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Lean construction as a driver of innovation – Case Finnish construction industry

ABSTRACT

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The Finnish construction industry has faced large-scale criticism because of poor quality buildings. In addition to poor quality, the industry is also concerned about poor profitability and poor productivity. Good experiences from Lean manufacturing has gathered attention in the construction industry, which has responded with different kind of Lean initiatives and pilot projects to the problems that the industry is facing. In this thesis the most used Lean construction methods are elaborated and discussed. Innovations are needed to tackle these concerns and this thesis tries to shed light whether Lean could function as a driver in construction innovations. By presenting few possible ways that innovations can emerge, this thesis uses these ways to identify innovations. With qualitative and explorative research design, the results showed that collaborative project delivery methods could function as a driver in innovations. Moreover, Takt time production could also drive product and process innovations in the industry.

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Rakennusala Suomessa on tunnettu huonosta laadusta, äärimmäisen heikosta tuottavuuskehityksestä ja heikosta innovaatioaktiivisuudesta. Hyvät kokemukset Lean-ajattelun hyödyntämisestä valmistavassa teollisuudessa ovat herättäneet paljon mielenkiintoa rakennusalalla, joka pyrkii vastaamaan kritiikkiin käynnistämällä aloitteita ja pilottiprojekteja Lean-ajattelun hyödyntämiseksi rakennusalalla. Tässä diplomityössä käytiin läpi keskeisimmät Lean-ajattelun metodit rakennusalalla. Innovaatiot ovat suuressa roolissa, jotta rakennusala kykenee kehittämään omaa tuottavuuttansa ja parantamaan laatua. Tässä diplomityössä esitettiin muutamia mahdollisia reittejä, joilla voidaan havaita syntyviä innovaatioita. Laadullisen ja eksploratiivisen tutkimuskäytännön avulla, tässä diplomityössä haastateltiin rakennusalan eri toimijoita, jonka tarkoitus oli etsiä viitteitä voiko Lean-ajattelu toimia innovaatioajurina rakennusalalla. Tuloksista voitiin päätellä, että varsinkin yhteistyötä ja luottamusta edistävillä projektitoteutusmuodoilla voi olla positiivinen vaikutus innovatiivisuuteen inkrementaalisten innovaatioiden muodossa. Lisäksi tahtiaikatuotanto havaittiin toiseksi mahdolliseksi ajuriksi tuote-prosessi-innovaatioiden kehityksessä.

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These two years at LUT university have truly opened my mind and it has been tremendously wonderful time for me to study at Lappeenranta. Doing my Master's at LUT was like opening the Pandora's box in the field of management. I am grateful to all teachers who have shared their expertise within all the lectures. Especially I would like to thank my examiner, Prof. Ojanen for his valuable guidance during this thesis.

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LIST OF ABBREVIATIONS

CFCI	The Confederation of Finnish construction industries RT
KPI	Key Performance Indicator
LSE	Large-Scale Enterprise
PDCA	Plan, Do, Check, Act
R&D	Research and Development
TPS	Toyota Production System
TVD	Target Value Design

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1. Introduction

1.1. Background

The Finnish construction industry has been gathering public attention recently due to projects that are plagued with budget overruns, delayed schedules and quality issues. Especially projects that are funded by the Finnish state and communities, and ultimately taxpayers, are in the eye of criticism.(Kauppalehti 2019) The doubling of the Finnish Parliament house renovation project and multi-million overruns in the Finnish music house building and the Olympic stadium are merely the tip of an iceberg. It is not only publicly funded projects that have faced issues. The Finnish house building industry is struggling with quality issues and low margins that have been prolonged for decades. The industry is thus facing growing pressure to change their business models and come up with something new in order to respond to this criticism and weak development. (Tiilikainen 2013)

In 2012, the Confederation of Finnish construction industries (CFCI) launched a query to Finnish construction companies to explore what are the biggest reasons for poor quality in the industry from their point of view. The query results were narrowed down into two domains: scheduling and lack of the overview of the project. Scheduling problems arose from too optimistic schedule planning and from lack of sufficient planning time, which leads to problems in the construction site. Lack of an overview in projects was another domain of reasons and it included the poor distribution of responsibilities in the construction site and lack of cooperation between the contractor and designer, among other reasons.(Rakennusteollisuus Ry 2012)

In a similar vein, a study was conducted in Canada, concerning factors that cause cost and schedule overruns. The query was divided into reconstruction and new construction segments, since these two project models have significant differences in the project scope and schedule.(McKim, Hegazy et al. 2000) The results of this

Canadian study are in line with the CFCI's analysis, stating that the project scope changes affects the schedule and budget most significantly in new construction projects, while the biggest effect on schedule delays in reconstruction projects were unforeseen site conditions. It can also be detected from the results that the design and project scope change play a significant role in schedule and budget overruns, implicating that there are issues with collaboration in the projects. Full results are shown in Figure 1.

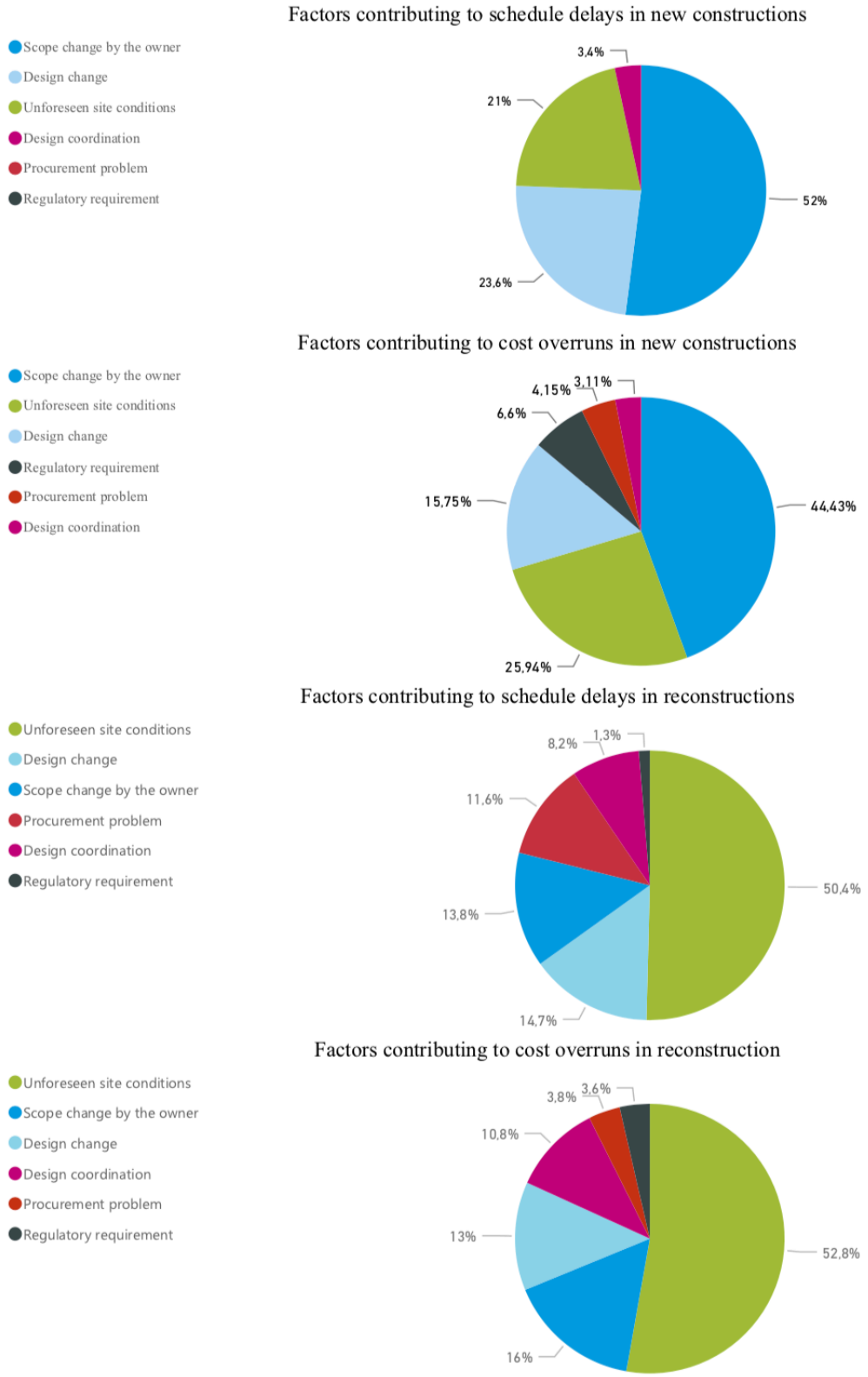

Figure 1. Factors that affect schedule and budget in reconstructions and new constructions (McKim, Hegazy et al. 2000)

Results from the queries from CFCI and McKim, Hegazy et al. condensed problems in the industry that already have been acknowledged by all who have worked in the industry. Fragmentation of the industry is one of the major reasons why issues emerge in the industry where in the simplest and smallest construction projects have multiple stakeholders that do not work effectively together.(Haapasalo, Aaltonen et al. 2018)

The problems underlined in the literature are profound in the industry. In order to elaborate on current innovation activity in the Finnish construction industry, the categorization of innovation capability is presented to give a more structural view of the present conditions. One way to categorize innovation capability within an industry is provided by Rush, Bessant et al. (2007) which states that there are four types of companies:

- Type 1: Unaware or passive
- Type 2: Reactive
- Type 3: Strategic
- Type 4: Creative.

Type 1 companies are prone to competitive forces, that may have serious effects on a company's vitality and survival. These companies most often do not see or understand technological change that would improve their competitiveness. Type 2 companies on the other hand are aware of technological changes but most often lack with a clear path to follow in order to reap benefits from technological changes. Companies that are both aware of technological change and are able to adapt and adjust with technological changes, are included in type 3 category. Type 3 companies have sufficient innovation capability and may have a track record of incremental innovations to a certain extent. Finally, type 4 category companies are capable of re-writing the rules in an industry by having diverse and international knowledge base.

The Finnish construction company, and companies within the industry, may have understanding about technological changes and capabilities for setting targets for new incremental innovations, but they may lack the capability for re-writing the rules within the industry. For example, a nine-year case study from Spain concluded that construction companies are aware of the need to change and that they are capable of doing so. However, the types of innovations are incremental, for example utilizing Plan-Do-Check-Act-cycle in their innovation strategy.(Yepes, Pellicer et al. 2016) In addition, a study covering 52 construction companies in Turkey, concluded that the construction companies have managerial capabilities for technology transfer.(Demirdöğen, Işık 2016) Innovation capability in Finnish construction industry have similarities with the outcomes of these studies. Vesa (2014) investigated Finnish construction product companies in his dissertation and he commented that the innovation activity in the Finnish construction industry has been rather ineffective despite companies are aware of the importance of technological change.

Innovativeness of contractors and sub-contractors is also affected by heavy price competitive environment, that does not leave too much space for innovation.(Vesa 2014) Most often sub-contractors are chosen for a construction project after the building design is on a good way and therefore, they have diminished power over new innovative solutions for the project. Incentives for innovation are also rather low when contractual models provide reasonable profit for sub-contractors and innovation might be perceived as a threat that endangers these reasonable profits.(Vesa 2014)

Naoum, Lock et al. (2010) conducted a survey regarding barriers which hinder innovation in British construction industry. The study was aiming to get architects' perception of the poor innovativeness in the industry, thus giving a fruitful approach from the stakeholders' who usually interact in projects from the very beginning until the handoff of a project. The study revealed four domains with a corresponding significance level that hinder innovation in the industry. The highest significance

was gathered around “industry attitude” domain, which consisted of conservatism, lack of knowledge and training and finally, unfamiliarity with new techniques. The second highest domain was “risk”, with the highest significance in cost following with time and quality. The third domain was stated as “fragmentation”, including separation of design, the separation of construction and finally, separation of design and construction. The least significance was gathered around “legislation”, comprising of planning restrictions, health and safety and building regulations and certifications, from example BREEAM-certifications.(Naoum, Lock et al. 2010) Figure 2 depicts full results of from the study.

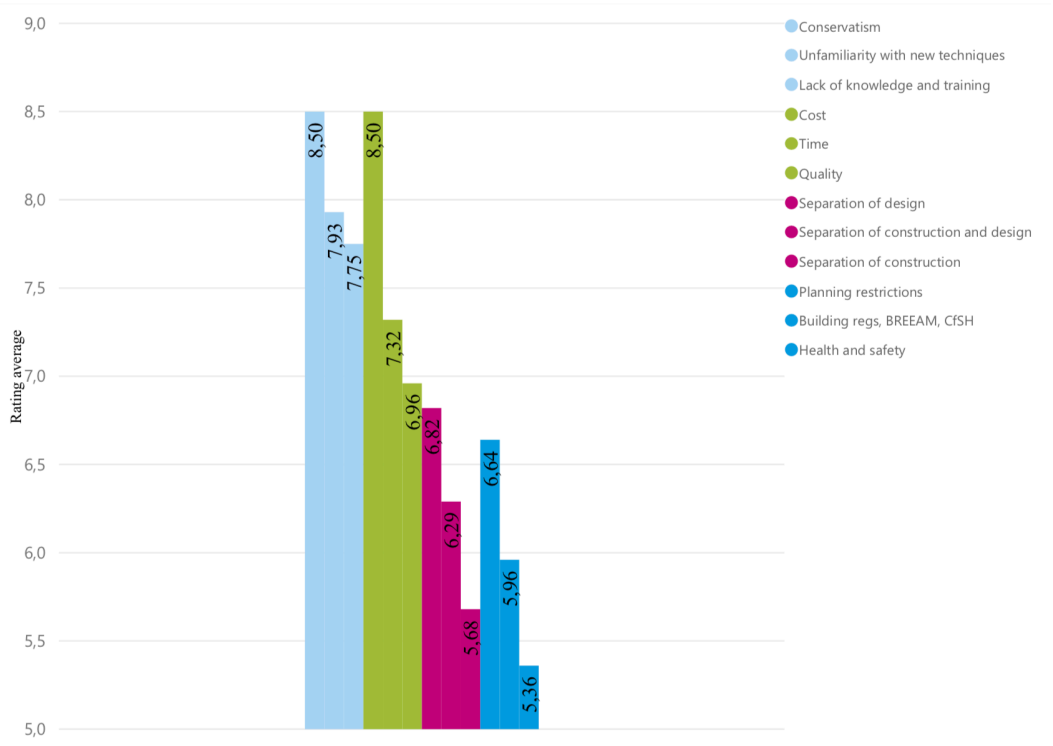

Figure 2. British architects’ perceptions of barriers to innovation in the British construction industry (Naoum, Lock et al. 2010)

Despite having an anemic short-term innovation trajectory, the literature provides possible courses where this kind of business environment might lead to in terms of innovation. As discussed in this thesis, and according to Schumpeter’s theory of creative destruction, mature businesses tend to witness major breakthrough innovations or suffer as being outdated by new businesses.(Schumpeter 2013)

History provides a good example of upheavals of this kind. Before inventing refrigeration cycle, the ice manufacturing industry used natural ice as a source of fresh ice. This ice was used in shipping industry where the ice could keep heat-sensitive cargo fresh until undocking in foreign harbors. What is interesting, the ice manufacturing industry lived side-by-side with the emerging refrigeration industry and proceeded to foster incremental innovations in this old and mature business. This phenomenon is known as sailing-ship effect in which two technologies, mature and emerging, are rivaling and companies in mature business continue to put efforts in mature technology.(Tidd & Bessant 2013)

Given these circumstances, interest in Lean philosophy in the construction industry has risen in the preceding decades. In the manufacturing industry, Lean philosophy has established solid foundation bringing concepts of reducing waste and introducing flow to production lines resulting in increased customer value among other benefits.(Majerus 2016) Encouraging experiences of improved processes from other fields of industry may have risen interest towards Lean philosophy in the construction industry. The spearhead of Lean construction implementation in Finland has been the infrastructure industry, which has utilized integrated contract policy in several projects. So far many of these projects have seen reduced execution times and decreased costs that puts more pressure on the building sector to implement Lean-philosophy.(Lean Construction Institute Finland 2015a) The tendency to budget and schedule overruns has raised questions whether buildings could be built within the boundaries which are set at the project.

