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PREVENTING THE PARADE OF DELAYS IN TAKT PRODUCTION

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ABSTRACT

In recent years, takt has become an increasingly more common method to structure work in construction projects. Because of the tight coupling of activities in takt, ensuring that activities are done on time is crucial. The literature stresses having good takt plans and discusses how to react to delays in the takt production. However, there exists little literature about how site management can work proactively during takt execution to prevent delays.

This paper presents a case study of Consto – a major construction company in Norway – and their experience working proactively to prevent takt production delays. The paper identifies several causes for delays experienced in the company and several approaches used in the case company to prevent them.

We found that if delays were not prevented, they tended to propagate and compound through the production system, leading to a parade of delays. Furthermore, working proactively to prevent delays is contingent on having a high degree of buy-in and commitment from all trades participating in the takt. A key to achieving this was to involve all the trades in the takt planning process actively.

KEYWORDS

Lean construction, takt, production planning and control.

INTRODUCTION

In recent years, takt has become an increasingly common method in construction projects. Takt is a method to structure work on site (Frandson et al. 2013). The method entails dividing the building into takt areas with approximately the same amount of work and then let a trade work undisturbed by others in each area. All trades are given the same amount of time in all areas – the takt time – before they hand over the area to the following trade. The implementation of takt planning in construction is often visualized as a train with connected cars moving through the takt areas (Haghsheno et al. 2016; Haugen et al. 2020). The cars contain a production unit – e.g. a trade – working in the takt area undisturbed by other participants. Takt relies on a close coupling between the trades. Time buffers between the trades are typically minimized. It is, therefore, crucial for a trade to finish their area in time to not cause further delays for the following trades.

Tommelein et al. (1999) present the Parade of Trades game to illustrate the impact workflow variability has on trades at construction sites. The trades are sequentially

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dependent. Thus, an unreliable workflow will result in work stations – i.e. train cars in takt – being unable to realize their full production capacity and therefore lead to waste. As we show in this paper, not properly ensuring a reliable flow in takt production will result in a parade of delays – as in Location-Based Management System (LBMS) is referred to as cascading delays (Seppänen 2009).

The literature underlines the importance of the takt planning process to make a robust takt plan to prevent production delays (Frandson et al. 2014). However, Haghsheno et al. (2016) claim that the takt plan is not a fixed document, but a plan developed throughout the project. Binninger et al. (2017) suggest adjustment mechanisms to deal with the disruption in the takt plan's execution. Common for all their suggested adjustment mechanisms is that they are implemented after a delay already has occurred in the plan. There is a dearth of information in the literature about how delays can be prevented, after the takt plan is made.

The purpose of this paper is to look at how managers on site can prevent delays proactively in executing the takt. To do so, we present a case study of a major construction company in Norway, Consto. The paper starts by presenting the theoretical background for the paper. After that, we outline the methodology for the case study. In the result section, we present causes for delays in takt identified in the case study and the different approaches used in the case company to avoid these delays. The discussion section considers the overall implications of our findings. Finally, we present the paper's conclusion and suggest further work.

THEORETICAL BACKGROUND

There are various approaches to takt production. However, according to Frandson et al. (2013), all takt planning procedures have in common that they evolve a rough production plan into an increasingly detailed and finalized production schedule throughout the iterations. The literature refers to two major approaches – *takt time planning* (TTP) and *takt planning and takt control* (TPTC) (Lehtovaara et al. 2020). The two approaches have much in common. They differ in how takt areas are defined and the degree of trade involvement in the planning process. TTP areas are formulated by finding the smallest repetitive sections of the operation, while TPTC areas are formulated by finding similar work densities. TTP emphasizes trade participation in the overall decision-making phase, while TPTC prioritizes the client's desires as a key planning criterion and prefers predetermined and streamlined control behaviour.

In TPTC, the takt production is controlled through daily takt meetings (Haghsheno et al. 2016). The frequent handovers in the production allow accurate and short-cycled control of individual work; deviations from the plan will disturb the takt and be visible at the handover. This fact makes it possible to react to the disruption at an early stage. However, not all changes to the plan are deviations. A takt plan is not a fixed schedule but rather an execution plan evolving throughout the project. Binninger et al. (2017) propose adjustment mechanisms to absorb disruptions or changes in framework conditions. The long-term goal is to reduce the need for adjustments by continuous learning and better predictions in the takt planning.

