analyzation with the occupational staff. Essential benefit of the mobile applications is further analyzing of the observations and additional data. Safety level can be brought up by maintaining safety data and practices based on constant observations. Due to the fact that every observation has three different tags that help the tracing, the analyzation process gets also easier. The software allows filtering and searching through database with references. The further analysis can also produce new safety data if the observations are, for example, linked into places in the software by GPS or mapping in the future. This could help to produce safety information related to hazardous places in the construction sites. These kinds of places can then be further studied in order to avoid future hazards. The observations can produce a massive amount of indirect information about the safety matters of construction sites.

The observations collect data for other purposes also. For example, valuable information about different sub-contractors can be produced by analyzing the information gotten from the observations. This kind of information can be used for example valuating contractors or quality assessments. The original purpose of the observations and information in safety management can be extended to site management and even for competitive bidding. It can be stated that the information through these observations is essential and very useful in many ways; the question is whether it is exploited.

7. DISCUSSION AND CONLUSIONS

7.1 Evaluation of the research

This study was conducted in collaboration with the software developer and the construction company. The biggest benefit of the case study was the feedback gotten straight from the users of the application tool. The interviews helped the process of launching the application and the valuable feedback was discussed with the construction company and the software developer.

All in all this research succeeded to answer the research questions well and found suitable features for safety management tools in construction. Especially the safety observation software was discussed thoroughly and the new version was created based on the interview feedback. The feedback gotten from the real users was invaluable in this research and the software is ready to be launched into further use.

7.2 The obtained main results

The benefits of the mobile technology presented in the chapter 3.4 can be extended to the use of the mobile application for safety observations. *Time savings, improved productivity, more transparent process, better information quality* and *faster resolution to problems* are all benefits that this kind of software can provide. The interviews on the test period in the construction sites showed that these benefits can be achieved. The application is easy to use when filling the safety observation forms, which makes safety information collection effective at site. The traceability of the observations and ability of everyone with user account viewing information from the database makes the process of safety observations more transparent. Furthermore, the functionality of assigning responsibilities to the observations allows faster resolution to the problems when information distribution is more focused. The digital safety observations are relatively easy to fill and report but the process of the observation has not been yet standardized and more practical knowledge is needed in order to achieve agile processes. It is also important to identify the roles of different users in this process to maintain clear chain of practices. The roles of the users should be determined by the organizational view and introduced to every part of this process.

The number and quality of safety observations are also relevant issues to acknowledge. It is important to determine the type and description of relevant and wanted observa-

tions. The relevance of the observations can be evaluated by contemplating the safety improvement in larger scale. What kinds of observations are more likely to improve safety issues and what kinds of observations are only stating the current situation at site? The main goal of the relevant observations is the impact on the safety practices. The trivial and minor defect reporting improves local safety issues at site but the larger scale impact is a result of a number of relevant observations. The guidance and orientation must be determined at the organizational level and brought to site level by clear guidelines. The guidance is important in order to achieve better quality of observations and to avoid irrelevant data. Observations should be made based on safety improvement and good practices, as opposed to quantity goals. The right kind of motivation and understanding of the process are the key factors in achieving functional safety observation system.

7.3 Recommendations towards the construction industry

Mobile technology is becoming more and more common in construction sites during the next years and the number of devices is increasing. There is a great deal of possibilities that can be achieved with the help of mobile devices safety improvement being one of them. The real benefits allow site management to keep better track on the phase of the site. It is possible that most of the construction companies are planning to provide mobile devices to the whole staff rather than the management personnel only. The impacts of this kind of an expansion are wide-ranging. The widened use of mobile technology means more traceable processes and allows better social connectivity at site. However, exploitation and effective use of the mobile technology require features which are appropriate for construction sites and software solutions must be carefully selected.

The mobile tools for management purposes are developing quickly and the differences between the applications are minor. This will lead to competitive markets between localized tools. The problem with international tools is that Finland has such a unique system for safety management, that few of the applications are suitable for Finnish safety management purposes as such. [Sulankivi et al., 2016] The possibility to configure needed forms and auditing reports can be counted as an advantage in software markets.