Lean thinking involves several tools which have been shown to have a significant effect on improving processes.(Shah & Ward 2003) Lean thinking modifies companies value chain where it is implemented.(Bhasin & Burcher 2006) The literature shows a vast number of examples where new value chains produce new innovations.(Roper, Du et al. 2008) Lean thinking includes many methods that are based on identifying waste and improving processes continuously for instance. Last Planner System and Just-In-Time deliveries are a few Lean methods that have been used in the construction industry in Finland and abroad for a while.(Ballard 2000)

(Lean Construction Institute Finland 2015b) What is more, these methods provide collaborative environment in the fragmented industry. In this context, it is appealing to study the effects of Lean construction since the set-up clearly differs compared with traditional construction processes.

1.2. Aims and limitations

In order to tackle these vast challenges the industry is facing, innovation is needed to overcome poor productivity development and substandard quality. The construction industry is fragmented into multiple layers of stakeholders, all of which have incentives of their own that necessarily do not add up to a common goal. Individual stakeholders may be tempted to optimize their own work with an expense of others. Lean construction provides a paradigm shift from traditional partial optimization to the optimization of the entity, thus generating new environment for engineering and contractors to come up with something novel. A new environment can be rich in terms of new opportunities. This leads to the first research question of this thesis:

Research question 1: How Lean construction could function as a driver for innovation in the construction industry?

The first research question aims find traces of innovations which have had Lean construction as a kick starter and thus enabled an innovation to emerge. Research on this topic is scarce especially in Finland, where Lean construction is a relatively new concept particularly in the buildings sector. There is a scarcity of studies investigating the direct evidences of innovations that may have be affected by Lean philosophy in the beginning. Many companies may have heard of Lean or Lean construction and some companies are rigorously implementing Lean construction methods into their business. Benefits of Lean implementation are encouraging but understanding of exploiting Lean paradigm fully may remain unanswered. This leads to the seconds research question of this thesis:

Research question 2: How do companies see Lean construction from an innovation point of view?

As previously mentioned, Lean construction is a new philosophy consisting of several methods that aim to satisfy customer needs better by raising quality, reducing waste and shorten execution time by introducing flow to processes. This new set of methodologies may generate new opportunities to companies which exercise Lean methods. This leads to the third and final research question:

Research question 3: How could companies exploit the methodologies of Lean construction in their own innovation strategy?

This research is focused on Finnish construction industry, and more specifically the house-building sector. Despite the fact that there are similarities with other sectors, such as the infrastructure sector, the results might not be applicable in these sectors due to the data gathering sample. In a similar way, geographical limitation must be considered since processes might differ nationally. Another constraint is the number of interviewees and the total amount of data which was analyzed. Even though some degree of saturation was gained in some themes in the data, it is not safe to say that all of the patterns supports deeper analysis. Related to the data, also the research design imposes some limitations. Since the research design employed qualitative, semi-structured interviews, all generalizations should be considered carefully from the conclusions.

1.3. Structure of the thesis

This thesis consists of three major parts all where the first part includes introduction and the theoretical background to this thesis. The introduction provides a background to the thesis and considers innovation generation mechanisms and covers literature review providing the framework for this thesis. Research questions are presented in the first part after the introduction, giving a context to the research

questions. Additionally, the definition of innovation is presented and how innovations emerge, is discussed.

The second part of this thesis focuses on innovation sources and Lean philosophy, containing two chapters. Innovation sources discusses some sources that are utilized in the construction industry, thus giving a background to investigating the effects of Lean philosophy on innovation in the construction industry. In order to comprehend and provide Lean philosophy point of view to this thesis, Lean and Lean construction development trajectory and main principles are elaborated.

The third and last part of this thesis consist of the research part, including methods, which provides the research design used combined with justification for chosen methods. Then, results are presented from the interview data which was analyzed. Finally, in the discussion part, conclusions and recommendations are given also providing paths for future research. All aforementioned parts and chapters are depicted in Figure 3, which gives a visual and structured input-output presentation of this thesis.

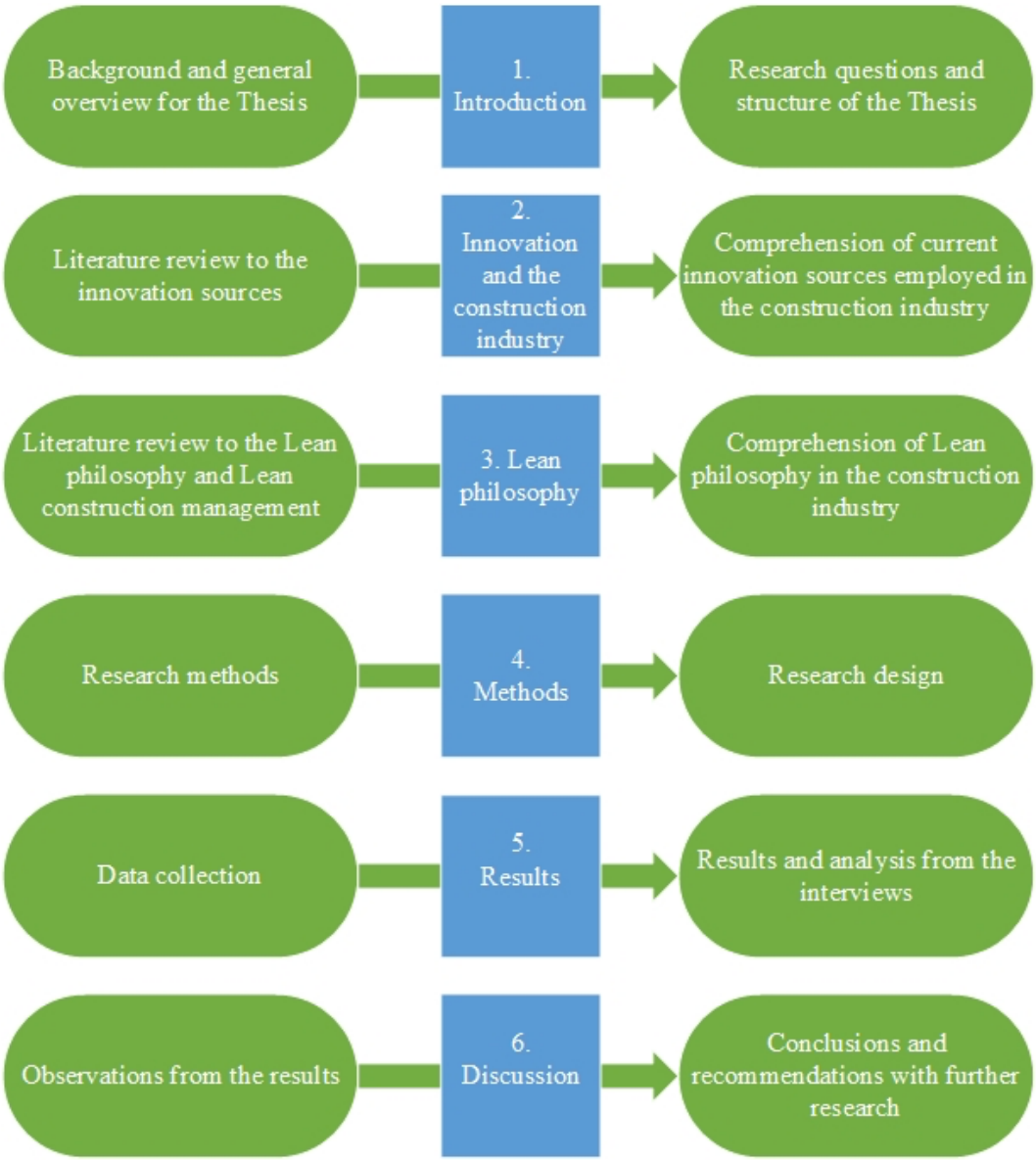

Figure 3. Structure of the thesis

2. Innovation and the construction industry

Innovation as a term is widely known, yet a rather dispersed concept. An excessive usage of the term has caused inflation resulting in a blurry image and sometimes even negative associations.(Vesa 2014) Therefore, it is essential to define what innovations are and how they emerge in order to examine innovations within Lean construction context.

Innovations have shaped our civilization since the dawn of humankind. It is not exaggeration to say that humankind would still be living in caves and figuring how to survive over an incoming winter without coming up with concepts that could mould the environment more beneficial for humans. Through millenniums, the humankind has exploited its creativity in seafaring, space exploration and energy harnessing among countless others. This breathtaking innovation track record of humankind does not show signs of retirement. In the modern world, innovations play a key role when companies are trying to compete with each other with better products and services. Thus, innovations are the very basis of improvement in business creating interest to examine innovations.

Joseph Schumpeter brought the importance of innovations into daylight by publishing his framework of creative destruction where he claimed that innovations are exclusively the reason for fluctuations in business.(Schumpeter 2013) He explained that the nature of economies is dynamic, an opposite of static, mathematical worldview and which leads to a reallocation of resources from time to time. An implication of this is the division between winners and losers; companies that stick with old models and technology, will be wiped out as the victorious models and technologies rule. It is not only companies that are affected by creative destruction. The history shows several cases when entire industries have diminished as new industries have emerged with new, groundbreaking technology. A good example of this could be the emergence of internet, which has had tremendous effects on banking, shopping and communications for instance.(Tidd & Bessant 2013) Schumpeter gave his own thought that more efficient allocation

of resources as well as improvements and innovations are key factors why some companies diminish as others prevail.

Porter stated the importance of innovation as of it is a source of competitive advantage. Moreover, Porter defined innovation as "new technologies and new way of doing things" and added that innovations do not necessarily include a technological breakthrough or even novelty if the innovations have not been pursued conscientiously before.(Porter 1985) Another point of view is provided by Tidd and Bessant (2013) with an example of Thomas Edison who argued that innovation is not just an idea but also successful in terms of economic and technical success. This implies that innovation should have economic success in order to differentiate it from an invention. In a similar vein, former British prime minister Tony Blair put together the concept of innovation writing that innovations are exploitation of new ideas in order to provide and defend successful businesses. (Robinson 2004) Schumpeter defined innovations in a similar matter as Porter, writing that innovations are commercially successful inventions which necessary do not need to be novel.

Internal structures and processes were argued to cause the poor innovation activity in the construction industry.(Sizova, Zhutaeva et al. 2018) This internal inertia is especially brought by different interests from different parties, relatively short-term projects and the uniqueness of a construction project. This is condensed by Jukka Pekkanen, a director from CFCI, stating that "If a car factory would be compared with a construction project, the manufactured car would be a prototype, the manufacturing facility would change its place and labor would change after manufacturing each car. The customer would provide the schedule and design most of the time."(Rakennusteollisuus Ry 2012)

The construction industry suffers from being highly fragmented. A typical construction process involves several stakeholders, such as main contractor, multiple layers of sub-contractors, architecture and engineering companies and consultants among others. Lui & Ngo (2004) argued that construction project

stakeholders might have an opportunistic tendency to increase their own performance by the cost that decreases the overall optimization of the project. Hence, levels of goodwill trust and competence trust were claimed to explain and overcome this opportunism. According to van der Valk, Sumo et al. (2016), goodwill trust and competence trust play a major role when examining an innovation performance of a company.

In a similar manner, commonly used contractual models in the construction industry do not enhance innovation, especially when the aim is to minimize expenditures by contracting the cheapest possible stakeholders in the bidding process.(Vesa 2014) Another restrictive aspect on innovation comes from the clients' taste, that is, consumers rather not buy a house which is experimentally designed and built since they favor buildings that are designed and built conservatively, and which retain their value through decades. (Ball 1999)

2.1. 4Ps innovation model

Innovation can be represented as four-dimensional innovation space, as provided by Tidd and Bessant.(2013) This 4Ps of innovation space is constructed by four dimensions each having spectrum from incremental to radical innovation type. The 4Ps model helps detecting and categorizing an innovation, which helps practitioners and researchers gaining common understanding about the nature of the innovation. A visualization of the 4Ps model is depicted in Figure 4.

