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IMPLEMENTATION OF OFF-SITE CONSTRUCTION MANAGEMENT IN RESIDENTIAL REAL ESTATE DEVELOPMENTS

Master's thesis
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I hereby declare that I have compiled the thesis independently
And all works, important standpoints and data by other authors
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has not been previously presented for grading.

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ABSTRACT

The low increase of the efficiency of construction industry together with increasing demands for quality of the buildings and limitations from urban planning is making the construction of buildings more expensive, which adds to the final prices for the customer. Experience of other industries has proven that standardisation and automation of production has led to increase of efficiency, which could be more effectively achieved in off-site construction production rather than on site. Estonia has a strong off-site construction industry, which is mostly focusing on exporting. This thesis is focusing on finding difficulties and proposing solution to problems that are hindering the cooperation between off-site construction companies and Estonian real estate developers.

Working together with off-site construction companies in business cases of real estate developer Pinered provided detailed insight and practical understanding of opportunities and bottlenecks for cooperation between real estate developers and off-site construction companies. The export focus of off-site construction companies is reducing their efficiency to compete in price with on-site construction. However, when both parties strive for cooperation from the beginning of the design phase, there are possibilities for cost-effective solutions as was proved in the cases of Pinered.

Based on the literature review and work on practical case studies the author conducted qualitative research to gain further insight about the situation. The 12 experts of the industry interviewed for this thesis shared their view of the situation in the Estonian real estate market and identified the possible cooperation opportunities for real estate developers and off-site construction companies. In general opinion real estate market is open for off-site construction solutions, provided that they are time efficient and competitive cost. However, the production price today is more expensive, than on-site construction, which is the main argument for developers deciding between construction methods. The main components for higher price are orientation on export markets, relatively small scope and uniqueness of the real estate projects. Additionally, the cooperation with local authorities is difficult which makes the planning of the process complicated and reduces the advantages of off-site construction method.
Keywords: real estate, construction, management, cooperation, efficiency

INTRODUCTION

The real estate sector is under a strong strain of low supply of construction together with changes in demand due to development of technology, which has been amplified by the COVID-19 crisis. The fast growth of construction prices and low availability of land in urban areas have decreased the availability of real estate to large part of the population with lower income. As a result, the home ownership especially among younger generation is declining. This decline for example has impact on fertility (Makszin & Bohle, 2020), when young couples postpone their family plans due to insecurity regarding their housing. Real estate development starts with acquiring the land needed for development, designing suitable product, constructing the building and ends in sales of the real estate. The construction is the main component of the development in terms of cost and duration. The key for successful construction project is conscious approach towards the whole process starting from the planning. Although biggest and most expensive setbacks appear during the construction itself (Kask, et al., 2018), they often originate from planning and preparations phase.

After brief downturn during the COVID-19 crisis, the real estate sector has recovered fast with the help of government support. A new major challenge in the post-COVID-19 world for real estate market will be adaption to new ways of office and remotely working balance (PwC, 2022). The flexibility of office hours would make it easier to commute and encourage population to move out of the centres, where real estate is cheaper and therefore more affordable. This trend needs to be supported by smart general planning by the local authorities to ensure availability of facilities needed for everyday life in close proximity (Guzman, Arellana, Oviedo, & Moncada Aristizabal, 2021).

Low supply of housing has created gap between demand and offer (T. Rosen, Bank, Hall, Reed, & Goldman, 2021). One way to increase the supply of housing would be to increase the efficiency of construction production, however the growth of efficiency in construction industry is slower than in other industries (McKinsey&Company, 2017). This thesis investigates ways of increasing construction production efficiency by moving some processes of construction production off-site.

There are examples in the world of successful implementation of off-site construction in real estate developments in high rise buildings (van der Ham & Opdenakker, 2021) and residential developments in Australia (Navaratnam, Ngo, Gunawardena, & Henderson, 2019). However, the implementation of off-site construction production is smaller than expected despite of the advantages it has over traditional construction (Steinhardt, Manley, Bildsten, & Widen, 2019). The reason for low application might be connected with lack of experience in managing the cooperation between on-site and off-site construction. Successful examples of cooperation between real estate developers and off-site construction companies have been in constant cooperation throughout the project (Jiang, Li, Li, & Gao, 2018) (van der Ham & Opdenakker, 2021)

Estonia has strong and well-developed off-site construction industry, which is mainly focused on wooden houses (Puitmajaklaster, 2018) and is mainly focused on export to Scandinavia (Unt, Võrk, & Varblane, 2018). However, the cooperation between Estonian off-site construction companies with local real estate developers is low. The goal of this thesis is to find opportunities for real estate developers for cooperation with off-site construction companies in order to increase the efficiency of construction production. This master thesis focuses on empirical study of following research questions:

1.Which are the key characteristics that describe the cooperation between real estate developers and off-site construction companies?

2.How can off-site construction relieve the construction related bottlenecks of real estate industry?

3.What are the limitations of implementation of off-site construction in residential real estate developments in Estonia?

The case studies of this master thesis are analysing business cases of a local real estate developer whose goal is to increase efficiency of the construction process by implementing off-site construction in the production process. The cases provided a thorough overview of the impact of off-site construction to the real estate as product, reception by clients, marketing channels and assessment of business risks and opportunities. As results of these business cases, opportunities and limitations for cooperation on small scale residential real estate developments were identified. The interviews conducted in the research part of the thesis provided subjective opinions of people who are working daily basis in the fields of real estate development and construction. Their valuable input helped the author to achieve the goal of this thesis, which is to identify the specific specialities of situation on Estonian real estate market and its cooperation possibilities with off-site construction companies.

The author would like to thank all the participants of the interviews for their valuable contribution to the qualitative research conducted for this thesis and Roode Liias and Kristjan Jasinski for supervising the thesis and providing valuable support and feedback.

1. THEORETICAL BACKGROUND

The chapter focuses on analysing the existing literature to describe the situation in residential real estate and construction industry. The aim is to give an overview of the theoretical background of the industry, describe the current situation in residential real estate and off-site construction companies. The studies conducted around the world will provide examples of successes and bottlenecks of the cooperation between real estate developers and off-site construction companies.

1.1. Global residential real estate and construction industry

Construction is important sector of business as it contributes around 10% to country's GDP (Kask, et al., 2018). An important characteristic of construction business is that it is mostly focused on local market and its demand depends on the progress of the other industries. If other, often exporting industries, are growing, they often invest in facilities, which are then built by construction companies.

Construction activity and its contribution to the rest of the economy is affected by the cycles of the economy. For example, in 2007 at the height of the real estate boom, when everyone on the market were buying, construction contributed almost 11% to the EU area GDP (Kask, et al., 2018). The additional investments by the companies increased the demand for construction. At the same time rising wages of the workers combined with the fast growth of real estate prices, which were predicted to continue gave an incentive for the demand for residential real estate. After the bubble had burst, there was a large supply of real estate on the market and the length of the project means it takes time to reduce the offering. As a result, by 2011 the share had dropped to only 7% (De Groote & Lefever, 2015) (Kask, et al., 2018). These two examples are good indicators of construction businesses' turnover dependence on the economic cycle. On the growth phase, its relative size compared to GDP is higher due to additional investment. During the decline phase, the contraction is relatively higher due to lack of investment in other sectors.

Globally the low supply of residential real estate is one of the major challenges for the construction and real estate industry. In United States, the low supply of the housing has created a gap between production and demand, which has contributed to rapid increase of renting and house prices (T. Rosen, Bank, Hall, Reed, & Goldman, 2021). In Western Europe, housing has a major role in deepening inequality. One example is homeownership of millennials, which is steadily declining. The reason behind it is the inability to purchase homes due to the lack of disposable income, which has dropped because of high debt burdens from student loans (Fuller, Johnston, & Regan, 2019) In East Central Europe the high levels of homes purchased without bank financing makes it difficult for young couples to form independent households. Young adults often have to rely on the support of their families to purchase a home. (Makszin & Bohle, 2020) Examples from the previous two articles highlight the issue, where younger people are not able to finance the purchase of new housing. As a result, there is a gap between the demand and supply of residential real estate. During the second half of 20th century the housing stock grew in average rate of 1,7% per year. The growth has declined to 0,7% in past decade. The result is gap of 5 500 000 underbuilt homes in United States in the past 20 years (T. Rosen, Bank, Hall, Reed, & Goldman, 2021).

The COVID-19 added a lot of strain to the construction and real estate market. Fortunately, it was relieved by government subsidies. Firstly, by direct subsidies and support from the government to the construction and real estate sector. Secondly the support to business to keep their revenues and directly to people to support their income. According to PricewaterhouseCoopers report the government totalled around 6 trillion dollars during the pandemic (PwC, 2022). At the same time the government support has increased inflation in real estate. The loose financial support to UK home owners during the crisis has fuelled the growth of home prices (Blakeley, 2020) As a result purchasing real estate will become available especially for people with lower income.

