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IMPROVING TAKT PRODUCTION'S MANAGEMENT OF SUBCONTRACTED LABOUR THROUGH THE METHODS OF KNOWLEDGE MANAGEMENT

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ABSTRACT

Maiju Örmä: Improving takt production's management of subcontracted labour through the methods of knowledge management
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Construction, as an industry, has not been able to improve its productivity as fast as other industries. Therefore, construction industry has begun to examine other methods that could improve the productivity. One new method is takt production, which aims to recognise the reoccurring tasks in construction production and to eliminate waste in and between them. In construction, takt production is, however, still rather new method and there has not been published much research about it. In addition, implementing a new production method requires often changes in the practices concerning it, such as in the labour management. This research was executed for a Finnish construction company that has in the past few years began to examine how it could execute takt production in its housing production. This research aimed to recognise how the case company should change its management methods for subcontracted labour to succeed in takt production.

This research targeted to improve the case company's takt production's management of subcontracted labour through the methods of knowledge management. In addition, the research aimed to create management methods for subcontracted labour, which functionalities would be tested through a case study. The research was executed as qualitative case study, which utilized observation and workshop as its data collection techniques. The research was able to recognise repeating themes form the collected data from which it was able to construct development proposals for the case company's management methods for subcontracted labour.

The research's key results formed a four topic model for the management of subcontracted labour in which the management methods are divided into meetings, communication channels, visual tools and education materials. In addition, the research recognised the key success factors of takt production's management of subcontracted labour. These success factors included efficient knowledge transfer, using only thoroughly tested technology, deliveries planned according to takt schedule, managing challenges and obstacles and commitment in takt production.

Keywords: Lean construction, takt production, knowledge management, management of subcontracted labour, knowledge sharing, communication, knowledge creation

TIIVISTELMÄ

Maiju Örmä: Tahtituotannon aliurakan johtamisen parantaminen tietämyksenhallinnan menetelmin
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Rakentaminen alana ei ole pystynyt parantamaan tuottavuuttaan muiden alojen tavoin. Tämän vuoksi rakentamisessa on alettu tutkia uusia toimintatapoja, joiden kautta tuottavuutta voitaisiin parantaa. Yksi uusi menetelmä on tahtituotanto, jonka tavoitteena on tunnistaa rakentamisen toistuvat työvaiheet ja poistaa hukkaa niistä ja niiden väliltä. Tahtituotanto rakentamisessa on kuitenkin vielä melko uusi menetelmä, eikä siitä ole olemassa paljoa julkaistua tutkimusta. Lisäksi uuden tuotantotavan käyttöönotto vaatii usein muutoksia muissa siihen liittyvissä käytännöissä, kuten työn johtamisessa. Tämä työ on toteutettu suomalaiselle rakennusalan yritykselle, joka on viimeisten vuosien aikana alkanut tutkia, miten se voisi toteuttaa tahtituotanto asuntorakentamisessaan. Tässä työssä pyritään tunnistamaan, miten kohdeyrityksen tulisi muuttaa aliurakan johtamiseen liittyviä käytäntöjään tahtituotannossa menestymiseksi.

Tämän työn tavoitteena oli parantaa kohdeyrityksen tahtituotannon aliurakan johtamista tietämyksenhallinnan menetelmin. Lisäksi tavoitteena oli luoda aliurakan johtamiskäytännöt, joiden toimivuus on testattu tapaustutkimuksen avulla. Työ toteutettiin laadullisena tapaustutkimuksena, jonka datan keruu menetelmiin lukeutui havainnointi sekä workshop. Kerätystä datasta pyrittiin tunnistamaan toistuvia teemoja, joiden kautta työssä voitiin rakentaa kehitysehdotuksia kohdeyrityksen aliurakan johtamiskäytäntöihin.

Työn keskeisimpinä tuloksina muodostettiin neljä teemainen aliurakan johtamismalli, jossa johtamiskäytännöt jakautuivat palaverien, kommunikaatiokanavien, visuaalisten työkalujen sekä perehdytysmateriaalien alle. Lisäksi työssä tunnistettiin tahtituotannon aliurakan johtamisen keskeiset menestystekijät. Näihin menestystekijöihin lukeutui tehokas tietämyksen siirto, kokonaisvaltaisesti testatun teknologian käyttö, toimitusten suunnittelu tahtituotannon vaatimusten mukaan, haasteiden ja esteiden johtaminen sekä sitoutuminen tahtituotantoon.

Avainsanat: Lean rakentaminen, tahtituotanto, tietämyksenhallinta, aliurakan johtaminen, tiedon jakaminen, kommunikaatio, uuden tiedon luominen.

PREFACE

This research concludes my studies in Tampere University. During my studies, I have gained the most valuable knowledge, experiences and friendships that will last a lifetime. Even if the years have not always been easy, they definitely have been the best ones I have had. Although writing a thesis can be rather lonely task, there are several people who have guided and supported me through the process. First of all, I want to thank all the amazing people in the case company who have unselfishly offered their help and expertise. In addition, I want to thank my professors Nina Helander and Kalle Kähkönen for the guidance and support they have given me. Most importantly, I thank my wonderful family and friends without whom I could not have finish this paper and my studies.

Helsinki, 20 May 2019

Maiju Örmä

CONTENTS

1. INTRODUCTION

1.1 Research background

Construction industry is the largest sector in the world economy with approximately 10 trillion annual revenues. However, compared to other industries, construction has much lower productivity and it has not been able to adopt new technologies as fast. (BCG 2016; McKinsey 2017) As other industries have been able to transform themselves rather quickly in the age of digitalisation, construction has only taken slow steps towards development (McKinsey 2017).

Conventional construction is often compared to craft production, where it is common to use specialists to produce products one by one to the customer. Compared to mass production, craft production can be described slow and expensive. (Forbes & Ahmed 2011, p. 46, 58) Also, construction is often project-based, which can make it harder for them to improve their productivity. If, however, even some phases of the projects could be considered as processes, standardisation of these processes could benefit the improvements of the productivity. (McKinsey 2017) For example, in housing production, the building projects often consist the same steps even though the location and the scale may vary. Therefore, housing production could benefit from the mass-production approach when examining its productivity.

Lean production can be described as a combination of craft production and mass production (Womack et al. 2007, p. 10-11; Forbes & Ahmed 2011, p. 46). Lean construction utilises the lean production methods in construction and aims to improve productivity (Koskela 2019). Nevertheless, to successfully implement lean production methods to construction, the differences between construction and manufacturing should be understood. When adjusted in the context of construction, lean methods have, among other advantages, potential to increase a construction project's productivity.

Takt production is a production method based of lean construction. It examines the production through carefully determined processes, locations and durations. The production is seen as a flowing entirety and its processes is described through standardised set of tasks. These set of tasks and their locations are then described in detailed schedule. (Dlouhy et al. 2016) Many researches show that takt production has potential to reduce

the lead-time and thereby improve the productivity of the construction projects (Binninger et al. 2018; Chauan et al. 2018; Heinonen & Seppänen 2016). However, when the schedule is done in more detailed level, the production control should be more detailed too. Many researches give detailed instructions how the takt production plan should be done but fewer focus on how the management methods should be changed to ensure the productions success.

In a highly competitive business environment such as construction, knowledge can be considered as an organisational asset (Dang et al. 2018). In construction, where the production is often project-oriented, knowledge management can be seen as an important resource since it can offer advantages to organisational innovations and project success (Bishop et al. 2008). However, managing knowledge in construction can be much harder than in other industries. The employees tend to change a lot due to the project-based production taking their knowledge with them. (Dang et al. 2018) Moreover, as construction projects are often unique and separate entities, they contain a lot of learning and new knowledge. Efficient use of the methods of knowledge management could advance the construction project's use of this new knowledge and ensure the following projects could utilise the learning done during the project. (Giridhar et al. 2018)

1.2 Research topic and the case company

This research examines the management of subcontracted labour in takt production and how the methods of knowledge management can improve it. The topic was chosen through the case company's recognised need to determine the management methods of subcontracted labour. The need was recognised during the case company's first takt production pilot.

This master thesis is written to a Finnish construction company concentrating on their housing production. The case company is a rather new company, which has gone a rapid growth during the past decade. One of the case company's goals is to improve their productivity in housing production, which has led the company to examine takt production as a production method.

The case company had already executed a takt production pilot in one of its housing production's construction sites, and the pilot seemed to have had positive impacts on the production's lead-time. However, the case company's research in the first pilot site recognised a need to determine the management methods of subcontracted labour. In addition, the research executed identified issues in the existing management methods and recognised areas where to focus on the following takt production pilots.

1.3 Targets, scope and the research questions

This thesis aims to create new management methods for subcontracted labour through the methods of knowledge management. The goal is to form a set of management methods for subcontracted labour that will support takt production. This research aims to give proposals for the management of subcontracted labour, which functionality have been tested through a case study.

This thesis will answer the following main research question:

- "How the management of subcontracted labour can be improved through the methods of knowledge management in the context of takt production?"

In related to the main research question, the research answers the following sub questions:

- "What are the main issues and challenges in the case site's management of subcontracted labour?"
- "What are the key success factors of the management of subcontracted labour in the context of takt production?"

The research limits in the case company's housing production. Since the case company utilises takt production during this research only in the indoor phase, the research excludes all other phases of the housing production. Furthermore, this research focuses on the management of subcontracted labour. The management process is examined through knowledge management and the given proposals are formed based on the methods of knowledge management.

1.4 Structure of the thesis

This paper divides into eight main chapters. Figure 1 presents the chapters and their contents. After introduction, the second and third chapter explain the theoretical background. The second chapter explains the concept of takt production. First the chapter explains productivity in the context of construction industry and how construction industry differs from manufacturing. After that, the chapter explains the concept of lean and lean construction and examines the method of takt production. The third chapter continues the theoretical background by defining the methods of knowledge management relevant to this study. This chapter examines for example knowledge creation and knowledge transfer.

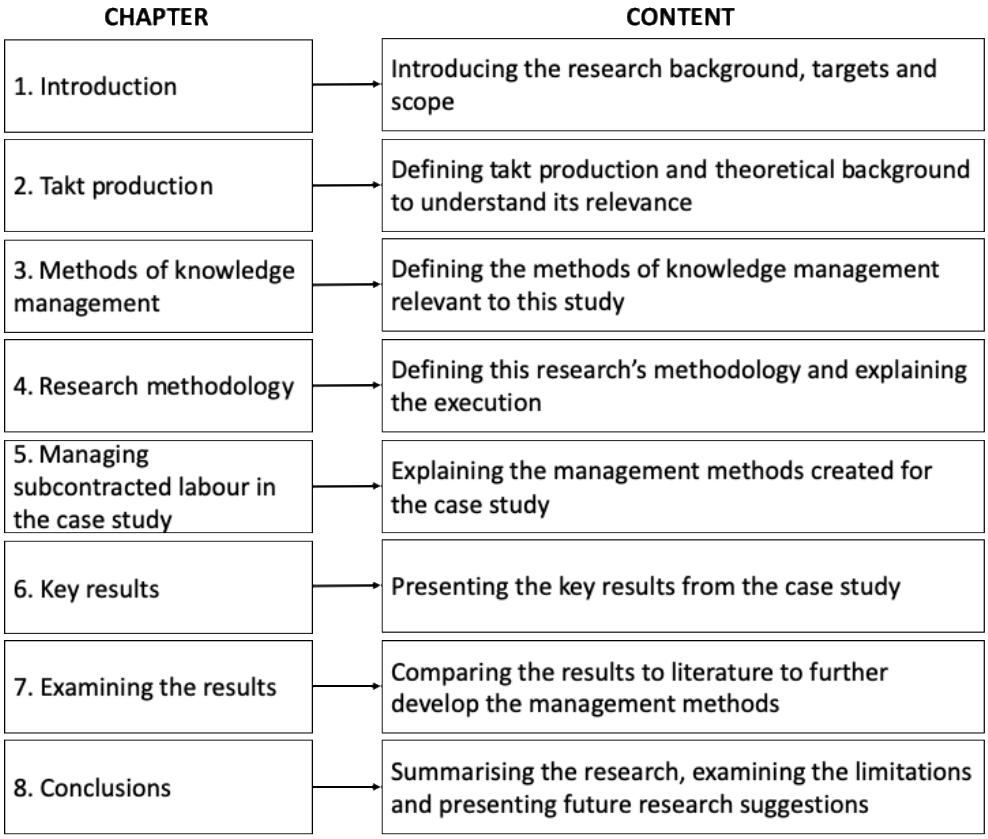

Figure 1. *The research phases and the structure of the thesis.*

The fourth chapter explains the research methodology. The chapter explains the constructive research approach and the research methods, i.e. workshop and observation. This chapter also introduces the case site in which the case study is executed. After that, the fifth chapter explains the management methods for subcontracted labour, which were created for the case study.

The sixth chapter presents the key results from the case study. The chapter combines the results from the observation and the concluding workshop. After that, the seventh chapter analyses the results of the case study and examines, how the management of subcontracted labour could be developed in the future. Finally, the eighth chapter summarises the research, examines its limitations and presents the future research needs identified during the research.

2. TAKT PRODUCTION

This master thesis examines the management of subcontracted labour in construction environments that utilise takt production. Takt production is a lean construction method, which aims to, among other advantages, increase construction's productivity (Binninger et al. 2018; Chauan et al. 2018; Heinonen & Seppänen 2016). Lean construction utilises the methods of lean production, which have been created in manufacturing environment (Koskela 2019). This chapter explains the concept of takt production. To understand the use of takt production better, this chapter begins by examining productivity in the context of construction, how construction differs from manufacturing and how the lean thinking can be utilised in construction. After this, the chapter presents takt production.

2.1 Productivity in construction

With approximately 10 trillion annual revenue, construction industry is considered as the world economy's largest sector (BCG 2016; McKinsey 2017). Construction industry differs from many other industries by for example its dependence on the public-sector and its numerous regularities (McKinsey 2017). Even though construction industry is economically the largest sector in the world economy, it has not been able to improve its productivity as fast as other industries (Forbes & Ahmed 2011, p. 1–2; McKinsey 2017). For example, in the last two decades world economy has been able to increase its labour productivity for 2.8 percent per year and manufacturing industry alone has increased its labour productivity 3.6 percent per year. The same time construction industry has only increased its labour productivity for one percent. (McKinsey 2017)

The term productivity is often used in various context. Productivity can be examined in different levels, and the exact definition is partly dependent on the examiner. (Uusi-Rauva 1997, p. 16) Nevertheless, when the productivity is measured, often described as the ratio between outputs and inputs of the matter examined (Uusi-Rauva 1997, p. 20). Uusi-Rauva (1997, p. 31–33) defines productivity as one of the elements of profitability. He describes the relationship between productivity and profitability improvements as a cycle. The cycle indicates that increasing productivity enables profitability to improve. This leads improvements in the requirements of the increasing productivity. Therefore, it can be said that increasing productivity is important for an organisation to improve its profitability. The figure 2 shows the cycle for increasing productivity.

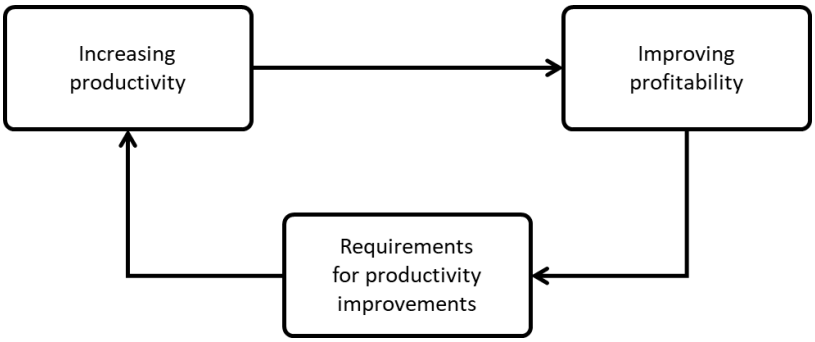

Figure 2. *Cycle of increasing productivity (after Uusi-Rauva 1997, p.33).*

Although productivity is traditionally seen as a quantitative meter, Forbes & Ahmed (2011, p. 23) argue that in construction industry productivity is typically considered more qualitative. They point out that productivity in construction is more complex than in manufacturing, which makes it harder to measure. In addition, they suggest that productivity is still largely unmeasured in construction. As an example, they argue that traditional construction project management tools examine deviances on schedule and costs rather than focusing on productivity. Furthermore, in construction, the projects are often evaluated by their ability to maintain the set production time, budget and quality. (Forbes & Ahmed 2011, p. 42)

However, Forbes & Ahmed (2011, p. 28–31) have identified factors, which have effects on the productivity of construction. According to them, one of the major causes of the poor productivity in construction are ineffective management practises. Forbes & Ahmed (2011, p. 28) identify four management practices, which improvements could improve the construction productivity: 1) planning, 2) resource and supply control, 3) supply and information feedback, and 4) selection of the right people to control certain functions.

