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Design and Development of Virtual Environments

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ICT IMPLEMENTATION IN ESTONIAN CONSTRUCTION INDUSTRY AND INDUSTRY RELATED BUSINESS OPPORTUNITIES FOR ICT START-UPS

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Abstract

This thesis studies the implementation of information and communications technologies (ICT) in Estonian construction sector. The use of ICT is rapidly growing in different areas of business, changing the ways things are done and is the core of most of the innovation. Although Estonia is one of the leading countries in several ICT areas and often praised for its innovative mindset and effective implementation of different solutions, the construction sector is lagging behind in the sense of ICT innovation.

The aim of the current research is to identify the hindrance posed by the construction industry to ICT innovation based on the experience of BIM implementation in Estonia. For the purpose of data collection interviews with industry participants, a survey and a preliminary testing of a minimum viable product of an IT solution built based on the findings from interviews were conducted. During the analysis the hindrances that need to be avoided and the hindrances that can be minimized and thus turned into opportunities for ICT start-up companies planning to enter the construction market were derived.

The results of the study show that there are six main hindrances that are caused by the fundamental structure of Estonian construction industry. The authors argue that by avoiding these six hindrances and minimizing the other hindrances identified, the IT start-ups can achieve a competitive advantage when entering the market.

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1 INTRODUCTION

1.1 Introduction

The relationship between country's long-run growth and development has been well studied. With the support of growingly open economies, most industries and segments worldwide today are forced to admit that innovation is playing the vital role in effective competition and thus leading the economies to develop (this holds true country wise as well as business entity wise). As early as in mid-1950-s, a prominent 20th century American professor and economists Dr. Moses Abramovitz stated that in the most fundamental level there are only two ways to increase the output of the economy (production): 1) by increasing the volume of the input into the production; or 2) by coming up with new solutions to receive more output for the constant amount of input, ie by innovation. (Rosenberg, 2004)

The latter becomes increasingly relevant when the country is facing scares labor force as a result of low birth rates and thus aging population. In case the economy (and thus the businesses within the economy) is not able to attract additional workforce from other counties, the input to the production in terms of labor force is decreasing instead of increasing, and thus leaves the economy only with the second option (to innovate). Therefore, investing into innovation and IT development is especially important for small countries with scarce labor force and with economize that are still catching up, Estonia being one of them. Additionally, the importance of investing in technology and supporting the innovation is ever growing with the roughly exponential improvement in technologies globally.

In overall terms, one could say that Estonia has been very successful in recognizing these developments. The government's strict policy today is to support and invest into ICT development. The main framework for government's strategy for years 2014 – 2020 is defined in the latest version of Konkurentsivõime kava "Eesti 2020" (Competitiveness plan "Estonia 2020"), confirmed by Estonian Government on 8th of May 2014. In the article 9, the document states that "In order to increase the potential for creative industries, for ICT sector and for key technologies, it is necessary to contribute into sector wide integration and internationalization

activities, but also in the area of financing. For achieving the additional value-added synergies between different fields, attention must be paid to human capital capabilities in its broadest sense. Successful cooperation requires the creation of the characteristics of people that are able to take into account the existence of a favorable environment. ICT and other key technologies serving as a foundation for other areas by supporting processes and initiating innovation have to be supported by taking the industry wide collaboration in adopting new solutions onto the whole new level". Also, it recognizes the necessity to create measures for promoting co-operation between entrepreneurs and ICT sector representatives" (Eesti 2020, 2014).

Estonia's government's support for ICT and the need to retain countries competitiveness while facing the natural constraints imposed by the size of the nation is reflecting already in numbers. In 2013, Estonia ranked 25th out of 142 countries based on the Global Innovation index, published in corporation with World Intellectual Property Organization, INSEAD, and Cornell University (Global Innovation Index, 2013). In 2012, Estonia ranked 22nd out of 157 countries based on the ICT Development Index (International Telecommunication Union, 2013).

The major leap towards ICT development and innovation in Estonia can be also seen in country's everyday business scene. BBC has even gone as far as it has praised Estonia as a new Silicon Valley. The number of start-up companies in Estonia per person is the highest in all of the Europe (Cassidy, 2014). The start-up companies have recognized the potential in different industries and are aiming to interrupt the way the traditional business is done. The industries affected by IT based startups are as diverse as ranging from banking industry (TransferWise) and payment providers (Fortumo) to taxi industry (Taxify) and agriculture (VitalFields).

However, a deeper look into this fast developing innovative economy in Estonia shows that the development is far from equal across the industries. When contrasting the industry's contribution into country's GDP with IT innovation in the sector, construction industry is the one to stand out.

In 2012, Estonian construction sector built for EUR 3 billion of which EUR 257 million was net profit. Its total contribution into country's GDP was 7.4%. The sector employed more than 58,000 people (Majandus- ja Kommunikatsiooniministeerium et al, 2012). To understand the relevance of construction industry in the economy, one can compare the figures to the manufacturing industry as a whole in 2012 which produces EUR 10 billion in revenue while employing approximately 100,000 people.

Despite its substantial share into country's economy, the industry is today lagging behind in terms of ICT innovation. It is relevant to note here that by stating this, the authors of this paper do not mean innovation in its all meanings. Construction industry is by its nature a creative industry and is thus innovative by its definition. However, the innovation in the industry is mainly product related, which is not in the in interest of this study. For the purpose of the current study, the authors define ICT innovation as a successful introduction of new IT solutions and/or related processes into the industry.

This gap between slow ICT innovation and relevance of the industry into country's GDP was recognized by the authors while searching for potential business ideas for a start-up project to be created in an academic environment during their final study year in Master's program of Design and Development of Virtual environments in Viljandi Culture Academy. On the one hand, the industry proved to be huge by its share to overall economy. Also, a lot of work and processed that could have been automated were found out to be still carried out manually. Combined together, these finding indicated that there could be an enormous potential for ICT startups to target construction industry as a potential client market. On the other hand, however, a lack of new implemented ICT solutions in the sector and very slow innovation when compared to other industries in Estonia served as a caution. Thus, it became essential to study the hindrances to implementing new ICT solutions in construction market. No previous research investigating mentioned hindrances by construction sector in Estonia were found. Therefore, the authors of this paper decided to reduce this gap.

This paper aims to answer the research question "**What are the hindrances to implementing new ICT solutions in Estonian construction market**?". Also, as the author's practical interest is to gain an insight into the potential success of their business idea, a secondary research question "What **are the opportunities for IT start-ups entering Estonian construction sector**?" will be answered. However, this will be done only to the extent considered reasonable in the context of this study.

In order to answer the research questions proposed, a qualitative study among industry participants was conducted. To focus the research and to enable unified data collection, the research was built up on the grounds of BIM model. BIM is the process of generating and managing building data during its life cycle. It is also a tool as well as a process and increases

productivity and accuracy in the design and construction of buildings. BIM uses 3D dynamic building modeling software and operates in real-time. It supports the continuous and immediate availability of project design scope, schedule and cost information that is high quality, reliable, integrated and fully coordinated. (Forbes and Ahmed 2011)

The decision for introducing the BIM model and building the research on it was based on the fact that BIM related ICT solutions for construction market were found out to be one of few solutions out in the market and also known by considerable share of industry participants. A study by Eesti Äritarkvara Liit (Estonian Business Software Alliance) in 2013 construction designers showed that little over 50% of industry practitioners are knowledgeable about BIM and that 8,13% have tried implementing it (Eesti Äritarkvara Liit, 2013). Even if these statistics are limited to only designers, it gives an overall indication of the level to what extent the solution is known. Given that there are already a limited number of construction companies in Estonia who have tried implementing the solution, it enables the representatives of these companies to share more detailed understanding about hindrances and obstacles encountered on the preliminary implementation process of BIM solutions. Also, an additional argument for introducing BIM was that most of the up-to-date academic research worldwide related to ICT innovation in construction market is covering BIM. Therefore, there is an opportunity to extend the existing research via identifying the limitations and aiming to fill that gap.

In addition to the authors practical interest, the findings of the current study could be useful to other IT start-ups considering construction industry as a potential market in Estonia or countries similar to Estonia (ie countries where the ICT innovation in construction industry is lagging behind more than in innovation led construction industries in other economies). Also, given that government has stated the relevance of ICT development in all creative industries, it might be useful for them to learn about the hindrances they will have to face when working with the construction industry.

The relevance of this study cannot be underestimated also when looking at the statistics for EU and US. Total construction output in EU amounted to €1,172 billion in 2012, and construction industry is said to be still one of the major engines of Europe's growth. It represents 9.1% of EU GDP with more than 3 million enterprises providing jobs to more than 14 million workers. This constitutes 6.8% to overall employment without counting the indirect employment generated in related sectors. Altogether 43.8 million people in EU depend on the construction sector

(European Construction Industry Federation, 2013). In comparison, in US the revenue generated by construction sector in 2012 was almost EUR700 billion being one of the US backbone industries while representing 7% of country's nominal GDP (Euromonitor International, 2012). As of 2012, the U.S. Bureau of Labor estimated that 5.64 million Americans were employed in the construction industry (Plunkett Research, 2013). In addition, Seaden (2001) writes that "The economic space of construction is much larger than that defined by traditional statistical records because it comprises the design of buildings and infrastructure (engineering and architectural services), the manufacture of buildings products and of machinery and equipment for construction, and operation and maintenance of facilities. (Seaden & Manseau 2001, 184)

The previous studies covered in Literature Review also show that the innovation lag in construction industry is a phenomenon for many countries.

1.2 General outline of the study

First, a general introduction to the study is provided covering the research topic and relevant research questions for this study. Second, an overview about relevant previous research is provided. Third, a methodology for the research and choice of study design is introduced. This is followed by data collection and data analysis based on which implications for the future are provided. Based on the findings a concept of the initial business idea are improved to take into account the main identified hindrances to ICT implementation in Estonian market. This is developed further into a real minimum viable product (MVP) which is given for possible users to test. Then, a feedback from initial MVP testing and attitude from target customers is collected. This is to obtain better confidence that the conclusions drawn from the first (main) part of the study could be regarded as reasonable assumptions to build ICT solutions for construction market on.

2 Literature Review

2.1 Generic description of the construction sector

There is a number of studies available analyzing the specific characteristics and structure of construction industry as well as discussing the aspects that needs to be consider when planning to enter the construction sector. This section aims to give a brief overview about the main discussion topics on this matter.

The construction sector companies are mostly private owned and therefore more focused on saving resources and increase profits, especially in today's market where competition is very strong and in public and private procurements companies often offer too low prices in order to get the contract and then starts the long negotiations with the client to reduce costs. "Intense competition in most developed markets and the consequential low profit margins for construction contractors, designers and suppliers led to the commoditization of this industry" (Skibniewski and Zavadskas 2013, 142).

Construction sector is very complex and has a lot of stakeholders present either throughout the whole life span of project or at specific stage/stages. Forbes and Ahmed (2011) have listed them as following:

1) Owners. They order the project and arrange design, financing and construction
2) Designer. Architects and engineers who interpret owners wishes. Usually also part of the construction team.
3) Constructors. Main- and sub-contractors who provide the workforce, materials, equipment etc. to furnish a completed facility.
4) The labor force. Foremen, craftsmen, journeymen and skilled or semiskilled apprentices.
5) Major suppliers. Equipment and material manufacturers and transporters.
6) Financial institutions such as banks and construction financial organizations.
7) Lawyers, insurers.
8) Federal and local regulators
9) Public services

10) Utilities
11) Safety professionals
12) Quality assurance/quality control professionals
13) Lean facilitators who provide support in the implementation of lean approaches in design and construction. (Forbes and Ahmed, 2011, 8)

As for the last described participant, lean facilitators, it is not so widely used yet, so it must be taken as a new participant not implemented by default but only when the owner is familiar with the lean concepts.

Despite the size of an industry and its wide spread grip of different participant, the industry as old, large and traditional as construction industry is not easy to modernize and change. Processes, people, traditions, work-flows - everything has evolved over time and settled in deeply. Old ways mean the printed construction drawings, un-systemized distribution of important data about work-flows and changes, pen-and-paper methods for information gathering. Forbes and Ahmed (2011) define the conventional construction site participants as craft production representatives and their tasks on the site are usually only communicated with general construction manager, thus resulting in interrupting in each others tasks due the project management methods that are not inter-communicational and are very limited in their ability to reduce project variability. (Forbes and Ahmed, 2011)

As Ergo Pikas describes, relying on different authors such as Diekmann et al, 2004, Koskela and Howell, 2002, Laufer 2009, LePatner, 2008, construction is wasteful and poor in terms of adding value to the client and that the criticism does not only regard construction technologies and methods; conventional construction is seen as being broken on a fundamental level (Pikas 2012, 1). It can be even argued that waste is one of the most fundamental problems for construction industry which is supported by the extensive research devoted to it. Due to this, a separate section in literature review was devoted to it.

2.1.1 Waste in construction

In order to understand the needs and problems for construction industry, it is vital to look at the waste in terms of wasted resources generated by the industry. Only process related waste is covered in this study, as environmental waste (trash) was considered irrelevant in current

context. Despite the research and attempts to reduce the problems around the waste, the waste is still hugely represented in construction processes.

Senaratne and Wijesiri try to define the waste in construction and say that generally the waste is associated with materials in the construction processes while activities such as inspection, delays, transportation of materials and others are not defined as non value-adding flow activities that may lead to waste (Alarcon, 1995). According to the same authors, relying on Womack and Jones (2003) waste can be described as any human activity which absorbs resources, but creates no value (Senaratne & Wijesiri 2008, 35)

In 1972 Construction Industry Cost Effectiveness (CICE) project was created by 200 largest U.S. companies. To promote quality, efficiency, productivity and cost-effectiveness. 1983 CICE created a report stating that in the $300 billion sector, even the modest application of the recommendations of the CICE team could save the industry $10 billion annually. In 2010 these observations are still relevant. (Forbes and Ahmed, 2011, 5). Koskela also has an article about "eighth" category of waste besides most used seven categories stated in Toyota Production System: overproduction, unnecessary transportation, inventory, motion, defects, over-processing and waiting (Leon, 1999). Koskelas eighth category is called "making-do" and means that the waste occurs when task is started but all its standard inputs, such as materials, machinery, tools, personnel etc, are not ready. It is the opposite of buffering where materials are waiting for processing. (Koskela, 2004) Serpell et al. (1995) synthesized different classifications of wastes that were identified by various researchers, under three groups that can be seen in the table below.

