

Suggestions for takt production subcontract clauses – a conceptual study

Suggestions
for takt
production

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Abstract

Purpose – This study aims to provide a foundation for the development of subcontracts that suit takt production in construction.

Design/methodology/approach – This is a non-empiric conceptual study, which integrates takt production and general construction literature into new proposals for subcontract clauses suitable for takt production in construction. This study uses literature reviews, from which proposals regarding takt production viable subcontract clauses are conducted via logical reasoning.

Findings – A total of 13 proposals for takt production applicable subcontracts are provided in this study. The proposals emphasize detailed and collaborative planning, suitable payment methods and flexibility for takt plan modification.

Originality/value – Previous takt literature has not properly addressed the development of subcontracts for takt production, despite regular attempts to use subcontracting in takt production. This study aims to aid main contractors to create fair and suitable subcontracts, so that adhering to takt schedules could be more viable in practice. This study also acts as a foundation for further empirical studies regarding the subject.

Keywords Takt production, Lean, Lean construction, Subcontract, Subcontracting

Paper type Conceptual paper

1. Introduction

1.1 Background and purpose statement for this paper

Takt production originates from Lean and has been used in construction production particularly in the past decade (Haghsheno *et al.*, 2016). Takt production has been claimed to stabilize construction production (Haghsheno *et al.*, 2016), clarify, standardize and routinize tasks (Fransson *et al.*, 2013; Binninger *et al.*, 2017a), shorten production lead times (Binninger *et al.*, 2018), as well as reduce waste and increase productivity (Vatne and Drevland, 2016). However, fully executing takt production in accordance with the current takt production models has been reported to be challenging (Linnik *et al.*, 2013; Lehtovaara *et al.*, 2020), which is why development should be pursued.

Takt production is a new phenomenon in construction and published data regarding it is limited. The publications are mostly conference papers, in which various authors have discussed takt production in a very fragmented manner. Practices in the practical implementation of takt production vary in different companies and countries (Gardarsson *et al.*, 2019), further adding to



the fragmentation of information. Fragmented data and reported varying practices currently make the implementation of takt production a challenging task in practice.

Based on experience, takt production implementation seems to require incorporating new takt practices with traditional construction practices. At least two key reasons can be identified for this. Firstly, the construction industry has established codes of conduct that currently make implementing takt production in practice challenging. Currently, takt production is often a mixture of the new and the old, rather than a down-to-the-detail fully reinvented production model. Furthermore, not every detail has to necessarily be reinvented for takt production to function properly. Currently, adhering to takt production challenges organizations and their employees to reevaluate and reinvent their thinking and routines, which may take time and practice. Secondly, knowledge gaps and differing opinions still exist regarding takt production in the context of construction, which directs contractors to trial-and-error and improvement-over-time approaches in practice (Lehtovaara *et al.*, 2020). For example, details regarding subcontracting are rarely discussed, yet subcontractors are regularly used in takt production projects (Dlouhy *et al.*, 2016; Gardarsson *et al.*, 2019; Lehtovaara *et al.*, 2020). There have been challenges regarding the implementation of takt production (Alhava *et al.*, 2019; Andersen and Fyhn, 2019; Lehtovaara *et al.*, 2019; Keskiniva *et al.*, 2020). Some of these problems stem from construction in general that are emphasized by the ambitious requirements of takt production. For example, production prerequisite management and worker commitment are not novel challenges. Takt production sets certain unconventional requirements for the subcontractors (Frandsen *et al.*, 2013; Dlouhy *et al.*, 2016; Lehtovaara *et al.*, 2019). However, suitable subcontracts related to such unconventional production practices have not been discussed in the previous takt production literature.

This study aims to create a conceptual foundation for the development of subcontract clauses suitable for takt production. The foundation aims to help main contractors develop subcontracts that facilitate takt production in a realistic and sustainable manner. The foundation consists of propositions that have not been empirically tested. Instead, future testing in practice is recommended based on this study. This study is important from the perspectives of the main contractor and the subcontractors. Unrealistic subcontracts can lead to many issues during the production phase. For example, if adhering to the takt plan is not economically viable for the subcontractors, it can disturb the production flow, as subcontractors are economically forced to deviate from the takt plan.

This is a conceptual paper. The subcontracting clauses are established via literature review and logical reasoning as a conceptual study. Such conceptual research method is deemed suitable for this study, as takt literature is limited but similarly themed challenges and contractual solutions have partly been discussed in general construction literature previously without takt context. For example, adhering to a steady production rate is not completely unique to takt production and stage payments have been recommended as a solution in general literature. Because takt production seems to currently be a mixture of the new and the old, considering general construction literature is a logical foundational solution in the current absence of takt production knowledge. As the proposals in this study are theoretically derived, they must be empirically validated in practice. This study strives to advance takt production research by concretizing further research needs related to subcontracts in the form of proposed solutions.