Possibly the easiest dimension of the 4Ps model is product innovation which is a physical entity, that fulfills the criteria of novelty and economic success. In addition to products, this dimension includes also service innovation, such as Spotify, for example.(Tidd & Bessant 2013)

Sometimes highly connected to product and service innovation, a process innovation is concerned with how products and services are created and delivered. Clear distinction can be difficult with product innovation, since often product and

service innovations are tied together with process innovations. An example of this would be the TPS, as it revolutionized the manufacturing of cars among other goods.(Tidd & Bessant 2013)

At the bottom of the vertical axis, position innovation represents innovations that establish a totally new market for a product that was sold in another market previously. One good example of a position innovation is low-cost airlines, that opened market for those who could not afford it before.(Tidd & Bessant 2013)

The fourth and last dimension is the paradigm innovation that is defined as "changes in the underlying mental models which frame what the organization does." The reframing of what an organization does have led to innovations such as Dyson's home appliances, that redefined high performance devices in the home appliance context.(Tidd & Bessant 2013)

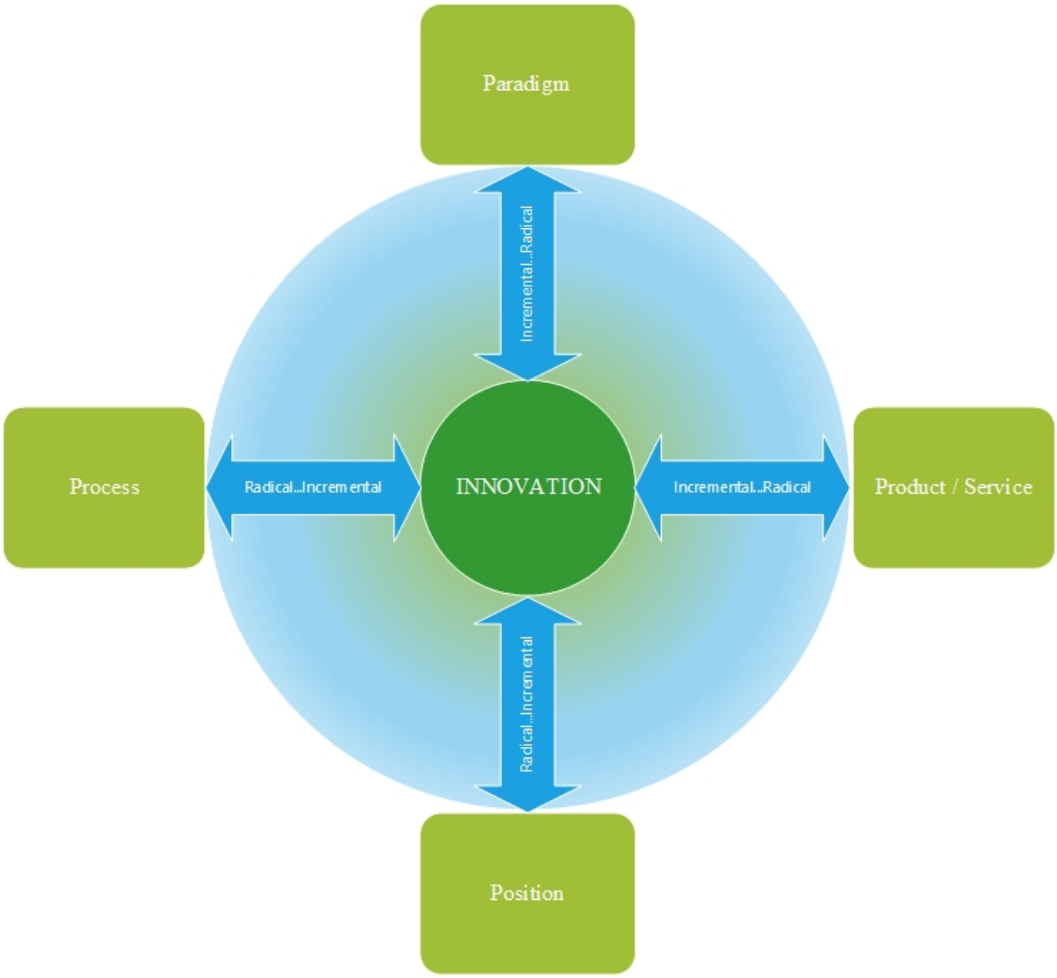

Figure 4 The 4 Ps model (Tidd & Bessant 2013)

It is essential to examine the nature of these four Ps that the model expresses, that is, the range from incremental to radical innovation. When considered incremental innovation, it is all about small steps that make the given dimension of innovation better that is already existing. Majority of innovations are incremental by their nature, since optimizing a process is easier to handle and comprehend from the implementation point of view than radical new process innovations, that may need vast amount of capital to be implemented.(Tidd & Bessant 2013) In addition, incremental innovations should not be underestimated because of their frequent time span that refines the examined innovation and ultimately leads to compounding effect. When compounding innovations have occurred, it is more difficult to benchmark and stay ahead of these innovations.

Radical innovations on the other hand are innovations that gather a lot of attention since they revolutionize a given product or a process. Occurrence of radical innovations is more infrequent, that of incremental innovations', but when taken a place it does have major effects on markets. Schumpeter's theory of innovation refers to these radical innovations that have game-changing effects and whereby companies can leverage substantial competitive advantage over competitors. This is also major threat to companies and even for industries, that fail to maintain their momentum among competitors' that succeed in having radical innovations.(Tidd & Bessant 2013)

2.2. Sources of innovation

The innovation literature provides several mechanisms for innovation sources which have been discovered in management research focused on this topic. Innovations can sometimes pop up by accidents and with some effort, little or great, it could be harnessed in the markets.(Tidd & Bessant 2013) More often innovations need deeper analysis of how innovations could emerge. By investigating these patterns, it could be plausible to detect by which path innovations could emerge. Moreover, presenting major innovation sources from the construction industry point of view, the effects of Lean philosophy on these sources give context to the conclusions whether Lean philosophy fosters innovations in the construction industry.

While evidences have been discovered that some principles of Lean philosophy enhance innovation by incremental steps in the car manufacturing industries among others, debate concerning the effects of Lean philosophy on innovation and innovativeness is still ongoing.(Helander, Bergqvist et al. 2015) For example, Majerus (2016) argued that Lean philosophy itself does not create innovation but does have interaction in the creation of an innovation. Therefore, in an attempt to explore the effects and interaction of Lean philosophy to innovation in the context of Finnish construction industry, and in more detail, does it foster innovation in the

construction industry, it is favorable to dig into sources of how innovations emerge in general.

As a result of the continuous research, Tidd and Bessant present several different mechanisms of which a few are presented here to provide a background for possible innovation mechanisms in Lean construction context.

2.2.1. Knowledge push and demand pull

In the twenty first century, LSE's are in a major role in knowledge push innovations by investing heavily into research and development. Knowledge push innovations can form into disruptive innovation, as in its nature knowledge push does not aim to satisfy the strictly defined need.(Tidd & Bessant 2013)

When having a closer look at knowledge push, development is mostly reached by small incremental steps with once-in-a-while breakthroughs. Typically, these small incremental steps involve improvements and refinement to the original product or process which eventually leads to breakthroughs as a result of rigorous research and development. An example of this technological trajectory comes from 3M where Spencer Silver developed a reusable adhesive or "a solution without a problem" as he described it by himself. Together with his colleague, Arthur Fry, the post-it notes were developed. (Tidd & Bessant 2013)

The opposite of knowledge push arises from customer demand pull. Demand pull is perhaps the most common assumption on how innovations emerge. As discussed before, Lean philosophy has been a process innovation which was developed in a response to scarce resources in the post-war Japan where resources were in short.(Modig & Åhlström 2016) Similarly, also in Japan, high power costs decreased Japanese aluminum sales which led to a new aluminum casting process where one energy-intensive step was replaced by re-engineering the process. (Porter 1985)

The obvious difference here between knowledge push and demand pull lies in client interaction, in which knowledge push diminishes client perspective whereas demand pull relies on it. However, the pattern here is the same with both mechanisms; incremental and small improvements are added to a product or process resulting as breakthroughs from time to time. Figures 5 and 6 depict knowledge pull and knowledge push in a visual form.

Figure 5. Knowledge push

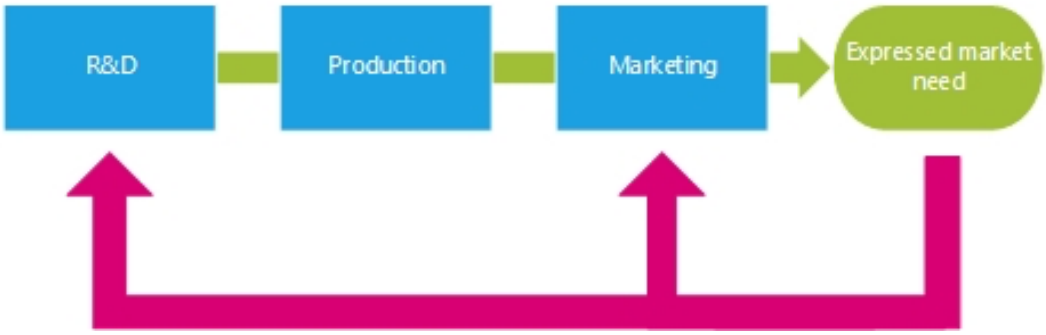

Figure 6. Knowledge pull

Knowledge push and demand pull in the construction industry innovation cannot be neglected. While there are no statistics regarding adopting knowledge-push driven innovations in the construction industry, some researchers assume that the innovation adaptation likelihood is not particularly high.(Sepasgozar, Davis et al. 2018) Reasons for this can be traced to the structure of the construction industry where projects can be highly complex. Companies may perceive new innovations as a risk that has an unknown effect or effects on the secondary or tertiary stakeholders of a project.(Slaughter 2000)

However, demand pull affects the industry bit differently than knowledge push. Almost all industries worldwide are affected by the climate change and raising worries about the environment has forced regulatory bodies establishing directives

and laws that define the energy consumption of a building, for instance. These regulations set new targets for the industry to catch, thus forcing the industry to innovate.(Goodland, Taggart et al. 2017) This source of innovation is closely tied with contracts and regulation, which is discussed later in this thesis in more detail.

2.2.2. Watching others

While it is worth to point out that replicating innovations from competitors involve significant risks if those are not carefully analyzed, copying ideas can be beneficial especially if copied ideas are improved and value adding features can be added. This particularly effective innovation screening method has been the backbone of developing Asian countries that have almost caught up developed countries in technological development.

One way of putting this method in practice is benchmarking. Benchmarking can be defined as "A measurement of the quality of an organization's policies, products, programs, strategies, etc., and their comparison with the standard measurements, or similar measurements of its peers."(Business dictionary 2019) In other words products or processes are compared with their corresponds in rivalling companies. Norbert Majerus from Goodyear explained the effectiveness of benchmarking. In the 1990's, Goodyear was going through difficult times as they had a lot of R&D projects which needed to shut down because of their eastern Europe competitors, that had benchmarked Goodyear's products and launched their own tires with decent quality, eating market size from Goodyear. (Majerus 2016)

Benchmarking in the construction industry can also foster innovations. In the construction industry context, benchmarking has extensive potential in company and industry level improvement. In an article that concerned with industry-wide benchmarking initiatives from Brazil, Chile, the United Kingdom and the United States concluded that innovation could be fostered if companies involved in these initiatives share knowledge and best practices, so that it promotes organizational

learning.(Costa, Formoso et al. 2006) It is also often stated that these initiatives have innovation as an objective, giving a structured path to innovation.

2.2.3. Recombinant innovation

Professor Hardagon came up with a solution to laptop wires when he was employed by Apple in the 1990's. The solution was so called gull-wing mechanism integrated into a charger where the wire could be wrapped around the gull-wings. However, he did not come up with this idea by himself but he merged an innovation from vacuum cleaners, where similar gull-wing has already been invented. The vacuum cleaners had their gull-wing design from fighter jets from world war 2. By integrating these technologies, Hardagon employed an innovation source known as recombinant innovation.(Kleiner 2004)

The trajectory of a recombinant innovation where two or more innovators first develop distinct technologies, technology A and C, as depicted in Figure 7. The technology B is then developed by the outcomes of technology A and C by the innovators, that had adopted these distinct parent technologies. Unlike with *branching innovation*, which develops new technologies only from one parent technology, recombinant innovation can create technological "shortcuts" that leverage opportunities from two or more parent technologies, and which could lead to technologies that could not have been discovered.(Frenken, Izquierdo et al. 2012)

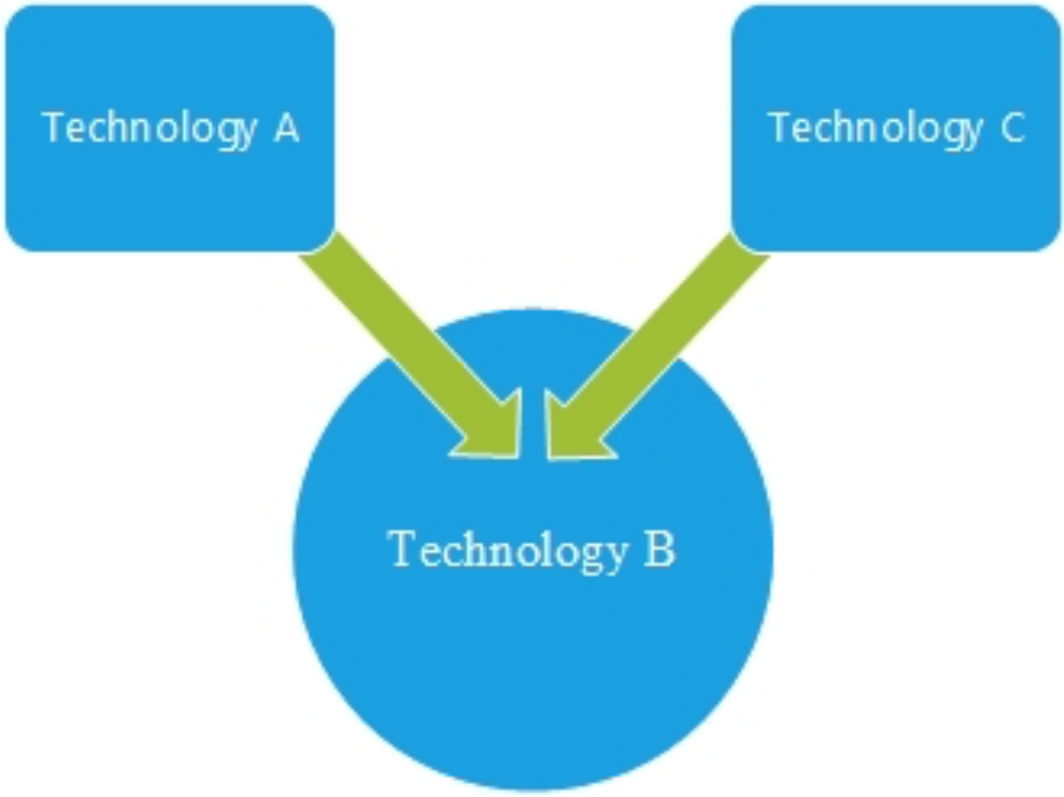

Figure 7. Development of recombinant innovation (Frenken, Izquierdo et al. 2012)

Recombinant innovation can foster both radical and incremental innovation but the mechanisms differ whether they foster radical or incremental innovations. This can be explained with related and unrelated variety of innovations and their contribution to incremental and radical innovations. Research suggests that related technologies enhance innovation activity, especially incremental innovations. The set-up changes with unrelated variety is considered. In order to chase disruptive innovations, it could be beneficial to consider unrelated variety where unrelated attributes are merged into a novel product or process.(Castaldi, Frenken et al. 2015)

Recombining intellectual property in order to generate new innovations has a growing importance since increased intellectual property require more human capital to process generated information. Accumulated knowledge needs to be delivered to the next generations in order to continue technological development. This phenomenon has quite practical consequences. For example, according to Jones'(2009) research, the average age of a Nobel prize winners inventing their ground-braking invention has increased by six years in the 20th century. This

implies that specialized knowledge should be studied more and individuals should work in teams, sharing their expertise thus generating new innovations, that require deeper knowledge from several fields.