In case of digitalization of construction practices, it is also important to acknowledge the risks related to mobile devices in general. The use of mobile devices raises concerns about data security and reliability of mobile information and technology. Further research concerning risk management of mobile applications in construction is needed. Also the guidance on the use of mobile devices in a hazardous environment must be released and introduced to the personnel. The concern is that the devices can occupy a person´s attention and the risk of accidents or injuries might increase. These risks related to mobile devices in construction are very similar to other industrial fields. There are

risks related to data distribution and data security, but concrete risks differ from general knowledge. Construction sites require durable devices that can be used in extreme weather conditions in the field. The possible risk of breaking the device is also relevant and needs to be addressed in order to get all of the benefits that mobile devices bring with.

7.4 Further research and future

Future of the digitalization in construction offers vast possibilities on safety improvement. The Internet of Things (IoT) development will bring whole new possibilities to provide information for safety improvement. IoT technology can allow new kinds of censors and monitoring devices to be connected to mobile safety management system in order to get information through the devices also. The development enables vast number of data to be analyzed and monitored at the same time. New technology enables also the use of new kinds of censors in evaluating the individual wellbeing and working conditions in construction sites in the future.

The amount of information in the safety management system is increasing rapidly and the analyzation of the information is getting more laborious. The Big Data analysis offers a way to manage the vast information in the future if the information is collected through different censors and other devices. The Big Data analysis aims to identify patterns and similarities in the information and by analyzing these patterns the conclusions for safety improvements can be drawn. The amount of information at the moment does not require these kinds of procedures but in the future research around this subject is definitely needed.

REFERENCES

Cooney M., (2012), 10 common mobile security problems to attack, PC World, [WWW], [http://www.pcworld.com/article/2010278/10-common-mobile-security-problems-to-attack.html]

Finlex (2009), Government Decree on the Safety of Construction Work (205/2009), Unofficial translation, Ministry of Social Affairs and Health- Finland, pages 41, [http://www.finlex.fi/en/laki/kaannokset/2009/en20090205.pdf]

Helander M., (1991), Safety Hazards and motivation for safe work in the construction industry, International journal of Industrial Ergonomics: Volume 8, Issue 3, Pages 205-223, [http://www.sciencedirect.com/science/article/pii/016981419190033I]

Hämäläinen P., (2010), Global Estimates of Occupational Accidents and Fatal Work-Related Diseases, Tampere University of technology, pages 99, [http://dspace.cc.tut.fi/dpub/bitstream/handle/123456789/6818/hamalainen.pdf?sequence=1&isAllowed=y]

InstaAudit- application, (2016), Web-based software, Insta Audit, [https://app.instaaudit.com/login]

Insta Audit, (2016), web pages, Insta Audit, [http://www.instaaudit.com/]

Kauppinen T., Mattila-Holappa P., Perkiö-Mäkelä M., Saalo A., Toikkanen J., Tuomivaara S., Uuksulainen S., Viluksela M., Virtanen S., (2012), Työ ja Terveys Suomessa 2012, Työterveyslaitos, pages 183-186, [http://www.ttl.fi/fi/verkkokirjat/tyo_ja_terveys_suomessa/Documents/Tyo_ja_Terveys_2012.pdf]

Kimoto K., Kazuyoshi E., Iwashita S., Fujiwara M., (2005), The application of PDA as mobile computing system on construction management, Automation in Construction: Volume 14, issue 4, pages 500-511, [http://www.sciencedirect.com/science/article/pii/S0926580504001268]

Kjellen U., (2000), Prevention of Accidents Trough Experience Feedback, Taylor and Francis Group, pages 3-77.

Knutas A., (2012), Rakennustarkastuksen mobiilityökalun suunnittelu ja toteuttaminen,Lappeenranta university of technology, pages 14-19, [http://www.doria.fi/xmlui/bitstream/handle/10024/74752/dippa_final_doria.pdf?sequence=1]

Laitinen H., Ruohonen I., (1993), Talonrakennustyömaan työturvallisuuden mittaaminen havainnoimalla: TR-mittarin kehittäminen ja testaus, Työterveyslaitos-Työturvallisuusosasto, Pages 1-19

Landrum D ., Crossnan K., Abrahamsen A., (2014), Building an effective stategy for managing construction risk, ACE Group, pages 7, [http://www.acegroup.com/esis-en/assets/white-paper-building-an-effective-strategy-for-managing-construction-risk.pdf]