1.2 The takt production method

In takt planning production is divided into small, repetitive segments based on location, time and work. Locations are ideally divided into similarly sized and repetitive takt areas (Frandsen *et al.*, 2013; Dlouhy *et al.*, 2016). Time is divided into static durations called takt time (Frandsen *et al.*, 2013). The duration of the takt time is usually between 1 and 5 workdays depending on the project (Dlouhy *et al.*, 2018). Work is divided into identical work

packages carried out in one takt area during one takt time (Dlouhy *et al.*, 2016). Takt scheduling is an iterative and time-consuming process, in which subcontractors can be used (Fransson *et al.*, 2013). Modifying the schedule during production is challenging, because there is little time to react to production disturbances. Furthermore, the number of details that require modification may be great if the takt schedule is detailed (Dlouhy *et al.*, 2018). Therefore, work packages are divided into work steps that can be completed flexibly as long as all work steps are completed within the takt time (Haghsheno *et al.*, 2016).

Detailed takt plans require more planning and coordination (Dlouhy *et al.*, 2018). Partly because of this, one week is the most used takt time, as it allows for more flexibility in the daily takt production management and because each weekend is a buffer (Binninger *et al.*, 2018). Dividing the plan into smaller segments increases the number of repetitions and steers to plan the task execution in detail (Haghsheno *et al.*, 2016). Some projects may require shorter takt times (Binninger *et al.*, 2018). For example, in an apartment building interior phase, a takt time of 1–2 workdays may be more suitable than a week (Lehtovaara *et al.*, 2019; Keskiniva *et al.*, 2020). In takt production, exceptionally precise and recurring milestones can be set, which can be monitored closely.

2. Method and structure

This study is based on a literature review of general construction and takt literature, from which new recommended subcontract clauses are concluded by means of logical reasoning. Takt construction literature is reviewed for current takt production practices, issues and recommendations that require subcontract clauses, presuming subcontracting is used. General construction literature is reviewed for contractual solutions, which purposes seem to align with the findings discovered in takt production literature.

2.1 Conceptual research method

Theoretical papers have a significant role in research. Conceptual papers do not contain or analyze data, as their focus is to integrate and propose new connections between existing concepts (such as in this study between takt production and traditional production) (Gilson and Goldberg, 2015), while, at the same time, serving as a reference point for new studies and a new kind of thinking (McGregor, 2018). The evidence is based on valid and credible logical argumentation, not on empirical testing of arguments (Whetten, 1989; McGregor, 2018). Particularly in cases where testing theory in practice is challenging, there is a place for conceptual papers (Gilson and Goldberg, 2015).

Conceptual papers begin with a short general description of the subject of the study, after which the subject is elaborated from a theoretical point of view (Gilson and Goldberg, 2015). A conceptual paper should focus on developing existing theory through several elements (Whetten, 1989). A competent conceptual paper can build theory by offering propositions regarding previously untested connections between concepts (Gilson and Goldberg, 2015; Whetten, 1989). The difference between a proposition and a hypothesis is that a proposition is not tested empirically (Whetten, 1989). Even so, if propositions are used, they should describe logical conclusions in such a form that hypotheses can be derived from them for future empirical studies (Whetten, 1989; Weick, 1989).

Takt production is novel, and there have been challenges in its implementation (Lehtovaara *et al.*, 2020). Current takt practices often differ from theoretical takt production (Lehtovaara *et al.*, 2021). Consequently, it is justifiable to develop conceptual takt production models even without empiricism, as comprehensive testing of theoretical takt production is currently challenging, particularly if the objective is to pilot several new development ideas at the same time. By theoretically developing the concept, the takt production model can be

made more viable in practice. In this study, the existing takt production theory is developed and new connections between it and general construction theory are created according to the process described by [Gilson and Goldberg \(2015\)](#), by proposing new contractual procedures that can be empirically tested in the future. The suitability of the subcontract clauses implemented in takt production is, thus, evaluated by means of logical reasoning according to the recommendation by [Whetten \(1989\)](#). The processes of the logical reasoning in this study are described in more detail below.

2.1.1 Logical reasoning in conceptual research. Logical reasoning is based on truthful arguments, i.e. premises, from which a new logical conclusion is drawn ([Ferguson and Priest, 2016](#)). If the premises are true and the logical chain of reasoning valid, the conclusion is also true ([Ferguson and Priest, 2016](#)). In this study, the premises assumed to be true are the contractual practices recommended in general production and the identified current practices, deficiencies and challenges related to takt production. By logical reasoning, propositions for subcontract clauses are determined based on these challenges and recommendations. The conclusions logically derived from the premises in this study are propositions, because they have not been empirically tested.

For example, a premise in general construction literature is that stage payments steer subcontractors to follow production schedules rigorously ([Potts, 1988](#)). Another premise is that following production schedules is exceptionally important in takt production because production schedules are drawn up in exceptional detail ([Haghsheno et al., 2016](#)), parties are committed to following them ([Lehtovaara et al., 2020](#)), and reactive schedule modification during production is challenging ([Lehtovaara et al., 2019](#)). The logical conclusion from *P1* and *P2* is that stage payments as a method to steer commitment to takt schedule is worth exploring.

2.2 Description of the literature reviews

Conceptual papers often generate new ideas by synthesizing and integrating data from existing literature ([McGregor, 2018](#)). Therefore, a literature review into the existing takt production literature was conducted in this study to investigate subcontracts in takt production. The purpose was to discover relevant themes regarding subcontracts in takt production in the literature and find relevant information related to them.