In addition, Forbes & Ahmed (2011, p. 29) identify the increasing use of subcontracting affecting on the productivity. They argue that when majority of the work is executed by subcontractors, it causes fragmentation in the project teams. Also, the pricing is often biased when subcontracting and the subcontractors might have to work with small budgets. The decision about which subcontractor is chosen, is often based on which subcontractor has the lowest bid (Forbes & Ahmed 2011, p. 42). This often compromises both quality and productivity (Forbes & Ahmed 2011, p. 29).

Although, the construction industry's poor productivity has been generally acknowledged, Forbes & Ahmed (2011, p. 2–3) argue that improving productivity has not been the focus on the industry. The industry still lacks methods that could unite the construction processes. In addition, productivity in construction is affected for example by the industry's strict regulations and environmental factors, such as weather conditions.

Forbes & Ahmed (2011, p. 2–5) state that construction industry needs new and innovative approaches to improve its productivity.

2.2 Differences between construction and manufacturing

Construction is often project-based (McKinsey 2017). The projects are unique entities since they are usually never designed or built the same way as earlier projects. Although a project usually contains many similar elements as earlier projects, the actual construction processes and activities often require adjustments to be suitable to this project particularly. Thus, the workers must undergo a learning curve in the beginning these activities. (Forbes & Ahmed 2011, p. 30)

Van Wassenaer (2017, p. 26) defines that a successful project must have a predetermined set of objectives. Traditionally, project management on construction concentrates on finishing the project within a given time and budget and fulfilling the construction codes. Construction projects often, however, overlook the customer satisfaction as the construction is executed to meet the construction codes in the minimum standards. (Forbes & Ahmed 2011, p. 42) The project management often must react quickly on the production obstacles, such as obstacles that cause changes on the schedule. These obstacles are often caused by unexpected happenings or poor communication. The quick reactions are usually aiming to maintain the schedule but often at the expense of additional costs. (Forbes & Ahmed 2011, p. 58)

Although lean construction is based on utilising the methods of lean production in construction, it is important to understand the differences between these two. Forbes & Ahmed (2011, p. 60) argue that overlooking these differences might create barriers on applying the manufacturing methods on construction. Salem et al. (2006) identify three features in construction, which separates it from manufacturing. First, the construction production usually occurs on-site. Second, the production in construction is one-of-kind. Third, the construction production in more complex. Forbes & Ahmed (2011, p. 60) agree on these differences. They emphasise the construction's habit to produce its products based on individual orders, the production environment not being as controlled as in manufacturing, and the production durations often to be much longer than in manufacturing.

Unlike in manufacturing, in construction projects, the labour is often performed by subcontractors (Sacks & Harel 2006; Thomas & Flynn 2011). In addition, both Forbes & Ahmed (2011, p. 29) and Sacks & Harel (2006) state that the use of subcontractors is

increasing. Sacks & Harel (2006) suggest the reasons could be the growing specialisation of trades, changing need for construction services and the urge to reduce risk. According to Forbes & Ahmed (2011, p. 58), conventional construction centres on craft production methods, which are often carried out with specialists such as different subcontractors. The use of specialists is often based on individual contracts creating adversarial positions.

The subcontractors are often chosen based on the price of their bid (Forbes & Ahmed 2011, p. 42). The contracts usually determine penalties for example from underperformance. The subcontractor's profit is often the difference between the bid and the actual costs, which leaves several risks for the subcontractor. For example, the changes on material prices or on availability of labour might cause additional costs for the subcontractor. (Forbes & Ahmed 2011, p. 58). To be price-competitive, the subcontractors often offer minimally acceptable quality and concentrate on finishing their tasks as fast as they can (Forbes & Ahmed 2011, p. 42, 58). Also, Forbes & Ahmed (2011, p. 58) identify that the parties do not tend to communicate with each other as they are only concerned their own tasks.

Often in construction projects, there is a difference in the objectives of the main contractor's and subcontractors' project managers. Sacks & Harel (2006) state that as the main contractor's project manager is often very concentrated on the project, a subcontractor's project manager might work on several construction projects simultaneously. Thus, the main contractor's construction might not be a priority to the subcontractor. The subcontractors focus is rather on how it can optimise its labour on all projects to perform the work required. As the optimisation usually rely on predefined plans, the variations on these plans often complicate the subcontractor's ability to work. These variations can be for example changes on time, quantity or rate.

Although many contractors have developed its own practices to manage subcontractors, there has not been many publications about it (Thomas & Flynn 2011). According to Thomas & Flynn (2011), the subcontractor management can be divided into two: the management of work and the management of people. They state that the problems concerning the management of work is often related on the schedule. Therefore, main contractors should help the subcontractors to work on the given schedule by offering assistance. Also, the fluent and regular communication with the subcontractor can help to detect the problems on time. This can be done by for example arranging meetings regularly. Thomas & Flynn (2011) also state that the main contractor should treat each subcontractor equally. Same standards should be expected from each subcontractor, such as the safe working practices and tidiness.

2.3 Lean methods in construction

Lean thinking and lean production are based on Toyota Production System (Chiarini et al. 2018; Koskela et al. 2019). The Japanese car manufacturer Toyota created a production system that was able to produce cars in an efficient and consistent process. The manufacturing process resulted in cars that lasted longer and had higher quality than its American competitors. (Liker 2006, p. 3–5) Toyota's advantage in car manufacturing based in its ability to use operative excellence as strategic tool, develop its strategies, relationships, culture, management and teams, and sustain learning organisation (Liker 2006, p. 6). According to Liker (2006, p. 6), the Toyota Production System is based on 14 principles, which are utilised globally in Toyota's factories. These same principles form the Toyota Way model, which is more closely explained in chapter 2.3.1.

According to Liker (2006, p. 7), a lean organisation can be defined as an organisation, which executes Toyota Production System in all its functions. In other words, lean covers the whole organisation, not only the production. Lean thinking bases on an idea that a product 'flows' through processes that add value to it. All parts of the production, which do not add value are considered as waste and should be eliminated. The lean ideology is also based on the ideology of continuous improvement.

Lean producers concentrate on creating a value-added process flow, which means that all elements or actions that do not add value to the end product or service should be eliminates (Liker 2006, p. 27–29; Forbes & Ahmed 2011, p. 46). The elements or actions, which do not add value are called wastes. Toyota has recognised seven types of waste, which do not add value: 1) overproduction, 2) waiting, 3) unnecessary transportation, 4) over processing, 5) unnecessary inventory, 6) unnecessary motion, and 7) defects. (Liker 2006 28–29; Forbes & Ahmed 2011, p. 47–48). However, Liker (2006, p. 38) emphasises that even though lean is often seen as the production method that eliminates waste, waste elimination is only a third of the equation, which has made lean production a success.

Lean construction was first created to offer solutions for specific problems in the construction industry (Koskela et al. 2019). The aim was to adapt techniques from the manufacturing industry to improve construction industry's productivity (Forbes & Ahmed 2011, p. 52–53). Even though lean construction as a concept has become common in construction industry, the literature at the time does not recognise a single definition for it (Gao & Low, 2014). Nowadays lean construction has evolved from the practices to

specific problems into more comprehensive method for the industry. For example, according to Koskela et al. (2019), lean construction has lately become more about adaption of the methods of lean production.

2.3.1 The Toyota Way model

The Toyota Way model was created by Jeffrey K. Liker based on his 20-year-long research of Toyota (Liker 2006, p. 6). Liker (2006, p. 27) separates the Toyota Way from Toyota Production System by stating that Toyota Production System is the example of the accomplishments the Toyota Way can achieve in ideal cases. Liker (2006, p. 6–7) lists 14 principles that form the Toyota Way. The principles are divided under four parts: 1) philosophy, 2) process, 3) people and partner, and 4) problem solving (Liker 2006, p. 6). The principles and the parts are presented in figure 3 as a four 'P' model.

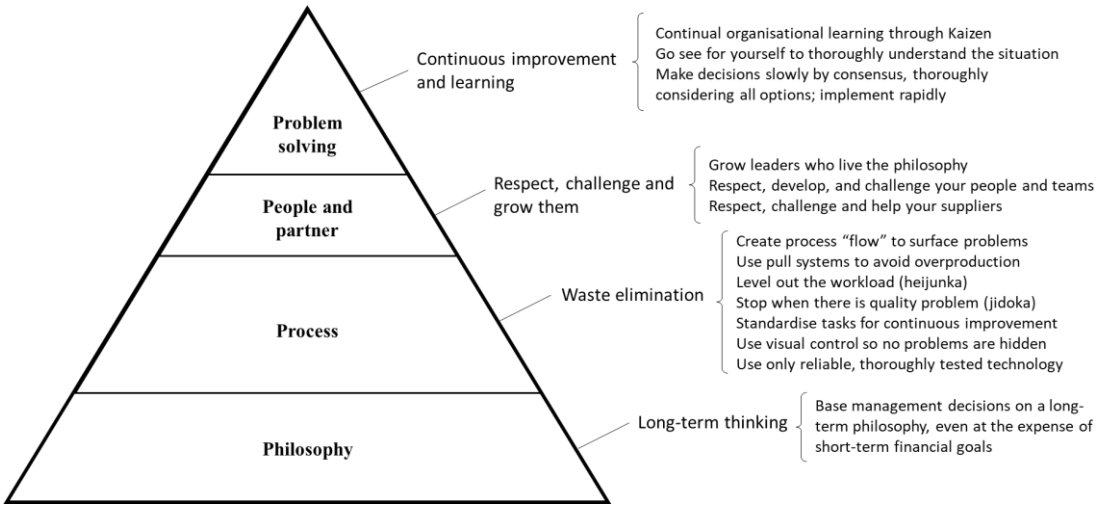

Figure 3. *A four 'P' model for Toyota Way (after Liker 2006, p.6).*

Figure 3 presents the Toyota Way model as an entity that contains all four parts. According to Liker (2006, p. 12–13), many organisations, which consider themselves as lean organisations, are mostly focusing in the process part of the Toyota Way model. Even though the process part contains many concrete practices, which can improve the organisations processes, lean reaches its full potentials only when executed as an ideology that reaches the whole organisation. Liker (2006, p. 41) also states that by using only few principles of the Toyota Way, the companies may accomplish short-term improvements, but do not achieve lasting results.

As stated before, the Toyota Way model and its principles are based on car manufacturing. As lean construction examines the utilisation of the lean production methods in construction, Gao & Low (2014) provide an insight how the complete Toyota Way model could be adapted to construction. They observe each part of the model as individual

models and transform the 14 principles of the Toyota Way to be suitable for construction industry.

The first part, philosophy, encourages in long-term thinking (Liker 2006, p. 7–9). The first part contains the first principle, which suggest that all decisions should be based on a long-term philosophy even if these decisions were in contradiction with some short-term financial targets. The principle underlines that the basis in all actions should be value creation. All activities should be evaluated based on how well it creates value for the customer, society and economy. (Liker 2006, p. 37) Gao & Low (2014) examine the philosophy model and its principle through constant purpose, customer focus, self-reliance and responsibility, and long-term perspective. According to them, especially customer focus is important in construction. This can be also applied in other operators in the field, such as subcontractors and suppliers. Gao & Low (2014) state that in construction, the customer needs tend to change rapidly. Therefore, construction organisations should be able to quickly react to the changing customer needs.

The second part is process. This part suggest that a right process produces right outcomes. The part emphasises waste elimination and utilises many Toyota Production System tools. This part includes seven principles: process flow, pull system, levelling the workload, stop in the case of a problem, standardising tasks, visual controls, use of reliable and tested technology. (Liker 2006, p. 37–39) Gao & Low (2014) state that this part's principles have supported many organisations to gain improvements in their operations and productivity. They remind, however, that the differences between construction and manufacturing should be considered to apply the principles successfully in construction.

The third part of the model is the people and partner. This part encourages the organisation to respect, challenge and grow its people and partners. This part consists of three principles. First, the model suggests the organisation to grow leaders, who understand both the work and the organisation philosophy. Second, the model guides to develop exceptional people and teams. Third, the model suggests respecting the partners by challenging and helping them. (Liker 2006, p. 39–40) According to Gao & Low (2014), in the context of construction, this part's principles should be adapted to consider all stakeholders involved. They emphasise this part's association to leadership and management and state them to be essential to complete lean activities.

The fourth part is about problem solving and it guides the organisation to continuous improvement and learning. The part contains three principles: go see it yourself, make

decisions slowly and implement them quickly, and develop your organisation as a learning organisation. (Liker 2006, p. 40–41) Gao & Low (2014) state that this part emphasises the importance of management commitment. The leaders should be truly interested to understand the problems to make better decisions and then able to implement the decision fast. The problems should be considered as possibilities to improve and ultimately as possibilities to create continuous improvement.

2.3.2 The definition and terminology of takt production

In literature, takt production is still rather new concept. For example, at the time being, there has not been a single scientific article published concerning takt production in construction. Therefore, this thesis examines takt production through the conference papers published in the annual conferences of International Group for Lean Construction.

The term takt production is used in this paper to describe the production method utilising the ideology of takt. The production method is based on lean ideology and it aims to improve productivity (Binninger et al. 2018; Chauan et al. 2018; Heinonen & Seppänen 2016). The goal is to shorten the lead times of building projects by removing waste. This is done by breaking the work down in smaller entireties and removing the waste, such as unnecessary waiting times (Chauan et al. 2018).

Breaking down the work allows the production to be examined through takts. Dlouhy et al. (2018) define the term takt as an actor, which causes a repeating action in regular timescale. Takt is an entirety, which can be divided into three dimensions: takt time, takt process and takt location. Takt time is the time that is needed to complete the action. Takt time is constant during every takt. Takt process is the content of the takt. Takt location is the location, where the takt takes place. Figure 4 presents an example of a takt schedule and how the dimensions appear on it.

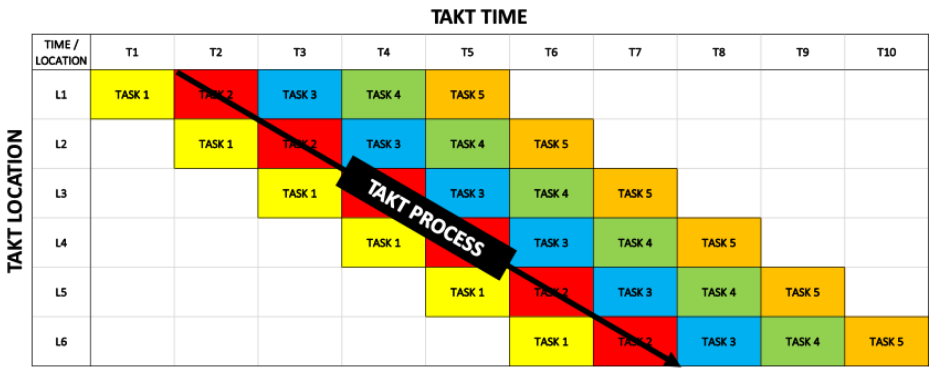

Figure 4. *Takt schedule and the takt dimensions.*

This paper examines takt production through the methods of takt time planning (Frandson et al. 2013) and takt planning and takt control (Dlouhy et al. 2016). These two methods both examine construction production through takt times, takt locations and takt processes (Chauan et al. 2018). Both of these methods aim to create a production plan such as the example of a takt schedule in figure 4.

Takt time planning is a method to create a construction production schedule using the concept of takt time (Frandson et al. 2013). Frandson et al. (2013) defines takt time planning through six phases: gathering information, definition of work zones, understanding the task order, balancing the workflow, understanding individual task durations, and creating the production plan.