Commonly mentioned wastes	Occasionally mentioned wastes	Unmentioned wastes
Waste due waiting periods	Over production	Pilferage
Defects	Safety costs	Management time spent on fire-fighting
Excess materials	Equipment wear and tear	
Waste due to design errors	Resting time	
Transport/handling time	Inventing work	
Activity details	Clarification needs	
Waste due to operations		
Excessive space/stock		

Rework		

Fig. 1. A synthesis of identified wastes (*Source:* Senaratne & Wijesiri 2008, 36)

Senaratne and Wijesiri also add that these are usually considered as temporal wastes and are therefore intangible and invisible, so this may be a reason for construction companies not seeing the existence of these wastes (Senaratne & Wijesiri 2008, 36).

Studies suggest that approximately ten years ago in the USA, Scandinavia and Britain up to 30% of construction is rework, labor is used at only 40-60% of potential efficiency, accidents can account for 3-6% of total project costs, and at least 10% of materials are wasted. (The Construction Task Force, 1998)

The same conclusions are reached by Ekholm and Molnar who state that relying on Josephson and Saukkoriipi (2005), Byggkommitten (2004) and Apleberger et al (2007), several investigations have shown that ”waste” within the construction sector is large and that many measures for rendering the processes more effective are possible (Ekholm & Molnar 2009, 430).

More specific data is brought out by American Institute of Architects in its Integrated Project Delivery Guide where is illustrated the inefficiencies and waste in the construction industry with an example from the *Economist* article from 2000 which identifies 30% waste in the US construction industry; a NIST study from 2004 targets lack of AEC software interoperability as costing the industry $15.8B annually; and a US Bureau of Labor Statistics study shows construction alone, out of all non-farm industries, as decreasing in productivity since 1964, while all other non-farm industries have increased productivity by over 200% during the same period (The American Institute of Architects 2007).

2.1.2 Information Flow in Construction Process

Another aspect to consider when analyzing construction industry and looking at the complex aspects of construction sector is the information flow in construction process. Onyegiri et al. quote Emmitt and Gorse (2003) by saying that communication between construction industry participants and organizations are concerned with information exchange, dealings with drawings, specifications; cost data, programs plus other design and management information. (Onyegiri, Nwachukwu & Jamike 2011, 462). Many construction businesses rely still on manual processes

and traditional communication tools like phones and e-mails. (Dave, Body & Koskela, 2010). Construction industry is by its nature labor intense and therefore generates large amount of information to be exchanged between different parties. Thus, accurate and smooth information management is crucial for the industry. With most of this still done manually, there is still a huge improvement to be achieved.

The relevance of information flow management becomes even more important in the light of the life-time of the building. The active process may end with the grand opening of the building, main contractor is several years afterwards attached because of the warranty issues, but eventually there is only the client or the owner left. Eastman et al. said that there are many owners who consider construction itself as a relatively small capital expenditure compared to the whole life-span costs or operational costs that occur over time (Eastman, Teicholz, Sacks & Liston 2008). So during the whole lifespan of the building, information is needed for the renovations, maintenance and other issues. Therefore it is very important that the whole construction process is well archived and systemized thorough the whole process in order to give reliable information during the years to come.

2.1.3 Innovation in construction

When talking about construction sector, innovations can be divided into two modes: 'bounded', where the implications of innovation are restricted within a single, coherent sphere of influence, and 'unbounded', where the effects of implementation spill over beyond this. Bounded innovations are adequately explained within the construction literature. However, less discussed are unbounded innovations, where many firms' collaboration is required for successful implementation, even though many innovations can be considered unbounded within construction's inter-organizational context. (Harty 2005, 512) So in order to apply innovative solutions, often different participants must be taken into account or get them to use new technologies.

Another approach to innovation in construction was brought out by Seaden and Manseau (2001). They said that as every construction project can be considered a prototype so starting on a new and different site usually with a different owner, there is an opportunity and tendency to do something new every time. Construction practitioners and their clients have often interpreted this as innovative behavior.(Seaden & Manseau 2001) According to Slaughter (1998) two set of

models must be approached when discussing construction industry and the specifics of construction companies: 1) the magnitude of change from current state-of-the-art associated with innovation and 2) the expected linkages of the innovation to other components and systems. At the same time these models can be divided into radical and incremental innovation models, depending on the magnitude of the changes. (Slaughter 1998, 227) Usman and Said (2012) have researched some of the definitions such as the one by Egmond and Ligny (2005) which states that innovations in the construction industry refers to the process of development, distribution and application of technologies a new or improved product, process or service and knowledge with the purpose to improve productivity and to suit the customer's requirements. Also in the same study authors refer to Toole (1998) who defines innovation process as application of technology that is new to an organization and that significantly improves the design and construction by decreasing the cost, increasing the performance and improving the business process. (Usman & Said 2012, 2) The Toole's definition emphasizes on the importance of cost reducing which is key factor to implement innovative solutions in a private sector therefore it is important to calculate the costs and possible revenues, direct or indirect, for the decision makers in order to succeed with the process. ICT innovation refers to the introduction of new ICT initiatives to an organization. The organizational process of introducing ICT initiatives for adoption by expected users is defined as ICT diffusion. (Peansupap & Walker 2006, 365) It is quite safe to say that innovation in a old and traditional sectors can happen when there is a possible positive economical outcome.

Innovations in construction can often increase the technical feasibility of construction undertakings but they may also provide significant benefits that can not be adequately measured in direct monetary savings and gain but can add to company's competitive position: improved reputation, ease of work and attracting new promising hires (Slaughter 1998, 226).

2.2 ICT

The importance and benefits of ICT development and ICT implementation across different industries to boost efficiency and support innovation in other areas has been studied thoroughly. The following paragraph provides a brief explanation on what is meant by ICT and gives few examples on previous research supporting the underlying assumption for the current study, i.e. that ICT creates value for other industries.

ICT in general stands for information communication technology. Onyegiri, Nwachukwu ja Jamike explain in their article relying on Adriaanse and Voordjik (2005) "ICT is a neutral provider of input for decision making" (Onyegiri, Nwachukwu & Jamike 2011, 462). In this point of view communication is no more than distribution of information. Researching different authors they came up with the following diagram.

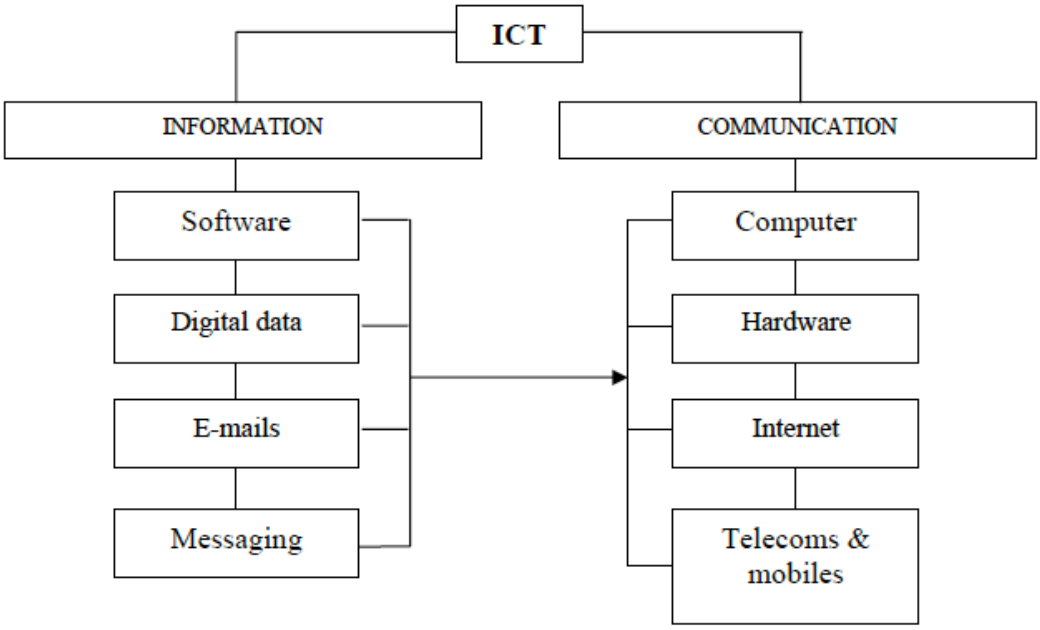

Fig 2. A simple diagram showing the flow of information trough a medium of communication (*Source*: Onyegiri, Nwachukwu ja Jamike 2011, 462)

For the last 20–30 years the ICT infrastructure has been built, the performance and density will continue to improve and increase, but a turning point has now been reached. Current threshold is similar to the turning point all industrial eras have experienced. During installation phase, new solutions are used to increase the efficiency in the old system, during deployment phase the new system reaches maturity, allowing it to deliver entirely new solutions. Initially, the transformation happened in the "information sectors", within e.g. music, video or book sectors etc, and now we start to see the first signs of a serious change in the "heavy sectors", such as car and mobility, construction, agriculture and retail sectors, as well as in basic business models. (Ernst & Young 2012)

Arengufond study cites according to different studies by European Commission (2007), van Ark and Inklaar (2005) and Kok (2004) that between 2000-2004 half of the growth of productivity in

economy in OECD and EU countries came from the implementing ICT solutions and organizational reforms connected to ICT (Eesti Arengufond 2009).

2.3 Minimum viable product

For the field testing we created a minimum viable product (MVP) version of the Lynxreports. Eric Ries identifies the MVP as version of the product that is done with minimum amount of effort and least amount of development time. The MVP lacks many features that may prove essential later on but includes the core features to do the most basic tasks. (Ries, 2011). Our MVP was designed to work on a tablet with Android operation system. It did not have the server support and all the data was stored in the tablet. Also the design of the application was not final but very basic with most emphasize on the usability and user-experience.

2.4 ICT in Construction Industry

In this section of the literature review, a brief overview about relevant aspects of ICT usage in construction industry is provided. Also, an overview about existing solutions and the extent to which they are used is presented.

ICT first evolved in construction sector to help in synthesizing or analyzing information and first two major applications were the finite element analysis program (FEAP) in the 1970s and the drafting software (AutoCAD) in the 1980s. Bigger leap was taken since 1990s and at the beginning of 2010, ICT-supported technology had become the norm (Forbes and Ahmed 2011, 203). However, although the participants in construction sector are evidently using ICT solutions, especially in the drawing-phase and to lesser extent in communication and management process, the overall construction process is still somewhat mixed with old and new ways. The transition from old ways to information technology has been well illustrated by Turk (1997).

Needs	**Item**	**Traditional technology (becoming obsolete)**	**ICT supported technology**

Information processing and management	Project	Drafts, folders	Document management, product and process models
	Company	Archive, microfilm	Data warehouses
	Country	Library, building regulations	National construction information systems
	World	Journals, conferences	Global ICT networks
Interaction facilities	Man with man	Speech, phone, fax, mail	e-mail, video conferences
	Man with application		3D visualization, virtual reality, graphical user interfaces
	Man with machine	Direct contact	Indirect contact using computers
	Application with machine		Robotics, remote sensors
Time saving	Just-in-time	Book look-up, library look-up, phone call to expert	Database look-up, internet search
	Just-in-case	Reading books, magazines, journals, schools, visiting conferences	Subscriptions to customized content, distance learning

Fig 3. Traditional and ICT supported Technologies in Construction. (*Source:* Forbes & Ahmed 2011, 204)

A large scale adoption of Information and Communication Technology in construction stands to derive great advantages only if experience of its use can be gained at an early stage (Peansupap & Walker, 338). Certainly a lot of information is changed by emails or project-management systems, but although completed digitally, lot of the drawings and plans are used on paper by the participants in different planning and construction phases. “Though these methods have

improved the timely exchange of information, they have done little to reduce the severity and frequency of conflicts caused by paper documents" (Eastman et al. 2008). There is also a strong tradition to use pen and paper. In a way it is considered more comfortable and on the other side, there have not been any better alternatives until now.

It is also brought out in a case study by Peansupap and Walker that the lack of technology awareness that influences ICT investment decisions is because senior managers were unaware of key potential ICT innovation benefits. Lack of technology awareness may also obscure the ICT investment opportunity. This is because knowledge about a construction process (such as estimating or cost control) may be limited to more conventional/traditional methods rather than how ICT may be used to effectively re-engineer these processes (Peansupap & Walker, 370). Fernandez-Solis et al. also declare that among the reasons that one of the approaches for the lack of ICT use in construction sector is complex nature of construction industry (Fernandez-Solis 2008 and Mossmann 2009), low tech workforce and processes, lack of soft skills, lack of education and lack of computer literacy among practitioners (Fernandez-Solis et al 2013). Controversial to Fernandez-Solis's et al's studies is the McGraw Hill Construction annual report on the biggest economies construction sector which shows the rapid growth of the BIM solutions meaning that general approach to using modern solutions is changing (McGraw Hill Construction 2014).

The sector study by European Commission was held on 2006. Based on literature, interviews, case studies and survey its objective was to describe how companies in this industry use ICT for conducting business, to assess the impact of this development for firms and for the industry as a whole, and to indicate possible implications for policy. This report stated that the lack of ICT in construction sector is due the typical nature of the service provided in construction which, being an on-site and often highly customized service, does not lend itself to the typical e-business concept which is rather adapted to manufacturing industries. (European Commission 2006) In practice, real-life contingencies and multiple interdependencies complicate the adoption of new tools and processes and there is little to guide the practitioner through the messy and contingent process of adoption and diffusion that can be made in to five features: the collaboration upon which construction work is based, its organization around particular projects, the centrality of communication to its performance, the importance of inter-organizational relations, and the way power is distributed. (Harty 2005, 513)

2.4.1 Available ICT Solutions for Construction Industry

Forbes and Ahmed (2011) have thoroughly studied the construction sector's ICT solutions and gathered data and historic background about different tools used in different stages of construction. They have included tools for design and management process into a chart seen below.

ICT Tools	Design	Management
Information Management and services	• Integrated CAD systems (informational databases) • BIM – Building Information Modeling	• Online bidding/permits • Online building information services • Online project administration systems Shared project databases
Communications	• Animated 3D/4D visualizations • Virtual design studios • Simulation techniques	• Online project management and control
Processing and computing	• Integrated CAD systems (structural analysis and design)	• Model-based cost estimation • Planning and scheduling software's • E-commerce applications • BIM • Virtual Design and Construction (VDC)

Fig. 4. Tools for Design and Management Processes in Construction.(*Source:* Forbes & Ahmed 2011, 205)

ICT tools for design are mainly different CAD solutions – 2D and 3D modeling, integration of graphical and non-graphical design information, integration of the data structure and user-interface, integration of two or more applications (design and analysis, drafting functions etc.).

Management processes have more different areas covered and are sub-categorized as following by Forbes and Ahmed.