The takt production literature searches were conducted in the Scopus database. The used search term was “Takt”, and “Engineering” was used to limit the results. Altogether 45 books and conference or journal quality papers have been published about takt production. Twenty-one results studied one or more case projects. The key points presented in [Table 1](#) were deemed relevant in the development of the subcontracts. In the selection, the relevance and validity of the sources and the relevancy regarding takt production subcontracts were evaluated. The planning and control phases of takt production were both included, as they both can involve subcontractor activities.

At the beginning of the study, a presumption was made that traditional construction literature would contain information useful in drafting takt production subcontracts. Therefore, further information was sought in general literature based on the discovered takt production themes. The search was conducted in the Scopus database and in the custom search engine of the university of the authors of this study. The search terms used were subcontract*; partnering; payment methods; and procurement. The term “Construction Industry” was used to limit the search. The search terms were selected based on the themes mentioned above. [Table 2](#) presents the relevant themes and found sources regarding subcontracts covered in general literature.

Suggestions for takt production

Theme	Facts that must be considered in the subcontracts	Literature source
Subcontractor role in takt planning	Takt production should be planned in workshops cooperatively with the subcontractors. Collaboration is emphasized in takt production	Fransson <i>et al.</i> (2013), Fransson <i>et al.</i> (2015); Gardarsson <i>et al.</i> (2019), Haugen <i>et al.</i> (2020)
	Subcontractors must be familiarized early with takt production for collaborative takt planning and production execution	Gardarsson <i>et al.</i> (2019), Lehtovaara <i>et al.</i> (2020)
	The takt plan may be modified during production (which logically requires flexibility from the subcontracts)	Gardarsson <i>et al.</i> (2019)
Takt production control	Subcontractors partake in daily takt meetings during takt production, which have their own requirements and procedures	Dlouhy <i>et al.</i> (2016)
	Logistics in takt production should be planned precisely	Lehtovaara <i>et al.</i> (2019)
	The execution of takt production has been challenging	Lehtovaara <i>et al.</i> (2019), Lehtovaara <i>et al.</i> (2020)
Takt production subcontracts	Delayed takt production is restored with additional resources and overtime work	Gardarsson <i>et al.</i> (2019), Dlouhy <i>et al.</i> (2019)
	Digitalization can be utilized for monitoring and information transfer in takt production and workers can be used for status reporting	Alhava <i>et al.</i> (2019)
	Suitable payment methods for subcontractors must be studied further in takt production	Vatne and Drevland (2016), Lehtovaara <i>et al.</i> (2019)
	Production rates are equalized in takt production, which must be considered in subcontracts	Linnik <i>et al.</i> (2013), Fransson <i>et al.</i> (2015)

Table 1. Matters to be considered in the development of takt production subcontracts based on the literature review

Relevant themes in general construction literature	Literature sources
Creating trust and collaboration between the main contractor and subcontractor via subcontracts	Eriksson and Laan (2007a); Eriksson (2008), Yin <i>et al.</i> (2014); Wong and Cheung (2005); Pesämaa <i>et al.</i> (2009); Arditi and Chotibhongs (2005)
Suitable subcontract payment method selection	Whitticks (2005), McGuinness (2008); ICE (2009)
Requirement for fair subcontracts	Uher (1991), Arditi and Chotibhongs (2005); Yik <i>et al.</i> (2006), Uher and Davenport (2009)
Subcontractor participation in production planning	Marchington <i>et al.</i> (1992), Maloney and Federle (1993); Coffey (2000)
Early subcontractor informing and training to achieve fair subcontracts and production plan adherence	Thomas and Flynn (2011); Shen <i>et al.</i> (2017)
Subcontractor steering with stage payments	Potts (1988); McGuinness (2008), ICE (2009)
Procedures and responsibilities regarding production delays	Uher (1991), Uher and Davenport (2009)

Table 2. Themes and sources in general construction literature

3. Results

3.1 Subcontracts in construction – status based on the literature review

Production involves many organizations that have their own interests, objectives and competences, making construction management complex. Procurement is an important part of production planning and coordination, and successful procurement enables cost, quality and risk management (Pesämaa *et al.*, 2009). Typically, in the procurement of subcontracts, not

enough attention is paid to the generation of trust and collaboration even though they are essential for the success of a project (Eriksson and Laan, 2007; Eriksson, 2008; Yin *et al.*, 2014).

Viable procurement requires functioning tender evaluation criteria. Lowest price tendering has been criticized and claimed to cause disputes and confrontations that lead to rising costs, longer construction periods, deterioration of quality and poor customer satisfaction (Pesämaa *et al.*, 2009). Lowest price tendering also reduces long-term cooperation, as project parties vary between projects (Dubois and Gadde, 2000; Ahola *et al.*, 2008). Lowest price tendering-based procurement is most appropriate for simple and standardized tasks with little uncertainties (Eriksson, 2008). Main contractors often use limited tendering in the selection of subcontractors or negotiate directly with one subcontractor (Eriksson, 2008). The emphasis on cooperation in the selection of contractors has increased, as it is considered to lead to better results (Wong and Cheung, 2005; Pesämaa *et al.*, 2009).