The first phase is gathering information and it identifies every step of the production by examining what work must be done and where it needs to be done. The second phase is the definition of work zones. The work zones are the areas the tasks are executed. The aim is to identify locations in which different tasks can be finished in the same duration. The third phase is understanding the task order. This phase the aims to create a detailed information about the production order. After that, the fourth phase is balancing the workflow. This phase aims to create a workflow in which all the tasks are finished in the same duration. The phase also utilises the following phase, which is understanding the individual task durations. Finally, when the task durations and the workflow is balanced, it results in the final phase: creating a production plan. This phase identifies the takt time and generates the plan for the when and where each tasks is completed. (Frandson et al. 2013)

Takt planning and takt control was introduced by Dlouhy et al. (2016). In this method, takt production is examined through three levels: macro level, norm level, and micro level. The macro level analyses the process. It aims to create a milestone plan to define priorities in the aspect of customer value. (Dlouhy et al. 2016) According to Dlouhy et al. (2016), the collaboration between the parties involved should start at this level to achieve a common vision for the production. This level defines and optimises the construction phases and generates a project structure.

The following level, the norm level, is the takt planning. This level utilises the project structure made in the macro level. The level identifies the process steps for each work package. After this, the work is balanced by defining the number of workers needed in each work package. As a result, this level generates a plan, which presents the balanced work packages and the locations they occur. (Dlouhy et al. 2016)

The final level is the micro level, which is the takt control. This level sets the work packages designed in the norm level in the takt timeframe. (Dlouhy et al. 2016) According to Dlouhy et al. (2016), this level should be executed together with the subcontractors and the management of construction should occur in takt status meetings. The takt status meetings are a short gatherings in which all workers meet with the accountable foremen. Dlouhy et al. (2016) also suggest that the meetings should gather its information on a takt control board.

3. THE METHODS OF KNOWLEDGE MANAGEMENT

This research examines the methods of knowledge management through knowledge management processes: knowledge creation, knowledge sharing and knowledge utilisation. Knowledge creation is the process in which the organisations create new knowledge. Knowledge sharing is the process, where knowledge is moved. (Kianto et al. 2019) However, since knowledge sharing is often mixed with knowledge transfer (Liyanage et al. 2009), this research examines the concept of knowledge transfer within the process of knowledge sharing. Knowledge utilisation is the third part of the knowledge management process. According to Kianto et al. (2019), in knowledge utilisation, the knowledge is stored, retrieved, accessed and used due to strategic purposes.

This chapter aims to recognise important knowledge management practices that will form the topics for the management methods utilised in the case study. The chapter begins with a definition of knowledge management. After that, the chapter continuous by examining the knowledge management processes, concentrating on knowledge creation and knowledge sharing and transfer. In the end of this chapter, the recognised management practises are concluded.

3.1 Knowledge management

In today's business environment, knowledge can be considered as an organisational asset (Dang et al. 2018). Alavi et al. (2005) define knowledge as information that has been processed in individuals' minds. Knowledge can be divided into two types of knowledge: explicit knowledge and tacit knowledge (Nonaka et al. 1996). Explicit knowledge is codified and usually easy to share as tacit knowledge is knowledge in an abstract form, often personal and hard to transfer (Nonaka et al. 2000; Dhanaraj et al. 2004).

According to Riege (2005), knowledge can be examined as an intangible asset that organisations develop through time. He argues that although an organisation can be considered as the owner of its intangible asset, individual's tacit knowledge such as skills cannot be owned. For example, if the individual's tacit knowledge is not transformed to an organisation's common knowledge, there is a risk that this knowledge will disappear when they leave the organisation. In addition, Riege (2005) states that individual's tacit knowledge can expire if it is not increased or updated with new knowledge.

There are several ways to define knowledge management. Yeung et al. (2016) define knowledge management as a systematic approach to manage organisational knowledge. Gupta et al. (2000) state that knowledge management is the management of organisational knowledge that aims to make organisations act smarter. Successful use of knowledge management can lead to increase in competitiveness, more innovative products, and value creation (Gupta et al. 2000; Bishop et al. 2008; Dang et al. 2018).

Knowledge management is also often examined through different processes or phases. For example, Bhatt (2001) examines knowledge management through five phases: knowledge creation, validation, presentation, distribution and application. Kianto et al. (2019), on the other hand, examine it through three overlapping processes: knowledge creation, knowledge sharing and knowledge utilisation. This research focuses on the processes described by Kianto et al. (2019).

To effectively manage knowledge, organisations should understand the factors that influence on it (Yeh et al. 2006). Yeh et al. (2006) examine knowledge management enablers, which are the factors that influence on an organisation's ability to manage its knowledge. In their article, they identify organisational culture, strategy and leadership, people and information technology as the knowledge management enablers.

Organisational culture is essential to knowledge management since it can encourage to knowledge creation, knowledge sharing and learning (Gupta et al. 2000). Yeh et al. (2006) define organisation culture as a combination of value, beliefs, behaviours, and symbols. According to them, every organisation has a different culture, which is forms the organisation values and is seen in the employees' behaviours. Adeinat & Abdulfatah (2019) identify organisational culture as one the knowledge management's success factors as it can direct the employees' values and attitudes. They state that organisational culture can, for example, support the management of organisational changes.

Yeh et al. (2006) argue that it is essential to have a strategy and people who are committed to it. They define that a strategy can be either aggressive or conservation. In an aggressive strategy, the organisation is the creator of the knowledge as in the conservation strategy the organisation is the user of the knowledge. To create new organisational advantages, organisations should seek knowledge outside the organisation borders and apply the aggressive strategy. However, all organisations tend to be different and therefore, the strategy should always be designed to fit an organisation's characteristics and needs (Riege 2005).

Since knowledge is created and shared by people, people can be considered as an important enabler of knowledge management. As the people play a core role in many

knowledge management processes, organisations should be able to encourage them to take part in the processes. (Yeh et al. 2006) For example, even though learning happens at organisation and network level, it begins with learning done by individuals (Karkoulian et al. 2013). Since learning often results into new knowledge, skills and behaviours (Karkoulian et al. 2013), it is essential that organisations encourage their employees to learn. Furthermore, knowledge is usually hard to access since it often locates in individuals' minds (Riege 2005). Thus an individual's tacit knowledge cannot be transformed as organisational knowledge if the individual is not willing to share it (Yeh et al. 2006). According to Gupta et al. (2000), encouraging people to share their information is one of the biggest challenges in knowledge management and it often requires a change in organisational culture and in management practices, and technology that supports it.

Yeh et al. (2006) name information technology as a knowledge management enabler since it can support knowledge management practices such as communication and collaboration. Also Alavi & Leidner (2001) state that information technology can favour knowledge management by supporting the knowledge management processes: knowledge creation, knowledge transfer and sharing, and knowledge utilisation. Although the information technology can make some processes much more efficient, they highlight that technology itself do not solve all the knowledge management issues. However, Yeh et al. (2006) argue that information technology can increase the employee motivations to share knowledge by, for example, providing information channels. In addition, they state that the lack of information technology might even prevent communication.

3.2 Creating new knowledge through SECI model

Organisations' ability to create new knowledge can be considered as a success factor in today's competitive business environment. One of the most known description about an organisation's knowledge creation is the SECI model. (Baldé et al. 2018) SECI model was created by Nonaka & Takeuchi (1995). The model describes how tacit and explicit knowledge transform through the modes of 'knowledge conversions' creating new knowledge (Nonaka et al. 1996).

According to Nonaka et al. (2000), the organisational knowledge creation is a continuous process that forms a spiral. This 'knowledge spiral' is created from the movements in the four knowledge conversions. In the SECI model, each of the knowledge conversions add quality and quantity to both explicit and tacit knowledge (Baldé et al. 2018). Figure 5 presents the four modes of knowledge conversions and the knowledge spiral.

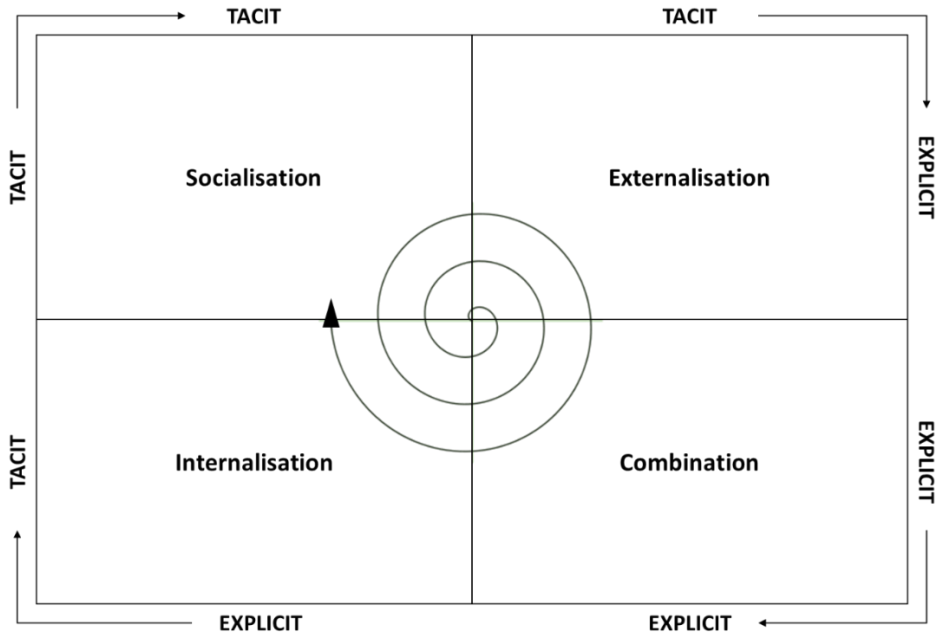

Figure 5. *SECI model, its modes of knowledge conversions and the knowledge spiral.*

The figure 5 shows the modes of knowledge creation combined with the spiral of knowledge. Usually the knowledge creation process starts on socialisation although any of the modes could be the first one (Nonaka et al. 2000). The process of organisational knowledge creation is based on the assumption that human interactions between individuals with different types and contents of knowledge creates new knowledge (Nonaka et al. 1996). According to Nonaka et al. (2000) knowledge is created in organisations through interactions between tacit and explicit knowledge. In SECI model, these interactions are called 'knowledge conversions.' SECI model consist of four modes of knowledge conversions: socialisation, externalisation, combination, and internalisation.

Socialisation is the knowledge conversion mode in which the individuals share their tacit knowledge. Through shared experiences, this mode converts the individuals' existing tacit knowledge into a new common tacit knowledge. (Nonaka et al. 1996) Socialisation requires an interaction where the individuals are in the same time and space since tacit knowledge is often dependent on time space. Typical example of socialisation is an internship where the individual learns the tacit knowledge by experience. Then again, socialisation can also happen in informal social meetings outside of the workplace. (Nonaka et al. 1996; Nonaka et al. 2000)

The next mode of knowledge conversion, externalisation, converts the tacit knowledge into explicit knowledge. This mode forms the new common tacit knowledge into an explicit form making it the foundation on the new knowledge. (Nonaka et al. 2000) This

mode aims to transform the tacit knowledge into a form that can be understood by others (Baldé et al. 2018).

The SECI model continues with combination, where the explicit knowledge is transformed into more complex and systematic form (Nonaka et al. 2000). According to Baldé et al. (2018) combination can be examined through three processes. The first process is to combine the explicit knowledge with existing explicit knowledge, which can be either from an internal or external source. The second process is sharing the explicit knowledge for example in meetings. Finally, the third process is making the needed alterations in the explicit knowledge aiming to more usable results.

The fourth and final knowledge conversion mode is internalisation. In this mode the explicit knowledge is transformed into tacit knowledge by sharing the explicit knowledge through the organisation thus making it the individuals' new tacit knowledge. After the individuals have internalised the tacit knowledge, they can share it within individuals through socialisation starting a new spiral of knowledge creation. (Nonaka et al. 2000)

3.3 Knowledge sharing and knowledge transfer

3.3.1 Differences between knowledge transfer and knowledge sharing

One part of knowledge management is the knowledge transfer. Liyanage et al. (2009) argue that there is not one clear definition for knowledge transfer. According to them, the term is often mixed with knowledge sharing even a clear difference between them can be identified. Liyanage et al. (2009) state that knowledge transfer can be defined as the movement of knowledge from one place to another. The place can be a physical place, person or knowledge ownership. Knowledge sharing, on the other hand, is a process only between people, where the knowledge is mutually exchanged. For example, Xiao et al. (2017) define knowledge sharing as an exchange process, where knowledge sharing includes two parties; one that donates the knowledge and one that collects it.

Liyanage et al. (2009) suggest that knowledge sharing can be considered as a part of knowledge transfer. Xiao et al. (2017) emphasise the importance of knowledge sharing as a critical part of knowledge management. They state that while knowledge management is seen as one of the most important factors in organisational competitive advantage, knowledge sharing can be considered as one of the enablers of knowledge management's success. According to Bishop et al. (2008), knowledge sharing aims to a common understanding of the knowledge. A key element in knowledge sharing is effective communication (Schwartz 2007; Bishop et al. 2008).

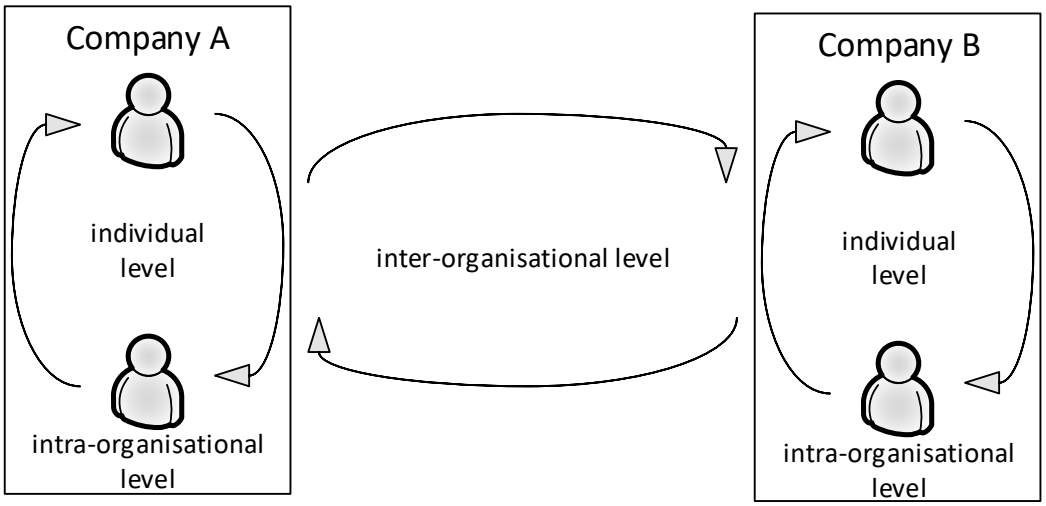

Figure 6. *Levels of knowledge transfer (after Wilkesmann et al. 2009).*

Another way to examine the differences between knowledge transfer and knowledge sharing is the levels they occur. Liyanage et al. (2009) state that knowledge sharing in organisations occurs often in individual level whereas knowledge transfer occurs in multiple levels. Yang (2007) supports this by stating that knowledge sharing happens when individual assists or learns from others. He also emphasises that knowledge sharing relies on individuals own willingness to do so. Wilkesmann et al. (2009) categorise knowledge transfer into three levels: 1) individual level, 2) intra-organisational level, and 3) inter-organisational level. Figure 6 presents these levels of knowledge transfer.

3.3.2 Effective knowledge transfer

Effective knowledge transfer allows a team members work better together (Cruz et al. 2009). One important factor for effective knowledge transfer is organisational culture (Goh 2002). Lilleoere & Hansen (2011) argue that the most important enabler for knowledge sharing is a culture that encourages to knowledge sharing. Although organisational culture has many dimensions, Goh (2002) states that especially co-operation and collaboration is crucial to knowledge transfer. Therefore, Goh (2002) suggests these should be encouraged in organisations and included within the organisational culture. Lilleoere & Hansen (2011) emphasise the social aspect of knowledge sharing. Knowledge sharing is often affected by the relationships and a good relationship between individuals may increase the individual's motivations to share their knowledge.