- Model-based cost estimation. Tool for consulting, contracting and maintenance corporations to generate quick and accurate cost estimates despite different data formats and standards
- Online bidding. Bidders can submit and edit their bids online, thus saving time and costs
- Online permits. Government and other permits can be applied and issued online.
- Shared project databases. Storage and retrieval of data from a central location independent of time on locational constraints. Cloud-solutions.
- Online project administration systems. Information about projects status, directory of contractors, vendors, suppliers; project drawings etc.
- Online project management. Using handheld or laptop computers, continuous data can be provided from the construction site. Digital cameras attached to the computers can be used to record videos and photos from the site.
- E-commerce applications. Buyers and suppliers can conduct business online.
- Integrated computer aided design systems. Complete solution of architectural, drafting and engineering design problems. Removes the redundancies in the design process.
- Animated 3D/4D visualization. Provide a view what a finished product may look like. Adding time to the 3D visual, turns it into 4D to simulate the progress of construction work.
- Virtual design studios. Designers and experts at different locations can interact with each other using audio and video conferencing. Same screen can be shared and same program thereby entering the same virtual reality. (Forbes and Ahmed 2011, 206-213)

These categories only show the possibilities of ICT in construction and most of them are being used at least in some extent. However, the available solutions are limited and used in isolation producing value to a specific user only. Keeping in mind that during the construction process different professionals, i.e. different parties, are working on different locations and with different tasks, the solutions used in isolations do not create much value unless the value can be passed on to other parties. Therefore, a need exists still to include them all into a systemic and co-operative environment which requires a new approach for the whole process. It's not only the specific parts that need to be innovated, but the whole system has to be seen together.

A considerable attempt to achieve this was made with introducing BIM (Building Information Modeling). Forbes and Ahmed (2011) define BIM as following: “BIM is the process of generating and managing building data during its life cycle. It is also a tool as well as a process and increases productivity and accuracy in the design and construction of buildings. BIM uses 3D dynamic building modeling software and operates in real-time. It supports the continuous and immediate availability of project design scope, schedule and cost information that is high quality, reliable, integrated and fully coordinated”. (Forbes & Ahmed 2011) The concept of BIM will be covered in detail in the next chapter.

The problem with BIM, however, is its underlying assumptions for successful implementation. For successful implementation in the industry it requires mutual agreement and action by different parties, including actions by regulatory bodies. However, due to different interest of different parties, it takes time (even decades) to achieve this. Also, one of the preconditions for BIM implementation is that several hindrances imposed by the construction industry need to be overcome, unfortunately, the research on these hindrances is today lacking and the extent to which the hindrances influence successful implementation of BIM solutions in different economies is still relatively unclear.

Despite the requirements imposed by the underlying assumptions on successful BIM implementation, it is still unarguably the best solution to meet the needs of the sector and deal with the waste in construction industry. Also, the first attempts to implementing BIM in Estonia have already made. Therefore, the authors of this paper decided to build their study on investigating the hindrances on process wide implementation of ICT solutions in Estonian construction industry on the experience and knowledge gained by industry participants during the initial attempts to implement BIM. Also, other wider spread solutions were looked for; however, there did not seem to be any better alternatives. The usage of CAD solutions is of course more wide spread today, but the conversion to CAD models happened already so long ago that the experience from that period may not be relevant today.

There have been some attempts to introduce mobile solutions to improve the information flow management in construction industry. For example in the quality inspection processes there are already quite many solutions for quicker reports carrying more detailed information. Here is a short over-view of some of them.

Tool	Information
Archipad www.archipad.com	Description: Mobile solution for iOS platform for tracking and managing construction site meetings and creating punch lists. It is targeted for all the participants on the construction site. Features: iOS. Adding project drawings to the mobile device, adding comments directly on the drawings, following the progress with punch-list (problems to be attended). Pricing: Very simple free version, main version 550€. Cloud-based co-operation environment called Archiweb needs extra subscription 0-199€ per months depending on the plan.
Inspectwise www.inspectwise.com	Description: integrated iPad + Cloud service for managing and sharing inspections Features: iOS. inspections are stored in the Cloud, users can add accounts and invite partners and customers to log in and view the inspections. Individual inspections can be assigned to individual accounts, also allowing control over what 3rd parties can access when they log in the cloud environment. Pricing: monthly subscriptions from 29-399€
Checkd www.checkd.no	Description: Checkd is a mobile software suite developed specifically for construction field workers. Features: iOS, Android, Windows. Can generate reports with photos on attached to the construction drawing with comments, have a full control over the equipment and deviations. Pricing: 30€ per month
Easytoinspect www.easytoinspect.com	Description: Easytoinspect is mobile application to create inspections, check and audits. Features: iOS and Android. Checks directly on location with mobile app, sends the report by e-mail, analyses periodically all reports from database, determines frequent problem areas, monitors the follow up on nonconformities via website, custom or predefined checklists, in-depth analyses based on pre-set filters. Pricing: 7.50-200€ per year (plus some additional costs per user)

Snapinspect www.snapinspect.com	Description: inspect properties, creates reports and delivers them using mobile device. More aimed to real-estate managers. Features: iOS, Android. Generates reports with photos attached to the property drawing with comments, creates reports and shares by email, property portfolio, inspection schedule, tenant contact details + owner contacts details, video option, multiple users and collaboration. Pricing: not available

The list goes on even in this rather specified case, but it illustrates that the ICT market has understood the possibilities and pains of the construction sector and is willing to contribute and innovate in order to be there first for the mobile revolution. Until now most of the ICT solutions for construction sector were tied with the stationary computing (desktops, servers etc.) but as the mobile devices are rapidly improving in computing power, usability and battery time, it is time for the new wave of ICT solution. The question is, how it should be done, so that the benefit for the all parties would be maximized?

However, the research on mobile solutions is done on more theoretical level discussing the potential as there is no empirical evidence on the implementation yet (Deibert, Heinzl & Hemmer 2009). Therefore, these studies will be used as a guide for analyzing the results of current research and were not considered relevant in the cortex of literature review.

2.4.2 BIM

To give the reader a better understanding of the underling solution and related model for current study, in this section, a short overview about previous research on BIM is provided and the status of BIM in Estonia is presented.

The instruction of BIM began from the concept of lean construction. Although all activities expend cost and consume time, Lean Construction argues that only conversion activities add value and these should be made more efficient, whereas, non-value adding flow activities need to be reduced or eliminated. Moreover, the same authors rely on Alacorn (1995) when saying that traditional thinking of construction focuses on conversion activities and ignores flow and value considerations. (Senaratne & Wijesiri 2008) To put it in other words, the waste of resources

(previously discussed in this paper) was not analyzed deeply or correctly enough in order to reduce the costs and therefore admitting the seriousness of the problem led to introduction of BIM.

Building Information Modeling is the most used concept when it comes to researching for ICT in construction sector. Jerry Laiserin writes in the foreword of "BIM Handbook" that the earliest documented example he has found for the concept of BIM was a working prototype of "Building Description System" by Charles M. "Chuck" Eastman (Eastman et al. 2008). Over the years it was evolved during different phases and it was more strongly fixed in the beginning of 21st century. In the glossary of BIM Handbook BIM is definition as following: "a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital machine-readable documentation about a building, its performance, its planning, its construction, and later its operation". And to specify "with BIM technology, an accurate virtual model of a building is constructed digitally. When completed, the computer-generated model contains precise geometry and relevant data needed to support the construction, fabrication and procurement activities needed to realize the building." (Eastman et al. 2008). Sacks, Koskela, Dave and Owen write in their paper "Interaction of Lean and Building Information Modeling in Construction" that according to Sacks et. al (2004) BIM software tools are characterized by the ability to compile virtual models of buildings using machine-readable parametric objects that exhibit behavior commensurate with the need to design, analyze, and test a building design (Sacks et al 2010, 968). More simply put the BIM is a digital environment where all the relevant and most updated information of the construction should be presented from the very beginning to the very end of the process.

McGraw Hill Construction conducts an annual survey to measure BIM implementation using the data from 10 different countries: Australia, Brazil, Canada, France, Germany, Japan, New Zealand, South Korea, United States and United Kingdom. They have come up with very specific statistics about BIM and most notable is the data about the US which shows that between 2007-2012, adoption of BIM went from 28% to 71%. Their latest report about the 2013 shows that in all the studied countries combined, more than 60% of the projects are now conducted with very high level of BIM implementation. (McGraw Hill Construction 2014). Survey conducted among construction designer in Estonia in 2013 by Estonian Business Software Society showed that 53.44% of the answered companies have met the BIM solutions but only 8.13% are actively using it. 62.99% of the companies who were aware of BIM were not

sure when will they start using it. 63.33% of the users use it only for visualizing and also for tracking mistakes and data output. (Eesti Äritarkvara Liit 2013) However, the data above should be treated with scepticism. Inkinen (2010) writes that when Skanska AS conducted survey among 44 architecture bureaus, 2/3 were sure they are using BIM modeling but actually it was due the lack of actual knowledge what it is and a lot of these "models" are not acceptable or usable as BIM models (Liias, Witt, Alt & Saidla 2013).

Educational approach to BIM in Estonia is mostly handled by Tallinn University of Applied Sciences and Tallinn University of Technology. There are many pilot projects run in Estonia, yet, there has been no evaluation or studies afterwards on them (Liias et al 2013).
12th of January 2011 the NGO Estonian BIM was registered in order to popularize the know-how and technology of BIM, to develop and to manage the competence and to make contacts and co-operation. State Real Estate Ltd (Riigi Kinnisvara AS) has created a guidelines for the basic BIM solutions but as they state it is a limited solution and only for the drawing phase. These guidelines deal only with:

- 3D visualization for drawings
- simulations for the energy and heating requirements
- more precise and faster calculations of the volumes of the construction
- controlling the conflicts in the drawings (Riigi Kinnisvara Aktsiaselts 2013)

More precise guidelines have not yet been implemented and the NGO Estonian BIM blog and their Facebook page have not been updated more than a year (as of 19.05.2014).

2.5 Barriers to ICT innovation in construction industry

When looking at the previous research conducted on hindrances to ICT adoption in construction industry, the work is limited. There are number of studies analyzing the barriers to innovation derived from the complexity and specifics of the industry. For example Gann (2000) and Winch (1998) conclude that the fragmented nature of construction process is the main obstacle to introducing new solutions; Blayse and Manley (2004) conclude the same for the long lifespan of construction process and products. Dulaimi (2005) and Veshosky (1998) blame the conservative nature of the professionals working for the industry. Despite the existing work, there is little

research investigating the industry wide hindrances in specific markets while building upon real experience of industry participants.

The most similar to what current paper aims to achieve is the study conducted by Martin Hooper. Martin Hooper (2012) emphasizes on the fact that despite the strong support for BIM from previous academic work and proof for BIM's usefulness from construction industry practices around the world the construction industry still faces major difficulties in moving forward with wider implementation of BIM model. In order to understand the barriers to BIM collaboration, an investigation into BIM implementation prerequisites was conducted.

Aiming to develop processes and methods that support organizations in implementation on use of BIM-technologies, the author focuses on the peculiarities and specific needs of the industry. The research identifies via the case studies, workshops and industry interviews with existing BIM-user organizations and known user groups in Sweden a list of factors hindering BIM collaboration. In order to be able to identify also the factors that may not be immediately obvious, a consideration to a variety of different classifications was allowed: contractual, technical, economical and other. The main factors identified cover a number of interconnected hindrances related to standards, communication processes and socio-technical system and are listed below.

Contractual

- Responsibility for correctness of data
- Common practice to deliver the BIM model as requested, but only take legal responsibility for extracted 2d paper documents.
- BIM model has no contractual status.
- Clarity of purpose (BIM-Uses) missing Lack of branch standard language in connection with BIM-Concepts
- Lack of branch standard method of defining and controlling BIM-Deliveries - ie: BIM Delivery Schedule
- Lack of branch standard method of detailing and controlling responsibility for data - ie: Object Author Matrix
- Lack of branch standard method of developing a strategic BIM-Plan - ie: BIM Goal, BIM-Uses, BIM-Info Exchanges

- Lack of branch standard method of describing expected level of detail at various project stages
- Consultants are still required to print out and send 2D paper drawings - it is
- these that have contractual status
- Lack of branch standard method of detailing authorized uses of BIM data
- consultants often asked to waive rights

Technical

- eg Interoperability
- Consultants must still provide 2d drawings (paper and / or pdf) of design information (in addition to the model)
- This requirement for double information hinders the demand for BIM.
- Still much repetition in data entry due to lack of information stewardship, reliability, chain of information responsibility.
- Knowledge about each other's BIM-Information requirements
- Awareness amongst AEC participants for what information is relevant at what time for what purpose.
- Awareness for information levels and lack of common expectation of how LOD should develop through DCO phases.
- Lack of standard method to define status of model content and level of accuracy
- Lack of standard method of reviewing and approving model content.

Economic

- eg Difficulties is realizing ROI Big financial investment for consultants both in equipment and training.
- Imbalanced investment v. economic benefit across sector
- Little scope to realize win-win initiatives
- Difficulties is distinguishing and defining the boundaries between company BIM business strategy, project based BIM-Strategy and national BIM-Strategy.
- Time & money catch - when there is high economy and pressure in the industry there is not the time to spend in developing BIM expertise, when there is a depressed economy there isn't the money to invest in BIM.

Other (social/psychological etc)

- Low client interest in BIM
- Traditional process mindset
- Resistance to change
- Fragmented industry compartments efficiency initiatives

The author also argues that given the complexity and scope of the BIM model, an engagement from all levels (top/down, bottom/up) together with suitable balance of push (government mandate) and pull (construction industry initiative) may be critical for its success.

2.6 The gap in previous literature review and relevance of this study

In conclusion, previous academic work dealing with BIM and ICT implementation in construction industry have been conducted from the perspective of construction industry analyzing the usefulness of the solutions for the industry and how ICT fits into construction process taking into consideration its peculiarities and complex nature. However, there is limited work on investigating the industry wide hindrances in specific markets (including Estonia) while building upon real experience of industry participants. Also, no authors have approach the issue from the perspective of IT businesses (i.e. looking for the opportunities for new IT solutions via understanding the hindrances imposed by the industry).The authors of this paper aim to reduce this cap.

Given that the research by M. Hooper (2012) carried out in Sweden is to some extent similar to what this paper aims to do and can be regarded as a predecessor to this study then findings from his study will be used to build up the qualitative analysis on. The purpose of current study is thus to find out the hindrances to ICT implementation in Estonian construction industry and based on the findings to derive the opportunities for IT startups to target the construction market as target clients. The results of this thesis could be helpful for both the construction sector participants, as well for the ICT sector.