Leino A., (2008), Analysis and effective use of safety performance information in a construction company, Helsinki University of technology: Lifelong learning Institute Dipoli, security management training, pages 1-28

Leino A., Suvanto J., (2011), Use of good Management Practices (Finland), European Agency for Safety and Health at Work, pages 7, [http://archive.beswic.be/data/case-studies/use-of-good-safety-management-practices/Good%20safety%20management%20case%20study.pdf]

McKerchar R., (2015), 5 Mobile device risks in your business, Naked Security by Sophos, [WWW], [https://nakedsecurity.sophos.com/2015/03/02/5-biggest-mobile-device-risks-in-your-business/]

Oedewald P., Gotcheva N., Viitanen K., Wahlström M., (2015), Safety culture and organizational resilience in the nuclear industry troughout the different lifecycle phases, VTT Technical research centre of Finland, pages 12-47, [http://www.vtt.fi/inf/pdf/technology/2015/T222.pdf]

Priha E., Repo S., Savinainen M., Lappalainen J., Oksa P., (2009), Rakennusalan terveys ja turvallisuus 2000-luvulla: Rakennusalan riskiprofiili, Työterveyslaitos, pages 1-32, [http://www.ttl.fi/fi/tyoturvallisuus_ja_riskien_hallinta/riskien_hallinta/Documents/Rakennusalan%20profiili_240809.pdf]

Reiman T., Pietikäinen E., Oedewald P., (2008), Turvallisuuskulttuuri- Teoria ja arviointi, VTT Technical research centre of Finland, pages 110, [http://www.vtt.fi/inf/pdf/publications/2008/P700.pdf]

Sage, (2015), Construction IT survey, [WWW], [http://go.na.sage.com/cre-construction-it-survey]

Sage, (2016), 2016 Construction technology outlook, [WWW], [https://www.sage.com/na/~/media/sage-job-ready/assets/2015-sage-technology-survey-infographic-final]

Sauni S., Rantanen E., (2000-2016), Rakentamisen turvallisuuden hallinta, [WWW], [http://virtual.vtt.fi/virtual/proj3/ytya/rak-tt.htm]

Sigloch W., (2016), Pedestrians Crossing Streets: Distraction by Smartphone poses risks, DEKRA Accident Research, [WWW], [http://www.dekra.com/c/document_library/get_file?uuid=6c852f72-895f-4a58-be9a-16b795db0323&groupId=10100]

Skanska, 2009, Skanskan turvallisuushavainnot menestyivät Euroopan työturvallisuuskilpailussa, [WWW], [http://www.skanska.fi/fi/media/uutinen/?nid=VyKDDnDf]

Spangenberg S., Baarts C., Dyreborg J., Jenses L., Kines P., Mikkelsen K., (2003) Factors contributing to the differences in work related injury rates between Danish and Swedish construction workers, Safety Science Volume 41, issue 6, pages 517-530, [http://www.sciencedirect.com/science/article/pii/S0925753502000073]

Sulankivi K., Kontio K., Kiviniemi M., (2016), Improving safety at building construction sites by means of BIM and mobile tools, WBC16 Proceedings: Volume IV, Tampereen teknillinen yliopisto, Rakennustekniikan laitos, pages 165-177

Tappura S., Hyytinen T., Kivistö-Rahnasto J., Nenonen N., Vasara J., (2015), Turvallisuuden johtajat- Esimiesten johtajuus, osaaminen ja sitoutuminen, Tampereen teknillinen yliopisto, pages 144, [http://www.tut.fi/cs/groups/public/@l915/@web/@p/documents/liit/x149267.pdf]

Tappura S., Hämäläinen P., Saarela K-L., Luukkonen O., (2010), Mittaaminen osana työturvallisuuden johtamista, Työturvallisuuskeskus TTK, pages 28, [http://ttk.fi/files/4642/Mittaaminen_osana_tyoturvallisuuden_johtamista.pdf]

TVK, (2015), Työtapaturmat- Tilastojulkaisu 2015, Tapaturmavakuutuskeskus (TVK), pages 30-34, [http://www.tvk.fi/fi/Julkaisut-ja-lomakkeet]