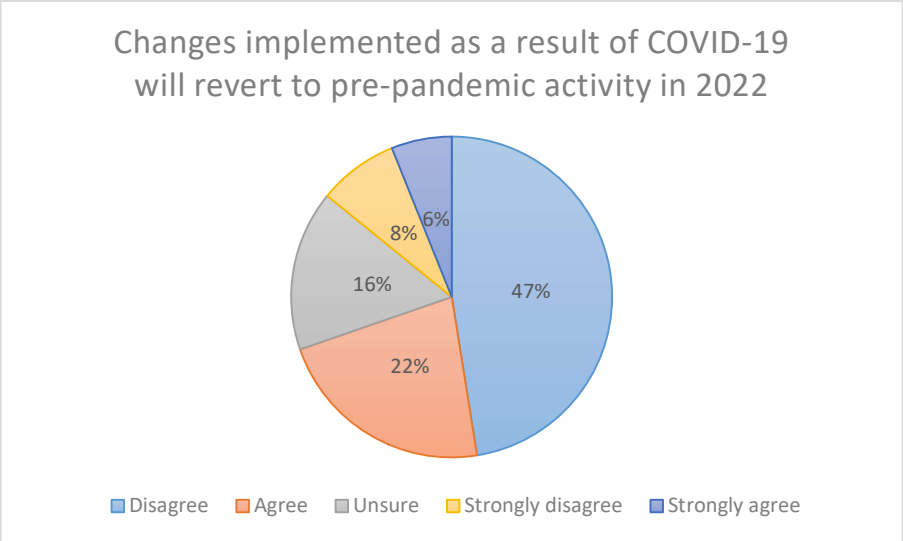

Figure 1. Perseveration of COVID-19 changes in 2022

Source: Emerging trends in real estate (PwC, 2022)

As can be seen in Figure 1 the future of post pandemic world will allow and require more flexibility for the physical space around us. Possibility of working remotely will enable families to move further from their jobs, often to locations where the prices of real estate are cheaper. This trend will make larger homes available for buyers. Commuting length is becoming less important in decisions on jobs or housing (PwC, 2022). Several of the changes caused by COVID-19 are expected to be irreversible. This trend however increases for example the importance of 15-minutes city, where all the facilities needed for everyday life should be reached within 15 minutes by walking or cycling. Often achieved in tensely populated areas, it requires deliberate actions of urban planning (Guzman, Arellana, Oviedo, & Moncada Aristizabal, 2021).

The changes in people's habits mentioned in previous paragraph adds more demands to urban planning. The sustainable urban planning starts from identifying the issues that need to be tackled, then the solutions are proposed and implemented, finally the whole cycle is monitored and feedback from it is implemented in identifying new set of issues (Yigitcanlar & Teriman, 2015). Several successful cases around the world have shown that early identification of future major issues with implementation of adequate measures will prevent or reduce negative effect of the future events (Newman, 2020). Despite of wide recognition of the need for improved urban planning, there is no universal method, which is considered best practice by everyone. There are different approaches towards urban planning, which is influenced for example by geography, culture and availability of resources (Nikulina, Simon, NY, & Baumann, 2019). The examples

above are good characterisation of the challenges of urban planning, where well-being of citizens has to be balanced with sustainability of environment.

1.2. Off-site construction

Off-site construction is a construction method, where significant parts of the building are constructed not on the site, but prefabricated in a different location. Optimized production in an environment where waste resources and waste management is controlled has smaller negative impact to the environment (Benson & Rankin, 2016). The parts of the process could include design, planning, manufacturing, assembling and testing elements of the building in a location that is different from its construction site. The aim is to increase the speed, efficiency and quality of the final construction (Froese & Lopez, 2016). Off-site construction is an integrated planning and executing strategy, which has highest advantage over traditional construction in case of complex structures, difficult accessibility, low availability of labour in location or specific requirements for the construction (Puitmajaklaster, 2018). Because of these reasons, the variants of this construction method are gaining popularity. In Sweden, for example, 80% of construction of houses are made off-site (Navaratnam, Ngo, Gunawardena, & Henderson, 2019).
Depending on the production capabilities, requirements for the construction and financial optimization, there are different off-site construction methods used, which is described in Table 1.

Table 1. Comparison of on-site and off-site construction methods.

Method	**Availability**	**Time**	**Cost**
On-site	Available	Slow	Low
Complete building	Limited	Fastest	High
Modular	Limited	Fast	Medium
Element	Mostly available	Relatively fast	Medium
Combined	Available	Relatively slow	Low

Source: Authors assessments based on literature review.

Modular building consists of several complete smaller parts, which are prefabricated off-site and assembled together in final location. The modules provide the load bearing structure for the building (Navaratnam, Ngo, Gunawardena, & Henderson, 2019). In case of modular construction,

the modules are usually finalized to as complete as possible during the production. The aim is to reduce on-site construction to minimum. As can be seen in Table 1, construction production from modules is one of the fastest ways of construction, however due to the limitations of size eligible for transport, especially for longer distances, there are limits of possibilities to use this type of construction method. The modules are installed on the site usually with crane and can be stacked together either next or on top of each other. The limitations of the installation equipment influence the dimensions of the modules of the building (Jiang, Li, Li, & Gao, 2018).

Similarly, to modules, in case of element construction significant part of the work is finished off-site. Building from elements allows the finalization of vertical and horizontal components of the building, which will be installed on site with installation mechanisms supported by a competent assembly crew (Navaratnam, Ngo, Gunawardena, & Henderson, 2019). The Table 1 shows that construction from elements has the possibility to be an optimized solution, which provides opportunity to strive for lower cost of construction while keeping the speed of the process. These reasons make it a preference for real estate developers who have limited budgets (Hong, Qiping Shen, Li, Zhang, & Zhang, 2017).

One of the biggest constraints for off-site construction is transport. Buildings are usually with large dimensions. The transport infrastructure is built for much smaller units. As a result, fully complete buildings made off-site are usually small units like summer houses and temporary buildings. In case the final location is far from the production facility thorough planning has to be conducted to ensure that the transport of the building is feasible (Navaratnam, Ngo, Gunawardena, & Henderson, 2019). The Table 1 shows that this is the fastest method of construction installation, provided, that the prefabrication has completed off-site. If the access to the final location is feasible and cost acceptable this is the method to prefer. From production perspective the cost of the machinery has to be taken into consideration as it could be big contributor to the overall cost in case of very expensive equipment in the production line (Jiang, Li, Li, & Gao, 2018).

A very popular and efficient form of off-site construction is mass production of elements with fixed characteristics that are easy to produce in masses, which provides several advantages compared with on-site construction. Firstly, the production speed, because they are made on automated assembly lines. Second is price, because the product is optimized to be as cost efficient as possible. The materials are used and acquired already in suitable forms and measures which reduce the waste during the production process. At the same time the need to make the elements

in advance makes this way of construction relatively inflexible, which has proven to be limiting factor for choosing off-site construction (Razkenari, Fenner, Shojaei, Hakim, & Kibert, 2020). This kind of barrier can be removed with thought through planning, which can add another layer of advantage for off-site construction. Often these elements are made for parts of construction, which would be normally made in heights and therefore require additional scaffolding or machines to perform the tasks. In a case study by Mortensen Construction, installation of facade panels and modular bathrooms managed to reduce overall duration of the projects from 36 to 29 months (Antillón, Morris, & Gregor, 2015).

In the Table 1 it is indicated that the combined method is the closest one to the traditional on-site construction. Most of the tasks are performed on the site. However, some or several elements of the building could be produced off-site, if it is cheaper or significantly faster and would bring financial gain due to shorter construction period. To maximize the benefit from this kind of combination deeply integrated cooperation between all parties involved is required (Yahaya Wuni & Qiping Shen, 2019). Good example of such cooperation of prefabricated part of construction is prestressed hollow core slab, which is used in floors and roof ceilings. The technology was developed in the middle of 20th century and its design has remained roughly the same (Hoogenboom, 2005). The panel is made on automated construction lines using the standardized moulds and reinforcements. Due to the hollow parts of the structure, less material is used to produce a ceiling or roof construction (Hoogenboom, 2005). The reduced amount of material used, the speed of production and its efficiency has made prestressed hollow core slabs the most preferred solutions of building concrete ceilings and roofs.