Also, during the research process the authors of this research became knowledgeable about the fact that in parallel to this paper another study on a similar topic was being conducted. Margus Sarmet had identified a similar cap in academic research in Estonia. M. Sarmet, however, takes a

different approach and aims to investigate the matter using a quantitative design. For identifying the hindrances to IT innovation in Estonian construction industry he applies the approach developed by Community Innovation Survey (CIS). However, mentioned paper was not published by the final date of this paper, therefore, it is not covered in more detail in the literature review.

3 Methodology

3.1 Data Sources

Primary and secondary data was gathered for the research. Primary data was collected via semi-structured interviews with industry practitioners and via a questionnaire for understanding the general situation. Secondary data was collected from academic journals and magazines, from studies by local institutions and government, public statistical databases and through collaboration with researchers studying the similar topic.

3.2 Research design

The type of the current research is exploratory. The aim of the exploratory research is to discover insight and ideas behind studied phenomena. The exploratory research can be either qualitative or quantitative and has often no hypothesis due to lack of previous investigation into the matter.

The study was conducted using qualitative design. “Qualitative researchers aim to gather an in-depth understanding of human behavior and the reasons that govern such behavior. The qualitative method investigates the why and how of decision making, not just what, where, when. Hence, smaller but focused samples are more often used than large samples.” (Patton, 1987; Maxwell, 1996; Pope and Mays, 1995)

Qualitative design was chosen as it provides to be more effective for explaining human behavior and attitudes. Qualitative analysis is also better while investigating phenomena which are not easily measurable and thus need more detailed and deeper understanding. Despite the existence of previous research (Hooper 2012) investigating the hindrances and barriers for implementation ICT solutions (BIM) in construction market, the research is lacking in terms of analyzing which barriers can be tackled and which barriers are hard, if not impossible, to overcome. Plus, there is no clear indication or study investigating if the hindrances are similar for different markets. Therefore, given the limitations of the previous research and little to no previous study on Estonian market, the findings from previous studies cannot be taken for granted for Estonian market to base the research on. Also, given the early stage of ICT implementation in Estonian market, the number of possible study subjects is limited and therefore would not be sufficient to perform statistical analysis on the data and derive overall conclusions on whole population.

During the research three different data collection techniques were used to answer the research questions. First was literature study and relevant data findings about the subject. Second was detailed interviews with industry representatives who have the experience with implementation of BIM complemented by anonymous online-survey among the larger selection of construction sector participants and third was building a minimum viable product (MVP) of Lynxreports software using the findings from interviews for a field-testing and asking for a preliminary feedback from the industry practitioner (potential users).

The priority in the research was placed on semi-structured interviews. The qualitative online questionnaires and literature review was used to gain support to the results from qualitative analysis. The data from interviews and questionnaire was collected concurrently. Different types of methods were integrated. The questionnaire was carried out to gain support for the results from qualitative interviews as the number of interviewees was limited. The data collected via different means was integrated in the discussion part for overall research.

4 Data collection and results

4.1 Interviews with Industry Practitioners

The primary focus of the research was put on the interviews with industry practitioners. For interviews multiple-units single-case design was considered the most appropriate.

In order to assure the quality of the information gathered during the interviews, only test subjects who are familiar with BIM model and has experience in initial implementation of related ICT solutions were included into the sample. Good research participants need to be knowledgeable about the matter under the research; therefore, construction industry practitioners with no experience in ICT implementation and with no in-depth knowledge about BIM were excluded from the study. This left the researchers with limited number of potential research participants. Not to limit the sample size any further, representatives of all Estonian construction companies with some experience in BIM implementation and relevant knowledge were included in the study.

In order to find relevant study participants and establish the contacts, Ergo Pikas, who is one of the leading BIM innovators in Estonia, was contacted. His contribution to academic work researching BIM as well as active initiative in pushing the BIM and ICT implementation in Estonian construction market cannot be underestimated. With the help of Ergo Pikas a list of construction companies and their representatives with experience in BIM implementation was created. In order to get better assurance that all the relevant BIM practitioners had been identified, the Managing Director of Eesti Ehitusinseneride Liit (Estonian Association of Civil Engineering, EEL hereinafter) Tiia Ruben, was contacted. EEL has more than 750 individual member most of whom are working civil engineers in the field of general construction and road construction. The information from both individuals was corroborated with no differences, thus, the list of participants was treated as final sample for given study.

The interviews with relevant practitioners were conducted over the period of two week. As most of the interviewees expressed their wish to remain anonymous (given that they might not be representing the opinion and position of the whole company) the participants of the study will be referred as interviewee 1, interviewee 2 etc. in given paper. In total, eight construction industry

practitioners were interviewed: four of them representing design companies, two representing building companies and two representing supervisory companies.

Each study participant was interviewed using in-depth, exploratory approach using semi-structured interview structure. The general questions and interview topics to cover were predefined, see appendix 1, however, deviations were allowed to ensure more detailed understanding and some flexibility depending on the peculiarity of an interviewee. With the permission of participants, all the interviews were audio recorded. All the interviews lasted from 30 minutes up to one hour.

The interview protocol consisted of questions relating to BIM implementations and overall attitude towards ICT. As the study by Martin Hooper (see literature review) researching the hindrances to BIM implementations can be considered as a predecessor to this research and was a trigger for the authors of this study to investigate the hindrances and barriers to implementation of ICT solutions in construction industry in Estonia in detail and from different angle, the interview questions were structured based on the four categories of hindrances that Martin Hooper came up with: contractual, economical, technical and other. The same categories were used as criteria for grouping and interpreting case study findings.

In order to achieve shared meaning and to be able to draw any conclusions, a probing technique was applied. This was done via probing for the details of participants' experiences. Information to elaborate and clarify on what the respondent had said was asked constantly; this meant rephrasing what the person had said and asking for confirmation, paraphrasing the questions when the answer was unclear and asking a number of more detailed questions based on the received answers.

In the analysis of multiple holistic case study design of eight companies, main findings from individual interviews were grouped based on the field the respondents were working in. The findings from each field group (designers, builders, supervisors) were cross-compared with other cases and with findings from previous research (i.e. towards the four categories imposed by M. Hooper). In addition to identifying the hindrances to ICT implementation the authors looked for potential opportunities for ICT business ideas. The findings from qualitative interviews with industry participants were then analyzed together with the findings from the online questionnaire. Then, conclusions and implications were derived.

4.1.1 Interview Results

The list of general interview questions and relevant topics to be covered that was used as a guideline for the interviews is represented in Appendix 1. Detailed interviews (audio transcripts) are enclosed to the hard copies of the original paper. The most important findings and extracts from interview transcripts are presented below:

Constructors *(two industry practitioners)*

Human-based problems are mostly about the will, not money.

In Estonia there is not enough big projects for implementing BIM, today there is no point to implement BIM for the objects that are very simple or small.

Clients do not see the whole value of BIM – they like and value the visual side of BIM but do not know about the substantive gain (reducing costs, using BIM during the whole life-span of the building). If BIM is used correctly, then there is much less mistakes made during the construction and therefore less work for the supervisors.

The building process itself must be changed altogether (constructors and engineers should be involved already in the idea and sketching phase). Whole public procurement system is built up incorrectly and is thus an obstacle to fact implementation of as wide solutions. First, the project is ordered; then, construction procurement follows. But the constructor should be included already in the drawing phase to work with the designer about different solutions. As long as the cheapest price is the most important factor in public procurement, things will not change.

Single and smaller solutions only work when they can be implemented in the bigger process and management systems without extra trouble. Too many different solutions require hiring special person which is not favored.

Tablets are in use on management level, but the very basic-level worker still needs printed A4 drawing. Big touch-screens on the site (office) would be very useful for looking the 3D models.

Architects *(two industry practitioners)*

BIM is the future; however, it will still take up to 10 years to implement it in Estonia.

Clients will also understand soon that the BIM is useful during the whole life-span of the building. Today the clients do not know about the benefits of the BIM.

Reasons for design companies to start using use BIM: 1) object is so difficult that BIM is the most reasonable way (PERH, Postimaja) 2) it is required by client (State) 3) for export reasons (client is from other country, where BIM is the standard) 4) to avoid mistakes during drawing phase and therefore reduce costs for the whole process (re-drawing later) and to differ from the competitors - this is, however, a push more on a theoretical level. Today the industry is still on the waiting position, no one is taking the lead and it is not clearly seen if and when the benefits will be earned.

Problems with implementing BIM are that people 1) do not have the necessary skills; educating people to use the solution is extremely time consuming. Given that the Estonian construction industry is experiencing the labor scarcity, there is no available time for this. Recession that started 2008 was good in a way that people had time for educating themselves, however, then there was a problem of finances. This is an inevitable problem; 2) people are used with different software (architects) or pen and paper (other parties).

Learning to use 3D modeling + other BIM functions takes a lot of time and the software is not compatible with existing hardware. The problem is also the compatibility with different parties involved in the project and that the parties change together with the projects.

Construction sector has many workers from the older generations who's general IT skills are not sufficient, so even more ICT is not favored. Older people who are not familiar with using IT solutions will most likely never adapt to BIM technologies. They will take the consultancy role instead and will leave the work for younger. This is what happened during the transformation from paper to CAD. The problem with this, however, is again already scarce labor resources.

Different BIM software do not compile with each other. Sometimes even different versions of the same software do not compile (2013 with 2014 version). Big software companies are working against universal file platforms. Everyone wants to have their own. BuildSMART organization is lobbying for IFC format. IFC conversion option today is used in most of the programs but when converting from original software to IFC a lot of important information gets lost. IFC is going to be made obligatory so the big software companies have to include it. But the impact from it will be seen only in far future.

Money is a big problem. Most popular and functional BIM software's for drawing (both architectural and technical) can cost up to 25 000 EUR per license + 3000 EUR annual subscription fee. There are not enough big projects to cover the costs of software. Also, most of

the companies in Estonia are so small that individual investment by each company doesn't seem to justify the investment. Budget for designing is already too small in most of the projects, but clients still want to cut it. This imposes an extra constraint to raising the investments.

Nobody wants to test new things, everybody are looking for references or wait for others to experiment. This is an overall mentality for the industry. This comes from the nature of construction industry, i.e. most of the innovation in the industry comes from product innovation; however, to measure the quality and resistance of new materials takes many years. This has created a general risk aversion that will serve as a guide while dealing with other types of innovation. Usually the innovation is taken over from Finns, they do the testing and as both of the construction markets are inter-related, then the feedback from there is trusted. There is a strong need for pilot projects, RKAS should be doing these. Today the BIM is implemented mostly by private-sector.

As said by one of the interviewee's: "In Estonia it is impossible to sell premium-service in construction". BIM is considered as premium service and no-one is willing to pay extra. Client can not put price-tag on avoided mistakes so this is not a sales-argument.

Constructors are often not interested in too detailed drawings because this reduces their options for increasing their profit by using questionable methods or "trickery".

For everyday communication on a construction site, a single online tool would be perfect. There are already solutions in construction for the financial part – prices, budgeting etc. Today's solutions for BIM are Tekla, BIMsight, Autodesk Revit, Archicad; for project management Niini&Rauam project bank, Dropbox, Autodesk 360 + Autodesk serverfarms; online viewer profiles for viewing BIM models, however, working with problems.

Regarding the hardware solutions the rule of thumb is that designer has expensive software and powerful computer – constructor has mediocre computers and freeware – client has usual PC laptop, Macbook Air or iPad. As for tablets most of the popular software is designed for iOS or something that has Windows running on it but not for Android. Problem with iPad is too little RAM, so if drawings carry too much information, then iPad is not good. The use of mobile hardware is growing as the computing-power is improving. It is very useful for the sub-contractors who need the most precise information to organize their work. 2D drawings on the paper do not carry necessary details. BIM models in the tablet make sub-contractors work much easier.

Supervisors *(two industry practitioners)*

Clients do not understand the gain if they have never used it. The designer has to do anyway the quality design; constructor has to build quality building, attitude of "why do I need to pay more for BIM?". Basically, the cost for the design stays the same or gets only a bit higher, but client gets the detailed overview of the costs and the processes, plus the documentation is much more detailed. Therefore, the awareness among the client needs to be created. This is complicated task today.

When already experienced in BIM then reducing time for some tasks could be drastic i.e. calculating costs in 30 minutes in BIM model instead 1 week on paper. People do not have time to learn new solutions; everyday tasks take too much time. No reserves to hire someone just to study these things at first.

Most of the solutions come from Finland as the solutions have been tested there and Estonians trust Finns. Finns have already understood that all the systems can not be included in one program so the solution is to try to join different parts separately as much as possible. Smaller solutions are not so widely used yet but there is market for them if positioned correctly and compatible with other solutions.

Storing things digitally is important because finding information is quicker and CD's get old. Client does not want to buy any software although he is the one who needs it the most. So, the constructors sometimes buy it, in order to prove their decisions later for the client, if problems arise.

Using tablets is not favored yet as the screen is too small and does not give the overview of the whole. Specific software solutions used are Tekla BIMsight, Solibri and Buildercom.

Extra interview (with a representative of a Building and Housing Department in Ministry of Economic Affairs and Communications – M. Sarmet)

One of the reasons for little innovation in construction is about the metrics: the innovation is measured by the revenue in OSCD (how much of the revenue goes into innovation). According to OSCD, construction is low-technology industry. Low-tech= less than 5% goes for the innovation. That is why construction is statistically lagging behind. However, the volumes in construction are so big that ideally the money for the innovation should be equally big. Another metric is measuring people, i.e. how many people are educated etc. Also, innovation in

construction is lagging behind because of fair amount of casual workers, who are slower to learn and adapt new things, working in the industry. Even if the government would support buying software, then who would be able to use it? Time is also a factor as everything should be done as quickly as possible. So it is easier to use old methods and not to take any adventures.

More experts should be used in order to produce initial tasks. The simple client does not know how and what to order.

In 2016, there will be restrictions allowed for public procurements in EU. Probably most of the countries will use them and start requiring BIM. Estonia might do it partially. And from there on most likely the public sector will also follow.

Ten years ago it was from paper to digital and it gave huge gain in time. Same could be gained by going from today's 2D to full extent BIM solutions.

4.1.2 Discussion and analysis

The general feeling in construction industry is that the industry is on the edge of next big step in terms of ICT development. The change is predicted by the industry participants to be as huge and broad as was transition from paper drawings to CAD models. Nevertheless, the mentality of the whole sector is to wait and see how others will react and the standpoint is to not to introduce the solutions before someone else on the local market (or in Finland) has proved the concept/solution to be measurably beneficial for the business (the problem with BIM is that the benefits cannot be seen in the short-run and thus measured directly in money). Today, no one is willing to take the lead nor make the investment unless required by the third party (client, regulatory body) or by extreme conditions posed by the construction projects where the use of BIM related solutions seem to be inevitable. When asked to name available and most used IT solutions in construction process, all of the study participants consider BIM related solutions as the most relevant. Also CAD solutions and Office management solutions are common; however, these have been around for quite some time and are not considered as innovative solutions anymore. Knowledge about some additional solutions exist but with no deeper intention to implement them.