Goh (2002) identifies several factors, which influence on effective knowledge transfer. The factors are: 1) leadership, 2) problem seeking and solving, 3) support structures, 4) knowledge recipient, and 5) types of knowledge. The factors and their associations are presented in figure 7.

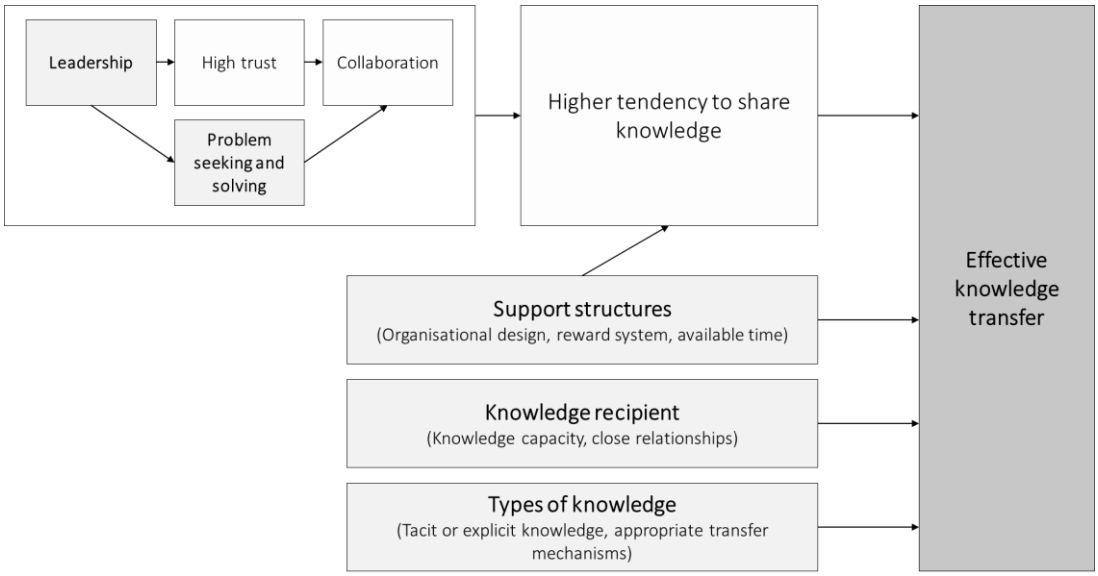

Figure 7. *Factors influencing on effective knowledge transfer (after Goh 2002).*

As figure 7 shows, effective knowledge transfer is influenced by several factors. According to Goh (2002), leaders have a central part on creating the conditions needed for effective knowledge transfer. The leaders can increase the motivation to share knowledge, influence on the culture and collaboration, and create trust and positive attitudes towards sharing. Leaders are role models, which can enhance effective knowledge transfer by example behaviour. According to Goh (2002), another important factor is problem seeking and solving. This factor suggests organisations to create a problem seeking and solving culture, which could improve the organisations continuous learning and improvement. The factor indicates to managing the employees' attitudes and encouraging the employees to share their knowledge.

Another factor influencing in knowledge transfer efficiency is support structures. Goh (2002) examines support structures through technology, training, and skill development, rewards and organisational design. Also, knowledge recipient plays an important role in efficient knowledge transfer. The relationship between parties involved in the knowledge transfer influence on how efficient the knowledge transfer is. Goh (2002) also highlights the importance of understanding the type of knowledge transferred. Whether the knowledge is tacit or explicit, it should be considered in the knowledge transfer process.

To gain potential advantages, such as potential growth, knowledge sharing should be a part of an organisation's daily processes (Riege 2005). Riege (2005) recognises three factors in which the organisations should concentrate to create a knowledge sharing culture. First, the organisations should encourage and motivate their employees to continuously create, transfer and utilise knowledge. Second, the organisations should apply

open and horizontal organisational structures that support transparent knowledge processes. In addition, the aim is to provide organisational culture that supports continuous learning and to clearly communicate about the organisation's strategy and targets related to knowledge sharing. The key is to lead by an example. Third, the organisations should use technology to support their knowledge sharing.

3.3.3 Knowledge sharing barriers

To successfully execute a knowledge management or knowledge sharing strategy, it is essential to recognise and understand the possible knowledge sharing barriers. According to many research, there are several barriers that have effects on knowledge sharing (Riege 2005; Schwartz 2007; Lilleoere & Hansen 2011; Vuori et al. 2018). These factors can be defined either as factors that reduce knowledge sharing or as factors that are crucial for the knowledge sharing's success (Vuori et al. 2018). One of the most significant challenges in knowledge sharing is getting the right knowledge from and to the right people at the right time (Riege 2005). In his article, Riege (2005) examines a broad range of knowledge sharing barriers. He divides the knowledge sharing barriers to individual, organisational and technological barriers.

According to Riege (2005), the individual barriers concern the individual characteristics and behaviours. The individual characteristics could be, for example, individuals' poor communication skills. On the other hand, the individual barriers may be also the differences between the knowledge sharer and receiver. For example, Riege (2005) lists several barriers that are caused by the different characteristics of individuals, such as age or gender differences, differences in national culture, and differences educational levels or experience levels.

In addition, Riege (2005) identifies many individual barriers concerning trust. For example, the individuals might lack trust for the source or the receiver of the knowledge. Furthermore, the individuals can also have lack of trust in their position in the organisation after their share their knowledge. Riege (2005) states, that some employees might consider their knowledge as power and fear that sharing knowledge could make them less important in the organisation. According to Gupta et al. (2018), this problem often originates from organisational culture.

The individual barriers might also refer to individuals' available resources such as time. According to Riege (2005), when there is a shortage in time, people tend to focus on tasks that they consider more beneficial to them. If the workplace does not encourage their employees to share their knowledge, due to lack of time, the employees tend to choose other tasks to do. Therefore, organisations should encourage their employees to

share their knowledge by, for example, designing its processes so there is time for knowledge sharing.

The organisational barriers are often related to the organisations ability to create an environment that allows and encourages knowledge sharing (Riege 2005). One substantial organisational barrier is the organisational culture. According to Riege (2005), organisational culture determines how much interactions the work requires. For example, since organisational culture guide the individual behaviours, it can encourage them to act against knowledge sharing by, for example, seeing the individual knowledge as power (Gupta et al. 2000). Another organisational barrier is the lack of leadership. Riege (2005) states that sharing knowledge is more or less completely voluntary and therefore, managers should create an environment that encourages people to share and utilise the knowledge of others. In addition, managers' commitment is essential in creating a knowledge sharing culture.

Technology can make knowledge sharing easier and therefore it can be considered as a facilitator of knowledge transfer (Riege 2005). However, technology can also be considered as a knowledge sharing barrier. Riege (2005) identifies barriers that relate to technology. For example, it is important to have the right technology. Riege (2005) states that if the technology does not match in the employees' needs, it can become a barrier to knowledge sharing.

3.4 Knowledge management practices for this research

Although this chapter examined knowledge management processes separately, they are tightly linked together. For example, SECI model is a well-known model for knowledge creation. However, it requires that individuals share their tacit knowledge, which links it tightly to knowledge sharing. It also combines the tacit knowledge to the organisations existing knowledge, which links it to knowledge utilisation.

This chapter has identified several enablers and barriers in effective knowledge management. The theoretical findings emphasised the importance of identifying the knowledge management barriers and enablers. A repeating element in both knowledge creation and knowledge transfer and sharing seemed to be communication. For example, Schwartz (2007) and Bishop et al. (2008) identified efficient communication as a key element in knowledge sharing and transfer.

In the context of construction site's management, communication can be improved through visual management (Tezel & Aziz 2017; Brady et al. 2018). Tezel et al. (2016)

define visual management to be a managerial strategy that highlights visual communication. According to Eaidgah et al. (2016), visual management consists of various tools and methods aiming to visualise information. Visual management aims to provide information where it is needed. In the context of construction sites, visual management can improve process transparency by supporting communication and effective decision making (Brady et al. 2018).

Tezel et al. (2016) define visual tools through four common characteristics. First, visual tools aims to provide the information to the employees in the work environment where the employees can easily access it. Second, the tools are created to answer to an information need before it occurs to avoid information lacks. Third, the information displayed combines the information to the process element such as space, materials, or tools. This means that the employees should not have to retrieve the information for example from a file. Fourth, the visual tools aim to present the information simply. For example, the information should use as few verbal or written information as possible.

Another way to improve communication, is to use technology that supports it. For example, according to Yeh et al. (2006), technology can support communication by offering communication channels. However, it should be noted that technology itself does not remove issues concerning communication (Alavi & Leidner 2001) but it can motivate the people to share their knowledge by removing barriers such as social distance (Riege 2005).

Both knowledge creation and knowledge transfer and sharing depend highly on individual's tacit knowledge. For example, Gupta et al. (2000) identified encouraging people to share their information as one of the biggest challenges in knowledge management. As the SECI model implies, one way to capture individuals' tacit knowledge is through socialisation. This social situation allows the individuals to share their tacit knowledge with each other. According to Nonaka et al. (2000), socialisation can happen in various contexts but it often occurs best in informal environments. The key is to gather the individuals together at the same time. This research examines the socialisation through meetings, where the idea is to gather all the parties involved together to capture their tacit knowledge.

The case company is also eager to learn about takt production. Since learning is usually done by individuals (Karkoulian et al. 2013), it is important to make sure the individual are able to learn during the production. Learning often results also in behaviours and attitudes (Karkoulian et al. 2013). Therefore, this research emphasises the importance of individual learning as a part of the management practices.

Hence, this research examines the management practices for subcontracted labour through communication, meetings and individual learning. Furthermore, the communication is examined through communication channels and visual tools. The individual learning is examined through education materials.

4. RESEARCH METHODOLOGY

This master thesis is a qualitative case study with a constructive research philosophy. The constructive research problem was chosen since its quality to form solutions or new constructs, which quality have been tested. A constructive research is problem-solving and question-driven, and the empiric materials connect the research problem and questions to its conclusions. (Oyegoke 2011) This research philosophy enabled the research to form new solutions that can be utilised in the case company's housing production. The research follows an inductive approach since it aims to form new theory (Saunders et al. 2016, p. 145–147).

Oyegoke (2011) describes the constructive research through six phases: 1) finding a relevant research problem, 2) understanding the topic, 3) designing the new construct, 4) demonstrating that the new construct work, 5) showing theoretical connections and the research contribution solution concept, and 6) examining the scope of applicability of the solution. The phases and how they are executed in this research are presented in the figure 7.

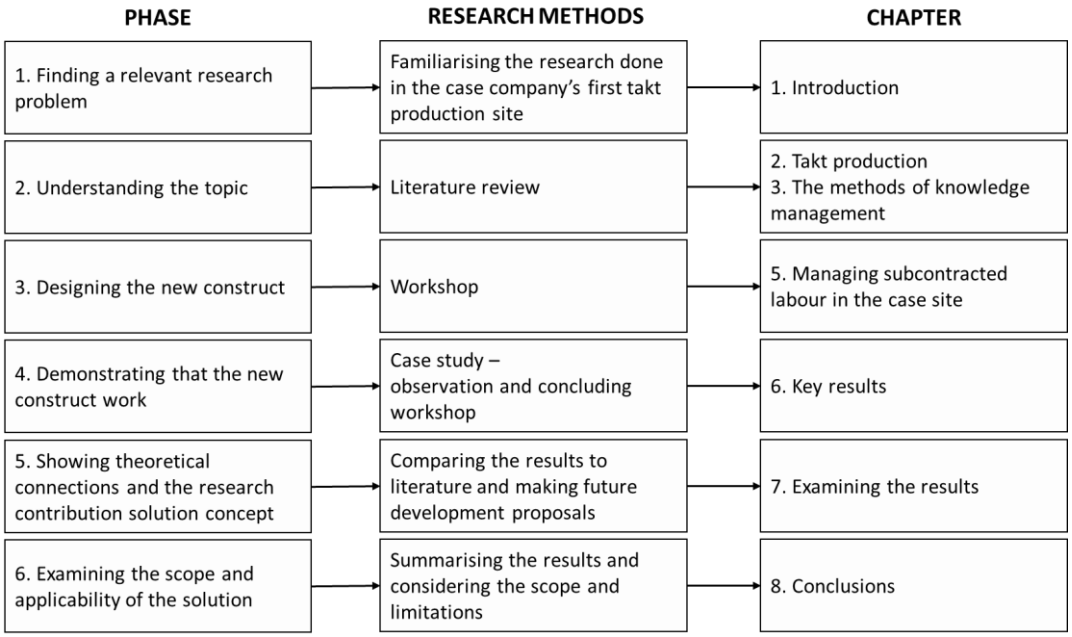

Figure 8. *The constructive research phases for this research.*

As the figure 7 shows, this research went through the six phases of the constructive research. First, the relevant research problem was found through the need identified in the case company's first takt production pilot. A research done by Mustonen (2018) showed several needs for more specific management methods for subcontracted labour

concerning takt production. After finding the topic, the second phase was to reach a general and comprehensive understanding of the topic through a literature review (Oyegoke 2011). The literature review in this study contained theoretical examinations of takt production and management of subcontracted labour. In addition, the methods of knowledge management were examined to gain a theoretical understanding of the methods that already exist. The theoretical understanding of the topic was extended by the study executed in the case company's first pilot site.

The research continued with the third phase: designing the new construct. In this research, the new construct was designed through a workshop. After this, the new construct's functionality was demonstrated via a case study. The case study was executed in the case company's takt production pilot site through observation and a concluding workshop. The results were then analysed, and the theoretical connections showed. Finally, the research examined the results usability and their limitations. This chapter continues with presenting the execution of the workshop to create the new construct and the case study to demonstrate the new constructs functionality.

4.1 Workshop

The new construct was designed through a workshop. Since the aim of the workshop was to create new knowledge, it followed the structure of the SECI model. The aim was to capture the tacit knowledge of the individuals, form it in explicit form and combining it to the case company's existing knowledge, and finally, transferring it into new tacit knowledge of the individuals. As a result, the workshop aimed to form management methods for subcontracted labour and specific guidelines how they should be used in the case site. The topics of the new management methods were partially determined beforehand from the study made in the first pilot site and from the literature review. The structure of the workshop is presented in table 1.

Table 1. *The structure of the workshop.*

Mode	**Phase**
Socialisation	Conversation about the management of subcontracted labour
Externalisation	Creating a set of management methods for subcontracted labour
Combination	Creating instructions for the methods
Internalisation	Understanding and agreement

The table 1 shows that the workshop covered the four phases and each of these phases completed one of the modes of the SECI model. The first phase was conversation about the management subcontracted labour. This phase combined the tacit knowledge of the individuals. The second phase was creating a set of management methods for subcontracted labour. In this phase the tacit knowledge shared was formed into an explicit form. The third phase was to create instructions for the methods. This phase aimed to help others to understand the created methods and the use of them. Finally, the fourth phase was understanding and agreement. This phase made sure that the created methods were truly understood, and the individuals agreed to follow them.

The workshop took place on the case site's takt planning meeting. The meeting included the case company's development personnel and all the case site's personnel involved in takt production. After the meeting, additional education about takt production was given to the site personnel. The workshop resulted a set of management practices, which are presented in chapter 5.

4.2 Case study

After creating a new design, a constructive research continued with demonstrating how the new design work. According to Oyegoke (2011) a pilot case study is the best way to test and to improve the new construct and demonstrate its functionalities. Hirsjärvi et al. (2007, p. 130–131) define a case study to collect detailed and intensive knowledge about a singular case or a small group of related cases. The aim is to form description about a certain phenomenon. This supports the research's inductive approach, which collects data to explore a phenomenon (Saunders et al. 2016, p. 145–147). In this research, the case study focuses on a single case. The phenomenon described is the functionalities of the formed management methods. The case study was executed in one of the case company's construction sites. The following chapters introduces the case site and explains the used data collection techniques, which were observation and concluding workshop.