Prestressed hollow core slabs are a good example successful combination of off-site prefabrication of elements, which are difficult to construct on site. Their characteristics have become industry standards, which makes them easy to use in construction projects. In order to fully benefit from this kind of off-site constructed elements, the process has to be efficient throughout the chain of events (Jiang, Li, Li, & Gao, 2018). For example, the elements are delivered to the construction site in a state, where they are quickly and easily installed with crane. This results in significant advantage in assembly duration comparing with on-site construction of these parts of the building. One of the possible applications of off-site construction is hotels, which are often built in the centres of the cities. Lack of space and busy traffic make it complicated, expensive and time consuming to build in these locations. At the same time the complexity of the construction is adding to the duration of construction projects. The construction of Empire State building started

in April 1930 and a within year it was finished and available for business within a year, projects in similar scale take 2 to 3 times longer to construct in 21st century (Sacks & Partouche, 2010). An opportunity to reduce the construction period is to build hotel from modules. Marriott hotel chain has used modular construction building its new 168 room hotel in New York (Marriott International Inc, 2019). The nature of hotel rooms, which makes them often identical supports the production of modules off-site. This construction method is supported by the same layout of the rooms, which makes it possible to produce several identical modules. CitizenM Bowery is a hotel built in New York, which has 300 guestrooms and its 210 modular steel units were prefabricated in Poland (van der Ham & Opdenakker, 2021). The fact that production was made in Poland, where production cost is cheaper helped the developer to overcome an important barrier of adoption of off-site construction management, which is the cost (Mao, Shen, ASCE, Pan, & Ye, 2015). The repetition of the units would increase the efficiency of implementing another layer of innovation, for example multi-dimensional BIM platforms, which can be used throughout the building's life-cycle (Zhong, et al., 2017). This kind of innovation would help implement more advanced automated maintenance solutions by hotel administrator.

1.3. Residential real estate and construction in Estonia

Until regaining independence, Estonian real estate market was state controlled. The development of private sector started 30 years ago. Together with arrival of home loans and financial products to the Estonian market the demand for new residential real estate increased significantly. The loan balance of home loans was 57 000 000€ on 31.12.2000. By 31.12.2007 the loan balance was 5 625 000 000€ (Eesti pank, 2022). The increase in loan balance was almost 100-fold within 7 years and the boom ended with a bust. However, most of the developers survived and the industry of residential real estate development kept on evolving. By the end of 2021 the loan balance was 8 904 000 000€ (Eesti pank, 2022), which 60% increase in 14 years.

One tool to describe the affordability of real estate is the ratio between a square metre of new real estate compared to average salary is an indicator, which is often used to assess the home prices in relation to purchase power of the home buyers. Before 2008 financial crisis, easy access to the bank financing resulted in rise of the price-salary ratio, which meant that the affordability of the real estate declined. Together with the financial crisis, the real estate crisis in Estonia halved the real estate prices and had significant impact on the ratio as well. After stabilizing at the beginning

of the decade, it has remained around 1,5 as can be seen in Figure 2. The last few years indicate, that the COVID-19 didn't affect the curve significantly. However, in the last year the relative purchase power has started to decline again. Uncertainty caused by the COVID-19 pandemic has caused companies decline in investments in commercial real estate. At the same time, the generous governmental support programs have increased the demand, which has made the housing business boom. Since the beginning of the 2020 the price has risen 34% (Land board, 2022).

Figure 2. Ratio of apartment price per square metre to average salary
Source: Statistics of Estonia (2021), Land board (2021), authors calculations

Estonian population outside of Tallinn is in decline (Statistics of Estonia, 2022). The decrease of demand for real estate means, that there are very little developments of new real estate outside of Tallinn, Tartu or Pärnu. In order to improve the situation government has launched a programme to support local authorities to develop new or restore existing housing to provide quality homes for its residents. By the end of 2020 seven of such projects has been completed (Kredex, 2020).
The price of land in densely populated areas of Tallinn, Tartu and Pärnu has increased faster than the inflation (Kredex, 2020). At the same time, the cost of construction increased 8,3% in 2021 (Statistics of Estonia, 2022). In order to reduce their costs, developers are developing further from the centres and using cheaper construction solutions and materials. The shifting demands from the market, which is becoming more tolerant towards commuting (PwC, 2022) is supporting the developments in less densely populated areas.

The construction sector in Estonia has had turbulent times since the beginning of 2020. Initially COVID-19 threatened to curb the demand. That didn't happen, the temporary decline lasted for less than a year and the volume of construction in 2021 was higher than in 2019 (Statistics of Estonia, 2022). Instead, there became the problems in trade routes and supply, which has increased the prices of certain materials. As a result, the prices of construction rose 8,3% in 2021 (Statistics of Estonia, 2022), which has made it difficult for main contractors to fulfil the contracts of fixed price and were made before the speedy increase of construction prices.

By division of specialisation the Estonian construction market is following – buildings, infrastructure and facilities (Kask, et al., 2018). Infrastructure stands for roads and other communications outside of the buildings, facilities mostly for technical installations, both in infrastructure and buildings.

The Figure 3 illustrates the distribution of the different types of non-residential buildings being built in Estonia. Commercial buildings, which are mostly focused on domestic commerce have the biggest share are followed by industrial real estate, which focus both on domestic market and export. This is a good example how construction sector is enabling other sectors to create products and provide services to the society in general.

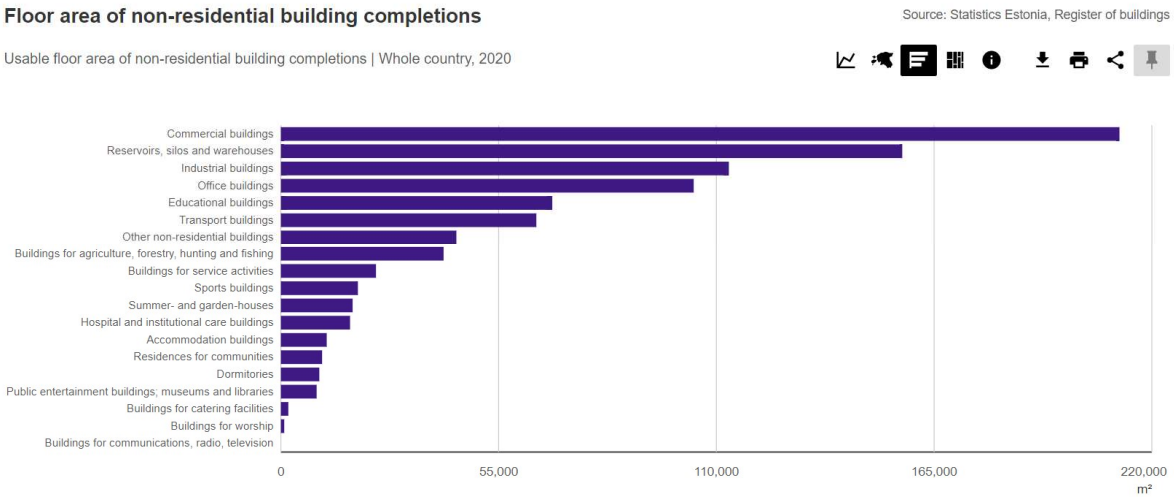

Figure 3. Non-residential building completions
Source: Statistics of Estonia(2020)

Increasing technical complexity and requirements by local authorities discourages people looking for home to build by themselves. Rising requirements and demand is one of the trends affecting residential real estate market (McKinsey&Company, 2017). This kind of increase is expanding the

market for real estate developers in Estonia and is creating opportunities for developments further from densely populated centres.

1.4. Challenges for the Estonian construction industry

The study of construction sector productivity, added value and analysis of economic impact (Kask, et al., 2018) makes a detailed analysis of the challenges of the construction industry in Estonia. The author has compared it with the challenges for the off-site construction industry (Puitmajaklaster, 2018) in Table 2.

Table 2. Challenges in Estonian construction industry

No	Challenge	On-Site construction	Off-Site construction
1	Client competence	Often the clients who order construction services have no previous experience.	Not Applicable (NA) Clients are usually experienced in ordering off-site construction
2	Not preferred career path	Construction is not popular among youth	Lack of qualified labour
3	Technology and digitalisation	Low digitalisation, automation and other innovation	Low digitalization of the sector and need for technological development
4	Market size	Construction is a location-based business. For most construction companies Estonia is their only market.	Loss of competitive edge towards Nordic
5	Productivity	The increase in productivity is lower than in other sectors	Not perceived as a problem
6	Curbing demand	The trends of recycling and reusing reduce the demand for new construction.	Need to find new export markets
7	Poor planning and preparation	The importance of preparation phases is underestimated	NA – planning and preparation are well implemented
8	Process management	Sector is focused more on quality of engineering than quality of process management	NA – process management is implemented
9	Different quality requirements	NA – mostly focused on Estonian market	The quality requirements of different markets are getting higher
10	Inflation	Significant increases in prices, depending on sector	Increase of prices of raw materials

Source: Analysis of construction sectors added value, productivity and economic impact (Kask, et al., 2018), Estonian Wooden House Cluster Strategy 2018-2025 (Puitmajaklaster, 2018).