One of (Binninger et al. 2017)'s adjustment mechanisms is train stoppage. Train stoppage means that every car stops their work until the reason for the delay is dealt with. This mechanism follows the Jidoka principle from Toyota Production System, also called autonomation (Womack and Jones 2003).

The literature suggests that takt can be combined with the use of the Last Planner System to improve production control (Binninger et al. 2017; Frandson et al. 2014; Kalsaas et al. 2015; Schöttle and Nesensohn 2019; Seppanen et al. 2010). The Last Planner System (LPS) is a staple of production planning and control within Lean Construction. LPS increases plan reliability by identifying what work *should* be done and ensures that it *can* and *will* be done (Ballard 2000). Schöttle and Nesensohn (2019) stress using LPS in all phases of construction to achieve production flow. They argue that it is critical to design a production system that spans from design till handover to the client for a project to succeed.

An important mechanism of LPS is that the people doing the work are involved in planning the work to ensure that plans are feasible in production. Another mechanism is the lookahead process. It makes upcoming work ready for production by analyzing constraints and removing them. Additionally, the system aims to match the workload and capacity within the production system.

Related to takt, Location Based Manager System (LBMS) is another method to structure work on site by dividing the building into work areas (Frandson et al. 2015). In contradiction to takt, LBMS allows trades to keep a steady crew size in production by adjusting the time used in each area to match the labor. A control mechanism in LBMS is to track production in every area and compare it with the planned production using flowline diagrams. By assuming that the current production continues, LBMS forecasts if the area will be finished in time or if measures are needed to increase productivity. Also, compared to takt, LBMS uses more time buffers to reduce the risk of deviations and to prevent cascading delays in production.

According to Seppänen (Seppänen 2009), cascading delays are chains of dependent problems that occur in production. Cascading delays are caused by resource delays, working out-of-sequence, and space congestion due to several trades working in the same areas. In LBMS, cascading delays affect the workflow on site. However, does it not tend to delay the overall schedule of the project due to buffers implemented.

Seppanen et al. (2010) proposed that cascading delay chains should decrease by combining LBMS with LPS. They found that LPS mechanisms as weekly plans and lookahead schedules complemented LBMS's control mechanisms by giving early warnings of potential, upcoming disruption to the production.

Regarding dealing with delays in takt, the literature mainly describes mechanisms that are retroactive. One notable exception is the use of LPS. The literature suggests LPS can complement takt production with proactive control mechanisms (Frandson et al., 2014). However, while the literature on LBMS describes the benefits of mechanisms such weekly meetings and lookahead planning, the takt literature contains few details on how the LPS proactively helps to maintain production in takt. Nor does the literature consider cascading delay chains in takt and how they affect the takt production.

METHODOLOGY

This paper is based on a case study of the Norwegian contractor Consto. The Consto group consists of 15 regional companies and operates nationwide. Their first experience with takt was building the A-wing at the University Hospital of North Norway in Tromsø – a complex project that started in 2015 and finished in 2018. Since 2015, they have used takt in several projects across the country, and they have developed their own strategy and procedures to plan and execute takt production.

To investigate Consto's practices and experiences, we interviewed seven informants with key roles, such as project managers, site superintendents, and foremen. Consto suggested informants with experience using takt. The informants came from different companies under the Consto umbrella. They had between them experience from ten unique project organizations using takt on a hospital, an airport project, and several apartment buildings and schools. All project examples used design-build contracts, with Consto responsible for the design phase as well as execution. In some of the projects, all the trades were sub-contracted. However, in most projects, Consto had their own trades crews for either carpentering or concrete or both. We used semi-structured interviews lasting between 45 minutes and two hours. These contained questions to reveal challenges in takt production and how they work to overcome, prevent, and learn from them.

We analyzed the interviews using a thematic coding approach per Robson and McCartan (2016). All interviews were transcribed, and the informants' statements were tagged with codes that identified what topic or theme. Some of the codes were predefined based on preliminary studies; however, the majority rose from the gathered data. After that, we grouped related codes into major themes before we placed all the themes into two main categories: causes for delays and elements for preventing these delays.

Also, we did a limited document analysis on internal brochures and presentations on the topic of Consto's planning and control approach, *Involverende Bygging i Consto* (Eng: Involving Construction in Consto). The purpose of the document analysis was to investigate Consto's building strategy and internal guidelines on implementing takt.