2.2.4. Contracts and regulation

Contracts are pivotal in the construction industry for their ability to facilitate cooperation between parties that may have conflicting interests. A construction project can be perceived as a product that is enabled to be produced by contracts that guide project work. While the importance of contracts is quite obvious, management research has also examined the relationship between the theory of contracts and innovation.

Lui & Ngo (2004) developed a model that considered goodwill trust and competence trust as enablers to hinder an opportunistic tendency of a construction project stakeholder. In this context, goodwill denotes to trustee intension of fulfilling their part of the deal, whereas competence trust refers to trustee's ability to fulfil their part of the deal by means of resources and skills. An opportunistic tendency is unfavorable for the reason that project participants may be tempted to exploit the environment for their own good with the cost of the entity. Thus, a project could be prone to schedule delays and budget overruns. These two dimensions of trust should have an effect on contracts that are signed by the stakeholders, in other words, considering the level of contractual details in the contract when concerning low or high goodwill trust and competence trust. Moreover, the level of goodwill trust, competence trust and contractual detail have a threshold which entails innovation outcomes. The managerial output of this model is that in order to enhance innovations output, one should put focus on the right level of goodwill trust, competence trust and contractual detail.(van der Valk, Sumo et al. 2016)

Regulation provides a powerful mechanism for an innovation source, but it has another side of the coin, as Tidd and Bessant point out that regulation can shut down

some ways of innovations. Nonetheless, regulation opens up ways for innovation as it can be seen in many industries.

A recent study conducted in Germany (Blind, Petersen et al. 2017) suggests more detailed viewpoint to regulation-induced innovation, where formally made standards and government-set regulations are distinguished from each other. Results show that in a market with a low level of uncertainty, standards have negative effect on companies' innovation production efficiency. In a market where high uncertainty prevails, standards show to have an opposite effect. The researchers suggest that explanation of this pattern in a market with low uncertainty might be in standardization bodies which are affected by dominant companies with saturated technology. In a market with high uncertainty, business environment changes fast disabling companies bending standards for their favor.

Government-set regulations on the other hand have opposite effect than standards. Regulations have positive effect on a market with low uncertainty and negative effect on a market with high uncertainty. The pattern here could be explained with possible information asymmetry in regulative bodies and underlying technologies in a market with low uncertainty. (Blind, Petersen et al. 2017)

Finnish construction industry is highly regulated by several officials and the regulation follows the whole building process from the preliminary design until the handover of the finished building. Despite recent deregulation attempts, the construction industry still has a lot regulation concerning fire safety, structural design and accessibility. From this point of view, the construction industry has great potential for regulation-related innovation.

2.2.5. Open innovation

The concept of open innovation is more clarifying to elaborate on the aspect of closed innovation. Large-scale enterprises, like IBM for instance, have had huge R&D expenditures as they sought it would be the road to successful innovations.

By employing this strategy, IBM was developing all the knowledge in-house and treated produced R&D experience as intellectual property which should not leak to the market, as shown in Figure 8.(Chesbrough 2003) Without a doubt, IBM has generated a lot of innovations, yet Intel and Microsoft could outperform IBM in computing industry. An opposite of this is open innovation, in which constraints of information flow is less restricted than in closed innovation. Companies that employ open innovation significantly acquire information and talent outside of the company's borders (see Figure 9). This does not mean that with open innovation, companies can eradicate their R&D as it would be obsolete and rely entirely on external ideas.(Chesbrough 2003)

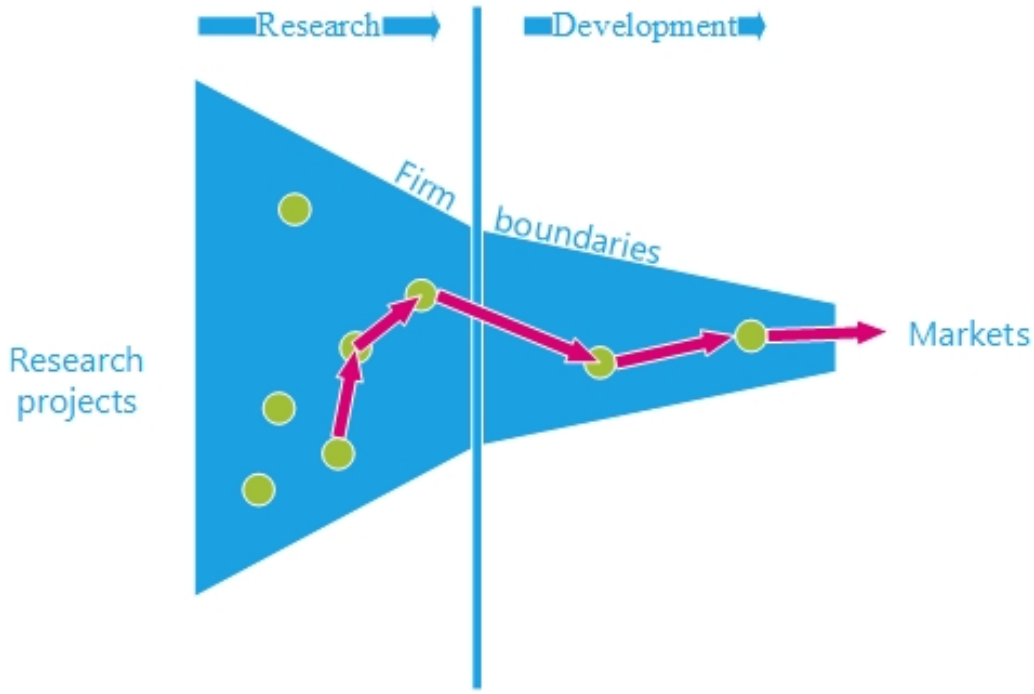

Figure 8. Closed innovation

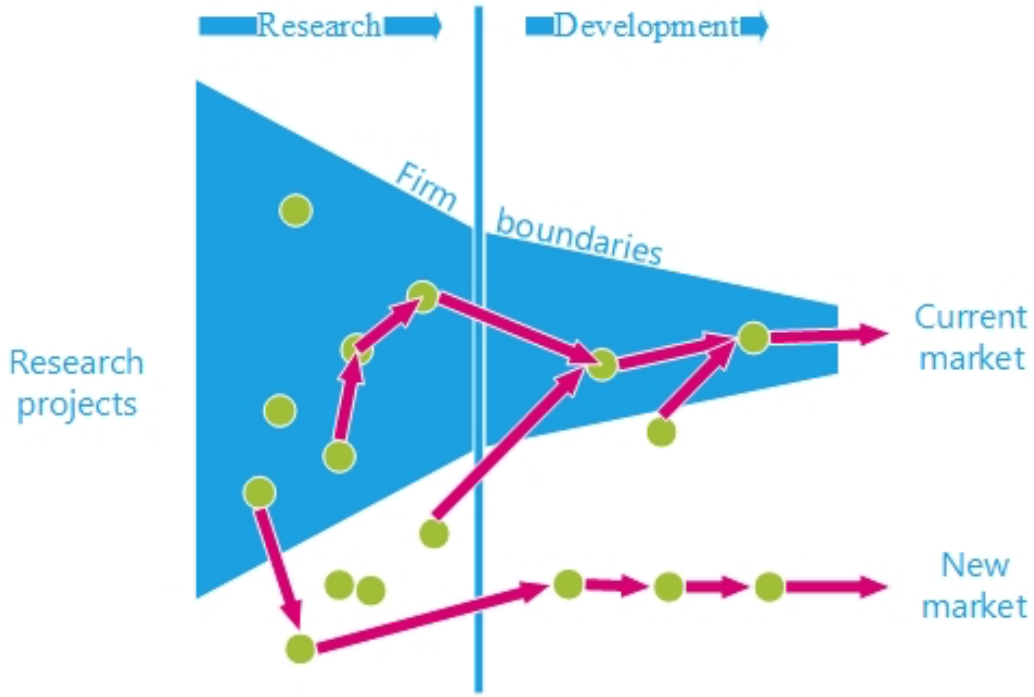

Figure 9. Open innovation

Open innovation utilizes both internal and external ideas and use R&D to reap the needed share of the ideas and develop them further. The driver for this knowledge sharing stems partially from the labor movement which is hard to prevent from happening from a company's point of view. Realization of that the best and the brightest do not need to be employed in order to innovate successfully has modified innovation strategies in many companies.(Chesbrough 2003) There are still important factors on an individual level that should be emphasized when considering thriving Open innovation strategy. Ultimately, individuals are the source for reaping external knowledge and subsequently combining it with existing knowledge in order to introduce innovations. Studies have shown that some key factors are for instance the background of individuals. That is, the diversity of education and to some extent previous work history. The way of this may be explained is that more diverse individuals enlarge their collective knowledge-base in a company, identifying knowledge that matters that could be ignored in less diverse group.(Bogers, Foss et al. 2018)

Foundation for open innovation in the construction industry is cast on its business model especially in Finland, where traditional project delivery involves several stakeholders.(Vesa 2014) These stakeholders usually meet together multiple times during the project, to which temporary organization is created. However, even though open innovation could be exploited in this environment, the project stakeholders do not often discuss about new knowledge by which projects could be executed more frictionlessly and what is also the most likely one of the greatest reasons why collaboration is not efficient at the industry. In a study conducted by Worsnop, Miraglia et al.(2016) experiences from an infrastructure mega project in London indicated that open and closed innovation lived concurrently during the project. Some stakeholders were reluctant to share knowledge whereas other stakeholders were favoring open innovation model that was explicitly introduced by the main contractor to this particular project. It was also concluded that the main contractor's role in exercising open innovation is relevant as they can foster the implementation of minor innovations to minor problems which are easy to implement.

2.2.6. Business ecosystem

Tracing back to 1930's a concept of the ecosystem was developed from the natural sciences, stating that ecosystems are all around the nature. The notion of ecosystems is used in social sciences and macro-economics, describing entities such as global economy as an ecosystem.(Valkokari 2015) One of the most famous derives of this ecosystem concept was harnessed by James Moore in 1993, defining the business ecosystem term. Moore's definition treats companies and organizations as organisms that are contributing to a common goal and which are in interaction with each other. Moore stated that innovations do not develop in an empty space, rather, innovations are dependent of necessary resources, such as capital, partners and suppliers among others.(Moore 2009) Business ecosystems usually consist of different layers, each having their own level of commitment to the ultimate goal. There are for example the core level that includes suppliers and focal companies,

which have had the highest commitment and perceived the value of the business ecosystem, while other layers are more loosely committed.(Valkokari 2015)

Business ecosystems are increasingly popular among industries, since companies perceive ever-changing business environment shifting into more fast-paced and globalized environment.(Moore 2009) Therefore, companies try to thrive in this fast-paced environment by collaborating with other companies, such as suppliers, distributors, clients, government organizations and competitors. The ultimate goal of business ecosystems is enhanced customer value, guiding the overall action of the ecosystem.(Valkokari 2015)

Business ecosystems have multiple dimensions depending on their context and purpose and implications of business ecosystems have countless varieties. One dimension of a business ecosystem can be detected from the Finnish construction industry, where digitalization-driven ecosystems have been formed, namely KIRADigi and KIRAHub ecosystems. The purpose of the former one was to propel digitalization by harmonizing information management, having an effect on legislation considering laws that hinder digital transformation and establish pilot projects to experiment digitalization in the industry. The latter one inherits KIRAdigi's legacy by embedding digitalization into holistic sustainable future in the industry.(KIRAHub 2019)

3. Lean philosophy

The origin of Lean trace back to the Toyota's factory where Taiichi Ohno, Shigeo Shingo and Eiji Toyoda developed TPS between 1948 and around 1970. In an economy of scarcity in the post-war Japan, Toyota developed the TPS by setting three underlying questions to define the production philosophy. First of all, *what is produced* underlined the importance to fully understand what the customer wants. Secondly, *when is produced,* stresses the importance of the schedule and the timing where all components are installed right when they should be. Lastly, *how much is produced* defines the level of quality. Indeed, customer value was the spearhead of action on the Toyota, defining all activity and forming the start to the Lean philosophy.(Modig & Åhlström 2016)

What was developed at the Toyota's factory was philosophy with the set of principles and methods supporting Toyota's strategy providing wide-range of products with right amount at right time without coining the strategy.(Modig & Åhlström 2016) The term Lean was coined by researches from the USA, namely John Krafcik and later James Womack, Daniel Jones and Daniel Roos. The start to Lean conquering in western manufacturing industries started from the work of aforementioned researches. Most notably, the book *Machine that Changed the World* by Womack and Jones brought Lean into publicity.

The seed of criticism to Lean traces back to this book too. In their book *Factory Physics,* Hopp and Spearman (2011) criticize Lean for the fact that some practitioners apply only Lean methods and tactics without understanding the philosophy behind Lean. This criticism is legitimate, since Lean was applied in given circumstances to a given company within its context. A number of Lean practitioners have tried to implement Lean methods which were developed at the Toyota factory and have failed.(Majerus 2016) Without comprehensive understanding about the Lean philosophy, Lean implementation will not yield a crop that much, or it will completely fail. Yet, this has not hindered the pace of which companies are trying to achieve "Leanness".