On the fundamental level, one of the outstanding reasons for slow ICT development in construction sector seems to be the industry structure itself. Given the industry specifics, there is a large concentration of SME-s forming a significant part of the industry as a whole. The

concentration of SME-s is even more extreme in Estonia then in other EU countries. If we look into statistics provided by the Ministry of Economic Affairs and Communications (Majandus- ja Kommunikatsiooniministeerium 2012), then approximately 90% of the companies in construction industry are less than 10 employees in size, which can be considered as micro-companies even in terms of SME-s. Most of the ICT solutions available today are, however, built for larger companies, this reflects also in the prices of the software.

The main findings based on the four categories introduced by M. Hooper together with identified barriers for ICT companies to enter the market followed by implications for IT start-ups are presented in separate sections for each category below.

Contractual

Current situation and hindrances identified

The whole process around construction projects is fragmented in terms of different small parties. Main contractor is working with numerous subcontractors and the parties are rotating depending on the project. Thus, specific project-wide implementation of BIM solutions is not enough; the process needs to be carried out each time the parties change and some new parties emerge. Also, rotation of the parties means more problems with software compatibility and no knowledge about other parties' software and technical competences. In addition, there is no clear understanding which party should be responsible for ensuring the correct implementation and usage of the solutions.

This leads also to another Estonian specific problem which is the size of the market. Given the small size of Estonian construction market, most of the projects built are not big and complicated enough to require process wide solution and regulation. As long as the solution is not meeting specific need of an individual player resulting in direct benefits for that same individual, there will be long time lags till something will be accepted.

Given the reach of the BIM system, it requires not only the people employed in construction sector to be knowledgeable about BIM, but also the client ordering the job and the regulatory body. Government's support and the way the industry is regulated today is counteracting to the fast and successful implementation of BIM today. Also, as private clients are not involved with the construction business on everyday bases, they are not familiar with the benefits of BIM,

therefore, not favoring the solution in the projects ordered by them. Also, in many occasions it is the case that the constructor, who will be the one baring the costs related to IT solutions, is the one who is not that interested in making the whole construction process more transparent.

Barriers that cannot be removed and must be avoided

As long as the successful implementation of new ICT solution depends on the assumption that different parties need to implement it in co-operation, there will be a huge resistance to it. Given that most of the projects in Estonia are very small compared to what they are in big economies and a large number of different micro-firms are involved in one project, the rotation of the parties upon a change in a project happens so much faster. Therefore, given that the companies work on a mutual project for so little time, there is no thrive to start implementing something mutually for any given project. This is a fundamental hindrance posed by the peculiarity of Estonian construction industry and therefore there is no way for IT start-ups to change this problem and thus ways to avoid these complication caused by the small size of companies and fast rotations of different parties working together should be found.

Implications / Opportunities for ICT startups

The start-ups should try to find a niche solution that would solve an individual pain for a specific customer. The benefit should be directly felt by the user. The potential IT solutions that these small construction companies would be willing to use need to be something that can be used independently from other parties. There needs to be a feeling that the investment into the ICT solution is directly correlated with the benefits from the investment made and that the benefits are not dependent on how the rest of the market acts.

Economical

Current situation and hindrances identified

Big share of construction companies in Estonia have less than ten employees. Given the size of the companies, the funds to be invested in ICT are limited for the company. The costs for BIM software are very high and most of the companies do not have the resources for the software or for hiring people to study and maintain it. For one to two men companies, the current price for simpler CAD solutions seem to be the maximum price they are able to pay, this, however, is approximately ten times less than the current BIM related solutions available on the market. Software is being updated very often but besides buying the license, an annual subscriptions

need to be paid in order to be able to use files from different versions even if the software is the same. Usually companies can only buy one type of software and it creates compatibility problems when working with others.

Even if it can be argued that finding financial resources is matter of a company and its priorities and that there should be also some companies who can afford to pay the price, the matter with time that needs to be spent on implementation and educating the employees to use the solutions arises. The general situation in Estonian construction market is that people are already overloaded and there is no available time to be spent on learning something new.

Given the large number of different parties involved with one construction project, the number of beneficiaries of integrated BIM solutions is also proportionally high. This result in uneven distribution of benefits and the received benefit by individual companies is not considered sufficient when compared to the investment that the solutions require. Even more, in Estonia the party benefitting the most is the client who pays no extra fee for BIM solutions, however, who fails to understand the need and usefulness of BIM based modeling in a construction process.

Barriers that cannot be removed and must be avoided

The main obstacle from economical viewpoint to implementing BIM is the "time & money catch" described by M. Hooper. This means that if there is money (the industry is booming), there is scarcity of available time to spend on educating people to use the software; however, when the industry is in a recession, there is time to spend on education, but there is nothing to finance it with, not to mention the lack of necessary resources for acquiring the IT solutions during the economic downturn. In Estonia, the impact of "time & money catch" is even more severe than in better developed economies. Due to price dumping on the market the costs are already reduced to the lowest even during the boom time. Also, the labor scarcity is amplified by construction workers leaving to other Scandinavian countries for a better pay. Therefore, no company will consider implementing new solutions that require thorough education of their employees even if the price offered is something that they would be able or willing to pay. The implementation of IT solution with this type of requirement can work only when the implementation is pushed by the regulatory bodies and those shaping the overall construction industry (worldwide). This is to large extent a case for BIM. This type of support is very unlikely for a starting IT business to achieve and thus the situation should be avoided.

Implications / Opportunities for ICT startups

If the target customer for ICT solution to be created by the startups is the construction company with the size of an average construction company in Estonia, the initial go and no-go decision should take into account the primary cost estimation for acquiring the new customer. If the solution can produce profits with customer price similar to price asked for CAD solutions, there might be an opportunity. Otherwise one should be extremely cautious.

What is even more important, the solutions should be extremely easy to use (intuitive) and require no specific training. The IT solution should help to save the time instead requiring extra time for using them.

Technical

Current situation and hindrances identified

It can be argued that the construction industry in Estonia is facing a leap in ICT development that can be compared to the extent that conversion from paper drawings to CAD modeling brought to the sector. This means introducing new technologies and training the stuff to obtain the needed skills for using the technologies and the way the process is in place today will be interrupted. In the light of this, the age of the people working in the sector has been considered as an obstacle by most of the interview participants. Even if the average age in construction industry in Estonia is lower than the age of people employed in other manufacturing industries, then the detailed look into the division of workforce shows that young people are mainly casual construction workers while approx. 70% of engineers are over 40 out of whom more than half are even over 50; also, 85% of executives are over 35. (Eesti Konjuktuuriinstituut/Estonian Institute of Economic Research, 2012) These two groups, however, are the ones to be most affected by the change, that is, on one hand, engineers and project designers are the ones who will be the users of new technologies and on the other hand, executives will be the ones making the decisions regarding the implementation, thus, taking the responsibility for the huge investments for the company.

Given the extent of the training and education needed in terms of time, it is estimated by the participants of the study that the BIM implementation in Estonia will reach today's level of innovation leaders in construction worldwide only after approximately ten years. Given that organizing trainings for the employees is not one of the core businesses for the construction companies, the time spent on training will most likely not justify itself. In the situation where the

ICT solutions need to be purchased before the stuff is able to use the programs, there will be uncertainty of the results. Despite the fact that most of the participants on the market are shearing an opinion that BIM solution or other similar ICT solutions are the future of construction business also in Estonia, there is no one to take an initiative and to be a test pilot.

Another issue today is that the relevant skills of construction industry workforce for implementing BIM technologies are lacking. Additionally, there are no professional training institutions teaching needed skills, plus, BIM education in Estonia is still on early stage (only few individuals in academic field have the relevant knowledge).

Also, derived from the lack of financial resources, not much investment has been directed to IT so far. This is the case for software as well as hardware. As a result, new solutions are not compatible or are not working correctly on the existing hardware. The situation gets even more complicated when there is a need for compatibility with other parties involved with the project.

Barriers that cannot be removed and must be avoided

IT solutions that require the latest technology in terms of hardware is not going to be welcomed by the industry. The hardware in place is relatively old and not meeting the general perception of the level of IT development taken for granted by IT companies.

Implications / Opportunities for ICT startups

From technical side, the solution to be developed should be built under the assumption that the existing IT hardware used by the construction companies is relatively old. However, when looking at the individual level, a lot of people working in construction are using the mobile devices (smart-phones, in some cases also the tab solutions) on personal level. Therefore, when aiming to build something that is easy to implement and familiar and intuitive for the users, mobile or tab solutions could be considered. As long as the investment in new hardware required by the company is only incremental and the solution produces direct value for the company as well as for the individual user, this should be still acceptable.

Other

Current situation and hindrances identified

As most of the innovation in construction industry happens in the form of product and material development, the results and the benefits of this type of innovation can be typically measured only after many years. This has resulted in overall mentality of the industry representatives to wait and see how the innovation has performed in other counties, then, how it has performed for other companies who have taken the lead in Estonia, and only then the innovation is welcomed. Even if the ICT innovation is very different in its nature and happens much faster, the attitude around the implementation of new solutions is still the same as in case of product innovation. Thus, no one is willing to be the first to take the risk and introduce the innovation. Fortunately, the Estonian market works in close proximity with Finnish market and therefore solutions tested by Finns are regarded to large extent as trusted. Construction industry in Finland is much bigger and therefore also much supportive to innovation.

Into this category falls also the general psychological factor. This means that people are comfortable with the ways how the things are done and are not happy with the changes and are thus resistant to innovation.

Barriers that cannot be removed and must be avoided

There is an unwillingness of the industry participants to be the first one to test the new solutions. This might pose a serious challenge for the Estonian start-ups who are used to the way of thinking "let's test the solution on the local market which is comfortably small and safe. Once it proves to work here, only then let's take it to the masses".

Implications / Opportunities for ICT startups

The strong presence of the psychological factor (people not being happy about the changes) should be tackled. The ICT solutions for construction industry existing today have not taken into consideration this factor. Thus, the authors of the paper argue that proposing a direct benefit not only for the company investing the money but also for the individual user should create an advantage to new technologies.

When it comes to the reluctance to test the solutions and to be the first one to adopt new technologies, then perhaps the testing for ICT solutions for construction market should be performed in Finland. This will give the Estonian startups also the advantage to learn about the bigger and more innovative markets from the very beginning which will be useful when planning to take the business global.

4.1.3 Conclusions and overall implications from industry interviews

In conclusion, the critical hindrances identified to BIM implementation in Estonian market that no IT company planning to enter the construction market should not ignore are:

- Time and money catch
- The construction process wide gain not felt by individual players
- Relatively old IT hardware in use and no plan to replace it on a larger scale
- Strong presence of psychological resistance to the change
- No willingness to be test the solution

If the IT solutions to be created cannot find a way around these hindrances there is little to no chance in succeeding with the technology. These are the obstacles that will be around for long time and therefore copying with them is beyond the limits of small start-up businesses. Once these listed hindrances can be avoided, other hindrances that will be affecting the success of the new IT solutions for construction can be minimized. The authors of this paper argue that finding a way how to reduce these hindrances could be the key to the success of the new technology for construction industry.

Given that the number of industry participants interviewed was limited to the list of people with BIM implementation experience in Estonia (all together eight people), a supportive anonymous questionnaire was conducted. The aim of the questionnaire was to gain some support to the findings from this part of the study before proceeding to building a real life IT solution guided by the finding from the interviews to collect a preliminary indication from a field testing to if the findings from this part of the study and suggestions presented above can be actually used as valid guidelines to build a successful IT solution on. Also, the survey was used for collecting thoughts to support the initial idea for the solution in the mind of the authors to build a minimum viable product on.

4.2 Survey of the Estonian construction market

In the second phase of the study, a survey was conducted in order to get the latest and most relevant information about the ICT use in the Estonian construction market in general (with no

emphasis on BIM or BIM related technologies). The selection of participants was made form the Estonian Association of Construction Entrepreneurs' member database which was available on their webpage. In order to be included in the survey, the company had to have: 1) at least 10 employees 2) working webpage 3) employees contact page with exact position and email address. Invitation to participate in the survey was sent to two site/field managers from each company. The site/field managers were selected randomly. The reason for approaching only companies with ten or more employees despite the fact that most of the construction companies in Estonia are with less than 10 employees is that these bigger companies work as main constructions and have the overview also about what is happening in smaller companies working under them as subcontractors.

Two people from each company was selected in order to raise the possibility of receiving an answer but at the same time avoiding disturbing a larger number of employees and therefore risking with getting a negative attitude towards the survey. Using site managers instead of IT or management level people in the survey was driven by the importance of industry knowledge of practitioners who have also the experience with working with other subcontractors.

Assuming the people in this field are not very IT literate and do not have the skills or will to use a lot of IT, a survey that was not complicated, was short enough and did not require any specific skills or concentration on details besides typing the answers was created. Also, the complexity of the sector with very many different players, approaches and general lack of homogeneity made questionnaire with pre-defined selectable answers impossible. Therefore, only open-ended questions aiming to collect qualitative answers were included to the survey.

Survey was anonymous but for possible correlations between the size of the company and use of ICT it was important to know the size of the company and also the main field of activity (main contractor, sub-contractor, site supervisor). Four main questions included to the questionnaire were following:

- If and how is ICT hardware (tablets, laptops, phones) and software (programs, applications) used in everyday construction processes?
- What are the main challenges and barriers for using (more) ICT solutions in everyday construction processes?
- What kind of modern ICT solutions (hardware and software) could be used in construction processes and how? What processes could be simplified or managed better by ICT?

- What could be the solutions to overcome these barriers and what should be taken into account when developing the ICT solutions for construction sector?

Out of the 45 people approached, 15 answered.

People who answered the survey represent a wide range of actors on the market. There were small (around 10), medium (up to 50), and large (50+) companies represented. There was some overlapping by some of the companies working both as main- and sub-contractors and also having a supervision department, but altogether there were 10 main-contractors, 3 sub-contractors and 2 supervising companies represented. The selection is not representative to draw statistically valid conclusions on the overall population, i.e. Estonian construction companies as a whole; however, it gives some indication to weather the overall attitude towards the ICT solution in construction market is supporting the findings that were collected in the context of BIM implementation in Estonian market.