4.2.1 Introduction to the case site

In the beginning of this research, the case company was starting its second takt production pilot in one of its construction sites. Therefore, the takt production pilot site was a natural choice to execute this research's case study. The case site is a residential block with 79 rental apartments. The apartments are studio and two-room apartments and their floor space vary from 28 to 40.5 square meters. The site personnel consist of a site

foreman, a site engineer and two site supervisors. The supervisors are the case site's personnel who are responsible of the site's and subcontractors' daily management

The takt production pilot in this case site concerns the building projects indoor phase. The takt plan was designed to have three separate set of tasks based on the location they occur. The sets were: 1) tasks located inside the apartments, excluding the bathrooms, 2) tasks located inside the bathrooms, and 3) tasks located in the common areas. The sets of tasks were named to be K-, M-, and Y-train, and the tasks they included were called wagons. Although all three trains were planned, the Y train, which included tasks located in common areas, were considered more as backup location. Table 2 presents the trains and the number of wagons.

Table 2. *Takt production in the case site.*

Train	Explanation	Number of wagons
K	Tasks located in the apartments, excluding bathrooms	40
M	Tasks located in the bathrooms	20
Y	Tasks located in the common areas	17

The takt time in this site were determined to be one day and the takt location to be 3 apartments. This meant that each task would happen at the same day in three apartments and in the end of that day the task would be completed in all these three apartments. The takt route was designed to start from the first floor and then continue upwards to upper floors in order. However, since the first floor only had four apartments, the first two takt times were set to happen in only two apartments. This would also allow the employees to have more time on learning in the beginning and the supervisors to have time to inspect the model work.

4.2.2 Observation

This case study used observation as one of its data collection techniques. Hirsjärvi et al. (2007 p. 207) identify observation to be a good technique to understand what happens in reality and whether people act in a way they say they do. As interviews or surveys collect data more about people's beliefs, opinions and experiences, observation was chosen to capture real-time data about issues and challenges and how the management methods were used when the issues and challenges occur.

The observation was executed as a participant observation, where the observer took a role in the group observed (Saunders et al. 2016, p. 356). In this case, the participant

observation type was observer-as-participant, where the researcher's identity was revealed for the group observed and the researcher observed the activities without taking part in them (Saunders et al. 2016, pp. 358–360). The observer-as-participant was chosen for this research since the researcher was able to participate in the case site's daily operations but did not take part in the management of subcontracted labour.

Observation was a rationalised choice as a data collection technique since it allowed the researcher to gain knowledge about the daily use of the management methods. In addition, observation enabled the researcher to detect other issues and challenges in the case site, which either had influence on or were influence from the management of subcontracted labour. Since the case site was only the second takt production pilot the case company had executed, the observation also allowed the researcher to recognise other research needs for takt production.

In this case study, the observation collected data from the case site for 9 weeks. Each week's observations from the case site were collected in an Excel table. The table also weekly answers to the following questions:

- What is the overall situation in the case site?
- How the takt production is proceeding? Is the production on schedule?
- Are the created management methods in use?

These observations were then concluded in a table, which can be found in the conclusions from the observation (Appendix A). The table presents the observations and their possible causes and impacts. During the observation, there were 15 repeating issues. The observations cause could be divided into five categories: lack of communication, problems with the use of Sitedrive, problems with deliveries, managing challenges and obstacles, and attitudes towards takt production.

During the observation, the attitudes towards takt production seemed to have changed. Also, as seen in the conclusions from the observation (Appendix A), the created management methods were not systematically used. The research identified a need for better understanding of the reasons behind these attitudes and actions. Therefore, the research was continued with a conclusion group discussion. This discussion is further explained in the following chapter.

4.2.3 Concluding workshop

The observation detected difficulties in the use of the created methods. Also, the conclusions of the observation (Appendix A) stated that the attitudes towards takt production

changed during the observation. Therefore, the case study was extended with a concluding workshop. The workshop aimed to identify how the site personnel experienced the management methods and how they would like to develop them further. In addition, the workshop targeted to understand why some of the management methods were not implemented during the production. The goal was to capture the tacit knowledge created during the production and transform it to new organisational knowledge.

This workshop continued the first workshop as the second round in the spiral of knowledge. The workshop went through all the four phases of the knowledge conversions: socialisation, externalisation, combining, and internalisation. The workshop started with socialisation by a discussion about takt production and how it went in the case site. Then the second phase of the workshop formed conclusions about the experiences on the site. After that, the experiences were combined to the existing management methods of the subcontracted labour. In the final phase, the new knowledge was internalised by agreeing in the development proposals the site personnel had on the management methods. The phases and their targets are presented in table 3.

Table 3. *The structure of the concluding workshop.*

Mode	**Phase**
Socialisation	Discussion about the takt production
Externalisation	Forming conclusion about the case site personnel's experiences
Combination	Combining the experiences to the created management methods
Internalisation	Understanding the site personnel's development proposals

The workshop was held after finishing the observation and the case site's personnel participated on it. As a result, the workshop identified the management practices that were experienced helpful. Also, the workshop resulted in understanding why the site personnel did not use all the management practices and how the site personnel wanted to continue the management of subcontracted labour in the future takt production sites.

4.3 Analysing the results

This research utilises thematic analysis as its data analysis technique. Saunders et al. (2016, p. 579) define thematic analysis as a generic approach for qualitative data analysis. The technique is flexible since it can be utilised in both large and small data sets, in deductive and inductive approaches, and objectivist and subjectivist position. The main

idea of thematic analysis is to identify key and repeating themes from the data set. The process starts with becoming familiar with the data. After that, the data is coded allowing the repeating themes to be searched and the relationships recognised. Finally, the themes are refined to answer better to the research questions and the propositions are tested to identify their functionality. (Saunders et al. 2016, p. 579–587)

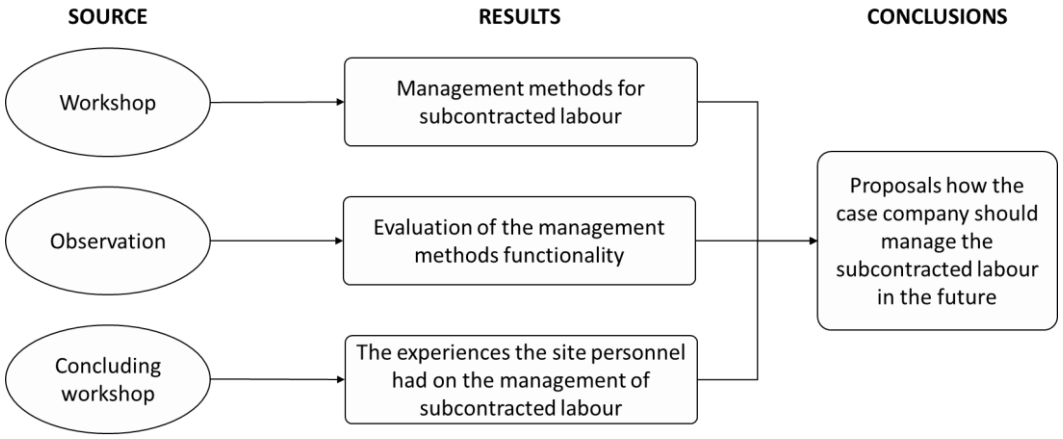

Figure 9. *The data sources, their results and the final conclusions.*

The research collected data from three sources. The sources and their results are presented in the figure 9. The first data set was collected from the first workshop, which formed the management practices for the case study. These results are presented in chapter 5. The second and third data sources were the observation and the concluding workshop executed during the case study. The thematic analysis was able to divide these results into six themes: 1) the use of the created management methods, 2) lack of communication, 3) problems with the use of Sitedrive, 4) problems with deliveries, 5) managing challenges and obstacles, and 6) attitudes towards takt production. The key results of these two data sources are presented under these themes in chapter 6.

5. MANAGING SUBCONTRACTED LABOUR IN THE CASE STUDY

Since literature do not determine specific methods how a takt production's subcontracted labour should be managed, this research formed a new solution for the case company's takt production pilot site. First, the research identified topics for the management of subcontracted labour through the knowledge management literature. The topics were recognised from the case company's earlier research and from the literature. The topics were: 1) meetings, 2) communication channels, 3) visual tools, and 4) education materials. The topics and their targets are presented in figure 10.

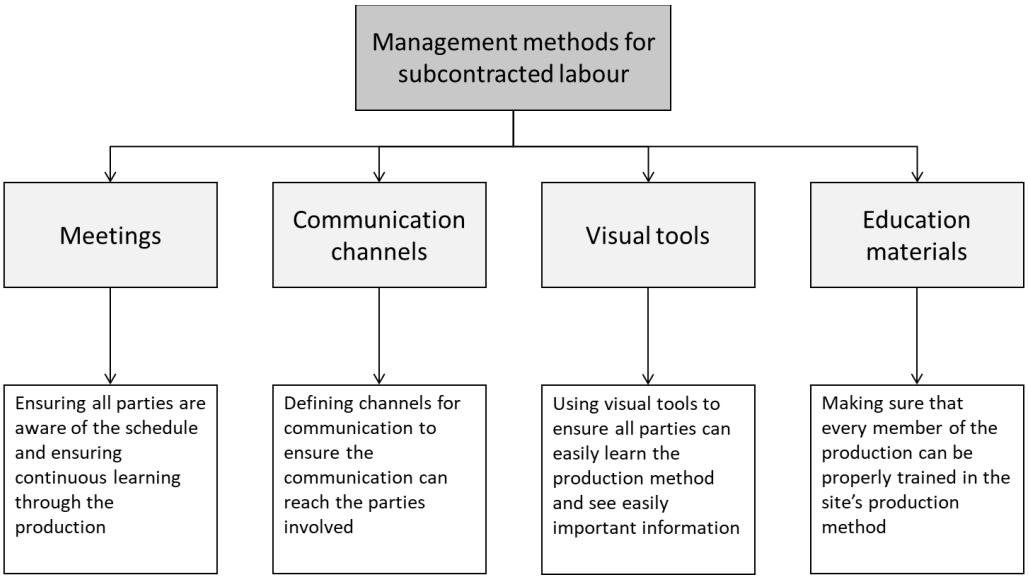

Figure 10. *The management methods for subcontracted labour and their targets.*

After the topics were determined, the research formed specific practices under each topic. The practices were created specifically for the case site's needs. The practices were determined in the workshop described in chapter 4.1. This chapter defines the methods and specific practices that were used and examined during the case study.

5.1 Meetings

Before this research, the case company had created meeting routines for takt production. These meeting routines were used in the case company's first pilot site. The research done by Mustonen (2018) identified, however, a need to develop these routines. Accord-

ing to her study, the meetings were experienced inefficient since there was no chairperson, their agenda was loose or not followed, all the parties did not participate in them, and the duration usually was longer than scheduled. Therefore, these meeting routines were further developed in the workshop.

The meetings were designed to support knowledge creation and knowledge transfer. In the case site, the meetings included both inter- and intra-organisational knowledge transfer. The transfer itself were mainly between individuals and therefore it can be considered as knowledge sharing. The meetings aimed to provide possibilities to share. Since takt production relies on detailed schedule, the meetings were designed to ensure all parties involved would be aware of the schedule. Also, the meetings aimed to detect and understand the issues and challenges, and the occurred obstacles to enable continuous learning throughout the production. The workshop created four types of meetings. These were: 1) morning meetings, 2) supervisor meetings, 3) subcontractor meetings, and 4) takt production meetings. The meetings were designed to reach all parties involved in takt production. The meetings, their targets, regularity and participants are presented in table 4.

Table 4. *The meeting routines.*

Meeting	**Regularity**	**Participants**	**Targets**
Morning meeting	Daily	Supervisors, employees	To ensure all employees know the day's goals and can start their tasks
Supervisor meeting	Daily	Site personnel	To ensure daily information sharing about takt production
Subcontractor meeting	Every other week	Site personnel, subcontractors' representative	To officially state issues and concerns about the production and agree on the future schedule
Takt production meeting	Weekly	Site personnel, subcontractors' foremen	To ensure everyone is aware the future schedule and all parties can execute it

The morning meeting is arranged daily in the beginning of the day. The aim is to ensure all employees are aware of the daily goals and can start them. The meeting also allows the employees to meet with each other and address certain issues directly to other employees. This meeting is arranged by the case company's supervisors, but other site personnel could also attend to it.

The supervisor meeting is the case company's internal meeting, where the issues recognised in the morning meeting can be shared with other site personnel. This meeting is an informal meeting, which aims to ensure the information about takt production is

shared between the site personnel. The meetings are arranged daily after the morning meetings.

The third meeting is subcontractor meeting. In this formal meeting the subcontractors' representatives would meet. This meeting allows the subcontractors address their concerns to both the case company and the other subcontractors. The meeting holds a lot of official purposes outside of takt production. However, in terms of takt production, this meeting allows the participants officially agree on the site's schedule and its proceeding. The meeting is arranged every other week.

The final meeting created is takt production meeting. In this meeting the supervisors' foremen meet with the site personnel. The meeting aims to ensure all participants are aware of the schedule and can execute it. This meeting allows the site personnel to solve possible challenges in the schedule with the subcontractors' foremen and all participants to share information about the production.

5.2 Communication channels

To ensure the daily communication in the case site would be efficient, the workshop wanted to create procedures for the communication channels. The aim was to make sure the information would always reach the right persons and that the important information would not be buried in a wrong communication channel. In addition, the communication channels targeted to create possibilities to share knowledge for both site personnel and subcontractors. The communication channels and their use are presented in the table 5.

Table 5. *Communication channels.*

Channel	**Use**
WhatsApp	• Informal communication channel between employees and supervisors
Congrid	• Main contractors' channel to inform about quality nonconformities
Sitedrive	• Channel to communicate about tasks and their schedules • Formal channel for employees to inform about obstacles, which prevent working • Formal channel to inform daily that tasks are started and completed

The workshop determined that the case would have three communication channels. The informal messaging would happen in WhatsApp. For example, the supervisors would use WhatsApp to inform the employees about site meetings. WhatsApp will also offer

the employees communicate to each other. Congrid was determined to be the main contractor's channel to inform about quality nonconformities.

Since Sitedrive was set to be the case site's scheduling system, the workshop wanted to utilise the features it offered concerning communication. Sitedrive allowed the employees to see their daily goals on their phones, inform the main contractor when the tasks are started and finished, and it allowed the employees state obstacles that prevented work. All these features were considered as good qualities to support the needs of takt production. Therefore, Sitedrive was determined to be the formal channel for employees to inform about obstacles that prevent work. Also, the subcontractors were required to use Sitedrive to inform daily, which tasks they have started and completed.

5.3 Visual tools

The workshop created a set of visual tools to ensure the employees would have the essential information at the location they would need it and to reduce the change of mistakes. These tools included an info board and clear visual presentation about the work locations. These tools aimed to improve the knowledge about takt production and to ensure all employees knew their work locations.

The info boards were designed to be set on each floor. These boards were designed to include relevant case personnel's information and visual prints that aim to improve the workers understanding about takt production. Each board have a floorplan, which present the takt locations and the takt route of the floor. This floorplan is presented in the figure 11. Also, the info board were designed to have a printed schedule, which would show the floor's schedule for the next three weeks. The schedule would be updated each Friday. This aimed to keep the workers up-to-date about the production and its updates.

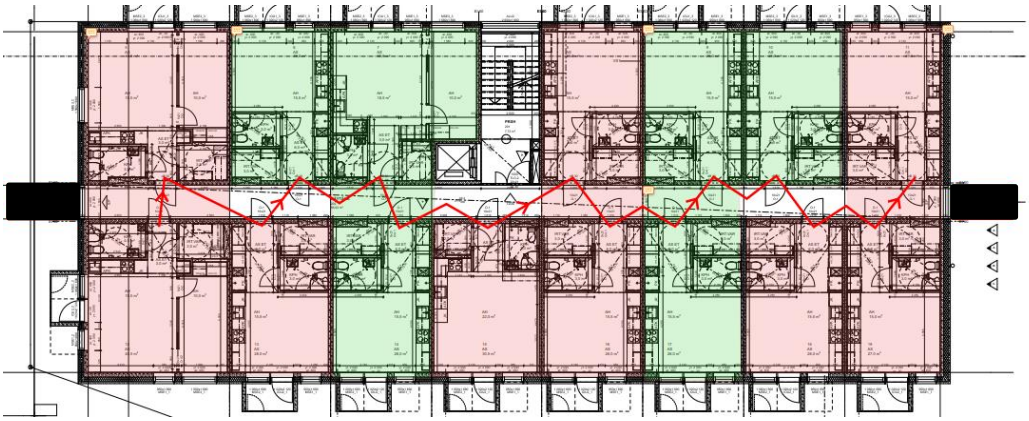

Figure 11. *Takt locations and the takt route.*

The takt production route is marked with red arrows in the figure 11. The same route was determined to be painted on each floor. Since the takt locations were named according to the apartment numbers, all apartments would also be named clearly by marking their number in the doorways. These two tools aimed to ensure all employees would work on the right location and reduce the change of errors.