3.1.1 Subcontracts in construction in general based on the literature review. The majority of construction is currently subcontracting (Dubois and Gadde, 2000; Kumaraswamy and Matthews, 2000; Arditi and Chotibhongs, 2005; Eriksson and Westerberg, 2011), making subcontracts critical. The responsibilities of project parties are defined in subcontracts, indicating liabilities and compensations during disputes (Yik *et al.*, 2006). Consequently, subcontractors consider the clauses to be the biggest risk for their operation (Uher and Davenport, 2009). Subcontracts should be fair to both parties. Even if partnering is sought, contracts must be clear and comprehensive. Otherwise, unclear cooperation arrangements related to production models may, unintentionally, change the responsibilities and distribution of risks between the contracting parties (Yik *et al.*, 2006).

Limited resources are a common challenge in construction. Shortage of workers on a site may be due to incorrect understanding of the workload or thinking that work can be done out of schedule (Thomas and Flynn, 2011). Furthermore, the resources may be divided between several sites, one of which may be late thus taking up more resources than planned (Thomas and Flynn, 2011). According to Thomas's and Flynn (2011) interviews, specifying to the subcontractors what is expected from them before production begins is the most important aspect.

Deciding the payment method is an essential part of drafting a subcontract. Payment method practices may vary according to country. According to ICE (2009), in most contracts the subcontractor is paid monthly for the work done based on unit prices defined in the contract. The contractor is paid for producing units but not steered to produce completed sections in one go (ICE, 2009). Because production involves several trades, handing areas over in schedule for the following trades is essential for production flow (McGuinness, 2008). Consequently, a reimbursable cost contract may be used to pay according to costs incurred (Whitticks, 2005). Reimbursable cost contracts increase flexibility, making it simpler to modify plans and plan collaboratively (Whitticks, 2005). The disadvantages of reimbursable cost contracts include that it is difficult to know the total cost in advance, there is no incentive for the subcontractor to reduce costs or fully complete tasks as rapidly as possible and the main contractor must supervise the accumulation of working hours (Whitticks, 2005).

Subcontractors can be steered toward completing areas swiftly via stage payments. The contractor is paid percentages of the contract price for completing milestones defined in the stage payments (ICE, 2009). Setting milestones ensures that the subcontract is completed at a steady production rate, allowing locations to be handed over to following trades at a steady pace (McGuinness, 2008). Furthermore, monitoring the progression of the subcontract becomes easier if milestones are set (Yik *et al.*, 2006).

Rigorous contractual requirements can be risky. A subcontractor may consider strict requirements as financial risks or unfair opportunism by the main contractor (Yik *et al.*, 2006) and may tender with higher prices to cover the risk (Yik *et al.*, 2006; Uher and

Davenport, 2009). This may partly be because in the experience of subcontractors, the in-house drafted conditions of the main contractor can sometimes be unfavorable to the subcontractor (Uher and Davenport, 2009). Furthermore, milestones increase the contractual requirements for the main contractor to ensure that there are locations available for the subcontractor at agreed times, which may reduce the willingness of the main contractor to set many milestones (McGuinness, 2008).

3.1.2 Integrating subcontractors in takt planning. Employee involvement refers to giving employees a wider influence than in the contractual job description, such as in problem-solving and decision-making (Marchington *et al.*, 1992). Involvement may include decisions regarding work methods, independent quality monitoring or scheduling work (Maloney and Federle, 1993). The objectives of involving subcontractors are better cooperation between the different parties, innovation, greater commitment and linking employee skills to production management (Maloney and Federle, 1993; Marchington *et al.*, 1992). Integrating subcontractors into planning may have positive effects from financial (Errasti *et al.*, 2007), schedule (Elfving *et al.*, 2005), quality (Errasti *et al.*, 2007) and innovation (Eriksson *et al.*, 2007a, 2007b) viewpoints.

Nearly all clients, main contractors and subcontractors that responded to Arditi and Chotibhongs's (2005) survey believed a partnering agreement to be beneficial for all parties. Particularly early pre-contract involvement is considered to have significant positive effects on developing mutual understanding, reducing constructability problems and improving scheduling and planning (Arditi and Chotibhongs, 2005). According to surveys, most construction workers are willing to influence their work (Maloney and Federle, 1993; Coffey, 2000).

Regarding collaborative takt planning, schedule changes should be approved by all subcontractors, because different tasks are closely linked, and schedule changes affect everybody (Gardarsson *et al.*, 2019). The participation of subcontractors in planning is a critical factor (Fransson *et al.*, 2013; Fransson *et al.*, 2015; Gardarsson *et al.*, 2019) because poorly planned or managed takt production subtly slips toward the traditional production method of weekly based control (Andersen and Fyhn, 2019; Lehtovaara *et al.*, 2019). Gardarsson (2019) describes a case, in which involving subcontractors in takt planning engaged the subcontractors to follow the takt schedule and solve problems independently. According to Gardarsson *et al.* (2019), this led to a reduction in construction defects and sick leaves. Yet, subcontractors are not always involved in early takt planning and scheduling (Fransson *et al.*, 2013; Dlouhy *et al.*, 2016; Gardarsson *et al.*, 2019). Subcontractors must be introduced to the takt production model for early collaborative planning to be possible (Gardarsson *et al.*, 2019).

In some takt projects, subcontractors have not been involved in early production planning but have participated in daily takt meetings that monitor the situation and aim to solve problems during production (Dlouhy *et al.*, 2016; Binninger *et al.*, 2017c; Gardarsson *et al.*, 2019). Once takt production has started, subcontractors can participate in minor daily collaborative production planning and problem-solving (Binninger *et al.*, 2017c) as well as in reporting the production status (Dlouhy *et al.*, 2016). Daily meetings have been found to be a functioning construction management method in several projects irrespective of takt time duration (Lehtovaara *et al.*, 2021).