4.2.1 Survey findings

ICT hardware (tablets, laptops, phones) and software (programs, applications) usage in construction process:

5 answers only stated that "is used" without any specifics. Computers (laptop and desktops) and mobile phones were the most used hardware while tablets were not mentioned at all. The software use was more versatile. While using AutoCAD and MS Office tools was expected, some of the participants added more specific information. No surprising findings compared to what was learned from the interviews, were not identified:

- Location setting software
- Lotus Notes for mobile + partial BIM solutions
- Project management programs (not specified) for time management, 3D solutions, project-bank, budgeting, money-flow, work-flow.

Challenges for ICT implementation

The main challenges and obstacles to ICT implementation in construction market identified by the survey were:

- Lack of ICT skills among the people (age, education)
- Traditional work-flows

- Resistance for the innovative solutions by the workers
- Incompetence of the management about modern solutions
- Companies use different solutions that does not compile with others
- Only some of the participants are using ICT solutions
- Lack of financial resources
- Lack of time
- Lack of suitable software solutions

The challenges mentioned in the survey answers match in general level the conclusions reached from the interviews. No additional obstacles compared to the interviews were identified. Thus the findings are supporting the conclusions reached from interviews and increase the confidence in relying on them while building up a real business idea.

Need for improvements by ICT:

6 participants provided no or answer to this question. Those who answered saw possible uses for ICT in the process as following:

- Most updated data should be always available on the site
- ICT could be helpful to run bigger projects
- All documents should be made available and accessible for all the parties
- Cloud solutions
- All inclusive project management program + 3D drawing integration + BIM

Some important comments were that ICT is simplifying the processes only for those who are able to use ICT solutions easily, for others, it is an extra pain and most likely there would be a resistance to using them. Another comment was on the importance of all the parties using ICT, not just some, to really win from the innovation.

The common nominator for the improvements listed could be the need for better data management and faster and more accurate information flow.

Possible ICT solutions suggested

For this question 3 participants gave no answer and one stated that time will be the solution, meaning that everything will be implemented but over time. Other answers gave a rather good input for the solutions and also complemented the previous question about the challenges.

- Quality of the staff needs to be raised
- When using ICT solution and storing information to the device, it has to arrive to all the participants, otherwise it is useless.
- New solutions have to be simple, accessible and reasonably priced
- Solutions for Estonian market must be modified and translated
- Need for a better communication channels between the site and the office

In summary, the findings from the survey proved to support the main findings from the interviews but with much less detail. Given that the survey results were supporting the conclusions and implications reached during the analysis of the interviews, the implications from the interviews were used to build an ICT solution for Estonian construction market that can be built into a real business. The findings from the third section (need for improvements by ICT) and the forth section (suggestions for possible ICT solutions) were used to improve the concept of IT solution to be built into a minimum viable product to be given for initial field testing.

5 MVP Testing

For testing the possibility to implement new ICT solutions in construction market created by a small start-up business, a real project for IT solution was drafted based on which a minimum viable product (MVP) was created. The MVP was then given to a test-user to collect an initial feedback. The preliminary vision for the IT solution for Estonian construction industry existed already before conducting the interviews and survey among industry participants, however, a detailed understanding of industry needs and, what is as important, a detailed understanding of the hindrances imposed by construction industry to successful implementation of IT solution in Estonia was lacking. Therefore, the MVP was created only after the findings of the current study described above were incorporated to the final draft of concept of IT solution for Estonian construction market.

The initial concept for the solution was improved by guided by the interview findings:

- Making sure that the solution does not require any specific training. It had to be intuitive to be grasped on the work process. Also, one of the customer benefit by the solution was reduction in working time (time and money catch)
- Offering a benefit to the individual user (save time, less manual work) as well as to the company (better quality reports).
- Avoiding radical changes in today's process (psychological resistance)
- Offering the solution for testing also to Finnish and Swedish companies (unwillingness to test the solution)

By incorporating the findings from the interviews to improving the concept for IT solution to be offered for the Estonian construction market, two means were achieved: the authors gained preliminary validation to their IT based solution built for the construction market, and what is more important, low level of proof that a real business can be built on the findings of the current study was achieved.

In following section a general overview of the concept of IT solution by the authors will be presented, relevant terms for understanding the idea will be explained and preliminary feedback from MVP testing will be presented.

5.1 Relevant background knowledge to understanding the solution

Quality inspections

Quality inspections are made by site supervisor and it is a mandatory part in building process in Estonia when it comes to public buildings. For building private houses it is not mandatory but still widely used by clients so that the whole construction process is done according to the project, following the legislation and is in the interest of the client.
Site supervisor is representing the client and has a contractual obligation to defend client's interests during the construction process. Depending on the contract and the specifics of the building, supervisor(s) have their scheduled inspection during every construction phase. They have to report all the problems to the main contractor and, if agreed, also to the client.

Forcada et. al (2010) have brought out different types of quality inspections that can be made:

- on site quality inspection. It is conducted by several site project managers and engineers whenever necessary until project is closed
- third party inspection which is an intensive and focused inspection conducted by managers and engineers from a general contractor's main office and construction sites
- external quality inspection, which is carried out by quality control entities or laboratories to control basically materials.

Construction site manager

Site manager is the contractor's representative on the site and responsible for the whole process. Depending on the size of the object, there can be several site managers. Tasks include to plan and execute the processes according to the timetable and budget, communicate activities with sub-contractors, site supervision and client. Site manager is responsible for everything on the site from workers security to logistics.

Sub-contractor

Sub-contractor is hired and is responsible in all matters only to the main contractor and has usually no connection with the client. Sub-contractors are usually focused on specific parts of the

whole process (electricity, piping, concrete etc.). Sub-contractors representative is communicating the information with site manager and gets all the tasks also from the manager.

5.2 Concept of proposed IT solution

Mobile software solution Lynxreports was founded by Tarmo Needo, member of the board in the construction supervision company Vealeidja and Rainer Tikk, IT development manager in LHV Bank. Idea came when Tarmo Needo analyzed the daily activities of construction supervisors and the lack of the use of ICT solution in the area in general. After introducing the original idea for the IT solution for the construction industry to the author of this paper, it was included as one of the semester projects in the Design and Development of Virtual Environments (DDVE) masters program. In couple of months the 4 member team of DDVE students worked with the business development of the solution (project was called Site Inspection then). After successfully defending the project at the end of the semester it got included to Tehnopol Start-up Incubator pre-incubation phase. From there on the original team continued with the project including also an author of this paper to the team and together with a back-end developer Anti Veeranna.

5.2.1 Lynxreports

Lynxreports is mobile reporting software for site inspectors allowing for automated report generation and immediate reporting.

Lynxreports is a software for mobile devices that goes with the supportive web-environment and is aimed for the construction supervisors and site managers to identify the issues, problems and questions on the construction site and instantly share them to all the necessary parties. Software allows uploading construction drawings into the mobile device as PDF's. After creating a new inspection folder or continuing with the existing one the user can start with the inspection. If there is an issue or problem found then the user can simply tap on the exact spot on the drawing, add a photo, add a description of the fault from the predefined list or type in the comment. Lynxreports is designed to be very simple, most of the actions should be able to complete with couple of touches and actual typing should be reserved only as the last option. That is the reason for predefined problem-list. Once the inspection is finished the program creates a report that can be shared as a PDF file or can be viewed on the Lynxreports web environment. User can add the necessary people who get the report on their email as a PDF or get the access to the web-environment to see all the reports connected with the recipient.

5.2.2 Customer (individual) problem solved by Lynxreports

Forcada et al relying on Young et al. (2008) have listed most important problems in current quality inspection process and on of the first is that a number of data collected manually with checklists, must be retyped to a computer by which the data input process is duplicated and also there is a possibility for input errors. These errors also may appear because of the non-unified or non-formatted data recording systems (e.g. checklists, notes, post-its, photos, spreadsheets) often yields data losses and damages. Problem is also in tracking and continuity as after the orders are sent out to correct the defects, it is not easy to find and monitor whether it has been corrected or corrected according to the requirements. Another problem arises from the shortage of on-site staff who can handle the quality issues. It is due the excessive management practices workload for crews to meet deadlines, a number of documents to manually fill out, inefficient communications, and poor quality assurance process. What is pointed out and is connected with our solution is the poor communication among on-site quality supervisors, contractors and crews and it is caused by using too many tools like phone, radio, fax, post-it's or verbal instructions. There is also no standard repository of data and feedback systems available to reuse the lessons from the past. (Forcada et. al 2010, 204).

The goal number one for Lynxreports is to change these things that are brought out above and help to save time on site. Scarcity of labor time was found out to be one of the main problems for the industry during the first part of this study. Lynxreports will reduce the time that is wasted on typing in the results of the inspection afterwards and attach photos from the camera.

Talking with the people working on the field and visiting the construction site with the supervision company showed that approximately 1/3 of the whole inspection hours go into the inserting the collected data to computer, linking the photos with location by written explanations and then sharing the whole thing to other parties. Also the drawings needed during the inspection are printed out, often too large to carry and can only be viewed in the offices next to the construction site.

Goal number two is to systemize the gathered info so it can be revisited, checked and commented as long as the problems are solved. Most relevant and updated information about problems and questions is always available. When solved, the processes can continue. As said before in the chapter about Lean Construction, the waste is not only about materials. Waste can occur, when problems are not discovered or dealt with on the earliest possible moment. It can

lead to the point where some of the built objects need to be at least partially destroyed. Therefore the fast and detailed communication between parties is utterly important. Also the waste of time is relevant, when there are some issues that need to be solved and the supervisor for example asks to stop the processes in order to fix it, but the information moves too slowly and some small change can take days to fix.

Third goal is to create a detailed archive so the problems can be later traced back in case the need arises. This can be necessary after the construction is finished and there are warranty issues or even legal questions about one's responsibility.

The important aspect of the solution is that it works independently from other systems and solutions and is able to generate direct benefit for the company as well as the individual user without any underlying requirement for other parties to use the solution in parallel to the user.

5.3 MVP

MVP design was worked out using the input from the possible users of the industry and included only the most important features. The input was gained from the industry practitioner offering to participate in the business creation. Design itself needed to be as simple and intuitive as possible: this was considered to be as one of the most important tasks in order to get the people in the industry to use it. Another priority was to include as much pre-defined options as possible so the user could insert the necessary information only by simple touch. In a later version there will be more of these predefined settings, covering most of the possible issues appearing on the construction site. For the MVP there were just some main categories added to cover the most usual aspects. Also we included the possibility to type on custom comments.

5.3.1 Content and features

MVP was installed to the test tablet, 10" screen Sony Xperia which is suitable for harder conditions having dust- and fall-proof body and basic water-resistance. In the MVP there was no logging in or signing up procedure needed. On the main screen of the app the user could choose whether to start new inspection, check the previous inspections or see the last inspected object. Also there was a location-based suggestion for the nearest object. If the favored object was selected or new inspection created, user could attach project drawings from Dropbox to the specific inspection folder.

When starting an inspection, the user could long-tap on the specific location on the drawing and includes the fault, problem or comment from the predefined categories or into the comment box. Also photo made by a tablet could be included to the specific location. When the inspection is finished, the report is automatically generated in PDF format and stored in the tablets memory and can be sent out by email-client.
The screenshots from the MVP for Lynxreports are included to Appendix 2.

5.4 Preliminary feedback from MVP

MVP was given for the test to the site supervisor on one of the biggest construction sites at the moment in Estonia, Põhja-Eesti Regionaalhaigla (Northern Estonian Regional Hospital, PERH). The size and the complexity of the construction demands for the several supervisors, specialized on different areas, to be on the site full time. Test was conducted by the general construction supervisor on one of the floors. Testing results were not included in the official reporting process with the main contractor afterwards cause the goal was only to test the usability and the functions of the MVP. The main objective was to get the users feedback about the application and about the possibilities and readiness and willingness to use it as a main tool for supervisor reports. Using a more IT-literate tester was deliberate to ensure that the MVP would be tested thoroughly and later comments would be more useful and professional.

Test user had tried other software earlier (Autocad360) and as some of the functionalities were similar, the learning process was quick. The logics and the user experience of the application in general were sufficient and it was concluded that the more specific predefined fault-lists and/or drop-down selections in the future versions are vital for the app to succeed. One of the main functionalities to keep in mind when using touch-screen hardware on the construction site is that the data input has to be made as simple as possible and typing in the text is not favored due several reasons which include climate, specifics of the construction environment, usability and the skills of the user. Even in the perfect conditions, the touch-screen typing with one hand takes too much effort. Also the quality of the photos might suffer in the darker areas, therefore, the separate flashlight was used but in the end-version of the application, more usable solution has to be found (attachable extra flash, better camera software). During the inspection and in the PDF report created afterwards, the language was Estonian, which was considered as essential by the user and also when conducting the interviews with industry practitioners. Report is shared later

with many different participants and the working language in construction processes is Estonian. This was also one of the most mentioned necessities for the successful software's on local market – local language.

Last but not least, important questions were that if there will be a full version with better functionalities and predefined settings, would it be used, can it work in the existing flow of the construction (would these reports be acceptable by all the participants) and would the user be ready to pay for it. After the initial testing, the answers to these questions were positive, most important of them being that it can be included in the existing workflow. Unfortunately, for the purpose of this study there were no time resources available to test the MVP on more people. However, based on the findings from the interviews several construction practitioners in Finland and Sweden were also contacted. After introducing the business idea and describing the solution, two Finnish representatives and one from Sweden proposed that they would like to test the product after the first version is ready.

Even thought the findings from MVP testing and from introducing the business idea generated during the process of this study are very limited, it gives at least some indication that the business built on the implications taking into consideration the peculiarities of Estonian construction market and hindrances posed by it to ICT implementation identified during this study are welcomed positively by the industry practitioner. What was also surprising and supporting the finding was the Finish and Swedish construction practitioner's very welcoming offer to take the solution for testing once the first version is ready.

6 Conclusion

The findings from the interviews with industry practitioners, from the survey conducted and from the initial finding of the MVP testing show that due to peculiarities of the construction industry there is a considerable number of hindrances posed by the industry to ICT innovation that were not dealt with when developing the IT solutions currently available for Estonian construction industry. The authors of this study argue that recognizing the hindrances identified in this study is the opportunity for IT startups willing to enter the construction market. Avoiding the core hindrances that are there due to the fundamental structure of Estonian business industry, which are:

- Time and money catch;
- The wide gain in construction process not felt by individual players;
- performing different functions;
- Relatively old IT hardware in use and no plan to replace it on a large scale;
- Strong presence of the psychological factor to resist the change;
- Unwillingness to be a test-user;

and minimizing other hindrances identified in this study could serve as a competitive advantage for a IT start-up company entering the market. The fundamental problem in the market seems to be the sacristy of the labor, thus, the time. Requiring the user to invest his time into new IT solutions should be treated with extreme caution. The potential, instead, could hide in reducing their time usage instead.