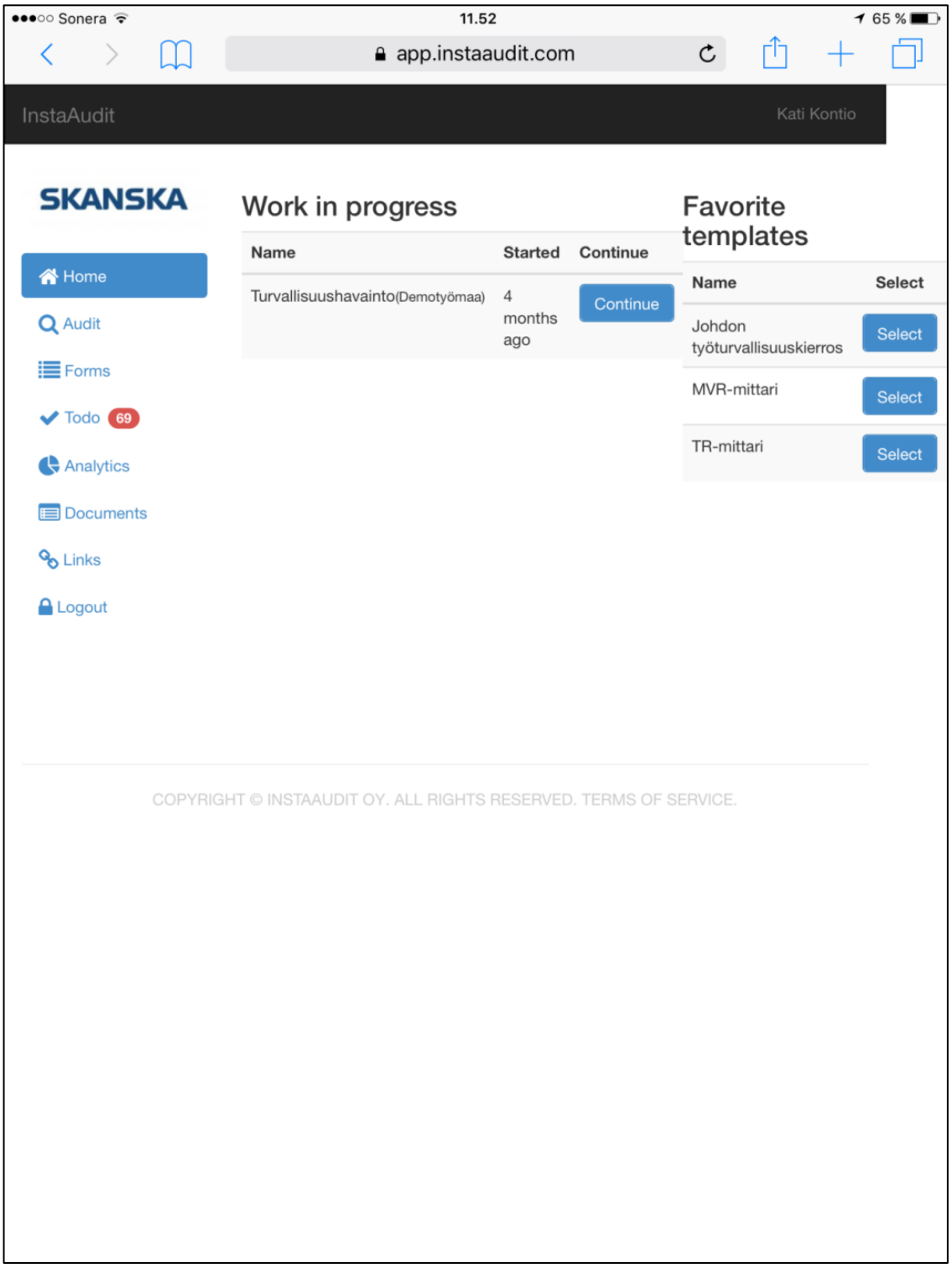
Vilkko T., (2007), Mobiiliteknologia liikkuvan työntekijän apuna, Lappeenrannan teknillinen yliopisto: Teknistaloudellinen tiedekunta, pages 1-69, [https://www.doria.fi/bitstream/handle/10024/33611/Dippa%20Teemu%20Vilkko%20-final.pdf?sequence=1]