3.1.3 Takt production subcontracts based on the literature review. Only a few mentions of suggestions regarding subcontracts exist in the takt literature (Gardarsson *et al.*, 2019; Lehtovaara *et al.*, 2019; Vatne and Drevland, 2016). However, the literature does include supplementary information that must be considered in the subcontracts. For example, the literature describes takt production practices that set expectations and limitations for the subcontractors, which logically relate to subcontracts.

The work of the subcontractor can be influenced within the limits of the contract. Subcontracting and subcontracts have been a challenge in most projects implementing

several lean construction tools (Shang and Pheng, 2014; Devaki and Jayanthi, 2018; Ayarkwa *et al.*, 2012) and in takt production projects (Vatne and Drevland, 2016; Lehtovaara *et al.*, 2019). For example, unfit clauses may make it difficult to adhere to a detailed takt production schedule (Lehtovaara *et al.*, 2019).

Takt production requires a suitable payment method (Vatne and Drevland, 2016; Lehtovaara *et al.*, 2019). A subcontractor cannot afford to keep workers in a site that constantly has too little work to do and generates poor income for the subcontractor (Thomas and Flynn, 2011). Also, a subcontractor may view contractually prohibiting working ahead of schedule as a risk and therefore submit a higher tender. These aspects may conflict with the objectives of takt production. This has not been covered in the literature from the viewpoint of takt production subcontracts.

Takt production requires a steady number of workers on the construction site, as work progresses at a steady pace (Dlouhy *et al.*, 2016), there is no significant time buffer between tasks (Dlouhy *et al.*, 2019), and takt production is used particularly in repetitive locations (Haghsheno *et al.*, 2016). Lehtovaara *et al.* (2021) mention that payments should be tied to reported progress of work packages. This way subcontractors could be motivated to follow the takt schedule (Lehtovaara *et al.*, 2021). Lehtovaara *et al.* (2021) do not mention stage payments in this context directly, but payments according to work package progression seem analogous to stage payments.

In takt production, unit priced subcontracts may steer subcontractors to leave small parts of tasks unfinished or undone altogether until the end of the subcontract, as finishing small tasks immediately may lower the subcontractor's hourly earnings (Lehtovaara *et al.*, 2019). Subcontractors may in such situations deviate from the schedule by reserving too many locations and optimizing only their own work (Lehtovaara *et al.*, 2021). This may impede or prevent consequent work packages to be carried out on schedule.

The hourly earnings of subcontractors may also rise because of takt production. Vatne and Drevland (2016) describe a project where production progressed smoothly, which resulted in hourly subcontractor earnings rising to 18% higher than average. Takt production did not lower project costs, as due to unit pricing, the subcontracts did not save money for the main contractor. The foremen recommended hourly rate subcontracting for smoothly executed takt production to benefit more from the shortened production lead time.

In lump sum subcontracts, the revenue increases by carrying out the subcontract rapidly. The faster the subcontract is completed, the higher the hourly earnings are for the subcontractor. In takt production, the objective is to standardize all production rates (Frandsen *et al.*, 2013; Dlouhy *et al.*, 2016). Therefore, faster rates are slowed down and slower rates hastened (Binninger *et al.*, 2017c). It is also recommended that the workload of workers is lowered to factor in uncertainties (Frandsen *et al.*, 2015). Another option is to make more laborious tasks slightly over-resourced by addition of workers (Frandsen *et al.*, 2015; Gardarsson *et al.*, 2019). For lump sum and unit price subcontracts, this means that the hourly earnings in slowed down subcontracts fall because of the reduced production rate. This may lead to complying with takt production being economically unattractive for a subcontractor if the subcontractor cannot respond to the reduction of production rate by cutting down its own resources or if there is no workable backlog outside the takt production [the use of which has been recommended by Frandsen *et al.* (2015) and Gardarsson *et al.* (2019)]. In relation to this, Lehtovaara *et al.* (2020) mention that sometimes when there has not been enough work, this has resulted either in a penalty for the main contractor or the subcontractor leaving the site to work elsewhere.

Reimbursable cost subcontracts are either based on trust between the main contractor and the subcontractor, or on monitoring of the subcontractor's working hours and costs

(Whitticks, 2005). The risk in hourly payments is that the subcontractor may try to slow down its production rate to generate more billable hours. It may be difficult to verify if the hours invoiced correspond to the actual hours worked, particularly if the employees are not always at the same site or if monitoring is infrequent. For this reason partnering with subcontractors should be considered, where work between the parties is based on trust and long-term cooperation (Lehtovaara *et al.*, 2020). On the other hand, takt production enables production monitoring in greater detail (Dlouhy *et al.*, 2018; Keskiniva *et al.*, 2021), which allows the comparison of hours worked and hours invoiced in more detail for example with digital tools.

3.2 Logical reasoning – the recommended subcontract clauses in takt production

Based on the literature, little has been written about the subcontract clauses suitable for takt production. On the other hand, the literature offers recommendations for takt production that should, based on logical reasoning, be considered in takt production subcontracts. To be able to execute takt production as planned, the subcontracts should be developed to better fit the takt production model.