The results of this study could serve as a guideline for other start-ups planning to enter the construction market. However, the findings of this study and implications for start-ups should be treated with limitations, as there was not enough time to develop the developed IT solution into a ready business product that could be already sold. Perhaps a suggestion for further research could be to take the findings of this study even further and analyze the hindrances identified on the light of the experience of a real IT business creation.

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8 Appendices

Appendix 1 Questions for the interviews

What was the incentive for using BIM solutions?

What were the biggest challenges when implementing BIM?

How much is BIM used today in Estonia and in what extent?

Who are using it?

How much changes it needs in the existing work-flows?

How much resources it takes both time and financial wise?

What is the gain for the company for using the BIM? -

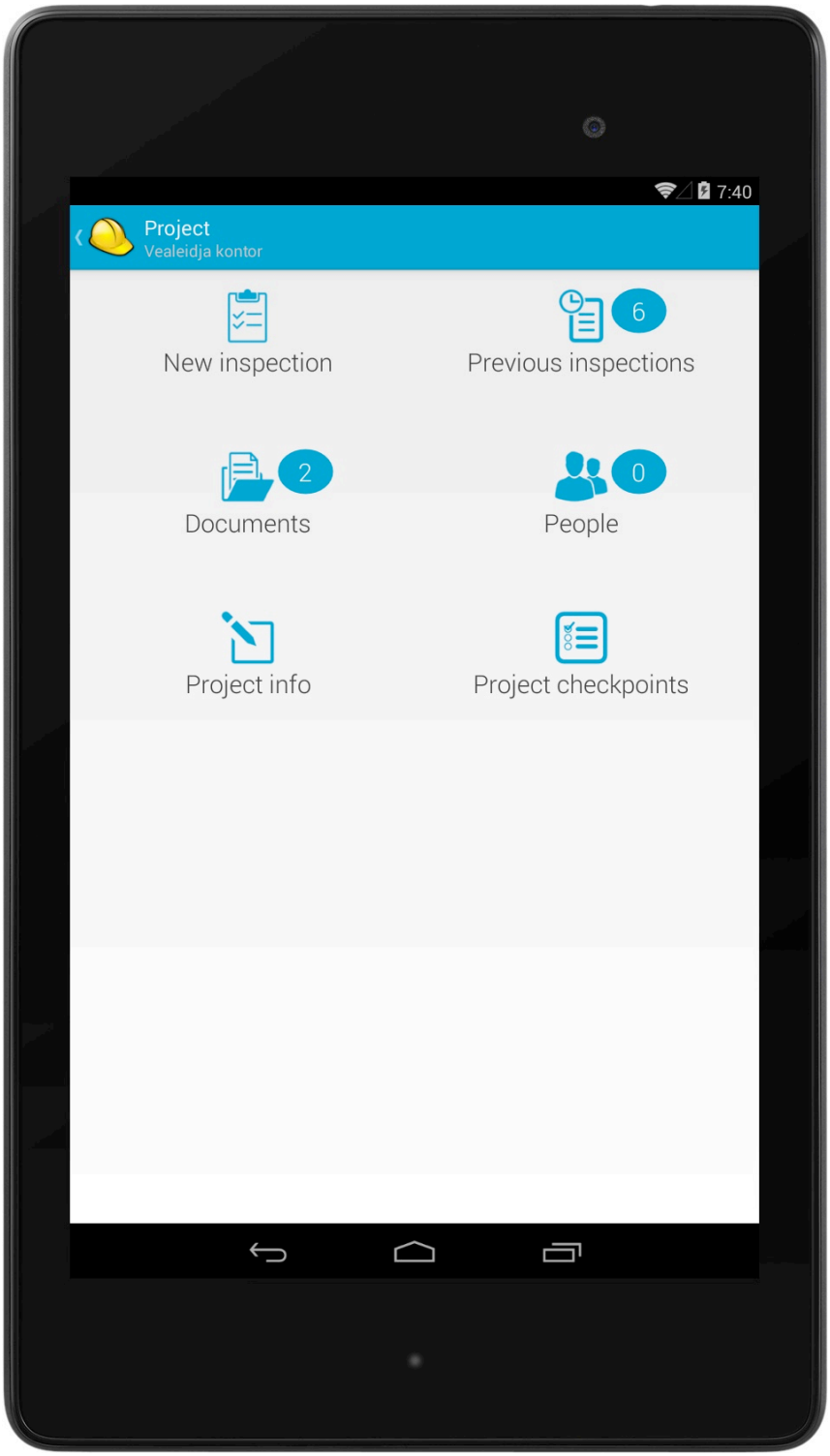
What other construction-specific solutions are you using both in software and hardware wise?

Do you use any smaller IT solutions?

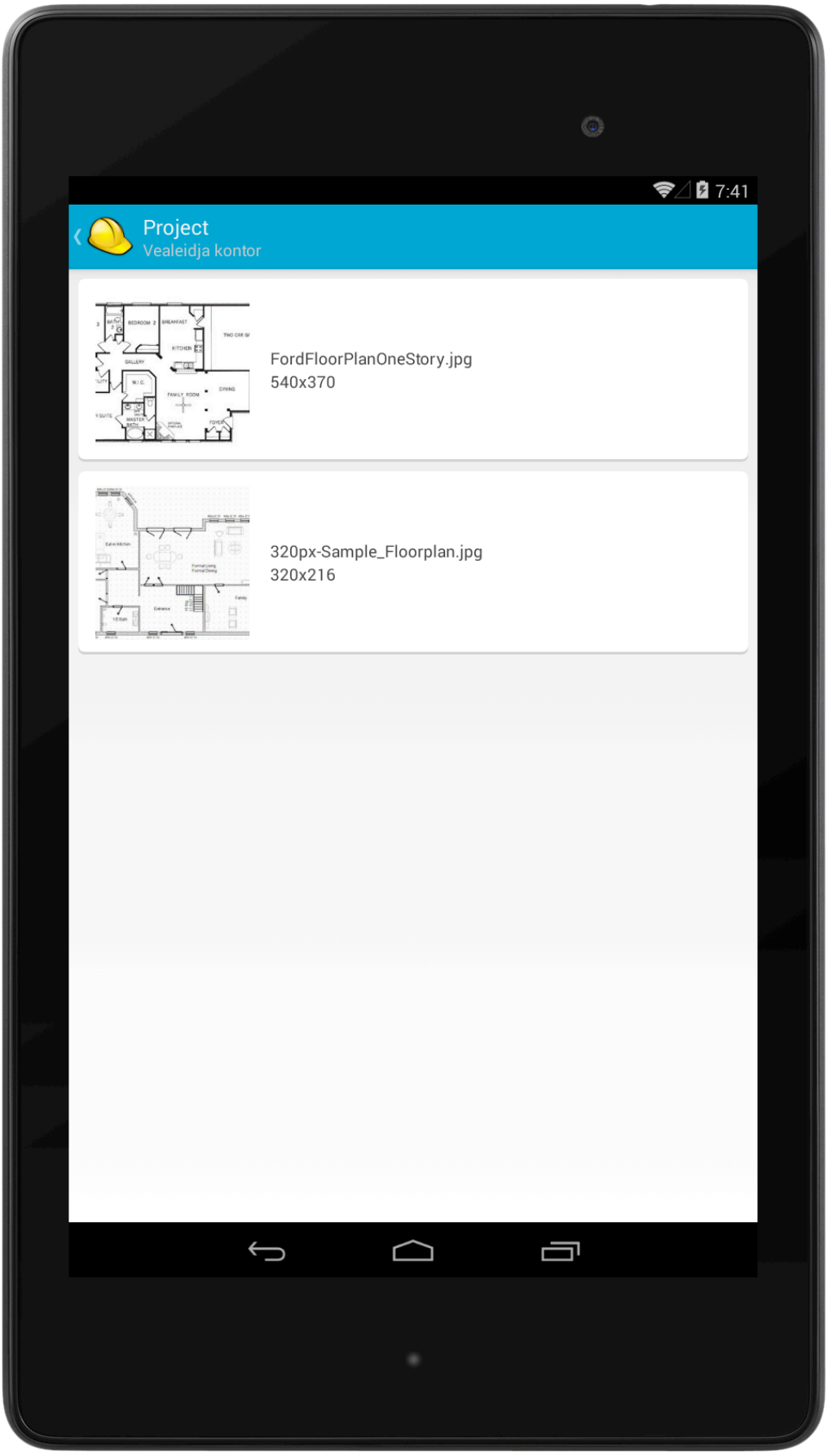
What are the main problems for lack of ICT in Estonian construction sector?

What other solutions besides BIM the sector might need?

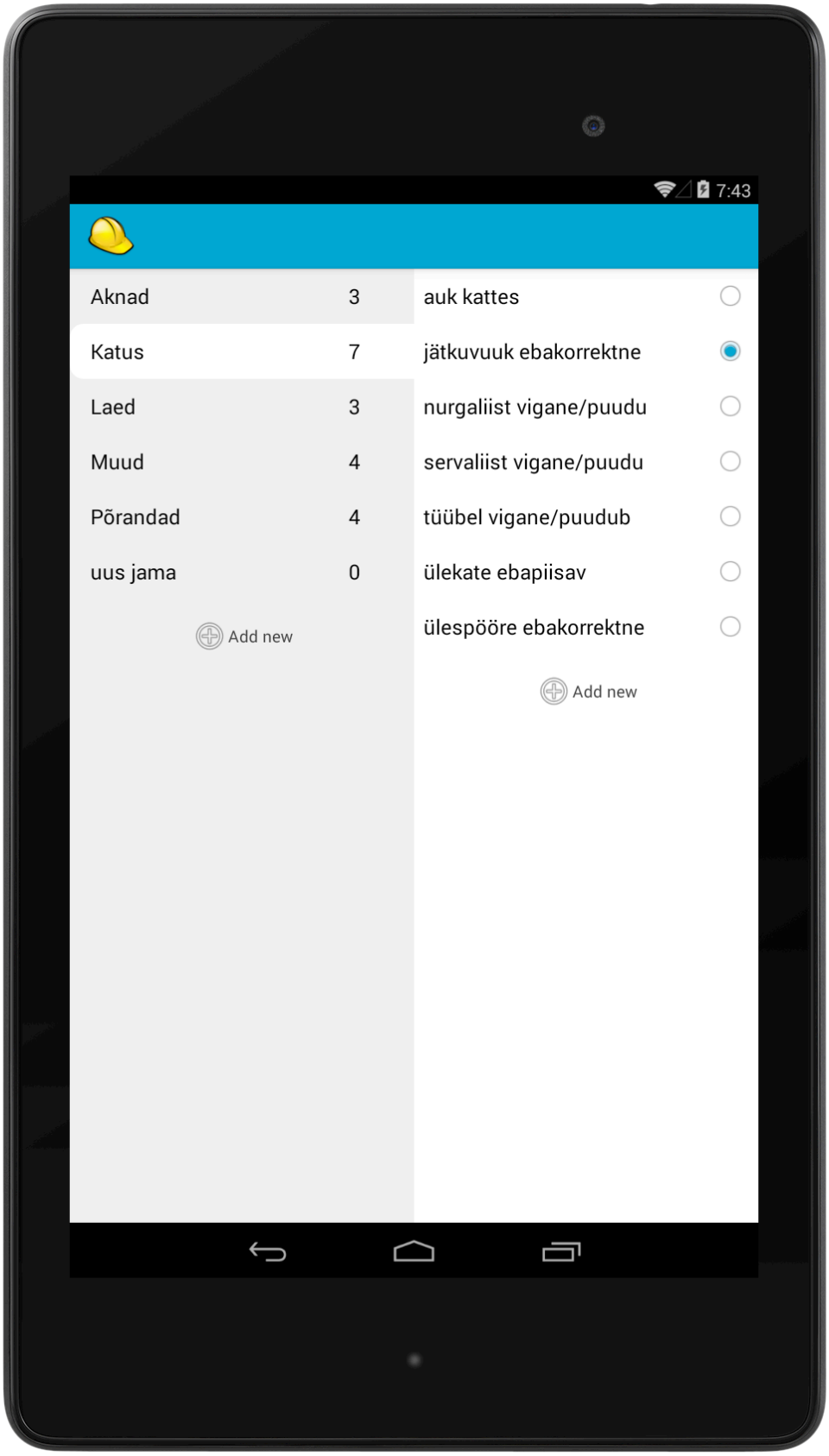
Appendix 2 Screenshots of the Lynxreports software MVP