In general, there are many viewpoints and arguments concerning the number of methods and principles that are part of Lean. However, there is consensus that the purpose of Lean is maximizing value for the customer by reducing waste and generating flow in processes.

Lean is often referred to five principle cycle that forms a framework for a company to increase its efficiency. These five principles are depicted in Figure 10. The cycle starts with defining the value from the ultimate customer point of view for a given product or process. Issues that could be treated in this phase include clarifying what customers truly need, why and when those needs are required and what this company is doing in order to meet those needs.(Lean Enterprise Institute 2019) This first principle is extremely important, and its meaning cannot be underestimated, since it is the foundation for this examined product or process and it guides the following principles.

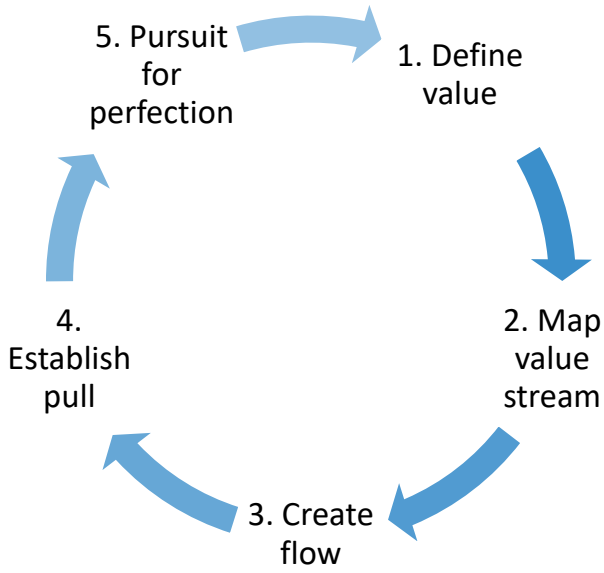

Figure 10. The lean principles (Lean Enterprise Institute 2019)

Value stream mapping is the second principle of Lean and it is the step that enables practitioners to understand where the value is formed and how it flows from the

beginning until it is given to the customer. It is essential to find the main steps of the value stream in order to find potential bottlenecks hindering the value flow, often called waste.(Torkkola 2015) An investigation on the TPS recognized seven types of waste which are (Lean Enterprise Institute 2019):

1. Transportation – Unnecessary movement of products and materials
2. Inventory – Products that are not finished but are still processed
3. Motion – Unnecessary movement of people
4. Waiting – Wasted time between the value stream
5. Over processing – Unnecessary high level of quality
6. Overproduction – Excessive production
7. Defects – Rework because of poor quality or wrong information

Waste identification from the value stream is essential in Lean philosophy for the reason that most processes have significant amount of wastes of different kind. It is estimated that rework waste in the construction industry in Australia alone is 35% of the total construction cost and over 50% of overrun costs.(Aziz, Hafez 2013) It is favorable to visualize the value stream so that the problems can be discussed to the relevant stakeholders in order to agree upon actions.

Traditionally, high resource efficiency has been perceived as a favorable target. It is therefore counterintuitive to pursuit for higher flow efficiency at the cost of lower resource efficiency. In order to achieve the comprehension of flow efficiency, it is advantageous to have the comprehension of full resource efficiency at a factory with an arbitrage number of processors that can process only one object at a time as seen Figure 10. Each object represents a product or a task in a value-adding process with a given processing time which fluctuates depending on an object. At a resource-enhancing factory, each processor generates an inventory, that does not add value. From the object's point of view, there is substantial amount of time at which nothing happens.(Modig & Åhlström 2016)

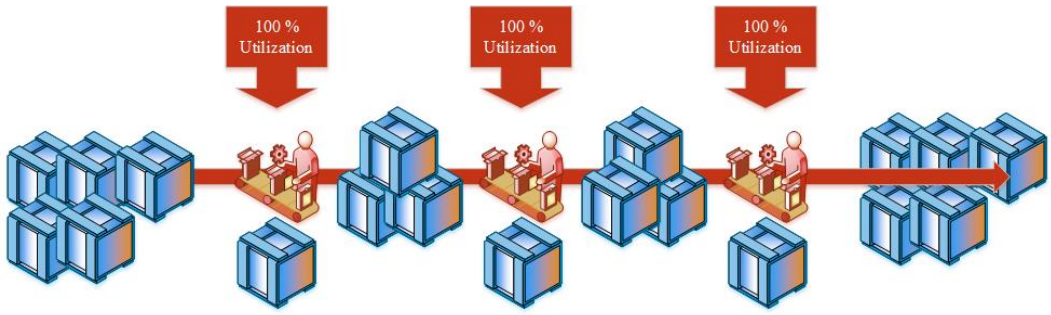

Figure 11. A resource-enhancing process

The set-up changes when the flow-enhancing process is dealt. The whole process is tuned to one cycle time so that all processors process the objects as fast as the slowest object is processed. This results in decreased inventories that do not compound between the processors as depicted in Figure 11. From the object's point of view, it is processed all the time in the process.(Modig & Åhlström 2016)

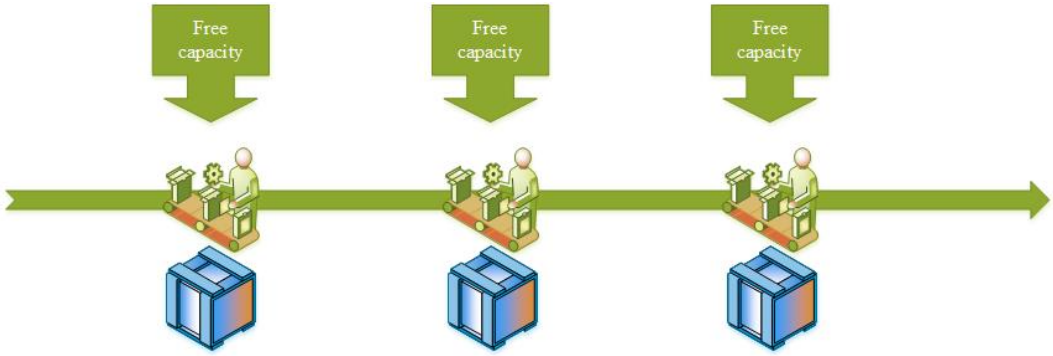

Figure 12. A flow-enhancing process

Another aspect in flow resourcing is that it controlled by pull production, which is the fourth Lean principle. Each processor is able to process the object only when there is demand for it. In other words, processor 3 begins processing an object only when it gets input from the process next-in-line. Practical implications from this are that customer needs can be satisfied more effectively by ensuring that the correct feedback is given to the process.(Modig & Åhlström 2016)

The last principle of Lean pursuits for perfection. Once all the other principles are established, constant attention for the process should be given in terms of improvement. Perfection is beyond attainable, but due to the dynamic nature of business, new issues may arise anywhere in the process, thus obstructing the effectiveness of the process and ultimately decreasing customer satisfaction.(Modig & Åhlström 2016)

3.1. Lean construction

The history of Lean construction traces back in early 1990's, especially when Ballard and Koskela began to examine construction management, its productivity and execution. Concurrently, the International Group of Lean Construction was established, which promoted further research on this topic.(Jacobs 2010)

Adaptation of lean philosophy in the construction industry has been slow due to various reasons ranging from the conservative attitude and lack of knowledge to the difficult implementation of manufacturing-based philosophy. According to Koskela(1992) , the manufacturing industry had already acknowledged and adopted a new production paradigm which saw production as a value adding conversion process. Koskela stated that this new production paradigm employed non-value adding flow coexisting with conversion. The manufacturing industry had already seen that flow processes should be diminished and conversion processes should be more efficient whereas the construction industry continued to use traditional managerial concepts which did not perceive flow important.(Koskela 1992)

In terms of production, the construction industry produces buildings with an engineer-to-order approach where each design time of a project is involved in the lead time of the project.(Dallasega, Rauch et al. 2018) Engineer-to-order approach is prone to significant delays and cost overruns as deviations in product deliveries and qualities are noted on-site. Therefore, knowledge sharing and informal discussion in a construction project is essential to ensure that the stakeholders have

adequate information on the requirements for engineering and production. (Dallasega, Rauch et al. 2018) The engineer-to-order approach is also perceived as a barrier to employing Lean philosophy in the construction industry.

3.2. Lean construction methods

In order to tackle aforementioned issues in construction, academic research and practitioners have induced many Lean based methods for the industry. As discussed before, Lean thinking involves a few methods that can be applied fairly easy to construction context while some others require deeper familiarization and moulding. This chapter focuses on some most commonly used Lean construction principles and provides an explanation and clarification of their usage in construction context. By elaborating existing Lean construction principles, better foundation for understanding possible drivers in this new paradigm could be achieved.

3.2.1. Last Planner

Last Planner production system is one of the most renown and widely implemented Lean construction principles in the construction industry. The basis for this production planning system is in realization that majority of weekly tasks and targets in the construction site were not met.(Ballard 2000) In general, Finnish construction industry can be split into two distinct parts which are the design phase executed by design engineers and the production executed by contractors. Problems typically arise firstly in the design phase due to the lack of source information, which leads to poorly allocated resourcing resulting in designs which do not meet their targets. In a similar vein, production phase suffers from poorly managed task phase planning resulting in poorly managed resourcing.(Svahn 2019)

In order to tackle these aforementioned problems, Last Planner production planner was invented in 1990's to help resource planning in the construction industry. The fundamental concept in the Last Planner system is that all stakeholders of the

project gather around to discuss about how the project should be executed, collaborating with other disciplines in order to understand the system-level requirements of their tasks. By freeing tacit knowledge of specific tasks to be executed, stakeholders are able to see barriers in front of their work in the project, thus smoothening workflow in the coming weeks. In terms of Lean principles, the Last planner employs third and fourth Lean principle, which are creating flow and establishing pull, respectively. (Ballard 2000)

In terms of a time horizon, Last Planner is divided into four phases that make distinction between accuracy of planning, as shown in Figure 13. The timeline starts from setting milestones and commitments in the "Should do"-phase. This "Should do"-phase is planned in collaboration with all construction project parties and a master plan is deduced from it. Next, the "can do"-phase is introduced which involves a look-ahead plan for the next six weeks. In this phase, constraints are taken into account and evaluation is done whether a job can be processed. The "will do"-phase is last phase of planning the tasks. This involves a detailed plan of tasks which are processed in the upcoming week. The ultimate phase is the "did"-phase which closes the Last Planner loop and involves learning. The "did" phase could be particularly fruitful in terms of innovation, since it forces project team to overcome mistakes that may have happened in the task execution thus paving the road to future innovations. (Pellicer, Cervero et al. 2015)

Figure 13. Phases of Last Planner(Pellicer, Cervero et al. 2015)

3.2.2. Visualization

The importance of visualization was well understood in the TPS in the early stage. By visualizing a process, the process owners and process developers were able to continuously follow the performance of the process and establish pull flow in the process. Kanban, which translates "card" or "visual card" is a way to present visually of how a process is flowing in given time. Figure 14 shows basics how Kanban works. Tasks can be divided into columns which represent a specific state of a project. For example, tasks which are ongoing, are in the work-in-progress column.

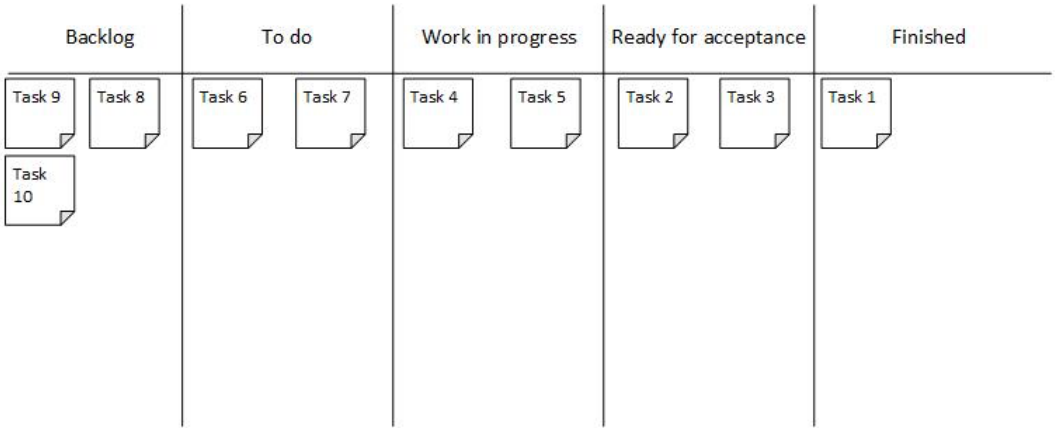

Figure 14. An example of Kanban visualization of production tasks

Process visualization in the construction industry has useful properties. According to Treckmann et al.(2009), visualization helps site managers in weekly work planning, decreases misconceptions related to miscommunication and increase safety when ongoing tasks are visualized. In a similar vein, Treckmann et al. proposed that 3D-modeling added with a project schedule, known as 4D-modeling, could be beneficial in order to inform all stakeholders from on-site workers to designers. The complexity of Kanban in the construction site context lies in the fact that the construction site is constantly moving factory and therefore visualization of the construction process might not be as powerful as 3D-visualization or 4D-modeling added with a schedule.(Tan, Horman et al. 2019)

4D-modeling addresses these aforementioned issues with the visualization of work at a construction site. An example of this is in Figure 15, which shows a section from a story in a BIM interface. In this kind of interface, all relevant stakeholders are able to see current situation at the construction site. It guides workers to see where it is possible to continue working and where not. From managerial aspect, 4D-modeling enables managers to seek schedule errors and see if work-in-progress inventories begin to compound in the construction site and take action when errors occur. Making it visual, 4D-modeling supports primarily second Lean principle, that is mapping the value stream.