3.2.1 *Considering cooperation in drafting subcontracts.* Based on the literature, takt production emphasizes cooperation between the production stakeholders. The following chapters introduce the premises (indicated by capital P and the number of the premise), found in the literature, regarding the significance of subcontracting cooperation in takt production:

- P1: Sometimes the main contractor drafts a subcontract that is favorable to the main contractor at the expense of the subcontractor (Uher, 1991; Arditi and Chotibhongs, 2005).
- P2: Unfair subcontracts hinder cooperation (Wong and Cheung, 2005).
- P3: Takt planning should use subcontractors (Frandsen *et al.*, 2013, 2015; Haugen *et al.*, 2020; Lehtovaara *et al.*, 2020).
- P4: It must be possible for the production stakeholders to follow the takt plan rigorously (Haghsheno *et al.*, 2016; Haugen *et al.*, 2020).
- P5: Open communication during the planning and implementation of takt production is important (Frandsen *et al.*, 2013; Dlouhy *et al.*, 2016).

Next, a new proposition is deduced from the premises above. To distinguish between the propositions and the premises, the propositions are from now on called conclusions (indicated by capital C and the number of the conclusion) and are presented in bold and inside square frames. The following conclusion can be logically drawn from P1 to P5:

- CI.** When drawing up a subcontract in takt production, the objectives of the subcontractor and the main contractor must be harmonized.

Subcontracts must be fair for it to be possible to rigorously implement takt production. Fair subcontracts are worth pursuing, in general, but in takt production they seem to be compulsory. This has not been previously mentioned regarding takt production.

Subcontracts must enable the cooperation between the main contractor and subcontractors. Next, the premises in the literature concerning the responsibilities of the subcontractor and the main contractor regarding subcontracts are described:

CI

- P6: Effective subcontracting requires that subcontractors know what the execution of production requires of them already in the procurement phase (Shen *et al.*, 2017).
- P7: The expectations regarding the subcontractor's task planning and scheduling, required production rate and staffing, quality, safety and possible other matters must be made clear in the procurement phase (Thomas and Flynn, 2011).
- P8: Collaborative planning of takt production in workshops is recommended (Fransson *et al.*, 2013), and for that reason among others, subcontractors must be orientated about takt production (Lehtovaara *et al.*, 2020).
- P9: Takt production logistics can be standardized with repeating takt area specific transportations (Lehtovaara *et al.*, 2019, 2020), in which case subcontractors must know their role in the logistics system.
- P10: Takt production should be steered in daily takt meetings, in which subcontractors must participate (Dlouhy *et al.*, 2016; Lehtovaara *et al.*, 2019).
- P11: Workers can be used in digital reporting of takt production progress (Alhava *et al.*, 2019).

From the above premises *P6–P11*, it can be logically concluded that:

- C2. The expectations regarding the tasks of the subcontractor must be clearly presented in the procurement phase. They must also be brought up in relation to takt production and its special features, and they can be demanded in subcontracts, if necessary.

These special features include, among others, participation in orientations and collaborative planning workshops, participation in production phase takt meetings, requirements regarding material and tool transportations and storage, adhering to the collaboratively planned takt schedule, always maintaining steady and adequate resources on the site and possibly documenting the production status depending on the monitoring process used by the main contractor. The special features of takt production have been sporadically covered in previous literature, but taking them into account in subcontracts has not been mentioned.

3.2.2 *Takt production progression management via subcontracts*. In takt production, firm and strictly monitored targets are set for production. There have been challenges in complying with takt production. Subcontractors can be steered to comply with these targets by means of subcontract clauses. Next, the premises regarding the management of takt production progression through subcontracts are described:

- *P12*: Tasks or work packages that have not finished in one go according to the takt plan have been a challenge in takt production (Lehtovaara *et al.*, 2021).
- *P13*: Fully complying with the first takt schedule version often fails (Lehtovaara *et al.*, 2021).
- *P14*: With smooth handovers, takt production tasks can follow one another independently (Haugen *et al.*, 2020).
- *P15*: There are at least two conditions for takt production handovers from one subcontractor to another: the location must be clean and the work packages 100% complete (Haugen *et al.*, 2020).
- *P16*: The main contractor and subcontractors should know what tasks and subtasks (including cleaning and inspections) must be completed before moving from one takt location to the next and what is the required quality for these tasks (Lehtovaara *et al.*, 2021).

- P17: It may be worthwhile to pay subcontractors based on work package progress (Lehtovaara *et al.*, 2021).
- P18: In stage payments, the project is divided into smaller sections, for the completion of which the contractor is paid percentages of the contract price (Potts, 1988).
- P19: Stage payments motivate the contractor to complete sections of the project in one go if the stage payments are tied to the stage of completion of the sections of the project (Potts, 1988).
- P20: Stage payments can be used to achieve steady progression of tasks (Potts, 1988).
- P21: Steady progression is one of the most important goals of takt production (Dlouhy *et al.*, 2016).

From the above premises *P12–P21*, it can be logically concluded that:

- C3. Stage payments should be tied to completing work packages, as this generates motivation for the subcontractor to fully complete work packages in one go ready for the next subcontractor.