RESULTS

This section presents the findings from the case study. The interviews were the primary source for these. Unless explicitly noted in the text, all the presented results stem from these. We have divided the findings into two categories: causes for delays and elements for preventing these delays.

CAUSES FOR DELAYS

Deliveries and logistics

According to the informants, one of the main reasons for delays in takt productions is late deliveries to the building site. Delay of delivery of materials, equipment, tools and other requirements prevent cars from completing their work in the takt area before the handover to the next car. The missing delivery or unfinished work will often affect the next car directly. However, sometimes the effect of the delay appears only later in the production.

Delayed deliveries can result from unexpected conditions such as bad weather, incidents or even a pandemic. However, in many cases, the reason for deliveries being late is that they are ordered too late. Trade contractors tend to postpone orders to maintain the opportunity to add on more materials or equipment to save shipping cost. Instead of making the orders as soon as possible, the participants postpone the orders as much as possible. It turns out that it is hard to evaluate when the last deadline for ordering is, and, in some cases, the contractors outright forget to make orders because of this waiting tactic.

On the other hand, too early deliveries to the building site are also reasons for delays in the takt production. Materials or equipment stored at the site takes up space and need resources such as workers, time, and planning. Using the takt areas as storage space inhibits the production directly, while using transport areas such as hallways or stairs slows down the logistic. An informant expressed that a significant challenge in takt is to handle the areas that are combined takt and transport areas to prevent the previously mentioned scenario. Also, dedicated storage areas slow down logistics due to deliveries needing more transfers than if delivered directly to the work area.

Errors

Building errors is another reason for delays in takt production. Errors require rework and tearing down the existing product, often leading to damage to trades' finished work in the takt area. Such occurrences cause a chain of correction work that affects the progress in the takt area.

Interestingly, many informants did not consider building errors to delay the takt because the correction work was handled outside or parallel to the takt production. However, later in the interviews, all informants admitted to correction work often tended to cause delays later in production. We found that congestion of correction work shortly before the planned completion of a takt area was often the reason for not completing the area on time.

Incorrect estimation

From the analysis, we discovered that if the input to the takt planning work is incorrect, it can lead cars working too slowly related to the plan and not finishing with the work in a takt area on time. Underestimated amount of work or areas not adequately sorted cold be causes for the delays. For example, floor plans are often used as the primary documents while planning the takt. Variables like room height can easily be forgotten in the process and cause more work or need for equipment – such as lifts – to complete the area.

According to one informant, overestimating efficiency was a cause for working too slow according to the project's plan. However, this is not a common problem, and other informants said that efficiency is often higher than expected in takt due to the high degree of repetition in work.

Available staffing and crew

We found that a lack of workers can be a reason for cars not being completed in time. The informants mentioned the constant need for more labor in the Norwegian construction industry as a cause for short-staffing in takt production periods. There is also a challenge with temporary labor replacing workers drilled in the cars' repetitive work. Sometimes, one worker needs two temp workers as a replacement, not because the temp workers are not qualified, but because the takt train's efficiency is tied to repetition.

An additional reason for a lack of workers is illness or injuries. Especially crucial for cars with small contractors and few workers. For example, if a car contains only one worker who gets an injury that makes it impossible for them to keep working the next takt time, the risk of not completing the takt area is high. As mentioned, it is not easy to find a replacement on short notice, and if one manages, it can be hard keeping up the required efficiency.

Communication and key roles

We found internal communication problems to be an underlying cause for delays. The main problem is replacing key roles and staff between the takt planning process and the start of the takt production, or later in the production itself. The informants emphasized that the takt planning process is more than just the end-product, the takt plan. The planning process is where all the takt production trades anchor the main goals and notions of collaborating. Being part of the process is vital for feeling ownership of the project and committing to the takt plan.

It is not easy to make people have ownership and commitment to the takt plan without involving them in the takt planning process. The informants claimed that this is why it is crucial to involve the right people from every trade in the takt planning process. The people in the planning process need to have a sufficient understanding of how the work is done and, at the same time, be able to plan. For example, when a trade representative is a manager with little or no attachment to the workers who will do the work. They often fail to consider essential parts of the work in the planning, and then they fail to communicate the importance of the plan to the workers. The result is the workers and crew leaders on the construction site lacking ownership and commitment.