5.4 Education materials

Since takt production is a rather new production method to both the case company and the subcontractors, the workshop created educational materials. The education materials aimed to give all parties involved in the production a better understanding about takt production. The materials were mainly designed for subcontractors' employees, but with few additional materials they could also be used in internal education.

The aim was to create materials that would generate understanding and positive attitudes towards takt production. The materials explained takt production through the following three questions:

- What is takt production?
- How does takt production affect the employees' work?
- How can the employees benefit from takt production?

After these questions were explained, the materials defined the routines the site would use, such as meetings and communication channels, and defined rules of the site. Since takt production requires the employees to work according a carefully designed schedule, the materials also included promises from the case company, which they would follow in return. The internal materials included also a supervisors' schedule. The schedule aimed to show how the supervisors' management routines needed to change to ensure takt productions proceeding. The weekly schedule is presented in the table 6.

Table 6. *Supervisors' schedule.*

Time	Monday	Tuesday	Wednesday	Thursday	Friday
07 00	**Morning meeting**	**Morning meeting**	**Morning meeting**	**Morning meeting**	**Morning meeting**
07 30					
08 00	**Supervisor meeting**	**Supervisor meeting**	**Supervisor meeting**	**Supervisor meeting**	**Weekly meeting (internal)**
08 30					
09 00					
09 30					
10 00					
10 30					
11 00	Lunch	Lunch	Lunch	Lunch	Lunch
11 30				Office tasks	
12 00			Office tasks		
12 30				Quality checks and model apartments	
13 00	Office tasks	Office tasks			Office tasks
13 30			**Employee meeting**	**Contractor meeting**	
14 00	Quality checks and model apartments	Quality checks and model apartments	Quality checks and model apartments		Quality checks and model apartments
14 30				**Takt production meeting**	
15 00	Schedule updates	Schedule updates	Schedule updates	Schedule updates	Schedule updates

Table 6 shows that the weekly schedule has two meetings that are not considered in takt production meetings. The weekly meeting occurring on Fridays is the case company's mandatory meeting. However, in this case site, the site personnel wanted to separate this meeting from the takt production meetings presented in chapter 5.1 and therefore it is not one of the takt production meetings. The employee meeting is a meeting occurring on every other Wednesday. In this meeting the site personnel informs the employees about future events and happening that might affect working. Although these meetings were a good opportunity to communicate with employees, they were not considered as a part of takt production meeting routines.

5.5 Summary of the management methods

The created practices aimed to ensure the case site's management of subcontracted labour would support takt production. Also, the aim was to ensure the knowledge would be transferred and shared between the parties by emphasising efficient communication and proper education. Figure 12 presents the created management methods for subcontracted labour.

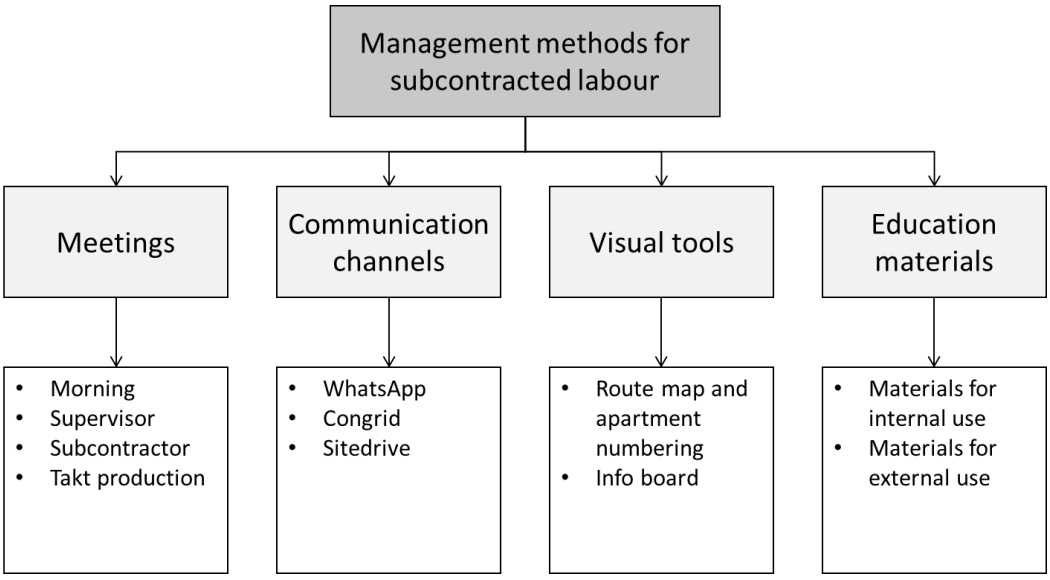

Figure 12. *Management methods for subcontracted labour and their practices for the case site.*

As the figure 12 shows, the created management methods for subcontracted labour were categorised under four topics: 1) meetings, 2) communication channels, 3) visual management, and 4) education materials. The meetings contained four meetings: morning, supervisor, subcontractor, and takt production meeting. The communication channels defined the use of three main channels: WhatsApp, Congrid, and Sitedrive. The visual tools included the route map and apartment numbering and info boards. And the final category, education materials, included the materials for internal and external use. After these specific practices were created, their functionality were tested in the case study, which key results are presented in the following chapter.

6. KEY RESULTS

The case study was executed in the case company's second takt production pilot site. The case study aimed to demonstrate how the created methods worked and how they should be further developed. This chapter presents the key results of the case study. The results are presented under the themes identified in the thematic analysis: 1) the use of the created management methods, 2) lack of communication, 3) problems with the use of Sitedrive, 4) problems with deliveries, 5) managing challenges and obstacles, and 6) attitudes towards takt production.

6.1 The use of the created management methods

Although the case site personnel took a part in creating the management methods for the case study, the created methods were not systematically used. Table 7 shows the use of the management methods during the observation. The table examines each of the created management method and whether the method was in use during the observation week. The table does not include the use of the communication channels since they are addressed separately in the end of this chapter. To understand why the methods were or were not used, this chapter includes the results of the concluding workshop.

Table 7. *The use of the created management methods during the observation.*

Observation week	Meetings				Education materials		Visual tools	
	Morning meeting	Supervisor meeting	Subcontractor meeting	Takt production meeting	Internal	External	Info board	Route map & apart. numbers
1		x						x
2		x						x
3	x	x			x			x
4	x	x						x
5	x	x	x	x				x
6	x	x						x
7	x	x	x					x
8	x	x						x
9	x	x	x					x

The meeting routines were created to ensure the communication about takt production would reach all parties involved. However, as the table 7 shows, the meeting routines

were rather variously used. The morning meetings were started on the third week of the observation. First the meetings were only an informal gathering where the supervisors tried to collect the employees in the morning before they went to the case site. The morning meetings, however, evolved during the observation. In the end, the morning meetings were a daily gathering, where the site personnel were able to reach out many of the employees and allow the employees to talk with each other. Although the site personnel developed the morning meeting during the observation, they still had problems to get all employees to participate in it. However, the site personnel saw potential in the meeting and named it to be one of the methods how they wanted to manage the subcontracted labour in the future.

The supervisor meeting was used regularly during the observation. The supervisor meeting was experienced as efficient way to communicate internally about the proceeding of the case site. The original target of the meeting was to ensure the information about takt production was shared between the site personnel daily. During the observation, the supervisor meeting seemed to reach its aim and evolve as an important part of the daily management. During the meeting, the site personnel informed each other about the daily actions and updated the production plan for the following eight weeks.

During the observation the subcontractor meeting was arranged every other week. However, as the table 7 point out, the subcontractor meeting was not arranged during the first four weeks of the observation. The first weeks of the observation placed in the holiday season and the case site's personnel decided to pause the meetings around the holiday. The subcontractor meeting was designed to allow subcontractors to officially state issues and concerns about the production and agree on the future schedule. During the observation, however, the meetings did not cover the takt schedule. Since some of the subcontractors had several issues, the meetings seemed to pass in problem solving.

The takt production meeting was only arranged once during the observation. The aim of the meeting was to ensure all parties are aware of the schedule and able to execute it. The site personnel, however, did not want to present the schedule, since they did not have an up-to-date schedule to present for the subcontractors. On the other hand, the site personnel considered that if the morning meeting was efficient, there was no need for a separate takt production meeting.

The education materials were only internally used through the production. During the observation, the materials were only used once to enhance the site personnel's knowledge of takt production. The education materials were not included in the case

site's orientation materials, which were presented to all employees in the beginning of their work.

During the observation the visual tools were partly used. The case site marked the route on the floors and numbered the apartments in the beginning of the observation. These were considered as good tools to ensure the employees can easily identify their work locations. The info board, however, were only partly used. The info boards were set to each floor and they consisted of the site personnel's contact information and the floor plan. Since the site personnel had problems with presenting an up-to-date schedule and the scheduling software did not offer an informative print, the info boards did not have a printed schedule.

The communication channels designed for the case site were not used as planned. The communication was mostly executed face to face, in the meetings and through phone calls, WhatsApp messages and emails. The main reason to this was to the missing properties of Sitedrive and the general use of it. The case site's personnel did not require the use of Sitedrive since the subcontractors did not seem to benefit from it. Although the software developers were keen to develop Sitedrive according the case site's needs, the developments were not implemented during the observation. Therefore, the use of Sitedrive was almost completely done by the site personnel. Congrid was used, but only in the case site's official quality inspections. The case study did not notice it as a communication channel.

6.2 Lack of communication

During the observation, the study recognised repeating challenges concerning communication. Although the created management methods determined several different tools for communication, five of the 15 observations could be traced into poor or missing communication. The observations made emphasises the importance of fluent communication during the production. This chapter presents the observations 1 to 5 from the conclusion from the observation (Appendix A).

The first observation indicated that the case site personnel did not have enough knowledge on how the HVAC should proceed prior indoor phase. The schedule made only indicated when certain tasks should be completed in the apartments. Since the meetings began in the beginning of the indoor phase, the case company was not aware that the subcontractor was not going to finish the tasks on time. Also, the site personnel did not have enough knowledge about the time needed on the HVAC tasks to detect the delays themselves. This caused the tasks following the HVAC to be delayed.

The second observation detected problems with the communication fluency. Since the case site's schedule determined daily goals for each day for the production, it can be assumed all parties the goals concerned should be aware of them. However, the daily goals were not fluently communicated between the partied involved. Since the takt production meeting was not arranged, the subcontractor meeting did not include takt production and the morning meetings were either not arranged or they did not reach all subcontractors the meetings could not ensure the employees knew their daily goals. Furthermore, since the schedule was neither printed on the floors or the updated on Sitedrive, the employees were not able to check the daily goals themselves. The communication about the daily goals were almost completely transferred to be the supervisors' responsibility. This observation also recognised that the subcontractors did not have enough knowledge about takt production. Some subcontractors were not even aware that the case site utilised takt production before they started in the case site. The created education materials were only in internal use, and the subcontractors' employees' orientation materials did not include the created takt production education materials.

The third observation emphasised that all the contractors were not aware of the takt production. This observation is also connected to the previous one. The subcontractors, who are not aware of the takt production, are not aware of the daily goals and therefore might not work in the pace required. This observation was mainly caused by the lack of communication about takt production. In other words, takt production was only rarely included in the meetings, the education materials were not used, and the schedule was not made visible to all parties.

The fourth observation stated that some tasks' requirements were not determined. This meant that the subcontractors had problems starting and finishing their first locations. One reason for this could be that the communication with the subcontractor were not efficient enough. In addition, the subcontractors do not attend to subcontractor meetings before their start their tasks in the construction site. Therefore, the subcontractors do not have the possibility to state the requirements for other subcontractors.

The fifth observation recognised the lack of subcontractors' participation in the meetings. This resulted problems in detecting issues and challenges the subcontractors faced. Also, this affected on the communication about takt production, such as the delays or other changes in the takt schedule. The meetings could have been more regularly arranged and the benefits more clearly communicated.

6.3 Problems with the use of Sitedrive

Sitedrive was named as one of the case site's communication channel when the management methods were created. The channel was set to be the only official channel for the employees to inform about obstacles that would affect their work. The system also included the case site's takt production schedule. Sitedrive offered a solution, which would help the case site to follow the proceeding of the schedule and to communicate about it with the subcontractors. Also, Sitedrive collected data about the production such as the task durations. During the observation, however, the use of Sitedrive seemed to address many challenges for the site personnel. In addition, since the system was not used correctly, the collected data were not able to offer accurate information about the production. Three out of the 15 problems could be addressed to the problems with the use of Sitedrive. This chapter presents the observations 6 to 8 from the conclusions from the observation (Appendix A).

First, the sixth observation recognised that the schedule was often not updated in the Sitedrive. Since the production did not proceed as first planned, the schedule seemed to change daily. Updating Sitedrive was considered rather time-consuming and therefore the site personnel did not want to update Sitedrive until the delayed tasks' actual occurring were certain. This led to a situation, where there was no up-to-date schedule available. Furthermore, the subcontractors were not able to use Sitedrive as required.

The seventh observation stated the fact that most of the employees did not use Sitedrive. The subcontractors did not see the benefits for using Sitedrive. At some point of the observation, the information about the task's status seemed to only in the heads of the supervisors. This seemed only to increase the supervisors' workload since they had to use Sitedrive behalf of the subcontractors.

Finally, the eighth observation pointed out that during the observation, the schedule was not printed on the floors. This was caused by the poor visualisations of Sitedrive. The system could not provide an informative print of the schedule. Since the schedule was only in Sitedrive, the case site's personnel did not have time to create a visualisation of the schedule via other tools. This issue was discussed with system provider but the solutions to the problem were not offered during the observation.

6.4 Problems with deliveries

The production suffered challenges caused by problems with deliveries. The deliveries can be divided into products delivered straight from a supplier and into products subcon-

tractor provides. Both types of deliveries had repeating challenges during the observation. This chapter presents the observations 9 and 10 from the conclusions from the observation (Appendix A).

The ninth observation detected problems adjusting delivery dates due the needs of the takt production. Some suppliers demanded exact delivery dates several weeks prior the delivery. The problem usually was that the delivery date was set too early. With some deliveries, the delivery batch was too large. Both problems meant that the products needed a temporary storage. Since the case site had rather small storage area, it often caused the storage area to be packed. When the products were finally needed, they needed to be sorted out to get to the right products in their final locations. If the delivery dates were set too late, it meant that the employees did not have the required equipment for the day's work.

The tenth observation recognised problems with the subcontractors' ability to provide articles or products when needed. The subcontractors were either not aware of the products needed each day or they had simply forgotten to order them. Therefore, the employees did not have the required equipment for the day's work, which caused delays on the schedule. In one case, the delay was several weeks. In some cases, the subcontractors were not aware the requirements takt production set for the deliveries, which caused the same results as the previous observation.

6.5 Managing challenges and obstacles

The case site also suffered problems concerning the management of challenges and obstacles. The eleventh observation detected issue where the subcontractors were not able to provide enough resources. One reason behind this was that the subcontractors were simply not able to provide as many employees as requested. In some cases, the subcontractors' employees were not able to work since sick leaves or other absences. The subcontractors were usually not able to provide substitutes. In both cases, the tasks did not finish on time, which caused delays on the following tasks. This chapter presents the observations 11 to 13 from the conclusions from the observation (Appendix A).

The twelfth observation stated that there were not enough resources who understand takt production. This was mostly caused by the lack of internal education. Also, the takt production pilot's targets were not determined. Since the case site's personnel had not experienced takt production before the pilot, the natural reaction when facing challenges was to shift the management of subcontracted labour towards traditional construction

site management. As the targets of the pilot was not determined, the site personnel focused on managing the site with the targets a construction site usually has.

The 13th observation recognised a problem with the subcontractors' ability to work in the pace scheduled. Since takt production's pace was not determined in contracts, the case site's personnel could not demand the subcontractors to work on a certain pace. This caused delays on the following tasks since they had to be postponed to maintain the pace in the rest of the production.