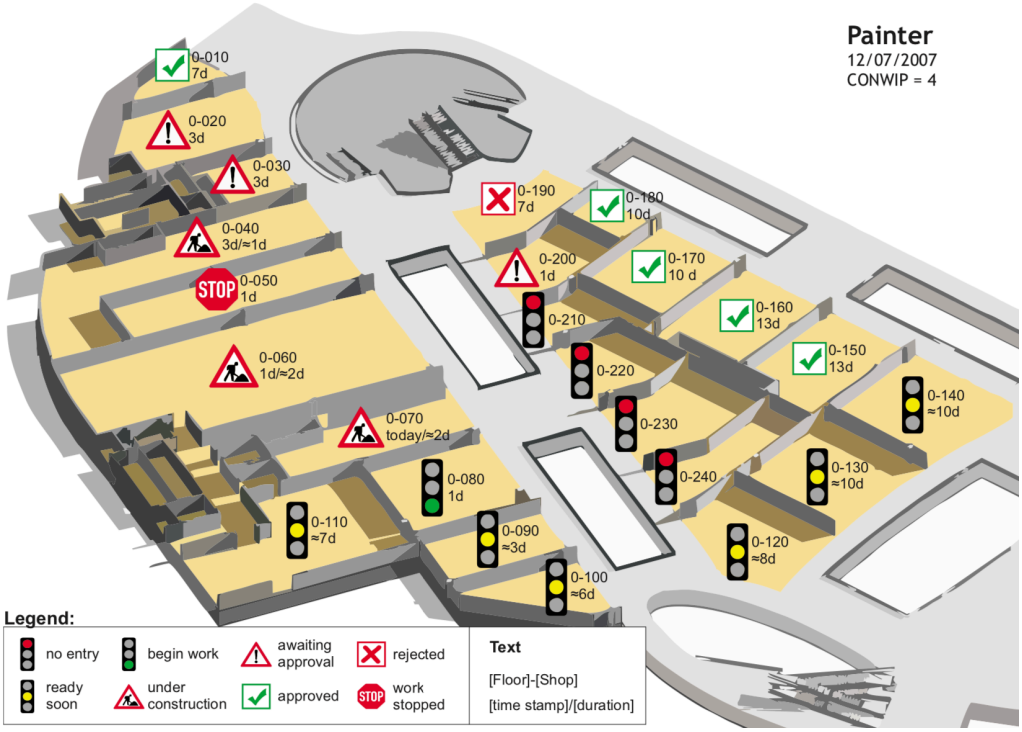

Figure 15. 4D-modelled storey of a building (Treckmann, Rozenfeld et al. 2009)

3.2.3. Target Value Design

One popularity gained approach to Lean in construction is the Target Value Design (TVD) in which the purpose is to have realistic targets for the end product, which is aimed to meet customer's demand fully. Purpose of this method is to improve value-added to the customer by integrating and participating in all necessary stakeholders to the construction project. In order to understand the necessity for TVD, it is purposeful to illustrate a project with and without TVD implementation in figure 16. Traditionally, construction projects have a tendency for budget overruns.

TVD involves usually Big Room facilitation which employs all participants in the decision-making chain in the construction project. By doing this, redesign can be reduced and realistic cost targets can be set. Customer involvement in the Big Room facilitation increases knowledge management to all participants and therefore sets

foundation for primary data which is crucial throughout the project. Last Planner method can be also used in the TVD to enhance schedule management in the project. (Macomber, Barberio 2007)

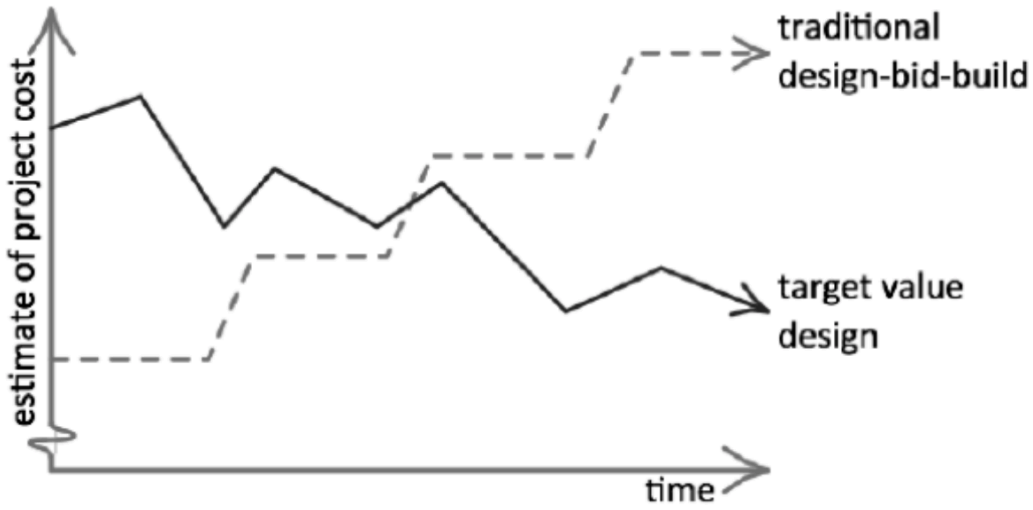

Figure 16. Comparison of an estimate of a project cost with and without TVD practise

From the innovation point of view, TVD can also be beneficial since the project team is oriented to follow the targets set by the project organization. Engineering and building a building consist of daily problem-solving cases some of which need fast resolution. In these conditions, a project team faces constant challenge which therefore leads to new opportunities to overcome problems. The TVD method encourages the project team to establish innovations by having smaller cross-sectional teams to have more informal discussion and idea sharing.

3.2.4. Takt time production

A controllable and predictable process and constant high quality of production has been in the spearhead of manufacturing industry for decades. Pursuing a controllable and a predictable process provides several advantages in product quality and productivity.(Cho, Erkoc 2009) For instance, steady workflow decreases inventory related costs and increases quality when rush hour related mistakes are excluded. In the manufacturing industry, the Takt time is one of the

key performance indicators and it is defined as time between the starts of the products.(Strategos Inc. 2007)

The concept of Takt time production in the construction industry is based on experience from the manufacturing industry. It can be represented as a production train, which travels through a building in which each wagon representing distinct discipline (Figure 17). Each discipline works in a certain area for a given time and thus enabling predicable workflow as the production train flows through the building. Takt time production relies on repeatability, which is often neglected in a construction project.(Lean Construction Institute Finland 2015c) Traditionally construction projects are perceived as engineer-to-order products which has led to the resource enhancing production paradigm which nurtures the idea of full resource exploitation of labor and machines.(Dallasega, Rauch et al. 2018) In reality, productivity is extremely low, even though the labor and machines are almost fully exploited.

Fragmentation and sub-optimization of a construction project are seen as troublemakers. In successful Takt time production these issues need to overcome since it would be difficult to control the whole supply chain without the collaboration of all necessary stakeholders. Optimization of the whole supply chain requires tight information flow throughout the supply chain so that concurrent development of the project is known and its effects can be analyzed for the subsequent steps. (Lean Construction Institute Finland 2015)

Implementation of Takt time production to the construction industry requires a deeper investigation of sub-processes involved in the construction. Takt time planning is vulnerable to error when the initial data end engineering concepts are changed after the production has started. Therefore, Takt time planning requires more from the designers to ensure smooth workflow.(Lean Construction Institute Finland 2015) Aforementioned issues are tackled by allowing a certain amount of buffer in each step, so when errors occur, some time is left to redo the emerged error.

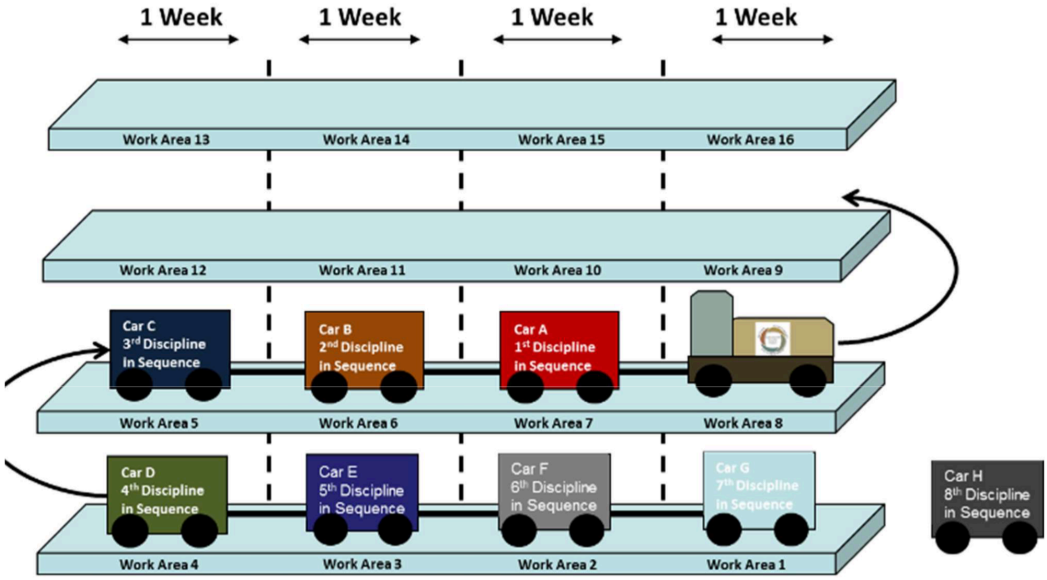

Figure 17. Production train (Seppänen 2018)

3.2.1. Cross-functional teams

Cross-functional teams are more widely known as Big Room collaboration in the construction industry. The former term is more self-explanatory: a project organization works as a cross-functional team in order to enhance information sharing and collaboration in order to tackle issues that have risen due to the fragmented nature of the construction industry. Big Room collaboration is preferred to start in early steps of a project to ensure that all parties involved with the project have the same knowledge of the project and thus share their doubts, obstacles and ideas. Information sharing is crucial in construction since project parties tend to carry out their work on their own silos and disabling information flows that are perceived as low importance matter but which may have a significant affect in other disciplines.(Lean Construction Institute 2019)

Big Room itself does not promote creative collaboration if other tools are not introduced in Big Room. If considered creativity in a team, one should consider the composition of the team and how different individuals contribute to the entity. In terms of innovation, the Big Room can be fruitful since differently thinking minds from different backgrounds and professions are brought into the same space to excel

the project. Ideas are potentially shared when the threshold of speaking up and sharing ideas is significantly smaller that in regular projects, where communication is primarily done via email or in project meetings. Innovativeness is hardly a black box with a given input causing given output. Individual roles make the team and while demographic background affects collaboration and creativity, an atmosphere of trust and secureness facilitates innovative climate in the team.(Somech, Drach-Zahavy 2013)

While the concept of Big Room is to forge a temporary project team from all necessary stakeholders and facilitate collaboration to the project, one of the most crucial factors that is almost a prerequisite for a successful Big Room is the level of emotional intelligence possessed and obtained by the managers who are participating in the Big Room. Personal emotional intelligence consists of how an individual identifies his or her own feelings and also how he or she perceives and identifies that of others. A highly emotional intelligent person is thus capable of reacting correctly to the emotions of others in terms of support and motivation and is capable of understanding causes for emotional behavior. What is more, the creation of feelings and successful goal setting with right emotional strategy supports an emotionally intelligent person to thrive for success. Importance of emotional intelligence is therefore essential. (Love, Edwards et al. 2011)

Emotional intelligence in a sense of construction projects includes active listening and creative, alternative thinking among others, is particularly essential in Big Room collaboration when the target is to establish innovative and effective project team.(Love, Edwards et al. 2011)

3.2.2. Continuous improvement

In a real-life event, a representative of a large-scale enterprise, invited Japanese Lean professional from Toyota to assess whether their operation on the enterprise was cutting-edge Lean. After showing their production lines to this Japanese Lean professional, he was asked several times if he would assess this level of Lean of the

enterprise. The answer was "*I do not know, I was not here yesterday*". The underlying point of this Japanese Lean professional's answer emphasized the importance of culture of learning. At Toyota, this was called *Kaizen,* continuous improvement.(Modig & Åhlström 2016)

The concept of Kaizen, or continuous improvement, was greatly contributed by the aftermath of Japanese manufacturing industry after World War 2. After Japan was rebuilt from dust, the Japanese labor unions had strong support among the people which therefore affected the way how Japanese management practices had to develop relationship with "blue-collar" labor. This development had great impact on labor-driven innovation, which emphasized the labors' ability to suggest small scale improvements which would then be discussed and implemented after. Concurrent managerial perspective on this development proposes that people who actually conduct the work are those who develop their work for example in weekly or monthly team meetings.(Styhre 2001)

Kaizen in Lean is not merely learning from mistakes and setting specific KPI's to measure the performance. In the aforementioned example, the representative of the LSE wanted to know their "Leanness" with specific KPI's, the Lean professional underlined the importance of incremental learning and improvement. Figure 18 explains the concept more visually: the fluctuating line represents operation with learning in random places. This means that a company or a person, acknowledges that improvement can be done but the reflection for improvement is done randomly without consistent reflection for performance. Therefore, the development is never going to compound.(TEDx Talks 2014) The straight, ascending line represents a company or a person who is reflecting the performance constantly and thus capable to compound development over time. In addition, continuous improvement includes so called Plan-Check-Do-Act-cycle, or PDCA-cycle, thus generating constant improvement to the operation.

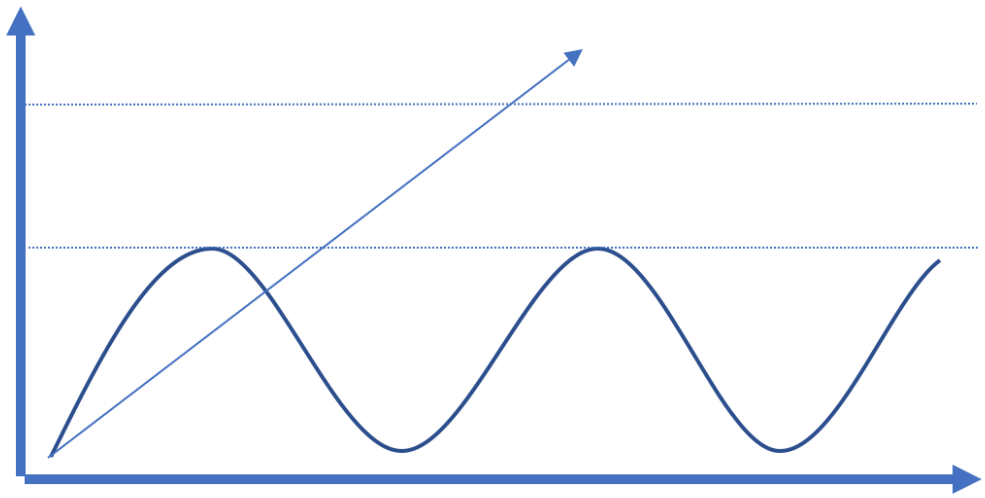

Figure 18. Kaizen development in a comparison with non-consistent development (TEDx Talks 2014)

4. Methods

In this chapter, the research design and methods are elaborated in more detail in order to shed light on rationale behind the chosen research methods. In addition to this, the process of the research is presented and explained providing details of how the interviews were conducted. The last part is concerned with reliability and validity providing information about the robustness and biases of different kind in this thesis.