In the literature, the use of stage payments has not been directly mentioned previously, but Lehtovaara *et al.* (2021) have mentioned payment per work package progress.

From the above premises, it can also be logically concluded that:

- C4. In stage payments, the work package specific start and finish dates defined in the preliminary takt schedule should not be set in stone, as they may have to be changed during production when the takt schedule is modified.

Locking up the dates based on the preliminary takt schedule makes it more difficult to modify the takt schedule later. The connection between subcontract clauses and the flexibility required in elaborating takt plans during production has not been previously discussed in the literature.

3.2.3 *Considering adequate revenue for subcontractors in subcontracts.* Based on the literature, there have been challenges regarding the selection of the subcontract revenue model in takt production. Next, the premises regarding subcontract revenue models are described:

- P22: More functioning revenue models, which consider the revenue logic of all stakeholders, are required in takt production subcontracting (Lehtovaara *et al.*, 2019).
- P23: Takt production aims to minimize work waiting for workers, which enhances the progression of areas and minimizes the amount of work in process (Linnik *et al.*, 2013; Lehtovaara *et al.*, 2021).
- P24: In takt production, workers must be underloaded, e.g. 70%–80% of possible capacity (Frandsen *et al.*, 2015). The purpose of underloading is to make sure that despite reasonable production rate variation, there is always enough workforce to complete tasks (Linnik *et al.*, 2013). If work is finished on time, the extra capacity can be used to complete the workable backlog or to prepare for handovers (Frandsen *et al.*, 2015; Lehtovaara *et al.*, 2021).
- P25: On the other hand, underloading may also lead to idle time (Linnik *et al.*, 2013) if there are not enough tasks in the workable backlog.

From the above premises *P22–P25*, it can be logically concluded that:

- C5. If subcontractors are not paid for idle time, compliance with takt production may cause resistance or it may be economically impossible.

Idle time has been mentioned previously in the takt production literature ([Linnik et al., 2013](#)), but taking considering it in subcontracts has not been discussed. If idle time cannot be allocated to workable backlog, compensation for idle time should be considered to make the subcontracts financially sustainable. In relation to compensating the subcontractors for idle time, two further propositions can be logically concluded:

- C6. If hourly payment is used, work hours calculations must consider the idle hours resulting from production rate standardization and underloading. The subcontractors must be compensated for them.
- C7. In unit price or lump sum payment methods, the economic viabilities of production rate standardization and restriction must be considered from the perspective of the subcontractors.

3.2.4 Considering practices regarding delays in takt production. Rigorous adherence to the takt plan is important. Because production delays may occur, corrective practices must be clearly defined in subcontracts. Next, the premises regarding the practices for delays are defined:

- P26: Practices regarding delays are usually defined in subcontracts ([Uher, 1991](#)).
- P27: There are several ways to react to delays, such as production crashing or modifying the schedule ([Pierce, 2013](#)).
- P28: In takt production, work packages are drawn up based on milestones defined together with the client, which is why the schedule must be followed and work packages completed on time ([Haghsheno et al., 2016](#)).
- P29: Because it is important to complete work packages on time, production crashing should be used after delays ([Haghsheno et al., 2016](#)).
- P30: With a takt time of one week, weekends act as a time buffer for production crashing ([Haghsheno et al., 2016](#)).
- P31: After formidable delays, production may be stopped for additional planning and problem-solving. Then it is possible to collaboratively reschedule as necessary ([Binninger et al., 2017a, 2017b, 2017c](#)).

From the above premises *P26–P31*, it can be logically concluded that:

- C8. The methods to make up for delays must be defined in subcontracts.

In projects with a takt time of less than one week, delay management is particularly challenging, as there is no weekend buffer at the end of every work package:

- C9. Takt production crashing may introduce extra costs, the responsibility for which must be defined in the subcontract.

The main contractor tends to ensure that the subcontractor compensates the main contractor for delays it has caused ([Uher, 1991](#)). On the other hand, main contractors often do not compensate subcontractors for delays the main contractor themselves cause ([Uher,](#)

1991). According to Uher (1991), it is for the best if terms like these work both ways. From the above premises, it can be further concluded that:

C10. Subcontracts must clearly define, under what kinds of circumstances and on what terms production crashing takes place.

For example, if a work package is delayed because of the subcontractor, the subcontractor may be required to complete the work package before the next takt at their own expense. Similarly, it must be clearly stated what is done when work packages must be crashed due to reasons beyond the responsibility of the subcontractor. Taking work package crashing into account in subcontracts has not been previously discussed in the literature. However, schedule crashing is not always appropriate, which is why:

C11. If the takt schedule cannot be crashed, the schedule is modified so that it is possible to steer production in the future.

Thus, production steering without an up-to-date plan can be avoided. Modifying the takt schedule is not a new recommendation but adding it as a secondary solution alongside primarily crashing is a new recommendation. Also, it is a new proposition that this matter should be considered in subcontracts.