APPENDIXES

Appendix 1: *The front page of the InstaAudit web-based software [InstaAudit-application, 2016]*

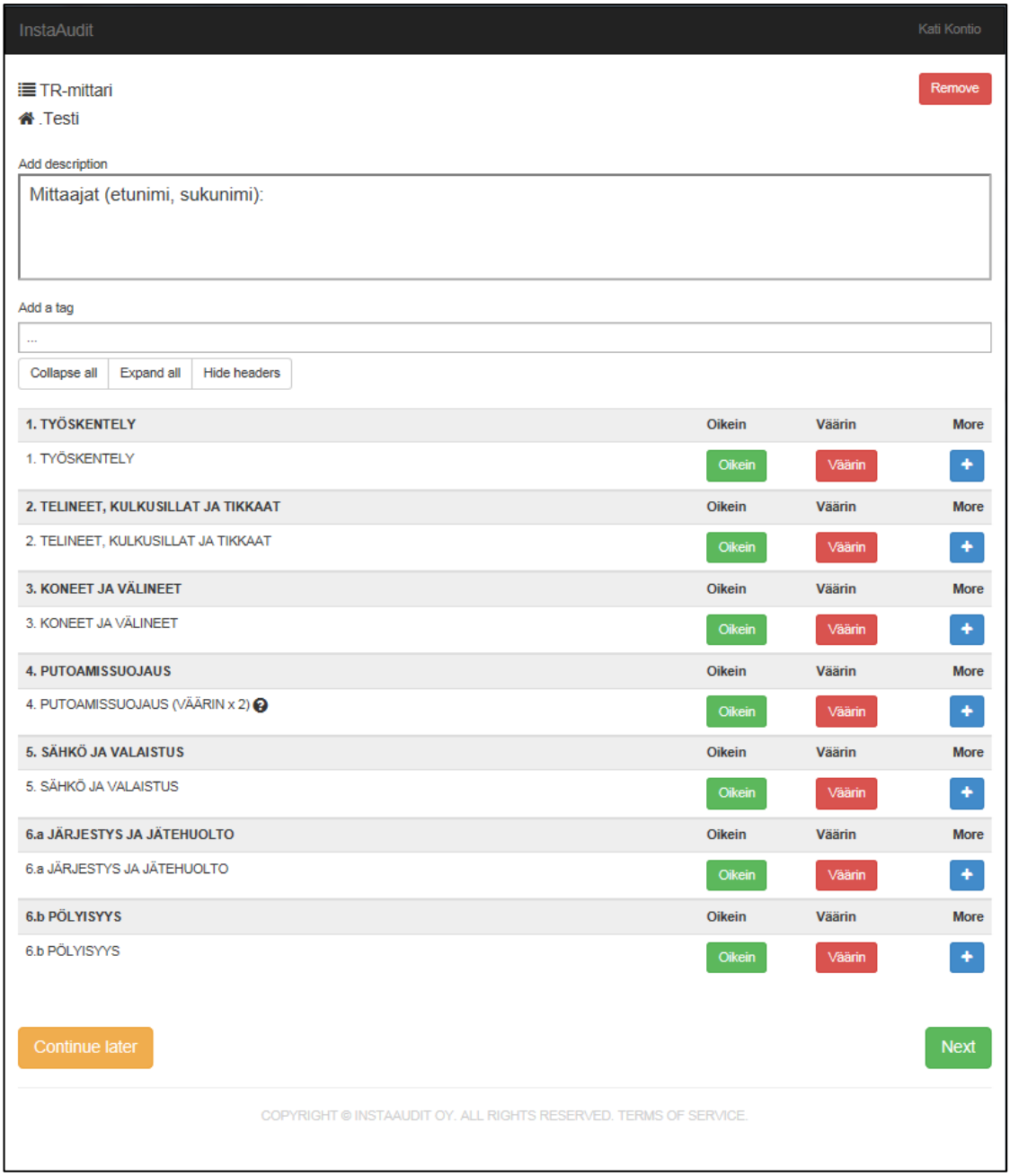
Appendix 2: *The InstaAudit safety level inspection form in web-based software. [InstaAudit- Application, 2016]*

Appendix 1



The front page of the InstaAudit web-based software [IA]

Appendix 2



The InstaAudit safety level inspection form in web-based software. [IA]