The client of the construction service is often not a professional of the field. This is caused by the fact that an important component of the real estate development, land, is in limited supply and almost always previously owned. In several cases the owner, who has no previous real estate development experience, wants to be in charge of the project and will not have the needed knowledge to successfully complete the project (Sarmet, 2014). The situation is better in off-site construction, because this construction method is usually chosen by more experienced developers. The relatively low implementation of new technology in the production is making profession of civil engineer less appealing to high school students (Kask, et al., 2018). This problem is affecting work on site and design of the projects. In addition, there is lack of qualified specialists like carpenters or plumbers. Same issue is limiting the offer of global construction supply (PwC, 2022). According to McKinsey construction sector is one of the least digitalised industries in the world. In United States it is in the penultimate position and in European Union the last (McKinsey&Company, 2017). The report identifies one of the main problems in manufacturing-style production systems, which are still widely used. The usage of outdated working methods limits the possibilities of digitisation of the industry.

A limiting factor for innovation and implementing large scale production for Estonian construction industry is the size of the market. Solution for off-site construction companies has been exporting to countries with higher cost of construction production. However, the increasing competition from countries with lower wage has made Estonian exporters lose its competitive edge (Puitmajaklaster, 2018). The organisation sees automation and increase of efficiency as tools to regain its competitiveness.

Low productivity is perceived as one of the major problems of construction industry. In United States the annual increase of added value in construction sector 1947 and 2010 has been 0,1%, compared with 4,5% in agriculture and 3,5% in manufacturing (McKinsey&Company, 2017).
The decline in demand does not apply for all the regions, but mostly where the population growth is negative. Instead of building new real estate, it is more economically efficient to renovate existing older buildings. In Estonia there is a governmentally coordinated initiative, which supports the renovation (Kredex, 2020). In Finland, the share of renovation in construction business has grown from 30% in 1980 to 50% in 2020 (Rajala, Ylä-Kujala, & Sinkkonen, 2022). In Europe the construction sector provides around 10% of the GDP (Murillo, Rocha, & Rodrigues, 2019), while the construction sector contributes around 12% to global GDP (Bertino, et al., 2021). The difference can be explained by increased role of renovation in developed countries (Rajala,

Ylä-Kujala, & Sinkkonen, 2022). The main issue for off-site construction companies is increased competition in export markets (Puitmajaklaster, 2018). However, the export markets in Table 3 are all developed countries and the increase of renovation of buildings could explain the change in demand.

The construction projects are having difficulties to meet the agreed deadlines due to poor project performance (Crowther & O. Ajayi, 2019). This is often caused by the underestimation planning and preparation phase together with low implementation of digital economy strategies (Santana Martins, Jorge Evangelista, W. A. Hammad, W. Y. Tam, & Haddad, 2020). The reason could be behind the preparation and education of civil engineers. The Estonian Association of Civil Engineers provides the qualification certification, which is required to work as a manager of construction project. The list of applicable training consists engineering and not management lessons (Eesti Ehitusinseneride liit, 2022), which could be one of the reasons for poor management quality in construction industry. In case of off-site construction, the on-time delivery is essential and therefore has increased the quality of planning and process management (van der Ham & Opdenakker, 2021).

For off-site construction companies, the diversification of export markets creates the need to take the different regulations of the markets into consideration (Puitmajaklaster, 2018). This has negative impact on cost efficiency. Another issue, which applies for both on- and off-site construction companies is rapidly increasing inflation, which was 18,8% in April 2022 (Statistics of Estonia, 2022). The increasing input prices are threatening to reduce the profitability together with decline in demand.

1.5. Off-site construction in Estonia

In Estonia off-site construction mostly represents timber buildings. In 2017 there were 131 companies, whose main activity was manufacturing wooden houses and elements. The turnover of the sector was 320 630 000€, while most of the revenue was generated in export markets (Puitmajaklaster, 2018). Off-site construction sector is one of the biggest employers in the construction industry. According to (Unt, Võrk, & Varblane, 2018) in 2016 wooden house factories had 2241 employees. Added value 48 114€ per employee is higher than on site construction. As a result of accumulated experience, close proximity of Scandinavian markets and strong cluster of

off-site construction, Estonia is the biggest exporter of wooden houses in Europe (Puitmajaklaster, 2018). The biggest export markets of Estonian off-site construction companies are in Table 3.

Table 3. Estonian timber buildings export markets and their GDP per capita

Country	Export of wooden construction in 2017	GDP per capita in 2017(USD)	Comparison with GDP per capita in Estonia 2017 (18955USD)
Norway	31%	75 611	398,90%
Sweden	23%	52 577	277,38%
Germany	17%	42 622	224,86%
Netherlands	7%	46 978	247,84%
Finland	6%	45 155	238,22%

Source: Statistics of Estonia (2020), Worldbank.org, authors calculations

There is a strong correlation between the wealth of the country and its ability to import construction products. In 2017 84% of the export of wooden houses went to 5 destination countries. As shown in table 3 the GDP per capita of the destination countries was at least two times higher than in Estonia. It clearly illustrates the situation, that the construction export is competitive in cases, where the destination market has relatively higher prices than the home market. Estonian Wooden House Cluster predicts that the competitiveness on export markets will reduce over time, because the wages in Estonia are increasing faster than in destination countries. (Puitmajaklaster, 2018). At the same time the competition from the former Soviet countries with lower wages is increasing. Export of wooden houses accounts for the majority of the construction export. In 2017 almost 300 million euros worth of wooden houses were exported. According to report of added value generated by construction industry (Kask, et al., 2018) construction is a very local business, compared to other industries. Off-site construction is breaking the trend with its 90% of export on wooden houses segment. The reason behind it is the specific requirements for construction in every country. An off-site company has to comply to the rules and regulations of the destination country. High level of timber engineering has enabled development and design of technically challenging buildings. An example is the highest wooden residential building in Bergen (urbanNext, 2022), which was built in Estonia by Kodumaja OÜ. It has 14 floors and at the time of the completion it was the highest of its kind in the world. ÖÖD hotels is well marketed example of complete

buildings, which are made by Estonian industry (ÖÖD hotels, 2022). Their compact size opens them specific market niches, which are being well exploited and promoted.

The literature review describes the main challenges in the construction and real estate industry based on the latest literature, reports and studies. The qualitative research will be based on these findings together with the input from practical cases of the next chapter.

2. METHODOLOGY

This chapter describes the use of qualitative research method, which has been chosen for this thesis. The aim of the research is to understand the background and detailed input to the questions about the implementation of off-site construction in real estate developments. In order to get diversity of responses different fields of professions were selected. The reason for diversification was to understand how the role or position in the sector influences persons opinion on certain topics and emphasis on different factors.

2.1. Research method and sample

The research method chosen for this thesis is qualitative research, because the aim of the study was to gain an in-depth understanding of different factors which influence the implementation of off-site construction in Estonian real estate development. The small size and fragmentation of Estonian real estate industry doesn't provide sufficient number of respondents for quantitative research. A reason for this selection is that qualitative research should be selected when the researcher wants to understand the interviewee's subjective view of the situation, rather than concrete facts and generalisation of a phenomenon (McGrath, Palmgren, & Liljedahl, 2019). Such research method allows researcher to reach to the level of individual and gain knowledge of more rare and specific issues.

This research method helps the interviewer to ask the interviewed experts to elaborate problems and specific topics. This kind of inductive research should begin with a clear purpose and statement of research questions. At the same time, it is important not to get too locked in the framework (Woo, O'Boyle, & Spector, 2017) Due to the relatively small number of Estonian real estate developers already using off-site construction for their developments, the people interviewed represented different positions who are involved in the development process of real estate.

Preparation for the semi-structured interviews was based on the work done with literature and insight of the issues gained during the case studies from real estate developer Pinered, which were conducted by author. The preparation work cannot be underestimated, because the quality of the research depends a lot on preparations. Accurate preparation by interviewer is needed and it has to include practical and conceptual preparations (Brinkmann & Kvale, 2006). After finishing the

preparations, the author did two test interviews to test the concept of the research questions and recording equipment together with practicing how to conduct the interview and implemented the feedback and improvements before starting the actual process.

The sample chosen for the interviews were representatives of real estate and construction industry, who are responsible for decisions, which influence the design of the products sold on the real estate market. The aim was to understand, which factors influence the cooperation between different entities of the real estate market.

The most important part of the sample chosen were real estate developers. Their responsibility is to find suitable land for development, design the real estate as product together with the architect, organise the construction and sales of the real estate. To test the validity of the research questions, the researcher should ask feedback before starting the qualitative interviews (McGrath, Palmgren, & Liljedahl, 2019). When preparing for the interviews, the author consulted with people active in the field to get better insight of the real estate industry and it helped to prepare the research questions. As a result of the consulting author realised, that in addition to focusing on existing relationships and projects, which are built using off-site construction method, the focus should be wider and concentrate on bottlenecks and opportunities of residential real estate construction production. Indicating the current difficulties and unused potential would help to increase the future cooperation potential between these two entities.