3.2.5 Allowing adequate flexibility for takt production in subcontracts. The takt plan may be modified during production. For this to be possible, subcontracts must not prevent it. Next, the premises related to allowing modifications to the takt schedule during production are presented:

- P32: Takt production is not a stable process: as production progresses, the plans must be honed, because the preliminary “estimated schedule” cannot be executed as such (Dlouhy *et al.*, 2016; Frandson and Tommelein, 2016).
- P33: Modification mechanisms exist for modifying the schedule during production (Binninger *et al.*, 2017a, 2017b, 2017c) that are described in P28.
- P34: Contractually locking up the takt production rate, start and finish dates and the workable backlog may make it difficult to modify the schedule during production.
- P35: At the beginning of a project, the suitability of takt production should be test-ran with a reduced workload, by reducing the initial size of the first few takt areas (Frandson *et al.*, 2013; Lehtovaara *et al.*, 2021).

From the above premises *P32–P35*, it can be logically concluded that:

C12. For it to be possible to modify takt plans, the subcontracts must allow it.

The first schedule version must be highly viable to minimize detailed and laborious replanning during production. Minimizing replanning also requires less flexibility from the subcontracts. The importance of the first takt schedule draft has not been previously emphasized in the literature. Subcontractors must understand that developing the takt schedule is in the interests of all stakeholders, or causes no harm to anyone. If making significant changes poses a risk to the revenue of the subcontractor, the subcontract may need to be renegotiated after the schedule modification, depending on the content of the original contract. The connection between subcontract clauses and takt schedule modification during production has not been previously discussed in the literature. Logically concluding from the above:

C13. Subcontract supplementation should be done together with subcontractors after collaborative planning and a test run.

The content of subcontracts should, simultaneously, strive for clauses that steer for takt schedule adherence and for retaining adequate flexibility for the development of the takt schedule during production. Matters to be supplemented include the uniform takt production rate, the start and finish dates of the subcontract and agreeing on the workable backlog. Subcontract supplementation has not been previously mentioned in the literature but seems to be advisable.

4. Conclusions

Takt production utilization in construction has increased over the last two decades. However, challenges exist in the implementation which are partly related to subcontracting and subcontracts. There are specific objectives and practices related to takt production. Considering these in subcontracts has not been previously discussed.

This article creates a foundation for subcontracts suitable for takt production. Based on a literature review and conceptually, by means of logical reasoning, this article develops subcontract clauses, for better implementation of takt production in the future. Fair and detailed subcontracts define common and clear ground rules for the main contractor and the subcontractor, which makes operating clearer.

Based on logical reasoning, 13 new recommendations were defined regarding the drafting of subcontracts. The expectations and needs of subcontractors and main contractors should be coordinated for takt production to be viable. The goals and requirements for the subcontractor should be made clear in the procurement phase already and they should be considered in subcontracts. Based on the literature, these requirements include collaborative takt planning workshops, daily takt meetings and other site meetings, having a steady number of resources on the construction site, work package completion in one go within the takt, responsibilities regarding material transportation, rigorously following the takt schedule and, if necessary, digital production status reporting.

Stage payments may be used to steer subcontractors to comply with takt production and complete work packages in one go. Leveling production rates may cause waiting, and the principles of paying for this must be addressed in subcontracts. The selected payment method for subcontracts must be suitable for takt production. Following the takt schedule is important, which is why liabilities and practices, such as production crashing, should be clearly defined in advance.

Takt plans must be modified during production, so subcontracts should be flexible enough to allow this. On the other hand, takt production sets detailed and frequent milestones for the subcontractors. Therefore, subcontract clauses should be supplemented partly in cooperation with the subcontractor to make the clauses realistic, applicable and reasonable. Based on this study, it is recommended that subcontracts are complemented during the first run study at the beginning of takt production when the workload is lighter. [Figure 1](#) illustrates a summary of the recommendations developed based on this study and their interrelations.

The recommendations of this study are preliminary, as they have not been tested in practice. Consequently, a recommended subject for further research is to study the subcontract clauses recommended in this article in practical takt production projects. Practical studies may also give rise to a need for new subcontract clauses to complement the recommendations of this study. Supplementing subcontracts during takt production should be studied more closely to find out what kinds of challenges and possibilities are related to it and what are the detailed recommended practices

Suggestions for takt production

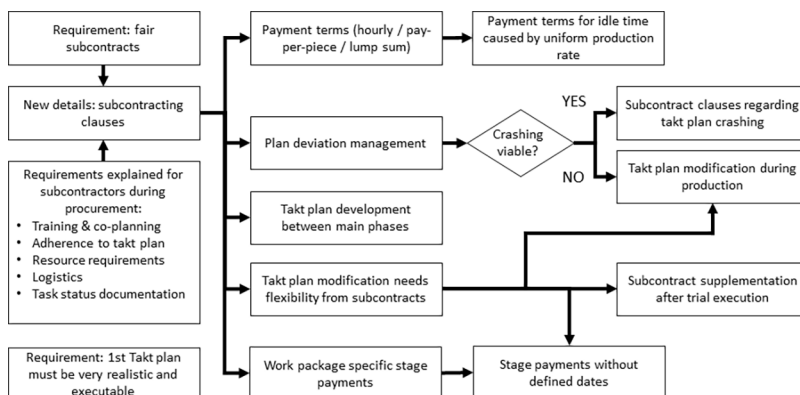


Figure 1.
Recommendations related to takt production subcontracts

regarding contract supplementation. Presumably, it may be necessary to adjust the content of subcontracts project by project, to some extent. For example, different types of projects or takt production cooperation that continues from project to project may, possibly, impact subcontract content requirements.

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