6.6 Attitudes towards takt production

During the observation, there was a clear change in the attitudes towards takt production. This chapter presents the observations 14 and 15 from the conclusion from the observation (Appendix A). The 14th observation recognised the site personnel's mistrust for takt schedule. The disappointments in the production seemed to have created negative attitudes towards the possibilities of takt production. In the end of the observation, the schedule did not lead the production although it still existed. The production was controlled by the terms of the subcontractors' abilities to finish tasks rather than the case sites personnel based on the wanted schedule.

The 15th observation also recognised that in the end of the observation the attitudes to all piloting for new methods was mostly negative. The case site had several pilot projects beside takt production. The site personnel's time seemed to be consumed mostly in tasks concerning different pilot projects. In the end of the observation, takt production was considered as one of the time-consuming pilots in the site rather than potential method to improve productivity. Thus, the site personnel's excitement about the new production method disappeared and the potential benefits of takt production were not seen any longer.

7. EXAMINING THE RESULTS

To successfully adopt lean principles in construction environment, Forbes & Ahmed (2011, p. 395) identify fundamentals that need to be considered. Firstly, there must be a willingness to change and to implement lean during the design stages. In addition, there should be commitment to training and learning, to reducing or eliminating waste, and to cost and performance measures. Furthermore, the successful lean implementation requires a quality oriented culture, a shared vision between all stakeholders, a collaborative relationships and effective use of information technology.

The case company was able to create a takt schedule, which had potential to reduce several months from the lead-time of the indoor phase. However, the actual production did not proceed as planned and the management of the subcontracted labour was not efficient. The case study also presented issues concerning the use of the created management methods for subcontracted labour. This chapter shows the theoretical connections between earlier research and this research's key results.

7.1 Identifying the success factors in takt production's management of subcontracted labour

The observation identified five topics in the case site, which created issues in the management of subcontracted labour (Appendix A). The topics were: 1) lack of communication, 2) problems with the use of Sitedrive, 3) problems with deliveries, 4) managing challenges and obstacles, and 5) attitudes towards takt production. This study suggests that the case company concentrate on these topics in their next takt production sites. Therefore, this chapter transforms these issues as success factors of the management of subcontracted labour. The success factors are presented in figure 13.

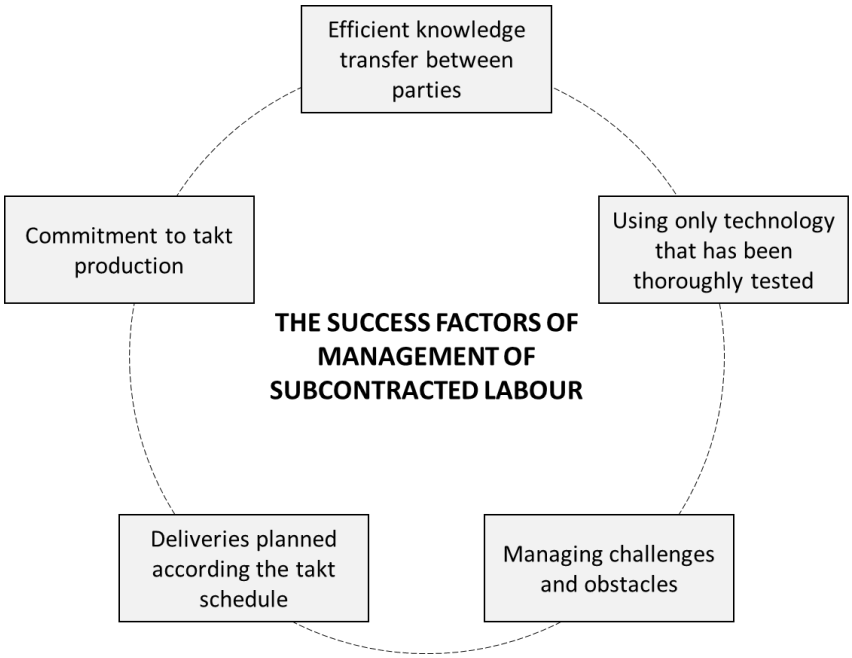

Figure 13. *The success factors in takt production's management of subcontracted labour.*

The figure 13 shows the success factors of the management of subcontracted labour, which were identified during the case study. The factors are: 1) efficient knowledge transfer between parties, 2) using only technology that has been thoroughly tested, 3) deliveries planned according the takt schedule, 4) managing challenges and obstacles, and 5) commitment to takt production. The following subchapters present theoretical arguments for the success factors and connects them in the case study's results.

7.1.1 Efficient knowledge transfer between parties

The case study's results recognised several issues that could have been prevented with efficient knowledge transfer. One important factor of effective knowledge transfer and sharing is organisational culture (Goh 2002; Lilleoere & Hansen 2011). Organisational culture can guide the employees' values, behaviours and assumptions (Alavi et al. 2005; Adeinat & Abdulfatah 2019). For example, an organisation's values often reflect on its teams' behaviours. Therefore, it is important that the organisation can create a culture that encourages knowledge transfer and sharing.

Furthermore, Goh (2002) suggests seven ways managers can be involved in making knowledge transfer effective: trust, culture of co-operation and collaboration, culture of continuous improvement and learning, organisational design that encourages horizontal communication, same level of skills among employees, encouraging knowledge transfer and sharing, and rewarding for the right reasons. The case study indicated a special need for the culture of co-operation and collaboration, culture of continuous improvement

and learning, encouraging horizontal communication, and encouraging knowledge transfer and sharing.

According to Goh (2002), a culture of co-operation and collaboration is essential to ensure effective knowledge transfer. The culture can be developed through encouraging individuals and groups to work together. In the case company's aspect, the site personnel should encourage the subcontractors to co-operate with the case company and each other. For example, Goh (2002) suggests the managers to encourage the individuals and groups to solve problems together.

The problem solving also links to the culture of continuous improvement and learning (Goh 2002). Since the production method was completely new to all site personnel, continuous improvement and learning should play an important part in the production. The observation also indicated that the subcontractors did not have enough knowledge about takt production, which made the labour to follow the conventional construction methods rather than utilising takt production. Therefore, the continuous improvement and learning should be one of the focus areas in the case company's takt production sites.

The managers should also encourage to horizontal communication (Goh 2002). According to Goh (2002), managers should ensure the communication will flow and the hierarchical barriers are minimized. The communication flow could be supported by using technology (Goh 2002; Riege 2005). However, to actually get the employees to use the technology, it needs to make the communication easier. In the case study, the communication fluency was one of the repeating issues identified. Therefore, the case company should also focus on identifying the barriers in the communication and eliminating them.

The managers should encourage knowledge transfer and sharing (Goh 2002; Lilleoere & Hansen 2011). The encouraging can happen for example through processes that allow knowledge transfer in informal contexts (Goh 2002). For example, Lilleoere & Hansen (2011) argue that good relationships between the parties increases the motivation to share knowledge. From the case company's aspect, the observation indicated a lack of subcontractors' participation in the meetings. Therefore, the site personnel should pursue to encourage the subcontractors to adapt a knowledge sharing attitude. Goh (2002) states that leaders have an important role in this. They can influence on the culture and act as role models (Goh 2002; Lilleoere & Hansen 2011).

7.1.2 Using only thoroughly tested technology

The case study indicated, that the use of unsuitable technology can cause issues in daily operations. The used technology did not seem to add value to the processes. The Toyota Way suggest the companies to use only thoroughly tested technology (Liker 2006, p. 39). According to Liker (2006, p. 160), the technology should always be thoroughly tested before implementing in the processes. This ensures that the technology will actually provide value to the process. If the technology cannot provide additional value or it includes risks that might have negative impacts on the process, it should not be used or the implementation should be done after the risks have been eliminated.

Since the case company is still standardising its takt production processes, the use of technology seemed to guide the processes in wrong directions. For example, since takt production is based on detailed schedule, the case site's personnel wanted to make the schedule visible to all parties involved in the production. However, the used scheduling system Sitedrive could not provide an informative print of the schedule. Therefore, the designed info boards did not have an updated schedule and the site personnel were not able to present an up-to-date schedule for the subcontractors.

Since Sitedrive was named as one of the case site's communication channels, and communication is a key element of knowledge sharing (Schwartz 2007; Bishop et al. 2008), the problems with Sitedrive can be compared to the knowledge sharing barriers. For example, the employees' needs were not in line with the system functionalities. Riege (2005) identifies this as one technology barriers of knowledge sharing. On the other hand, there could have been unrealistic expectations about Sitedrive's functionalities. For example, the site personnel trusted that the schedule could be printed from the system. Therefore the site personnel did not maintain an informative schedule in Excel, where it could have been easily printed out or presented to the subcontractors. The unrealistic expectations is also listed as one of the Riege's (2005) technology barriers.

Although technology was considered as a barrier in this study, there is no denial of its potential and importance. Riege (2005) states technology can reduce the formal communication barriers. In addition, Forbes & Ahmed (2011, p. 133–134) state that information technology can support a lean construction site's ability to manage its processes and speed up decision making. To successfully use technology, the case company should examine further the needs takt production and its processes sets for both the knowledge sharing and information technology. On the other hand, there is also a need to examine and evaluate the system functionalities, to avoid unrealistic expectations.

However, it should be noted that despite Sitedrive could not provide the wanted functionalities at the time of the case study, the system developers were keen to develop their solution to answer the case site's needs. In the future, the system might be a comprehensive tool to plan and manage takt production.

7.1.3 Deliveries planned according the takt schedule

The case study recognised challenges concerning the deliveries. The deliveries were either too late or too early, or in some cases the subcontractor had simply forgotten to order them. The Toyota Way encourages the organisations to use the pull system, which aims to eliminate over production. The principle emphasises the just-in-time production, which aims to give the customer the right amount of the right product at the right time. (Liker 2006, p. 104–105) Gao & Low (2014) suggest that in construction, just-in-time can be applied on the deliveries by planning the material delivery schedule. In the material delivery schedule, the materials needed are scheduled through the point of use.

The material delivery schedule could provide a solution to the issues identified from the deliveries. For example, the case company could provide a material requirement list for each apartment. The list could then guide the material orders. In the case the subcontractor provides the materials, the case company could use the list to ensure the subcontractor will be aware of the delivery requirements and schedule. The list could be used in the meetings for example to ensure the subcontractor will not forget to order the materials and to ensure the subcontractor understands the delivery batch size.

7.1.4 Managing challenges and obstacles

Even though the case site utilised completely different production method, conventional construction methods guided many case site's practices. First of all, takt production did not show in the case site's goals. The Toyota Way emphasises the long-term goal, in which all the decision should be based on (Liker 2006, p. 71–72). During the observation, it was clear that the site personnel was not aware of the targets for the takt production pilot. The site personnel pursued to the conventional construction targets and the takt production pilot seemed to be only an additional task.

In addition, according to Forbes & Ahmed (2011, p. 133–134), implementing lean methods in construction requires a willingness to change. They state that changing the methods from conventional construction to lean construction needs a change in behaviours. However, no one can be forced to change. The people should be motivated and encouraged to change (Forbes & Ahmed 2011, p. 133–134). In the case site, the site personnel was rewarded based on the conventional construction production goals, such as time,

costs and quality. This rewarding system did not seem to encourage takt production and motivate the personnel to change their managing behaviours. Therefore this study suggests the case company to consider updating their rewarding system in sites that utilise takt production.

Since the site personnel did not have previous experience from takt production, their expertise based on conventional construction management. Therefore, when issues occurred in takt production, the site personnel tend to lean on their experience and use the conventional construction management methods. This emphasises the need to support the site personnel to use takt production management practices. For example, the Toyota Way suggests the managers to stop the production when issues occur (Liker 2006, p. 129–130). In addition, Goh (2002) emphasise the importance of solving problems together. The site personnel should involve the subcontractors into the problem solving so all parties could learn from the problems.

Also, takt production should be more specifically determined in the subcontractors' contracts. For example, the observation pointed out that the subcontractors were not always able to provide the resources the takt production required. Since the contracts did not determine the resources needed, the site personnel were not able to lean on subcontractors' contracts. However, it is important to understand the subcontractors' role in the planning of the work. For example, Sacks & Harel (2006) emphasise that only the subcontractors can plan a realistic schedule for their own operations. Therefore, the contracts should be designed to encourage the subcontractors to plan their operations according to takt production for example by setting a required work pace.

Since the new production method required change in the employees' way of working, the site personnel should lead the change. Forbes & Ahmed (2011, p. 136) identify five actions the managers should take to successfully manage the change in production method. First, the managers should communicate with the employees why the change is made. Second, the managers should set performance standards to the subcontractors. Third, the new behaviours should be demonstrated clearly. Fourth, the new behaviour should be measured and rewarded. Fifth, the managers should support the change by making the changes positive for the parties involved.

7.1.5 Commitment to takt production

The case study indicated clearly that the attitudes towards takt production had changed, which caused challenges in takt production. Both lean production and knowledge management emphasise the role of the individual (Riege 2005; Liker 2006, p. 36; Yeh et al. 2006; Karkoulian et al. 2013). For example, Liker (2006, p. 36) states that since the

Toyota Way aims to offer the employees tools to continuously improve their operations, it increases the dependency on people. Moreover, organisational learning begins with learning by its individuals (Karkoulian et al. 2013). Therefore, it is important the individuals are committed to takt production and believe in its goals.

The site personnel was not properly educated in the beginning and they did not believe that they got enough support from the case company. A series of bad outcomes led to a mistrust for the takt schedule and the possibilities of its success. These attitudes could have been managed by offering proper training and support to the site personnel. For example, the Toyota Way encourages the employees to give and create development proposals and supports the employee commitment. However, it requires proper education, committed managers and culture that encourages to operate according the principles. (Liker 2006, p. 36) Since the management of subcontracted labour was the site personnel's responsibility, the negative attitudes towards takt production reflected to the subcontractors. Therefore, it is important to commit the site personnel into takt production.

Lack of commitment can also originate from the lack of training. Forbes & Ahmed (2011, p. 133–134) state that a successful implementation of lean methods in construction requires commitment to training and learning. They emphasise that all parties involved in the production should be trained in lean techniques and encouraged to learn. Since the case site did not use the education materials, the lack of commitment can also originate from lack of understanding. In related, lean construction also require commitment to waste elimination (Forbes & Ahmed 2011, p. 133–134). This also emphasises the importance of proper education since the employees need to understand why and how the waste can be eliminated.

As examined in the previous chapter, the site personnel's rewards and the subcontractors' contracts were still based on conventional construction production. Since takt production differs in most of its elements from conventional construction production, rewards and contracts should be adapted to new method. This study suggest that the commitment to takt production could be pursued through updating the reward systems and subcontracts, arranging proper education and creating a culture that encourages to takt production.

7.2 Development proposals for the management methods of subcontracted labour

Since the management methods were not systematically used through the observation, this study did not provide enough evidence about the functionality of every specific practices created for the case study. However, the case study recognised several repeating issues that indicated development proposals for the management of subcontracted labour.

First of all, the case study indicated a lack of communication. The meetings were created to allow communication and knowledge sharing between site personnel and the subcontractors, and between the subcontractors. The meetings are important part of knowledge management since they allow knowledge sharing between individuals. The meetings also enable knowledge creation since they offer a social situation where individuals can share their tacit knowledge. This can be examined as the socialisation mode of the SECI model.

The intra-organisational level of knowledge sharing were encouraged through the supervisor meeting. Through the observation the supervisor meeting was continuously arranged. These meetings were informal social situations where the site personnel communicate with each other and share knowledge. Since the meetings were very informal, they enabled the knowledge creation. In addition, the site personnel's experiences of these meetings were mostly positive. As the case study did not suggest problems in intra-organisational knowledge sharing, this research suggest that the case company would continue with informal supervisor meeting to ensure daily knowledge transfer between site personnel.

The inter-organisational level knowledge transfer were pursued through three meetings: morning meeting, takt production meeting and subcontractor meeting. Although the case site did not arrange all these meetings regularly, they all play an important role in the efficient knowledge transfer. During the case study, the meetings seemed to be the only event that allowed the subcontractors to communicate with each other. To ensure the efficient knowledge transfer between all parties, this research strongly suggests the meetings to continue in the case company's following takt production sites.