4.1. Research design

A research design can be described as an "onion" with several layers that affect the way a research is conducted.(Saunders, Lewis et al. 2009) The onion is a framework for research as a whole and it clarifies the path to a research while also giving information about the possible constraints in a given research design. While the research as a process is highly iterative requiring back-and-forth movement, research design can be expressed as distinct and chosen steps. The research onion can be seen in figure 19.

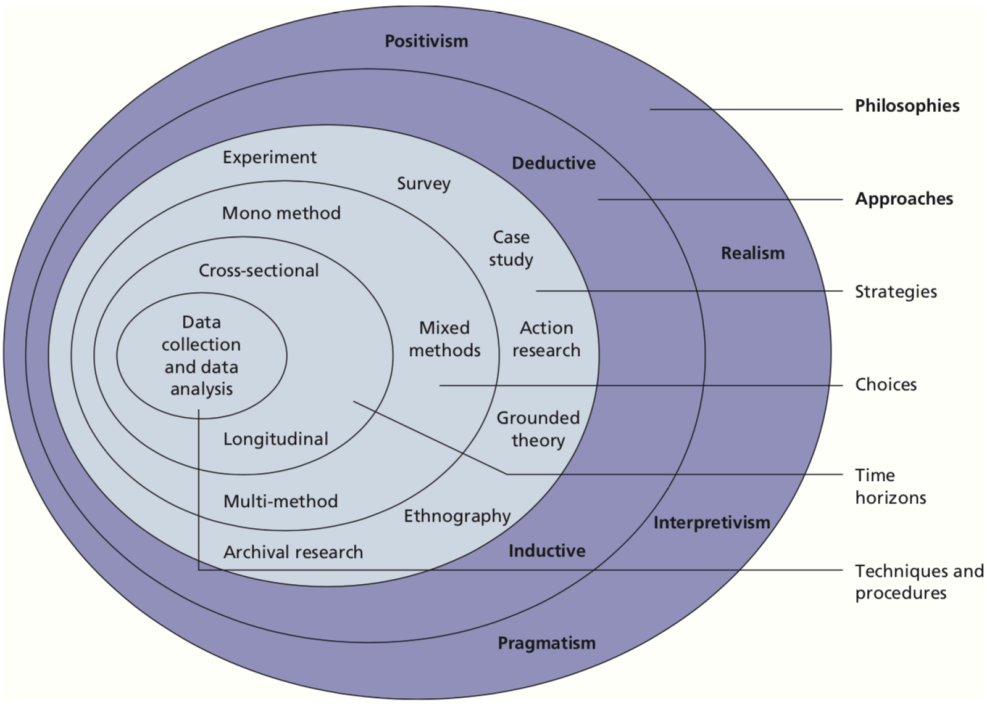

Figure 19. Research design "onion"(Saunders, Lewis et al. 2009)

One important theme in research is to think how knowledge is understood by the researcher. The research philosophy paves a path to further research design as it lays foundation of how new knowledge is perceived. Saunder and Lewis (2009) define these as "assumptions about the way in which you view the world." The research philosophy embraced in this thesis was interpretivism which enhances the term of "individuals as social actors". Interpretivism perceives individuals in their social context on the contrary of mere objects, in other words, comprehending social differences between individuals. An interpretivist researcher is therefore interested in "how people, as individuals or as a group, interpret and understand social events and settings."(Eriksson 2016) An interpretivist philosophy is therefore useful in the context of this thesis, where it is aimed to explore and understand a social phenomenon and how it is perceived.

For the same reason as in justification for the chosen philosophy, an inductive research approach was employed. In the inductive approach, a researcher would consciously conduct his or her research which is seen in the nature of how research

questions are formed and how the data will be collected and how the data will be analyzed. An inductive approach also gives opportunity for substituting the explanation for the investigated phenomenon, whereas the deductive approach might hinder that chance. The purpose of this thesis from the beginning was to explore and investigate certain phenomenon rather than make the generalizations of the gathered data. The inductive approach suits this purpose fine.(Saunders, Lewis et al. 2009)

Research strategy plays and important role in a research design and it directs other steps in research design as well. Decision for research strategy emerges from research questions and how the research aims to answer them. Having this in mind, case study strategy was chosen for this research for its capability to gain "rich understanding of the context of the research and the processes being enacted."(Morris, Wood 1991) In addition, an explorative nature of the strategy is particularly helpful when the research aims to find out "what is happening; to seek new insights; to ask questions and to assess phenomena in a new light."(Robson 2002) Since Lean construction as innovation driver is not researched widely, explorative study suits this research well.

Case study strategy is often selected when research is focused on researching a phenomenon in its real-life context. Case studies often employ interviews, like in this thesis, with triangulating the collected data. Triangulation decreases chances to make false assumptions and ensures that the collected data is interpreted correctly by testing collected data with another data. In this thesis, triangulation is done by analyzing interviews from several different sources, as it would not be sensible to use other methods, such as the questionnaire, in this explorative study where the researched phenomenon is still in its infancy and does not have great number of practitioners.

The way the data is collected is defined by methodological choices. Mono-method qualitative study methodology was employed in this thesis. The data was collected only from the interviews, where the interviewees were experts in the topic.

The time horizon of a study refers to the perspective of time in the study. The cross-sectional time horizon is more of a "snapshot" of the study, whereas the longitudinal time horizon takes the series of "snapshots". The difference in other word is that in the longitudinal time horizon the investigated phenomenon might change over time, but in the cross-sectional time horizon the study conducted deals only with a phenomenon in a given time. The time horizon in this study has cross-sectional perspective.

4.2. Research process

The research process in this thesis was highly iterative, in a similar vein that most researches using similar research design are. This has deepened the knowledge and purified this thesis to what it is when finishing. This subchapter elaborates the research process and explains each step in more detail, which are shown in Figure 20.

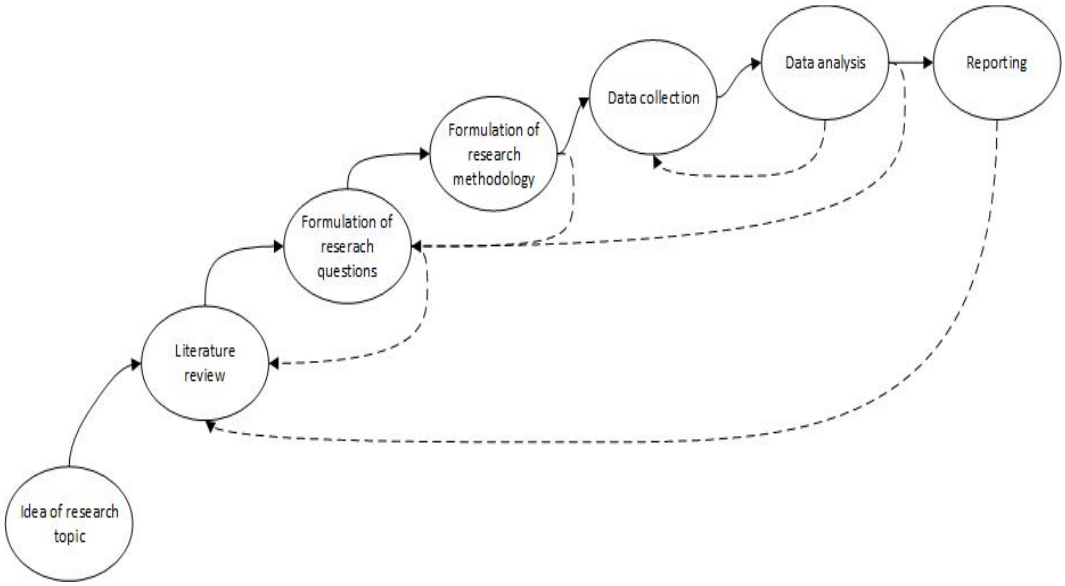

Figure 20. The research process

The idea for this thesis was to merge to subjects into one domain. After several ideas, the investigation of Lean construction from the innovation point of view was developed. Research questions were formed relatively quickly during the literature view as it turned out that Lean construction in Finnish construction industry was a

relatively new concept and not much effort was put on examining innovation within this new business environment.

Research methodology found its path after moulding the research questions and after it came quite obvious that qualitative data gathering should be favoured. Chosen research methods were stated and written down before any of the interviews were conducted. By doing this, it was easier to put focus on how interview questions should be formed and how these questions are helping to answer research questions. The data was gathered from after the research methodology was decided. The next chapter elaborates on how the interviews were held and how chosen interviewees were chosen.

4.2.1. Interviews

The interviews were semi-structured interviews in which it was possible to ask specific questions from the interviewees during the interview. Moreover, it was anticipated that some of the interviewees would have more than comprehensive knowledge concerning Lean construction, consequently giving more rich aspects than it would be possible within a structured interview. Indeed, some of the interviews lasted over an hour whereas the shortest ones were twenty minutes long. The interviews were conducted as face-to-face interviews, except one which was conducted via Skype audio call. All of the interviews were recorded with interviewees' consent to it. Total of seven interviews were conducted and all who were invited happily accepted the invitation.

The interview questions were derived from the literature review, in combination with industry-related knowledge form practitioners keeping the focus on the research questions. The aim was to gather data as long as it is saturated in order to "full picture" of the researched theme. However, there were practical reasons that had an effect on data gathering. The fact that Lean in Finnish construction industry is relatively new phenomenon means that Lean knowledge in construction industry

is in its baby steps at the moment. Interview candidates with proper knowledge of this phenomenon are somewhat small proportion to the whole industry.

The criteria for choosing the interviewees was the expertness in either Lean in construction or innovation. All interviewees except one were highly involved in Lean in their current or previous work environment. Another expertness from the innovation domain was interviewed in order to have a view from the innovation domain and having an insight of the current innovation technology trajectories. In general, all interviewees can be defined as experienced professionals in their field of business. Table 1 depicts all interviewees and their positions in their companies in a broad manner, ensuring their anonymity.

Table 1. Interviewees' positions in their companies

Interviewee's position	**Interviewee's company**
Director	Large-scale construction enterprise
Manager	Large-scale construction enterprise
Manager	Large-scale construction enterprise
Manager	Small consulting firm
Director	Large-scale construction company
Director	Medium-scale construction enterprise
Director	Small consulting firm

4.3. Reliability and validity

Reliability of a study relates to the findings of a study and whether these same findings would have discovered by another researcher. One way that affects reliability is interviewer bias. Interviewer bias was considered during the whole interview process so that as high reliability as possible could be gained. Interviewer bias is extremely difficult to tackle, since it arises from the way interview questions are formed and how they are asked, also in non-verbal manner. Underlying beliefs are source for this bias and most often it cannot be detected by the researcher. In order to overcome interviewer bias, commenting on interviewees' answers were kept as minimum as possible, preventing to impose of the researcher's own beliefs. Another reliability-weakening bias is interviewee bias which is related to

interviewee's ability or will to answer and elaborate on questions and themes. Interviewee bias is usually identified at highly controlled environment, where interviewees might feel insecure. The participants of the interviews were all either in managerial or directorial positions, therefore they might have had a higher degree of freedom of speech. In addition, all interviewee identities are kept anonymous in this thesis.

Validity is of a study is concerned with whether the analyzed data is really what it seems and whether right research design is employed for a given topic. In order to enhance validity, the interviewees were carefully picked by their role, past experience and expressed knowledge of the topic researched. However, given that professionals at this topic are scarce in Finland, the number or interviewees was not as high as it could be, resulting in a weaker saturation of the interview data. Some themes attained greater saturation than others and some interesting themes were found, but it would be difficult to judge that emerged themes would be true exactly how it was discovered in this thesis. Therefore, any generalizations would be difficult to back up as there would be most probably emerge other themes than these which were discovered. Further investigation on this topic should be conducted if a high level of confidence and saturation could be attained.

5. Results

In this chapter, the findings of the data that was gathered from the interviews is presented based on the themes that had been discussed in the interviews. After presenting the findings, discussion analyzes the findings and provides answers to the research questions together with recommendations. The final part provides the summary of this thesis.

Lean philosophy in the Finnish construction industry is relatively young. The earliest touches to Lean construction by the interviewees were mentioned in the early first decade of 2000 from various distinct sources. Some of the interviewees had developed deep knowledge about Lean in construction at the first try, whereas some had heard of it but were not convinced or understood fully the methods derived from Lean. The first connection to Lean construction had several ways too. The first buzz around this topic seemed to happen around 2006 when researchers from VTT initiated Last Planner implementation to the construction industry. However, for some reason these initiatives did not see break through.

Greater audience for Lean in Finnish construction industry was gathered as several larger initiatives were started, namely TUKEFIN1 and LCIFIN1 where some of the interviewees had developed deeper knowledge about Lean and Lean construction. These two initiatives were focusing on productivity and client satisfaction improvement and especially LCIFIN1 was focusing on Lean implementation to the industry. Both of these initiatives had multiple cooperation partners of which a few were in leading positions their industry segment. Arguably this have had a serious effect on awareness of Lean in the industry. Although the industry had these initiatives, knowledge from university was mentioned also as a source and a starting point for Lean philosophy.

The term *Lean construction* itself caused discussion and did not have clear and distinctive description. It could be detected from the interviews, that Lean construction had rather many perceptions ranging from the customer-oriented

philosophy, human-centered mindset to actual methods, such as Takt time planning and Last planner.

However, almost all respondents perceived Lean and Lean construction as a philosophy focusing on adding value to the customer ultimately empowering employees in the change. This could be perceived from the data as well, since some interviewees told that they had faced similar process improvement initiatives in their companies earlier. These earlier initiatives were not called Lean or Lean construction, but they had similar approaches with Lean.

The relationship between Lean construction and innovation was rather multi-dimensional and was perceived from several angles. First of all, the definition of innovation was understood from different contexts. As discussed previously in this thesis, innovations were distinguished into the product and the service, the process, the paradigm and the position innovations, each having two dimensions ranging from incremental to disruptive innovation. Innovations as a definition were mostly perceived as product and service or process innovations with incremental or disruptive nature. Moreover, the distinction between disruptive and incremental innovation was seen rather decisive in terms of innovation definition. Whether small steps in processes, such as new ways of conducting a meeting, could be defined as innovations, had opinions. In a similar vein, could innovations be defined just merely as something game-changing and concrete, had advocating thoughts. This underlying comprehension of innovation definition could also affect awareness of detecting innovations and particularly innovations in which Lean has been employed as a driver. Most concrete examples of innovations where Lean has been a driver were process innovations related to prefabricated mechanical installations which have employed the Takt time method in the installation phase. These innovations could be categorized in the more radical end of the radical-incremental spectrum, whereas the new-type-of-meeting-procedure innovations fill the incremental end. No examples were given to these tiniest innovations and it could be that these kinds of innovations are not usually recognized as innovations, but more of a “best practice” style procedures.