2.2. Data collection and analysis

The semi-structured interview consisted of 14 questions (Appendix 1), most of the questions were open and introduced a topic and allowed the person to talk about the things that seemed important in that field and were later followed by more specific questions to pinpoint the specific issues. The selection of questions was based on the input gathered from literature review and case studies to find answers to the research questions of this thesis. An example of a question of this type is asking general impression of using off-site construction for residential real estate. However qualitative interview is not meant to be constructed as an instrumental dialogue, which provides the researcher descriptions, narratives and text, which will be used and interpreted to achieve the predefined research interests (Brinkmann & Kvale, 2006). In attempt to reduce that kind of subjectivity, the author prepared some specific questions for all the interviewees.

All of the interviews were recorded and transcribed. In order to achieve the quality of recordings author carefully selected the logistics and facilities to minimize any kind of disturbance. The length of the interview was aimed to be longer than 45 minutes, to have enough time develop topics into more details. That aim was achieved in 10 interviews out of 12. The description of the situation and identification of bottlenecks in the industry were perceived rather similarly however to authors surprise, the opinions on what has caused the problems and how to solve them were rather different. In research point of view, it provided author opportunity use different perspectives to elaborate the opinions of the interviewees and offer possible reasons behind the different opinions. The recordings have been transcribed and the transcriptions are uploaded and the link is in Appendix 3.

Data was analysed qualitative content analysis, which is a suitable tool for empirical studies (Gläser-Zikuda, Hagenauer, & Stephan, 2020). First was reading and understanding the recurring codes, which was followed by identifying common themes. While working through the transcripts of the interviews, the author identified the similarities and differences of the opinions and highlighted them (Appendix 4). The results were compared with existing knowledge of literature and where necessary or possible elaborated further by the author and finally the conclusions were drawn. The opinions of the interviewees are presented in a coded form, the list of codes can be seen in Appendix 1.

In addition to the interviews the author has ordered market research from Turuuuringud OÜ for the real estate development project in Kiili, which consisted of 34 interviews and has been discussed in the thesis as a secondary source of information. The results have been discussed with the “Martin Varvas, Head of Design” of Pinered in the form of an interview and it has been coded with ITNM in the text.

3. Discussion

Based on research methodology the semi-structured interviews were conducted by the author. The interviews were one-to-one either via Microsoft Teams or live meetings. The data gathered during the interviews was analysed and key elements of specific specialities of situation on Estonian real estate market and its cooperation possibilities with off-site construction companies were identified. The following chapter describes the results of the research (Appendix 4) in comparison with the results of case studies and literature review.

3.1. Estonian real estate market

3.1.1 Current situation in Estonian real estate market

After the recovery from the financial crisis of 2008 few years later Estonian real estate market enjoyed relatively calm period for several years. The changes in amount of real estate deals and prices changed little compared with previous year. (Statistics of Estonia, 2022) In 2020 the COVID-19 froze the real estate market initially, but after strong support from the government the market started to boom (PwC, 2022). [INT2]:" People are driven by fear and greed. First there was fear of COVID. When it was over and everyone started spending, markets and prices started to rise and greed came." The sudden increase in demand, after the initial expectations has created lack in supply of materials, which has driven up the prices. The long duration of the real estate production process made it very difficult to predict the final cost of the product.

A big concern that was mentioned in several interviews was difficulty to generate business plans for new developments. The correct prediction of cost is very hard to make, together with unavailability of some materials. Another unknown was the customers interest to buy new homes. [INT6]:" After the events in Ukraine, we saw that Estonian real estate developers have two times less projects than normally." Despite of the reduced number of offers, people were still willing to buy homes, which was unexpected attitude from clients for developers and real estate agents interviewed.

In January 2021 Pinered, a real-estate development company, which has been the focus point for the authors Master's programme, purchased a development area near Kiili, which has building right to construct 13 terraced houses and thus create 62 new homes for people. At the beginning

of the process of the development market research was conducted by Pinered and Turuuuringud OÜ.
During the research 34 interviews were conducted in order to understand the needs of homebuyers, their motivations and decision-making process.

The interviews conducted brought out an interesting understanding among potential homebuyers – customers are more interested in number of rooms rather than square meters, which can be explained by the main target audience of terraced houses – young families. The customer expects that all of their children have their own room and the size of the room is not so important for some interviewees. [INTM]: "Some families want large rooms for kids, because they spend most of their time there. Others said that they need enough space for the bed and minimum space around it, no need to waste space – it's for sleeping after all." However, most of the interviewees would appreciate an additional room for guests or home-office, which is important to know for developers, as working from home is becoming increasingly popular (PwC, 2022).

While talking about situation in Estonian real estate, most of the interviewees talked about the size of the market. When describing the scope of Estonian real estate market, the common opinion was that it is mostly active around Tallinn, Tartu and Pärnu. [INT4]:" I will never forget when we visited my husband's grandmother who lives in Rõuge. She said that there is a new development near-by. We went to see it and it was built in 1984. And she was serious, for her it was a new development. [INT5]:" There was an example in Rakvere. Local authorities offered free land for development. As there were few clients interested in new real estate, banks weren't willing to finance it and there was no interest among developers. The reason could be that outside of larger towns, the decline in population is having its effect on demand."

The situation could be improved however by more attention from government to regional politics. The issue of changing needs from society towards local municipalities has been tackled in Denmark by changing its size and redefining its responsibilities (Fabricius Madsen, Pilgaard Kristensen, Fertner, Gravsholt Busck, & Jørgensen, 2013) [INT5]:" I see that this is something local authorities and government have missed. They should do something to improve the situation. I wish I knew the answer, I can only pinpoint the issue." In Italy the government has developed a strategy for helping distant regions to have access to essential services. After the changes in society created by COVID-19, it is reviewing its strategy to be up to date with changes in demand of population (Cotella & Vitale Brovarone, 2021). The crisis and uncertainty are discouraging

developers to expand the market. [INT11]:" We were just about to start a big development in Narva. But then the crisis in Ukraine started. The loss of client from Petersburg and sales prices already on the maximum limit, it was decided to put the development on hold."

According to the research conducted by Pinered and Turuuringud the areas around Tallinn, including Kiili, are gaining more popularity as a place to purchase real estate. [INTM]: "It was surprising as we initially thought the location is not as valuable as it actually is." Kiili is more often considered a positive location, where not only the cheapest solution works, but it is a respected area, where people want to move." It is evident that the urban sprawl is increasing and according to the research done by the author a distance of up to 45 minutes of commuting is tolerated by the customers in Tallinn, if the development offers a chance to have also some nature around and to have a small patch of grass just outside the door.

3.1.2. Expectations of the customers

Peoples' expectations of homes are changing over time. Some time ago, the main criteria for assessing size of a home were how many square metres it had. [INT2]:" The perceptions of Soviet times have been stuck for long. That all 3 room apartments are at least sixty square metres, 4 rooms have at least 85 and so on." Instead, today functionality has become more important. [INT6]:" Possibility to work in home-office as increased demands for more rooms." Clients are looking for more thought designs than before, not square meters, therefore the price of the square meter has risen more than price of home in relation. According to a report by PwC popularity of remote working, which has especially increased during COVID times, adds more demands on flexibility of real estate (PwC, 2022). Estonian real estate industry, which was established together with free market after break up of Soviet Union, has become more professional over the years. The interviewees explained that there is a generation of developers, who don't develop for themselves, but for the market. At the same time, markets expectations towards the quality of developments are increasing. [INT4]:" Buyers expect developers to have thought about the means how they will be able to use the home most efficiently."

Effectiveness has come out from both interviews done by the author and also from the interviews done by Turuuringud OÜ. [INTM]: "The first thing to pay attention to is people's ability to purchase a new home. There is a balance point at around 100 square meters if it is 100 square meters, then how to make the most of it." This gives developers a chance to design more customer friendly solutions, based on the needs of the typical customers.

In the opinion of the author the clients have started to make more conscious decisions when buying their homes and pay more attention on usability and functionality. To be competitive on the market, the developers are trying to understand the expectations of their customers and provide such homes.

The studies show improved environmental performance of off-site construction over on-site method (Steinhardt, Manley, Bildsten, & Widen, 2019). The topic of environmental, social, and governance (ESG) aimed to gather opinion of experts about the importance of ESG in Estonian real estate market. There were two recurring topics. First, the ESG was considered important, mainly the environmental part through energy efficiency. For the developers of Estonian real estate market low energy consumption of our developments is important. Where possible, solar panels are integrated into the developments. This approach is supported by practical demand on energy efficient homes, due to high price of energy carriers. [INT2]:" Energy efficiency has become a keyword. Developers, designers, even the government have been saying that energy efficient things will become more valuable. Those who have ignored it have millstone attached to them."