In addition, these meetings are also important in the aspect of knowledge creation. They offer a social event where the tacit knowledge is shared between different organisations and therefore, allows the case company to gather tacit knowledge outside the organisation borders. However, it is important to note that SECI model's socialisation often occurs

best in informal environments (Nonaka et al. 2000; Baldé et al. 2018) and therefore, the case company should keep the meetings as informal as possible.

Although the following meeting were not used or the use were not executed as planned, this research suggests that the case company would pursue these meetings and their targets. The meeting targets were expanded to ensure the site personnel will be aware why the meetings are arranged. The updated meeting targets for the inter-organisational meetings are presented in table 8.

Table 8. *The updated targets for the inter-organisational meetings.*

Meeting	**Targets**
Morning meeting	• To ensure all employees know the day's goals and can start their tasks • To allow the employees to share their concerns and problems and the solution can be worked out together • To encourage knowledge sharing and the culture of co-operation and collaboration
Subcontractor meeting	• To officially state issues and concerns about the production and agree on the future schedule • To officially confirm the subcontractors' commitment to takt production • To allow the subcontractors to participate in the future takt schedule planning
Takt production meeting	• To ensure everyone is aware the future schedule and all parties can execute it • To review the past mistakes and ensuring they will not occur again • To encourage the culture of co-operation and collaboration, and culture of continuous improvement and learning

The morning meeting aims to ensure all employees know their daily goals and are able to execute them. In addition, the morning meeting allows the employees share concerns daily and the supervisors to address a solution or encourage the participants to create the solution together. This meeting allows the site personnel to encourage the culture of co-operation and collaboration, and detect tacit knowledge from the employee level.

The takt production meeting aims to ensure all subcontractors' foremen are aware of the future schedule and are able to execute it. The meeting also allows the site personnel and the foremen to review the mistakes and obstacles from the past and make sure they will not occur again. This allows the site personnel to encourage both the culture of co-operation and collaboration, and the culture of continuous improvement and learning.

The subcontractor meeting was the only official meeting. These meetings could provide official confirmation about the subcontractors' commitment to takt production. The meeting also allows the subcontractors to participate in the production planning and therefore encourages to a culture of co-operation and collaboration. Although the case study indicated that the subcontractor meeting did not often include discussions about takt production, this study suggests that the meeting is considered as a part of takt production's management of subcontracted labour.

Although the communication channels and their use were defined, the communication was mainly executed face-to-face, via WhatsApp or by a phone. During the case study, neither Sitedrive nor Congrid were used as communication channels. The communication channels were the case sites attempt to make the knowledge transfer easier by utilising technology. During the case study, only WhatsApp seemed to make the knowledge sharing easier. Technology is an important part of knowledge sharing. However, if the used technology does not answer to the user needs, the technology can become a knowledge sharing barrier. (Riege 2005) Therefore, this research suggest further examination of the user needs and wider search of the technologies that would support them.

The management methods also included visual tools, which aimed to ensure the employees would have the right knowledge at the locations needed and to reduce the chance of mistake such as working in the wrong location. In construction site management, the visual tools can improve the communication (Tezel & Aziz 2017; Brady et al. 2018). The painted route map and the apartment numbering seemed to be an easy and low-priced solution to indicate the correct work locations. The info boards were not arranged as planned since the problems with printing the schedule. Since the visual tools aim to present information simply and in a way the employees can easily access it (Tezel et al. 2016), the printed schedule in the work locations could improve the knowledge about the takt production's time table and ensure their work in the right location. The research suggest the case company's future takt production sites would use both of these methods.

During the case study, the education materials were only used internally. Even though the materials were finished, the site personnel did not use them in the employee job orientation. However, the case study recognised a need for better understanding about takt production. In addition, Forbes & Ahmed (2011, p. 133–134) state that implementing lean methods in construction requires a commitment to training and learning. The subcontractors and their employees should be supported to learn the wanted work methods and behaviours. Therefore, the research suggests that the education materials would an

official part of takt production site's orientation materials. After the materials are used systematically, their functionality should be observed to develop materials that will truly encourage to takt production.

Although the case study was not able to collect proof from every management methods functionality, the research was able to notice their importance through the issues and challenges experienced in the case site. Hence, this research suggest that the case company will continue to manage the subcontracted labour in takt production sites through meetings, defining communication channels, visual tools and education materials. The suggested management methods are presented in figure 14.

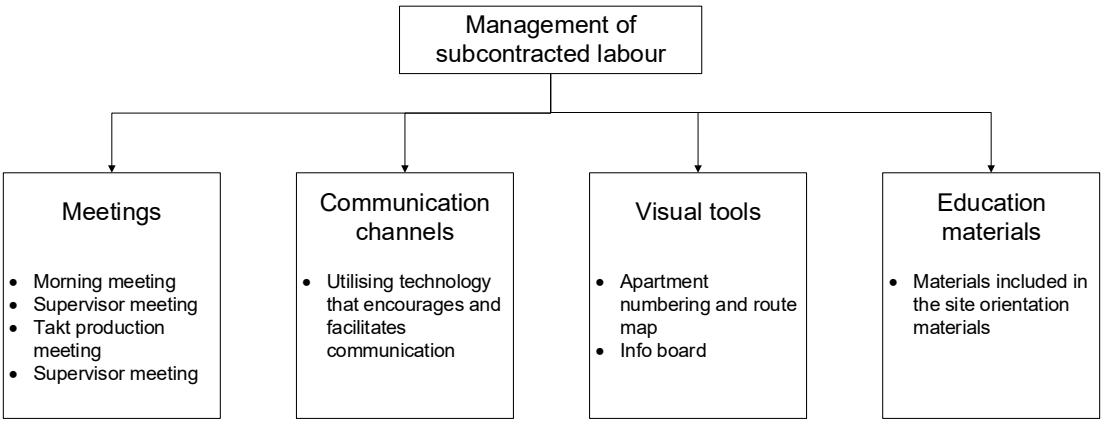

Figure 14. *Suggestion for the case company's management methods for subcontracted labour in the context of takt production.*

Figure 14 shows the suggested management methods. The meetings include all of the four meetings that were originally created for the case study. The communication channels, though, do not suggest any specific channels. The channels should be chosen based on a further mapping of the available solutions and the communication needs. The visual tools contain the apartment numbering and route maps, and the info boards. Education materials mean the same materials that were created for the case site but they should be included into the other site orientation materials and routines.

8. CONCLUSIONS

This chapter summarises the research targets and results. The chapter begins by examining the research's execution and how the research targets were reached. The chapter continues by evaluating the research limitations concerning the used research methods and execution. Finally, the chapter presents proposal for future research.

8.1 Summary of the research

The research aimed to improve the case company's takt production's management of subcontracted labour through the methods of knowledge management. In addition, the research targeted to form a set of management methods that the case company could utilise in its takt production sites. The research was executed as a qualitative case study in the case company's second takt production site. First, the research recognised topics from the knowledge management literature on which the case site's management should concentrate. These topics were also supported by the case company's earlier research. The topics were meetings, communication channels, visual tools and education materials. After that, specific management practices for the case site were created through a workshop. The functionality of these practices were examined through a case study. The case study was executes as an observation and a workshop. The results were formed through thematic analysis.

The research recognised issues and challenges in the case site's management of subcontracted labour. These issues and challenges were divided under five categories: 1) lack of communication, 2) problems with the use of Sitedrive, 3) problems with deliveries, 4) managing challenges and obstacles, and 5) attitudes towards takt production. Through these observations, the research was able to identify success factors of management of subcontracted labour in the context of takt production. The factors were: 1) efficient knowledge transfer between parties, 2) using only technology that has been thoroughly tested, 3) deliveries planned according the takt schedule, 4) managing challenges and obstacles, and 5) commitment to takt production. The success factors were then compared to earlier research, which resulted into development proposals. The success factors and the development proposals are presented in table 9.

Table 9. *Success factors of takt production's management of subcontracted labour and the development proposals.*

Success factor	Development proposals
Efficient knowledge transfer between parties	• Creating knowledge sharing culture and attitudes • Creating a working culture where the parties involved solve problems together • Creating a culture for continuous improvement and learning • Identifying and eliminating communication barriers
Using only thoroughly tested technology	• Identifying the needs takt production and its processes set for the technology • Evaluating the system functionalities to avoid unrealistic expectations
Deliveries planned according the takt schedule	• Utilising just-in-time production in deliveries • Creating a material delivery schedule
Managing challenges and obstacles	• Defining takt production targets • Rewards should be based on takt production goals • Subcontractors should be a part of problem solving so all parties involved could learn from it • Subcontractors should be encouraged to plan their work according to takt production by updating the contracts • Site personnel should lead the change in the changed production method
Commitment to takt production	• Committing individuals to takt production goals through proper training • Committing the site personnel by updating the reward system • Committing subcontractors by updating their contracts • Creating a culture that encourages takt production

Efficient knowledge transfer between parties was identified as one of the success factors of management of subcontracted labour. The case company should concentrate on creating a culture that emphasises knowledge sharing, continuous improvement and learning, and which encourages to solve the problems together. In addition, the case company should identify the barriers in communication and pursue to eliminate them. The research also identified the importance of using only thoroughly tested technology. The development proposals concerning this suggest to identifying the needs takt production sets for the technology. It is also important that the system functionalities are understood to avoid possible unrealistic expectations.

Moreover, takt production should be seen in the deliveries and management. The deliveries should be planned according the takt schedule by utilising the just-in-time production. The planning should result in a material delivery schedule through which the site

personnel can manage the deliveries. Furthermore, managing challenges and obstacles was also recognised as a success factor. The case company should help the site personnel to manage according to takt production by setting takt production goals and updating the rewards. The management can also be assisted by updating the subcontractors' contracts to match the takt production requirements.

The final success factor recognised was commitment to takt production. The case company should commit all individuals, site personnel and subcontractors to takt production. This can be pursued by creating a culture that encourages to it. Additionally, the research identified that the contracts and rewards can enhance the commitment as well as proper training and education. These success factors aimed to form focus points that the case company can utilise its takt production and the management of subcontracted labour.

In addition, the research formed management methods that the case company should use in its future takt production sites. The methods were created under the four topics that were recognised in the knowledge management literature: meetings, communication channels, visual tools and education materials. The research defined that the meetings aim to ensure knowledge sharing and creation, detecting problems and solving them. The communication channels were defined to reduce the risks of miscommunication and ease the knowledge transfer through technology. The visual tools were created to improve the site's communication. They aim to offer the employees knowledge in a simple and easy way at the place where they require it. Finally, the education materials aim to train the individuals into the new production method and encourage them to work according to takt production by explaining its key purposes.

This research's key purpose was to create management methods for subcontracted labour through the methods of knowledge management that the case company can utilise in their takt production site. In addition, the aim was to test their functionality through a case study. The created management methods were tested in the case company's construction site and the methods were further developed based on the observation and theoretical connections. Although the case study was not able to prove the functionality of the management practices that were not used, the research was able to show their importance through theoretical connections. Therefore, this research can be considered successful.

8.2 Research's limitations and future research proposals

This research limited to examine the management of subcontracted labour in sites that utilise takt production. Furthermore, the research limited on housing production and the

given management proposals might not be suitable to other construction production. The research was executed as a single case study. The specific management practices were designed precisely to the case company's and the case site's needs, and therefore they might not be suitable to other contexts. However, the research identified several focus points, which offer a more general view for the management of subcontracted labour in the context of takt production.

In addition, the case study were not able to gather information about all of the management practices functionality since they were not all used. However, the theoretical examination provided a general insight about the topic, which could be utilised by companies examining takt production and its management of subcontracted labour.

The research's data collection techniques were observation and workshops. These techniques relied highly on the researcher's observations. The researcher aimed to sustain an objective approach to the observations. However, this research recognises the possibilities in the researcher's subjective readings within the results.

Since takt production is still rather new concept and there is only limited amount of research executed, the research around it should be continued. For example, this research indicated a need for updates in the subcontracts and reward systems. Therefore, this research suggest a further research about how the construction site's contracts and rewards could encourage takt production. Furthermore, the research identified that the case site's progress was still measured and evaluated by the conventional construction measures. Therefore, there is a need to further examine the metrics that can be utilised in takt production.

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APPENDIX A: CONCLUSIONS FROM THE OBSERVATION

Observation		Cause	Impacts
Lack of communication			
1	HVAC does not proceed as planned.	The delays on HVAC were not detected early enough. Not enough communication about the schedule with the subcontractor. The site personnel did not have enough knowledge, how HVAC should proceed during the earlier phases of the construction process.	The tasks following HVAC were delayed and the whole takt schedule had issues on starting.
2	The communication between the site personnel and subcontractors was not fluent.	The schedule and the daily goals were not made visible to all parties (morning or takt production meetings were not arranged, the schedule was not printed on the floors). The education for takt production was not offered.	Subcontractors' lacked knowledge about takt production, schedule or the daily goals. The schedule was hard to update since the information about the tasks actual finishing times were hard to get.
3	The subcontractors are not aware of the takt production.	Takt production is not communicated clearly with the subcontractors. The meetings are not arranged, and the education materials are only in internal use. Takt schedule is not printed on the floors and Sitedrive is only in internal use.	The subcontractors do not plan their work according the takt schedule.
4	Some tasks' requirements are not completely determined.	The requirements are not completely determined before the tasks should start. The subcontractors do not participate in subcontractor meeting before they start their work in the case site.	The subcontractors have problems starting and finishing their first locations in the case site.
5	The subcontractors do not participate in the meetings.	The subcontractor meeting is the only meeting that has been arranged regularly throughout the production. The benefits for subcontractors are not clearly communicated.	The issues and challenges that the subcontractors have are not detected early enough. The communication about the takt schedule is not efficient.
Problems with the use of Sitedrive			
6	The updates on the schedule were not in Sitedrive.	The schedule seemed to change daily and updating the schedule in Sitedrive was considered rather time-consuming. The site personnel did not want to do the updates in Sitedrive until the future schedule seemed to be certain.	There was no up-to-date schedule available in the systems, and the subcontractors could not use Sitedrive as required.
7	The employees do not use Sitedrive.	The subcontractors do not see the benefits on using Sitedrive.	The awareness what tasks are completed is mainly in supervisors' heads. The supervisors' work load is increasing since they must mark the finished tasks themselves.

8	The schedule is not printed on the floors.	Sitedrive cannot provide an informative print of the schedule. Since the schedule is only in Sitedrive, site personnel do not have time to create a visualisation of the schedule via other tools.	The subcontractors' employees cannot see the schedule.
Problems with deliveries			
9	Deliveries from suppliers were hard to adjust for the needs of takt production.	Some suppliers required delivery dates to be set four weeks prior delivery and were not able to change the date since it was set. In some products the delivery batch was too large and could not be changed during the production.	The site's storage area was usually full of equipment. If the deliveries came too late, the employees did not have the required equipment for the day's work.
10	The subcontractor did not provide the articles or products when needed.	The subcontractor was not aware of the products needed each day or he or she had forgotten to order them.	The employees did not have the required equipment for the day's work or the site's storage area was filled with equipment, which were not needed in days/weeks.
Managing challenges and obstacles			
11	The subcontractors do not provide enough resources.	Subcontractors' employees are not able to work (sick leaves or other absences) or the subcontractors are not able to provide as many employees as planned.	The tasks do not finish on time and caused delays on the following tasks.
12	Lack of resources, who understand takt production.	The internal education has not been efficient enough. The takt production pilot's targets were not determined.	When facing challenges, the management of subcontracted labour shifts towards traditional construction sites management.
13	Subcontractors do not work in the pace scheduled.	Takt production or the work pace is not a part of the contracts.	The following tasks start are postponed so the pace for the rest of the production can be maintained.
Attitudes towards takt production			
14	Site personnel lack trust for takt schedule.	The prior disappointments seem to have created negative attitudes towards takt production.	Although the schedule exists, the schedule does not lead the production.
15	The attitudes towards piloting new methods are mostly negative.	The case site has several other pilot projects beside takt production. The site personnel's time is consumed mostly in task concerning the pilot projects.	Takt production is seen as one of the mandatory pilots in the site. The site personnel's excitement about the new production method has disappeared and the potential benefits from takt production are not seen any longer.