What was mentioned as drivers for innovation, few drivers were brought up during the interviews. Collaboration in the construction industry was mentioned as one of the most important drivers for innovation. In terms of Lean in construction, collaboration could be interpreted as overarching practice. Collaboration in the construction industry is mostly formed as integrated project deliveries, Big Room activity, Last planner, which all are methods of collaborating and which enables stakeholders to gain a holistic view of a project. Moreover, collaboration with an atmosphere of trust was said to remove barriers between stakeholders. Few interviewees discussed the current practices in projects that lead to distrust and an atmosphere of fear. The reason for this was said to emerge from managerial tradition to find out who is guilty for mistakes. Consequently, one of the biggest challenges is to form this atmosphere of trust in the project, so that each stakeholder is able to speak up and share thoughts and ideas without fearing that she will be judged. Integrated project deliveries might also pave the way for innovations.

The most concrete example of product and services innovation driver what was discussed was Takt time planning and production. Some of the interviewees and their companies where worked at, where heavily putting effort on Takt time production. It was also mentioned as the most important Lean-driven innovation method. While such optimism was brought up, the difficulties of the Takt time implementation were also brought up. Especially one interviewee had a concern whether the Takt time, and Lean philosophy in general, would decrease the level of freedom of the labor, subsequently undermining trust between the labor and management.

In a close connection to trust and freedom, another interviewee underlined the importance of empowering people and giving an example of how Kaizen works as a development mechanism utilized by the labor itself. The argument was that the labor knows the best their work and they the best to fix and develop their working environment. This empowering argument and the concern of decreasing the level of freedom in the work is somewhat in contradiction.

It was pointed out that some integrated project delivery methods, such as alliance project delivery, embed innovations as one of the strategic goals in a project. The aim is to find better solutions and decrease costs by innovating in an alliance project. These integrated project delivery methods, as well as continuous learning, may generate a systematic procedure for innovation. It encourages project participants to share ideas and coming up with new solutions and improvements.

When it comes to hindering factors related within innovations in the construction industry, present contractual models could be observed as a major barrier to innovativeness in the industry. As explained by some interviewees, the industry typically delivers projects so that the stakeholders are working in their own silos without comprehensive collaboration. As pointed out by one interviewee, contractors might get their work plans from a designer ready for implementation, which are assumed to be implemented with as little money spent as possible. Therefore, contractors might feel that it would be useless to develop anything if the main purpose of a construction project is to minimize expenditures. It was also pointed out that the prevailing atmosphere in the construction industry is highly pervaded with fear and command and control. It was not solely contractual models which gained criticism towards innovativeness in the construction. Prevailing culture was mentioned also as a barrier in the innovation activity and more precisely in the adaptation of new innovations. The prevailing culture in practice was expressed as mindsets that are cautious for new innovations and which state that development should not be done since there has not been development in the past, it should not be done now.

In addition to present contractual models, the lack of incentives to innovate were brought up in the interviews. This constraint was condensed by one interviewee stating that companies do not live in an economy of scarcity, meaning that companies still earn their profits reasonably well and efforts to innovate would threat this equilibrium. Some managers may see innovation as a concept that endangers business processes that have brought welfare to them.

6. Discussion

In this final chapter of this Thesis, preceding results from the interviews are discussed with the context of literature review with recommendations derived from the analysis. In addition, the research questions provided in Chapter 1 are answered in the conclusions. Finally, fruitful topics for further research are presented.

6.1. Conclusions

One of the targets of this thesis was to explore whether Lean philosophy drive innovations in the Finnish construction industry and if does so, what would be the nature of such innovations, in terms of the 4Ps model discussed previously in this thesis. First of all, innovation is a broad theme and does have several interpretations what can be called an innovation and what cannot. Innovation as a term have dimensions from economics to even politics and so how innovation as a term is perceived, may depend greatly on whom it is asked. However, the 4Ps model is quite a comprehensive tool concerning the definition of innovation and is an extremely useful tool for defining the dimension of an innovation.

6.1.1. The role of Lean as a driver for innovations

One aspect what should be pointed out if this thesis is that collaboration throughout the industry could have a positive effect on innovativeness in the industry. Removing the barriers of collaboration in the projects, such as contractual models that diminish the voice of all stakeholders could lead to better innovativeness.

The role of Lean philosophy in collaboration-enhanced methods is quite pivotal. Last Planner for example was developed to overcome errors in weekly task execution, counteracting these errors with collaboration.(Ballard 2000) As these collaborative project delivery methods become more popular, it is crucial to pinpoint the emotional intelligence skills of managers. They are in a pivotal role when these different collaborative methods are employed, and they are responsible

for their success. In terms of innovation, emotional intelligence skills, such as active listening, help to build an atmosphere of trust where innovation can be nurtured.(Love, Edwards et al. 2011)

The role of Kaizen should be emphasized in projects so that incremental improvements are brought up, discussed and implemented. While continuous improvement may not seem to have game-changing effect at first hand, the impact over time is much greater due to the compounding effect. Most probably the incremental innovations what was mentioned in the interviews, are the product of continuous improvement in the integrated project delivery methods. Such improvements have been observed in other studies earlier.(Suttie 2013)(Pease 2018) Aforementioned themes are represented in Figure 22.

Another aspect that can be pointed out of this thesis in terms of innovation is Takt time. The level of confidence with Takt time was not as clear as collaboration and integrated project delivery methods, but some companies have already put effort on process innovations that employ Takt time as their foundation and stated that Takt time will most likely be driver in innovations in the future. Some companies already have applications for Takt time driven production and have conducted pilot projects. While the development of Takt time planning and production is still in its infancy, it can be expected that it could function as a driver in the future, if the development trajectory is somewhat similar than in manufacturing industries.

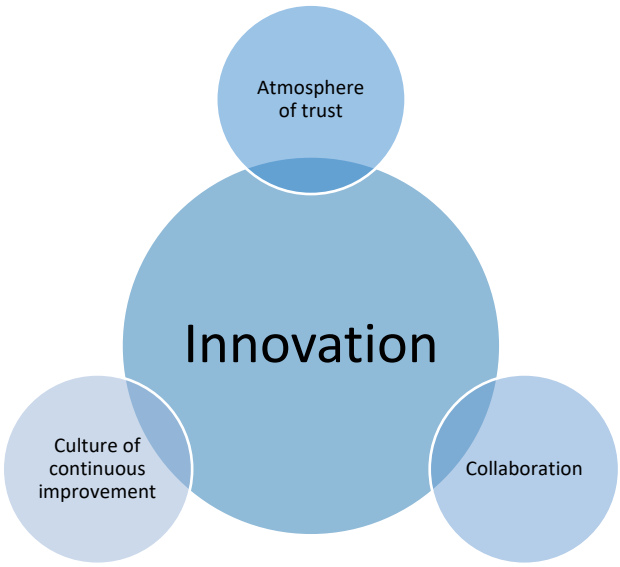

Figure 21. Drivers for innovation in Lean construction

6.1.1. Perceptions about Lean construction

If innovations are perceived as a threat to current business models that threatens companies' profits, what some Finnish construction companies may possess, innovativeness should be nurtured collectively in a way that the benefits would be collective too. It is most likely that the innovativeness in the industry will not see major breakthroughs if the companies are not incentivized to innovate. The role of contractual model is therefore essential. The construction industry in Finland is fragmented and together with contractual models that do not emphasize common goals and innovation, are hindering innovation activity in the industry.(Rakennusteollisuus Ry 2012) In order to counteract low innovativeness caused by fragmentation, integrative project delivery methods which include enhanced collaboration, are perceived essential. Moreover, respect for people was perceived as an enabling factor for successful project deliveries. These are in line with the current development which aim to enhance collaboration in the industry by favoring integrative contracts that enhance collaboration and collaborative methods. Procedures and contracts that level the risks and benefits of the project between all stakeholders are both accordance in the literature and pilot projects in

the industry.(Bossink 2004) Figure 21 depicts themes that emerged about how Lean construction was perceived.

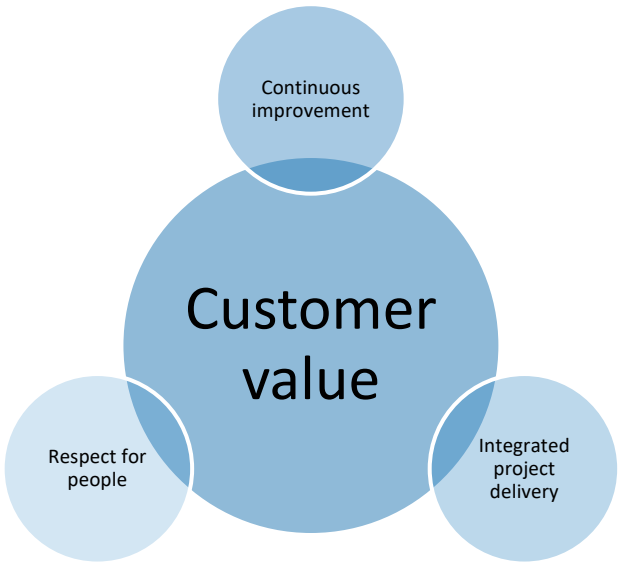

Figure 22. Perceptions about Lean construction

Takt time planning and production is one of the fundamental changes in the construction industry, changing the resource enhancing production to flow enhancing. Therefore, it is perceived as a major contributor for the development in the industry towards greater productivity and reduced errors. There are still doubtful minds that see Takt time as a development trajectory that decreases the autonomy of the labor thus decreasing motivation. In addition, Takt time planning and production is still in its infancy, and there are practical issues with the implementation.

While the development of Lean construction looks promising, a cultural change is needed in order to overcome implementation issues that arise from sceptic and conservative industry. Without a doubt, practitioners that are deeply familiar with Lean philosophy, are advocating its implementation. However, lean philosophy has been applied for a few decades in the industry, there are many practitioners who have not heard of Lean philosophy before. Overcoming this issue is far from easy,

but necessary for the successful and sustainable implementation of Lean philosophy.

6.1.2. Managerial implications

One of the reasons of why innovativeness is not emphasized in the construction industry is the current methods how projects are delivered. Project members are not seeking a common goal and when errors occur, effort is put on to find responsible for it. An environment of this kind is far from trustworthy and secure. Therefore, focus should be put on the level of goodwill trust between parties in order to create confidence. Moreover, an atmosphere of trust should be nurtured, so that all stakeholders feel safe to share their views and ideas. This finding is in line with literature that have concluded that innovativeness in team collaboration is affected by secureness and trust within the team and its' members.(Somech, Drach-Zahavy 2013) Moreover, the team composition itself affects innovation positively, when the stakeholders bear creative and different mindsets so that ideas can be refined and purified with other stakeholders' thoughts and interpretations.(Somech, Drach-Zahavy 2013) In relation to right mindsets in the projects, teams could exploit the theory of Open innovation by open barriers in the projects. In practice, this could be done by giving more emphasis on supply chain and interindustry development.(Vesa 2014) The voice of supply chain is often neglected in the project development phase, resulting in diminishing one important source of innovation.

In order to widen Takt time driven innovations in the industry, companies could consider exploiting it by watching pioneers' work and benchmark it afterwards. Therefore it would be beneficial for the industry as a whole, if it distributed lessons learnt from the pilot projects and develop Takt time planning and production further in collaboration. The fertility of Takt time driven innovation for major breakthroughs is considerable. Combining other technologies to the product, service and process innovations that were brought up in the interviews, could have significant opportunities for industry-level development. Sources for these kinds of

recombinant innovation could be acquired from business ecosystems, such as KIRAhub, that enhance digitalization in the industry.

Knowledge transfer in the industry is already in a good pace enabling companies to gather relevant information. For example, initiatives like LCIFIN1 provide up-to-date information on what has been done together with lessons learned provide a fruitful knowledge base for companies that intent to implement their own Takt time production. In addition to this, the theory of Open Innovation could be exploited. In practice, companies do not need to acquire the best and the brightest, as far as they nurture the importance of information sharing. Again, LCFIFIN-initiatives together with business ecosystems in the industry could be extremely beneficial for participating in companies to enhance their own innovation activity.

It is yet important to point out that the Lean as a paradigm has not been grasped in large-scale even though knowledge is spreading fast. The Lean philosophy in the Finnish construction industry is still relatively young and the construction industry have a reputation as a slow changer. Only time will shed light on the long-term effects of Lean philosophy in the Finnish construction industry.

This thesis constitutes to the body of knowledge, that collaborative methods derived from Lean enhance productivity, quality and innovation in the industry, when all project stakeholders share their understanding and the goals of what and how a project should be executed. These outcomes have been already seen in some projects in Finland, and it is now up to the industry, whether it puts effort on understanding Lean and implementing it.

6.2. Future research

As well as most studies, this thesis opens paths for further studies. This thesis explored qualitatively the emerging and fast-growing use of Lean philosophy in the Finnish house-building industry, and how the industry perceives Lean construction of the innovation point of view. Few obvious paths to further study emerge from

the method used in this thesis, or what was not investigated because of the research method used. One path is a statistical causal analysis of the relationship between Lean and innovation since this thesis did not investigate whether some Lean method conclusively provided a certain innovation.

This thesis employed cross-sectional research the time horizon and thus it provided a “snap-shot” of the explored phenomenon. Therefore, longitudinal study would provide precious information of the innovation trajectory shedding light how companies nurture the managerial aspects of Lean philosophy and how Lean-driven innovations are implemented and exploited in a given environment.

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Appendix

Interview questions

Domain 1: Lean Construction

1. When did you first hear about Lean Construction?
2. What is your opinion about Lean Construction?
3. How do you see the future of Lean Construction?

Domain 2: Innovations

1. How do you see Lean Construction from the innovation point of view?
2. What blocking factors you see in Lean construction implementation and in emergence of innovations?
3. Has Lean Construction produced innovations, and could you tell more about those?
4. Which Lean Construction method particularly drove that innovation?