At the same time globally climate change is perceived as higher environmental topic in real estate than in Estonia. Raising number of natural disasters by man-made climate change is calling for action (PwC, 2022). The second topic, which was mentioned in several interviews was cost. Implementing an ESG policy usually has its cost. Developers in general want to invest innovation and sustainability; at the same time, they have to be careful not to outrun the market. Successful implementation of ESG policies however can be an argument for increased appeal and be a reason to raise the price, but it has to be accepted by the market. [INT9]:" The end customer is the one who pays for it, that sets limitations for developers, who implement solutions that add value in the eyes of customer." Another way to implement these kinds of solutions would be to make them optional. A way to implement more sustainable solutions would be to offer them to client as extras. This kind of solution would allow the client to decide, which part of ESG he wants to have in his home. An aspect of sustainability, which didn't receive as much attention was the need for maintenance throughout the life cycle. [INT2]:" During my 20-year career in real estate, I haven't seen a building, which doesn't require to be repainted in five- or seven-years' time. I think the effort to maintain the state of the building should be also taken into consideration, when talking about sustainability." Social infrastructure was also mentioned, but it is mostly expected that local authorities take responsibility in this part of the policy. [INT4]:" Social infrastructure is usually

done according to the requirements by local authorities. The amount is regulated by local authorities. Developer don't have incentive to build them without the obligation."

Based on the market research made for the Kiili project it was known that there is a large enough market share who prefer wooden houses to live in, which supports the sustainable approach in real estate development. [INTM]:" Sales have shown that there is no significant difference for clients, whether the construction is timber or concrete. According to market research, there were around 30%, who definitely preferred concrete, at the same time around 10% said they definitely wanted timber. If we manage to be attractive to 70% of the customers instead of 90%, then, as seen from the sales numbers, it's enough." However, as the price is the main decision-making factor for the client implementing ESG policies have to be financially competitive with alternatives on the market.

The author learned from the research that both developers and customers are interested in the implementation of ESG principles. At the same time, the implementation has to be done in a way that it adds practical value to the developments.

A topic which gained attention from several experts interviewed was the lack of purchase power of young people. There are very few people in their twenties who can afford to buy a new home. Buying a new home requires a large amount of accumulated capital, which young people usually don't have. With the fast growth of prices over past years, this trend is deepening, which means that real estate has become less available for younger generation." However, there are opinions, which state that the issue should be regulated by market and not to interfere artificially. [INT5]:" Affordability is especially problem for young. However, I don't think it has to be tackled. I don't see home ownership as a fundamental right and not everyone has to own a home. I think that new real estate should be bought by those who are able to finance the purchase. Additionally, if there would be much support for young to be able to buy new real estate, it would increase the demand and prices." The young still need a place to live and are using renting meanwhile, which is increasing demand on rental market.

The increase in demand of rental apartments is also increasing demand for buying apartments to rent out. In addition to their first homes, there are several clients, who are buying their second or third home with financing from the bank to rent it out. The specialisation on rental apartments has introduced new type of homes to the market. [INT5]:" The demand of functionality has led us to

a situation, where rental apartments are very small, let's say 10 square metres, yet they provide all that's necessary." This is all good for rental market, but renting hinders the opportunity to buy real estate in longer term. Young families lack resources to finance a new home. Especially when they have been living in rental apartment, they will not have anything to sell and get financing from there. There is an increase of insecurity in younger families as a result, which affects their life choices (Makszin & Bohle, 2020).

The market research for Kiili development had similar results. Client of terraced house is mostly young family with small kids. It is often the first "own" home of the family. One of the main reasons was lack of funds to purchase a private house. [INTM]:" The first and most important thing to pay attention to and what was highlighted in the answers of the people is their ability to purchase a new home. The indicated price ceiling was at 200 000€. There is a balance point at around 100 square metres and if it is 100 square metres, how to make best use of it. And if we know that the most important room is living room, which has to have at least one third of those square metres." The opinion of author is similar with one of the experts that there shouldn't be too much support for the youth in purchase of the new real estate. It would encourage unsustainable financial decisions, which could damage the financial position of young families in the long term. The local authorities could help by providing a framework and initiatives for developers to provide affordable housing meant for younger generation.

3.1.3. Future trends and limitations of development

The increase in prices and peoples changing expectations for housing has created changes in the preferred areas of developments. In several interviews it was mentioned that the lack of available land in Tallinn is forcing developments to move out, to suburbs, where it is cheaper. The trend started already at the beginning of 2000s, but was stopped with the crisis of 2008. [INT5]:" There is a trend of developing outside of the centres, so to say on the fields. It was popular before the 2009 crisis, was quiet for a while and started again eight years ago." The problem of living in a suburb is need to commute for work or services. The increased acceptability of remote work has eased the issue of commuting, which has become less important criteria for home selection (PwC, 2022). [INT7]:" COVID has shown that remote work is possible for a lot of people. It also changes the real estate market." The availability of services for everyday life could be improved by clever planning from local authorities (Guzman, Arellana, Oviedo, & Moncada Aristizabal, 2021).

The semi-detached and private houses provide families with a green area of their own. An opinion of a real estate developer was that having their own private space around house outweighs the

close proximity of work. The market research of Pinered indicated that Kiili is gaining popularity as a place to purchase real estate. [INTM]:" We were surprised. We initially thought the location is not as valuable as it actually is. During the market research we understood that we don't have to design there the cheapest solutions, but accept the location as any good residential area, where people want to move." In authors opinion the low availability of affordable land for developments in Tallinn has created an incentive for developers to move further from the centre. In the buyer's perspective, the possibilities to perform daily tasks online together with the opportunities of remote work has increased the appeal of living in suburbs. These two supporting trends are increasing the number of new real estate developments in suburbs.

Local authorities have big impact on the functioning of real estate market. They are planning the use of lands in their jurisdiction. [INT3]:" Tallinn has strategies for developing infrastructure for bike lanes and public transport." The aim of these strategies is to create a coherent framework for development of the area. However, it is not always understood by the developers. Few other interviewed experts mentioned that the city planning council should disseminate better its visions. The developers are uninformed about what the planners want. Due to this information gap, there is a lot of friction. With inadequate information regarding the building rights, it is difficult for developers to plan correctly. There should be more information available about general plans for development. In this case, the developer is more aware of the limits when the purchase of land is made.

Local authorities are expected to take role for providing necessary framework for infrastructure. It was mentioned in interviews that with more people moving to suburbs, there are more traffic jams during morning rush hours. More cars need more parking spaces is created by authorities. If the priority wasn't car transport, people wouldn't use so many cars and wouldn't need so many parking places. At the same time decisions by local authorities influence the way how people live their everyday lives. Keeping all the different interests in balance on occasion slows down the progress. [INT6]:" Problem is the length of building permit application process. It is long and unpredictable, which makes rest of the planning difficult." With the changes in the world over the past years, the local authorities need to review and update their strategies to be ready to facilitate the general development in the best way (Cotella & Vitale Brovarone, 2021).

The higher incomes per capita and population density are main drivers' reasons for higher real estate demand in urban areas (OECD, 2020). New real estate developments outside of centres

could work together with local authorities, like has happened with renovation of buildings for rental purposes (Kredex, 2020). This kind of cooperation could be an opportunity for off-site construction companies. [INT5]:" I think building from elements is more possible in areas, where the price of the land is cheaper and the developer doesn't have to try to maximize the building rights." Another option for market expansion outside of the centres could be people's natural tendency to look for new experiences. [INT2]:" There is a circulation, people moving from countryside to smaller towns, from smaller towns to Tallinn and from Tallinn to countryside. Looking for something new, different." However, these people moving from urban areas are usually looking for privacy and do not fit the profile for real estate developments.

In the opinion of the author the real estate market of Estonia has matured a lot during the past decade. The increased professionalism developers aim to provide quality living space starting from thought trough concepts of the development areas to implementation of high standards of construction materials and technological systems. This trend has been helped by increase of client's awareness and purchase power. In order to improve the situation further, the state and local authorities could take bigger role in supporting the process by imposing clearer regulations on real estate and construction sector and use the tools of land planning to give better guided direction for urban planning.

3.2. Implementation of off-site construction in Estonian real estate market

While most of the production of Estonian off-site construction companies is exported there are examples of cooperation between off-site construction companies and Estonian real estate developers. The existing examples show, that there is potential for cooperation and the results of the interviews indicate that there are several possibilities for future improvement.

3.2.1 Situation of the cooperation

In one example the cooperation started from previous cooperation in Scandinavian market. [INT1]:" In 2018 we did an apartment building in Pärnu. It has four floors and everything besides the non-load bearing interior walls were made off-site. The developer has Scandinavian background so he knew how to involve off-site construction company into the process." However,

most of the production is exported (Puitmajaklaster, 2018). The reason could be in higher profit margins on Scandinavian markets. [INT11]:" We had a project negotiation with an Estonian developer some time ago. Two row houses. He made the calculations, that on-site construction cost was 2 million and off-site was 2.5 million. The numbers other way around would have made sense. The reason might be, that the price of this construction in Norway is more than 2.5 million, so it makes sense to export the production instead." However, there are signs of increase in cooperation. [INT1]:" Last year we exported around 20 percent and 5 years ago it was the other way around. In past few years, local developer has started to see us as a potential partner."