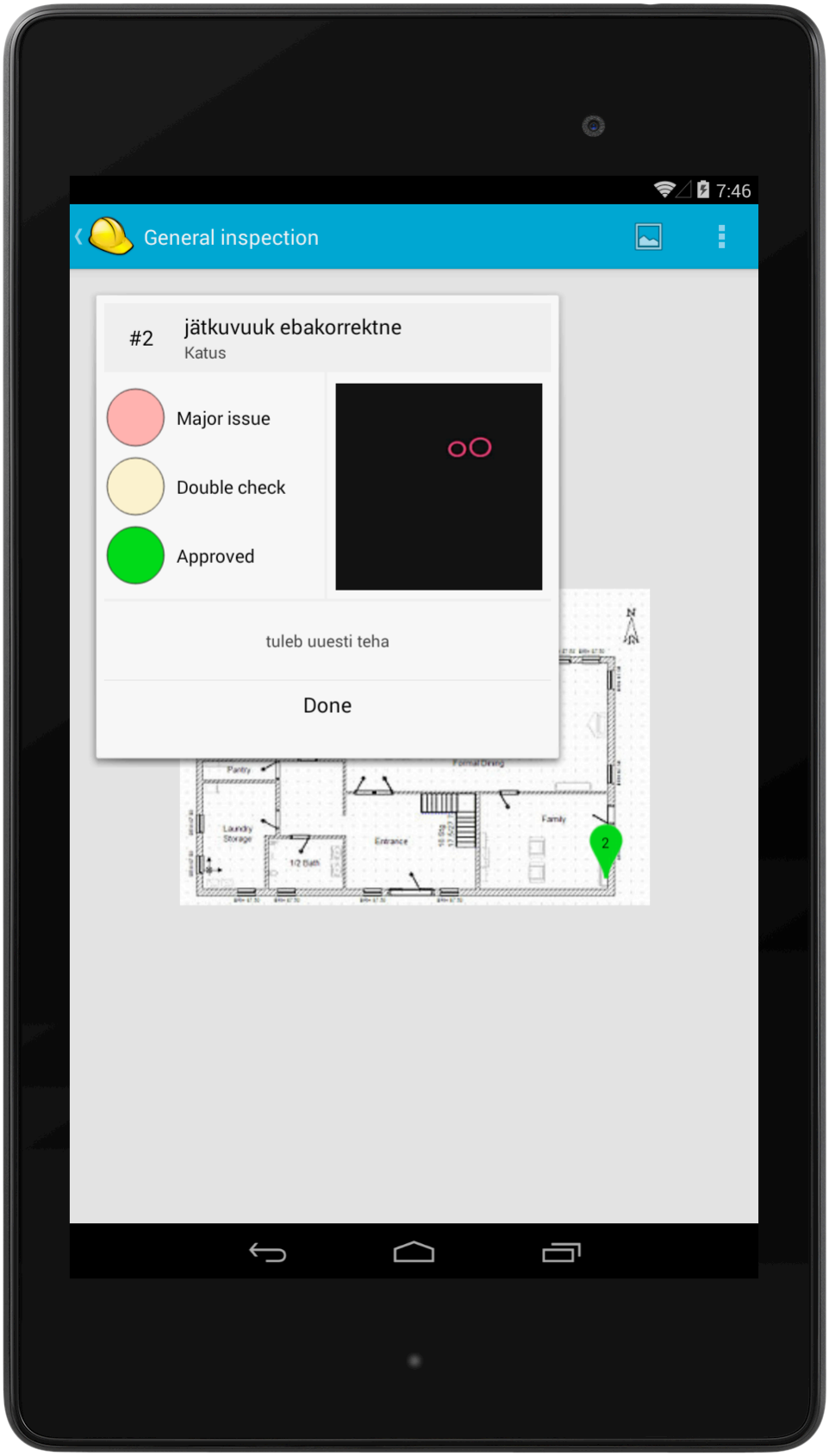
Starting page



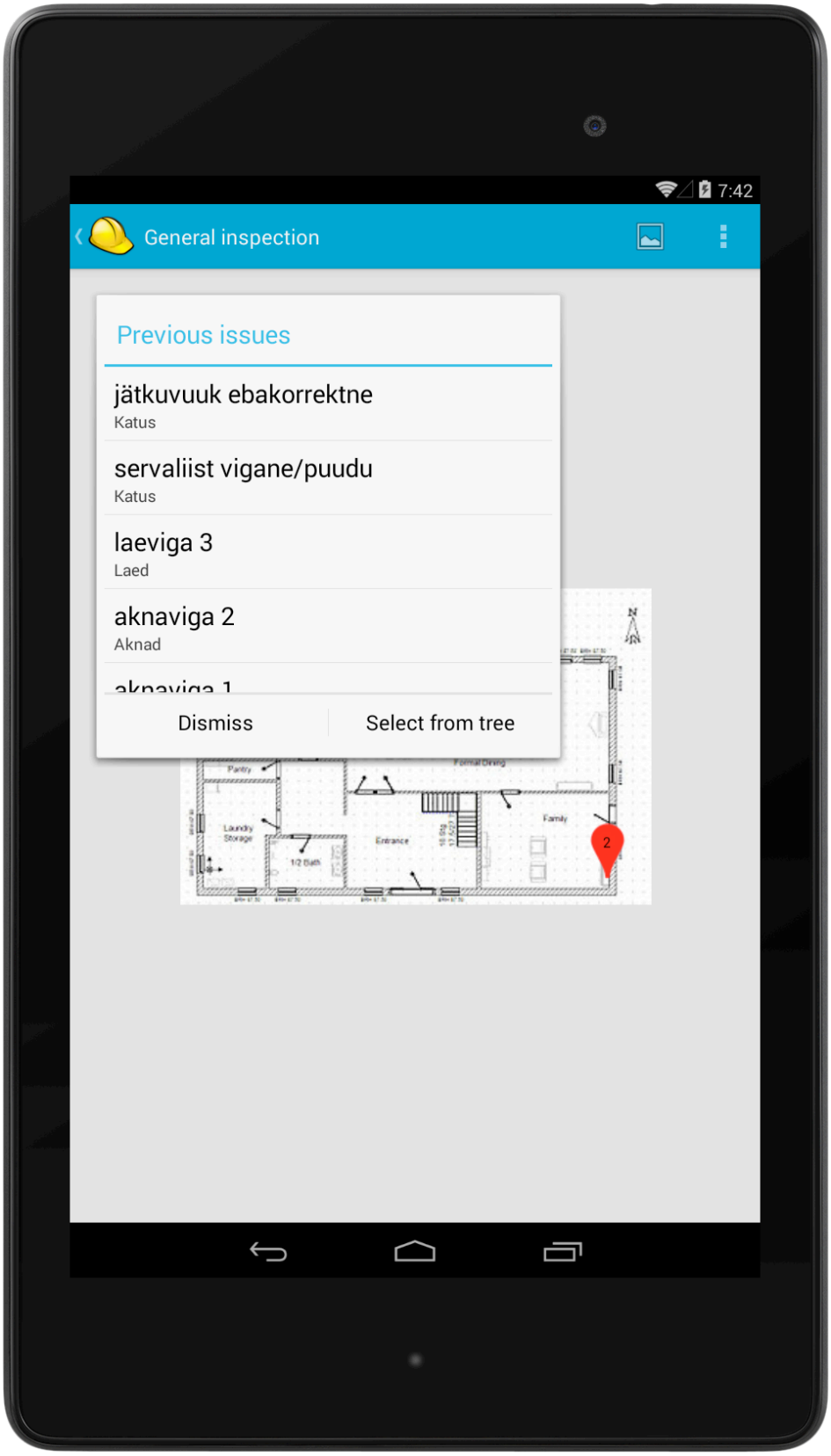
Selecting the floorplan for inspection



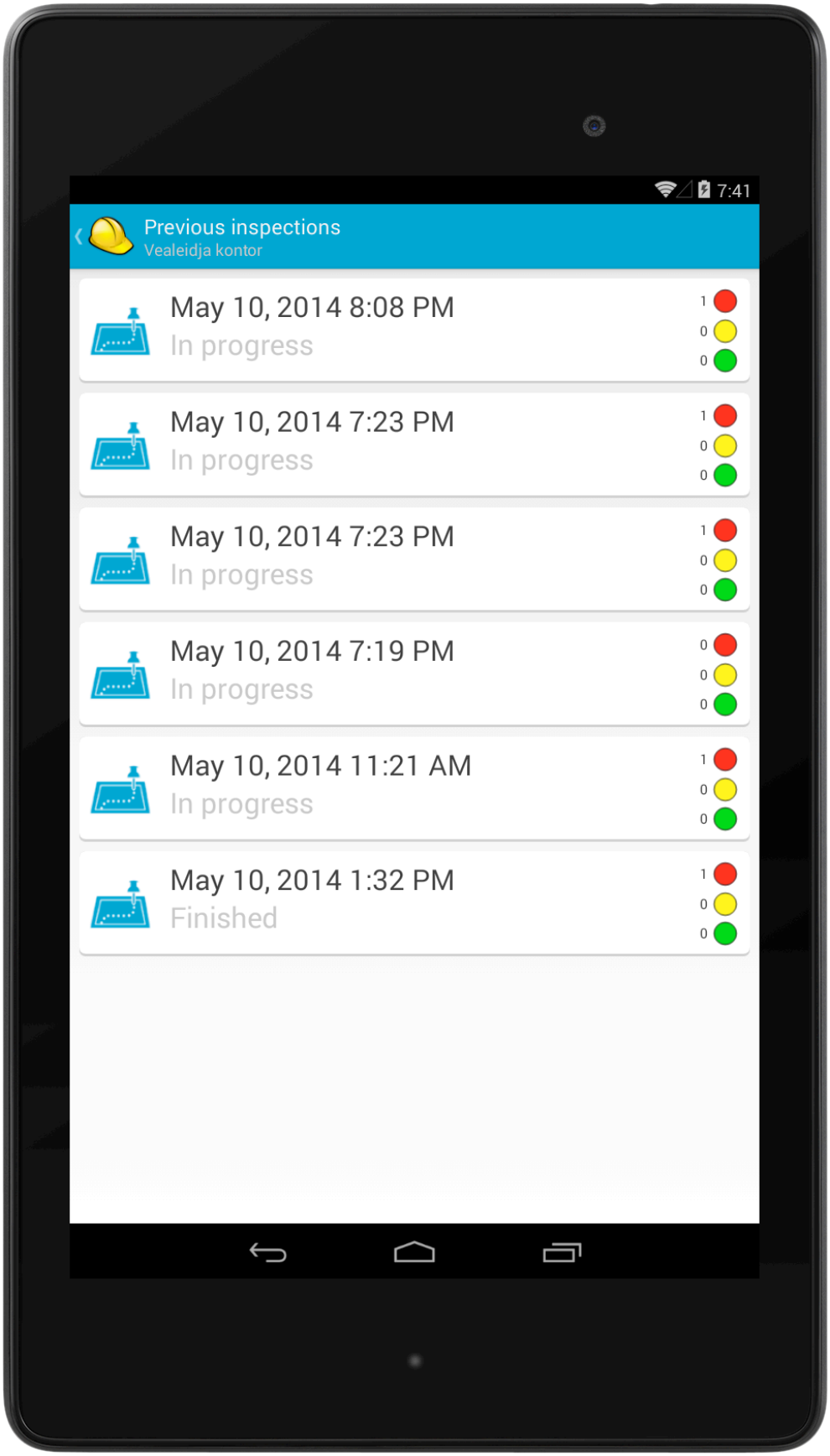
Predefined fault-list for quick selection. Column on the left has the main categories (windows, roof, ceilings etc.) and on the right column there are more specific comments concerning the selected main category (faulty finishing, missing screw etc).



Detailed information and color-based evaluation of the problem.



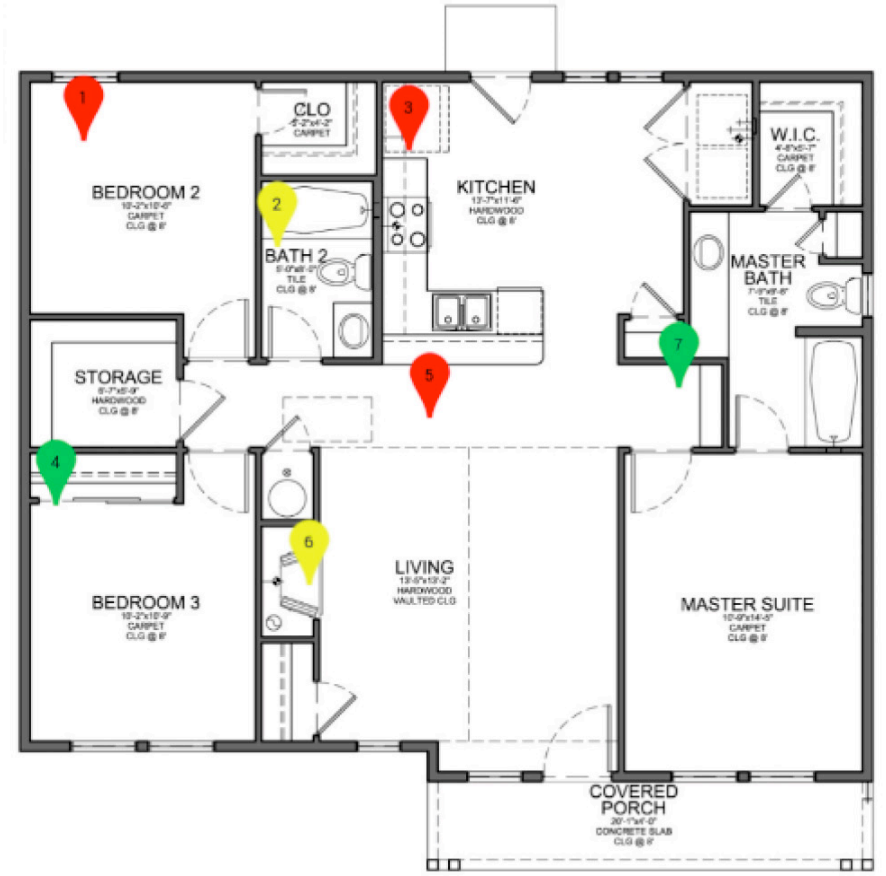
In the textbox are faults from the previous inspection that can be dismissed if they have been corrected. Red marking marks the spot where the fault is situated.



Inspections archive.

Appendice 3

PDF report generated automatically by Lynxreports at the end of the inspection



Kolmanda_korruse_plaan_vasak.png

- #1 **Ülekate ebapiisav.** Katused, kattematerjalid, PVC.
- #2 **Ülespööre ebakorrektne.** Katused, kattematerjalid, PVC.
- #3 **Kolmnurk nurgaliist vigane/puudub.** Seinad, kergkonstruktsioon, sõrestik.
- #4 **Tüübel vigane/puudub.** Seinad, sw paneel.
- #5 **Tüübel vigane/puudub.** Seinad, sw paneel.
- #6 **Tüübel vigane/puudub.** Seinad, sw paneel.
- #7 **Tüübel vigane/puudub.** Seinad, sw paneel.
- #8 **Tüübel vigane/puudub.** Seinad, sw paneel.

Clicking on the issue takes the user on the page in the document that is covering this problem (see the next screenshot).

#1 ÜLEKATE EBAPIISAV

Katused, kattematerjalid, PVC.

Siia tuleb käsitsi sisestatud tekst, kui keegi toksida viitsib. Probleemi täpsem kirjeldus, meetmed jms. Siia tuleb käsitsi sisestatud tekst, kui keegi toksida viitsib. Probleemi täpsem kirjeldus, meetmed jms..

Foto 1.1. See on pildi kommentaar.

This is the example photo of the issue no 1 with explanation of the problem. User can add more detailed commentary under the photo.

9 Summary in Estonian

Antud uurimustöö teemal “IKT lahenduste rakendamine Eesti ehitussektoris ning sektoriga seotud potentsiaal idufirmadele” uurib info- ja kommunikatsioonitehnoloogia (IKT) rakendamist Eesti ehitussektoris. IKT lahenduste juurutamine erinevates sektorites on kaasa toonud hüppelise kasvu innovatsiooni arengus. Vaatamata sellele, et Eesti paistab maailma mastaabis silma IKT innovatsiooni eestvedamisega, on IKT lahenduste juurutamine Eesti ehitussektoris täna maha jäänud. Antud uurimustöö eesmärk on tuvastada need põhjused ning sellest lähtuvalt analüüsida võimalusi idufirmadele IKT arendamiseks Eesti ehitussektoris.

Uurimustöö tarvis viidi läbi kvalitatiivsed intervjuud Eesti ehitussektori esindajatega, koostati anonüümne küsimustik ning loodi primaarse funktsionaalsusega lahendus hindamaks ehitussektori suhtumist uurimustöö baasil loodud IKT lahendusse.

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