When asked about the perception of clients towards off-site construction, the general opinion was positive. [INT9]:" As a client, it's important that the construction quality of the house is good, the way how it is built doesn't come first, client wants to be able to use it without interruptions." Similar response was given by the other interviewees and was concluded in market research done by Pinered for its development in Kiili. [INTM]:" Sales have shown that there is no significant difference for clients, whether the construction is timber or concrete. According to market research, there were around 30%, who definitely preferred concrete, at the same time around 10% said they definitely wanted timber. If we manage to be attractive to 70% of the customers instead of 90%, then, as seen from the sales numbers, it's enough." The opinion of the rest of the developers was favourable towards cooperation with off-site construction companies. [INT6]:" I personally think positively about off-site construction, because the possibility to achieve higher quality." Another opinion was similar. Most of the experts would use off-site construction, if the price of the elements would be suitable. Even if the perception of higher construction quality was thought not to be in awareness of the client, the faster completion of the project was a positive aspect for experts. [INT9]:" I see biggest benefit in saving time."

The biggest obstacle for the cooperation is cost. [INT6]:" Developer is willing to work together with main contractor and off-site construction partner as long as the price is in the right place. Usually what happens is that different alternatives are weighed and the cheapest one wins." Similar opinion was shared by other experts that in the end, the cost will decide what kind of construction method is used. When weighing alternatives, it often happens that there are cheaper alternatives than off-site wooden constructions. [INT11]:" Unfortunately, it is still cheaper in Estonia to build on site. There are 2 components influencing that. First, the transport is costly. Second, in case of the modules for example, you need to build additional unnecessary layers of construction." From the interviewed developers point on view the most important factor for the client is price. As long

as client is not willing to pay extra for off-site wooden construction, it will be difficult to implement off-site construction in large scale in Estonian real estate developments. Additionally in centres, where land is expensive, the developers aim to maximise the building right instead of construction efficiency by creating site specific solutions. [INT5]:" For developer, it is often financially more beneficial to make tailor made solutions on site to maximise the construction rights."

For the development in Kiili Pinered contacted over 20 off-site construction The companies were encouraged to offer solutions and alternatives, which would follow the design concept, but would be cost efficient for them to produce. This approach hadn't been often used before and raised interest among bidders. By the end of the first round of procurement there were 8 companies who sent their offers. During this process it became clear, that the offers made for the development were similar as they are usually done for export markets. [INTM]:" The reason why off-site construction companies are not focused on Estonian market is because it is easier for them to compete in the Nordic markets." Although the transport in Estonia would require less additional preparation work off-site, the companies are not used to do it, which adds to the final cost.

When comparing the offers, it became clear that the overall construction cost was over 20% more than in case of on-site construction, which made it necessary to look for alternatives. [INTM]:" Ideally the best comparison would be achieved when actually building both alternatives in parallel." As it was impossible to implement this approach, the theoretical work continued.
In order to understand the details of pricing, bidders were asked to write down more detailed offers. It allowed Pinered to compare the offers to each other and to on-site construction alternative, which gave a much better and detailed understanding of pricing of the items. During the analysis of the results the main reason for higher cost were discovered. Firstly, relatively high cost of logistics and installation cost on site. Secondly the cost of beams and ceilings, compared with on-site construction. Finally, the price of timber is more expensive than alternatives, which are not applicable for off-site construction methods.

After the analysis of the results, it was clear that using full extent of off-site construction would be financially unfeasible even with up to 2 months of shorter construction period and the financial gain from it. The team weighed the alternatives and negotiated with off-site construction companies. The first idea was to keep the original concept of the development of wooden houses, but implement more on-site construction in the process, where the off-site solutions were too expensive. For the smaller house with only one floor, financially viable solution was found quite

quickly. The exterior walls were in the same price range as built on site and would shorten the construction period by one month. Final round of tender was made for simplified solution and contract signed with a supplier. After the completion of the foundation, the walls, which are already complete by that time, will be installed. Afterwards the construction will continue on site like usually. For the larger house on two floors, it turned out that proportionally ceiling and roof were very expensive and even the wooden on-site alternatives still remained out of the budget. Therefore, a decision was made to make bigger changes in its construction and use concrete walls and hollow core slabs. [INTM]:" I don't think there are other alternatives. There is a need to test on projects and form a specific goal and implement the best available solutions today and see what happens. But it's a very expensive test."

3.2.2. Future possibilities

The faster completion time of construction provides opportunity for off-site construction to be competitive in overall cost of the project. [INT1]:" The construction time will be shorter and I think that it is most likely cheaper as well." This could be achieved by focusing on standardisation of production, which has proved efficient in other parts of construction industry. [INT11]:" Prefabricated concrete works, because its production is very optimised and automatised. They have very strict limitations, what they produce and do it efficiently." In addition to reduced cost of production, standardized products would help developers and designers to understand the limitations and possibilities of off-site construction.

Another opportunity for implementation could be in developments, which are built outside of the centres, where the architectural and safety regulations are less strict. Elements made by off-site construction companies could be a solution for smaller towns, but the local authorities need to show the initiative. In addition, the cost component of land is lower, which means that the buildings could be more adapted to the production efficiency of the off-site construction companies. [INT5]:" I think building from elements is more possible in areas, where the price of the land is cheaper and the developer doesn't have to try to maximize the building rights."

Changes in taxation could become beneficial as well due to the fact that there is less waste from production and the resources used are more environmentally friendly. [INT6]:" Europe will lead the initiative to increase the taxation of CO2 emissions, like production of concrete, which will make it relatively more expensive." In case the alternative construction solutions will become more expensive, it will improve the prices competitiveness of off-site timber constructions.

With evolvement of technology, wooden construction could be used to construct higher buildings. [INT1]:" I think higher buildings will be a trend of what can be built from elements. Like five floors and higher." There are few higher buildings constructed with off-site method. One example is an apartment building in Bergen (urbanNext, 2022) Improvement of CLT panels is one of the options for building higher structures from timber. This method offers possibility to build low carbon houses with many storeys. If used with combination of innovative technologies, it could lead to more sustainable and affordable housing (Lehmann, 2022).

In the opinion of the author the fact that there are already successful projects in Estonia is a good starting point for improvement of efficiency for those cooperations. The pursuit for more efficient and cost-effective solutions will help to gain from the previously mentioned opportunities.

3.3. Cooperation between different parties in the industry

The good cooperation throughout the development process is needed for successful results. Especially for efficient implementation for off-site construction, the cooperation between different parties of the project should be fluent (Jiang, Li, Li, & Gao, 2018). The assessment for the quality of cooperation in Estonian real estate and construction industries was good. [INT10]:" My experience says that the communication and cooperation between different parts of the industry is good." Some other experts said that the quality of the cooperation will eventually is determined by the combination of the people working for a project. The developer has the biggest role to ensure good environment for good cooperation. [INT6]:" I think that the key player here is developer. Its developer's decision how the process will be run. Which architect to choose, who else to involve at what stage." The increase of professionalism of Estonian developers was also mentioned. It was said that in general, the Estonian real estate developer is becoming more aware and professional. Very often they have well elaborated concept already at the beginning of the design.

The low implementation of technology in construction sector is one of big barrier of increase in efficiency in the industry (McKinsey&Company, 2017). The experts questioned during the research didn't mention low implementation of technology as a problem in the industry. The reason could be that most of the projects in residential real estate market are technically simple and with

small scope. [INT5]:” The small scope of projects is limiting the implementation of technology.” The successful examples of implementation advanced technology come from projects with large scope (Antillón, Morris, & Gregor, 2015) (van der Ham & Opdenakker, 2021). Another issue often referred to is the cost of implementing new technologies. In several cases I see that developer wants to use new technologies, but after calculations, they just don't fit in the budget. The technologies which have already proven themselves are favoured by the experts. For example, it was believed that there will be developments in solar panels and using electric cars. However, the conservative nature of industry also reflected on the experts. [INT5]:” I’m not a big fan of smart homes. I think we should use solutions that work. Every piece of equipment needs some maintenance. The more you have them, the more they consume. I think that as a concept, smart home shouldn't be crammed with technology, but provide client with well-working solution.”

A technology which gained attention was Building Information Modelling (BIM), which is widely considered as technology to improve the management and efficiency in the industry (Crowther & O. Ajayi, 2019) (Santana Martins, Jorge Evangelista, W. A. Hammad, W. Y. Tam, & Haddad, 2020). However, the problem is that the advantage of the digital model is not used on-site. [INT8]:” It frustrating to see, that the designs in BIM have a lot of information in it, but on-site they don't know how to use it.” Which results technology and industry to look for a common ground. [INT3]:” Implementing all of the features of the model in the design will increase its price up to two times. It makes sense on complex constructions. When designing apartment building of let’s say 20 apartments, the additional cost is too high and the benefits will not be used on the site. So, for me it seems like there is no reason to overdesign.”

The opinion of construction quality among the interviewed experts is good. However, some see room for improvement in quality, if there were more personnel of the main contractor on site. The issues with the quality are not only happening on site, but also in earlier part of the process. [INT9]:” The work quality of designers is poor. They are either not qualified or have too much time-pressure.” It is important to realize that biggest impact on the quality of the final construction is on decisions which are made in design phase, during the construction the design is executed and corrections are more difficult to be made (Kask, et al., 2018). [INT11]:” There is an example from a project in Norway. The designer tried to design the foundation with minimum amount of concrete. But there were so many variations in different types of foundations that it became very ineffective and instead of reducing cost it became more expensive due to excess working hours.”

There is a big opportunity to improve the quality of construction by implementing more off-site production into the process. [INT7]:" I believe that off-site construction has potential for higher quality than on-site, because it is in controlled environment." The off-site construction companies have implemented in-house quality control mechanisms and they control larger part of the construction process, than on-site, where the tasks are divided between several subcontractors. [INTM]:" Generally managing a construction site is like trying to control chaos. There are so many factors out of your control and that's why the planning is not taken too seriously."

In the opinion of the author the standardized production of off-site construction companies provides opportunity in long term cooperation with same developers for increased implementation of feedback from previous projects. In this way it would lead to higher construction quality and client satisfaction of their homes.

The opinions of the experts from the Estonian real estate industry together with the practical case studies of Pinered show, that there is a lot of potential for implementation of off-site construction in Estonian real estate market. The most important is the willingness of customers to purchase real estate, which has been built by using off-site construction methods. If there is demand for such product, real estate developers are interested in that kind of developments. Similarly, architects and real estate brokers had generally favourable opinion towards off-site construction.

The biggest limitation of implementation is higher cost compared with on-site construction, which motivates the industry still to prefer on-site construction, despite of the faster completion time and superior construction quality. To improve the situation, off-site construction industry needs to find ways how to become more price competitive. The most effective ways to achieve it, according to the experience from case studies of Pinered is to increase the cooperation with real estate developers in designs of the houses and optimize the production process to Estonian construction market needs.

3.4. Limitations and further research

The focus of this thesis was limited to understand the characteristics of cooperation between off-site construction companies that use timber as their main construction material and residential real estate companies. This decision was based on the practical case studies made by the author in real

estate developer Pinered. Due to this limitation off-site construction companies, which use different materials are not included in this thesis.

The business cases of Pinered were focused on Estonian companies. In the theoretical background of this thesis, there are several examples of successfully imported off-site construction production. The data gathered from Estonian off-site construction companies also show high volumes of export. To keep the practical work of this thesis within feasible limits, importing off-site construction from countries with lower wages was not considered. Taking into account the successful examples from elsewhere, it has potential for further research.

In the theoretical part of this thesis, it was pointed out that construction sector has been a low performer in implementing standardized production and automatization. This fact is considered to be the main factor for low increase in productivity of construction. Although off-site construction provides more oportunities to use mass production and automatization, it is still implemented in only few cases, most of them in companies who create specific more parts of construction. In the companies, which were part of the business cases of Pinered or interviewd for this thesis, significant part of work was done manually. Looking into the limitations for automatisation and best practices of how it has been implemented in the world has potential for future research.

CONCLUSION

In order to increase efficiency of construction production real estate developers and construction main contractors are looking for new solutions for improvement. The certain advantages of off-site construction have led to several cooperation projects like building hospital facade, semi-detached houses or room modules for hotel off-site. Despite of these examples, most of the construction work is still done on-site.

The goal of this thesis was to find opportunities for real estate developers for cooperation with off-site construction companies in order to increase the efficiency of construction production.
To achieve the goal author set up following research questions:
1.Which are the key characteristics that describe the cooperation between real estate developers and off-site construction companies?
2.How can off-site construction relieve the construction related bottlenecks of real estate industry?
3.What are the limitations of implementation of off-site construction in residential real estate developments in Estonia?

In the first part of the thesis author gathered theoretical background from different empirical studies and researches from around the world. The examples of studies conducted helped the author to gather facts and statistics about the situation in Estonian industry. The results of the research revealed good examples of cooperation between off-site construction companies with real estate developers. At the same time, several limitations were highlighted, which provided good input for the qualitative research.

The case studies that focused on Pinereds' work of implementing off-site construction in the production process to achieve efficiency in their real estate development projects reached to several practical outcomes in both cooperation opportunities and limitations. Pinered started cooperating with off-site construction companies on two of the projects, although with smaller scale than initially aimed. The limitations which prevented the cooperation in larger scale became another part of input for the qualitative research.

In the qualitative research the author aimed to get in-depth information about the subject and chose semi-structured interviews to achieve that goal. Total of 12 experts of different positions in the industry were interviewed and their opinions on the opportunities and bottlenecks of cooperation provided wide-ranging view on the subject.

The experts interviewed for this thesis had in general positive perception of implementation of off-site construction in Estonian real estate developments. Although it was mentioned, that the first projects had quality issues, the majority of constructions performed off-site are believed to have high quality. The production limitations do not significantly affect the architectural appeal of the buildings. Market research conducted by real estate developer Pinered concluded that the end consumers either doesn't have strong opinion on construction method or have slight preference towards higher quality of off-site construction method.

In contrast with the actual prices of production, most of the experts had the opinion, that as off-site construction is more efficient than on-site method, it is also cheaper than on site. At the same price comparison made by real estate developer Pinered for its semi-detached houses in the development Rabarebase showed that off-site construction was 10-20% more expensive than on-site alternatives. The real estate developers interviewed said that although they are open to use parts of off-site construction in their developments, it will happen only, if the cost is competitive in comparison with alternatives.

It was mentioned in several interviews, that there will be trend towards higher part of construction moving off-site, which was supported by belief that in controlled environment, it is easier to implement systems for higher quality of production. Additionally, the possibility to use more advanced tools and technologies, will help to achieve higher quality.

The experience from the case studies of Pinered reached to similar conclusion to the opinions of the experts. The parts of the construction that were produced off-site helped to reduce the length of the overall construction process, the cooperation went well and the quality of the work was very high. In the future there are opportunities for further and improved cooperation. For example, increase of the wages provide opportunity to gain competitive edge from automatization in the production facilities. Stricter regulations for CO_2 emission and waste management will be another opportunity for the off-site construction companies over the traditional production method.

In the opinion of the author off-site construction has several specific advantages over traditional on-site construction and therefore is used in several different constructions. It has proven to be effective in cases, where on-site construction has for example access limitations or production can be done in a country with lower price levels. In case of Estonian real estate market, despite of its advantages in speed and quality, the on-site construction method is more competitive in price and flexibility, which is the reason, why the cooperation between off-site construction companies and Estonian real estate developers has been successful in only limited number of projects.

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APPENDICES

Appendix 1. Interview questions

1.How would you describe the situation in Estonian residential real estate market?

2.What are the problems of Estonian real estate market?

3.Which trends will influence Estonian real estate market in 5 years' time?

4.How much will ESG trends impact Estonian real estate market?

5.What do you see as biggest constraints of real estate development?

6. What is the reason why people don't mind driving similar cars, but everyone wants to have home in their own way?

7.What is your opinion about off-site construction for residential developments?

8.What are the advantages of offsite construction for market perception of real estate?

9.What are the problems of offsite construction for market perception of real estate?

10.What is your opinion of the quality of cooperation between developers/architects/main contractors?

11.What could be an option to improve the cooperation between developers/architects/main contractors?

12.What kind of technology is missing from the industry or is not enough implemented?

13.What are the trends that will influence Estonian construction market?

14.What are the problems in Estonian construction market?

Appendix 2. List of interviews

Code	Interview conducted	Role	Location	Date
INTM*	In person	Real estate developer	Tallinn	01.04.2022
INT1	In person	Off-site construction	Rapla	11.04.2022
INT2	MS Teams	Real estate agent	Tallinn	21.04.2022
INT3	MS Teams	Architect	Tallinn	08.04.2022
INT4	In person	Real estate developer	Tallinn	18.04.2022
INT5	MS Teams	Real estate developer	Tallinn	14.04.2022
INT6	In person	Real estate developer	Tallinn	05.04.2022
INT7	In person	Main contractor	Tallinn	08.04.2022
INT8	In person	Architect	Tallinn	13.04.2022
INT9	MS Teams	Main contractor	Tallinn	09.04.2022
INT10	In person	Real estate agent	Harku	12.04.2022
INT11	In person	Off-site construction	Tartu	11.04.2022

*INTM is interview with Martin Varvas about practical cases of Pinered

Appendix 3. Interview transcripts

The transcriptions of interviews are available online via this link:
https://drive.google.com/drive/folders/1r69DQU-ErlkXtjIoc3GedkpXU1fA9dLH?usp=sharing

Appendix 4. Data analysis table

Structured summary of the findings of the interviews is available online via this link: https://docs.google.com/spreadsheets/d/1IFLGunqfAkVw9DVeFug6AaPj0xjOofwkiIxzGYzmriY/edit?usp=sharing

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