PREVENTING DELAYS

In the case study, we found several different approaches to prevent takt production delays. A similarity between all approaches is that they all benefit from a high degree of involvement from the trades with the takt planning and in the production phase. All the informants agreed that making disruptions, abnormal production, or uncertainties visible as soon as possible is crucial for preventing delays in takt. In the following, we will present the main strategies identified for preventing takt delays.

Weekly meetings

Some informants acknowledged that weekly meetings with all takt production trades were a key tool to prevent delays. The meetings included a status update from all trades and a lookahead planning discussion for the next three weeks focusing on the first one. Some informants recommended doing the meeting halfway through the one-week takt time so that the trades had time to discover potential delays and at the same time had sufficient time to do measures before the handover of the takt area.

The projects used several measures to correct issues identified in the weekly meetings. For example, some to ensure sufficient capacity, levelling up the work crew with more power to increase productivity and assigning overtime work. Other to find solutions to deal with obstacles such as late deliveries. Here, the typical approach was to get together all the relevant actors – e.g. trades and suppliers – and develop a plan of action to ensure minimal impact on the takt plan.

On the other hand, some informants reported having challenges with the weekly meetings. They had experienced trades showing up unprepared to clarify the status on site and look ahead to the following weeks. In some cases, the trades were described as too positive regarding their production halfway through the takt time and would not report potential delays in the meetings. The trades gambled on production speed increasing in the second half of the takt time without doing any measures, which often led to delays. Another concern was that the weekly meetings alone could not handle all challenges at a dynamic construction site. There is a need for more frequent meetings to distribute information and involve the trades. Many of the project organizations interviewed in this study claimed that Daily Huddle is a tool to meet these needs.

Daily Huddle

Many of the informants mentioned Daily Huddles as a significant tool to handle the day-to-day obstacles on site. They described Daily Huddles as a 15-minute meetings series taking place every morning out on the site. All participants on site, inside and outside the takt production, are represented. The Daily Huddle is a tool to distribute and gather information such as upcoming deliveries or production disruptions. In this way, solutions, especially to logistics challenges on site, can be solved effectively immediately after the challenge becomes visible, instead of waiting for the weekly meeting.

We found that some project organizations used Daily Huddle in combination with the weekly meetings. In contrast, others had gone over to relying solely on Daily Huddle as the production control and involvement mechanism. The projects that used only Daily Huddle saw no need for further involvement from the trades. Prioritizing the Daily Huddle led to increased benefits from them. The key was to involve the right roles with a good overview of the whole construction process and decision-making mandate in these meetings.

Consto's crew leader for carpentry typically led the Daily Huddle in projects that used both meeting series types. On the other hand, in projects using only Daily Huddle, the site superintendent led the meetings. By involving key roles such as the site superintendent and, in some cases, even the project manager in the Daily Huddle, chains of commands shortened, information flow increased, and the time from a challenge becoming visible to it being solved was reduced.

Prioritizing the time after the meeting, and solving the identified issues right away, was vital to benefit from the Daily Huddles. For example, in one project, nobody in the project organization was allowed to schedule appointments until one hour after the Daily Huddle. This rule ensured that they had the time to deal with potential needs that occurred in the meeting.

Planning phase

Another finding is that a well-structured handover process from design to execution can help prevent delays in the takt production. Some of the project organizations had used a meeting series called the 16-12-8-4-1 meeting series for this purpose. This series is parallel to the takt planning process. The main goal is to ensure that the design's detail level is sufficient and that the preconditions for construction are adequate.

The internal document *Involverende Bygging i Consto* states that the 16-12-8-4-1 series consists of five meetings 16, 12, 8, 4, and 1 weeks before the takt production starts. The first and the second meetings included the design team and the main contractor Consto. In the third meeting, eight weeks before the takt start, the design team hands over the drawings to the main contractor and sub-contractors. The last two meetings of the series focus on ensuring that the drawings are sufficiently detailed for construction. The last meeting of the series also ensures that all constraints for starting the takt have been removed.

All the informants in the study emphasized that the key to a smooth takt production is to ensure every participant feels ownership and commitment to the takt plan and that they are working towards the same overall goal. This ownership feeling and commitment can be created in the takt planning by involving the trades in the process. We found that it is essential to spend enough time on the takt planning so that crucial issues in the takt production are identified and solved. According to the informants, the project organization should strive to guarantee that the people who will actually do the takt production – i.e. crew leaders – are involved in the planning.

Often, Consto, as the main contractor, will be significantly more experienced and knowledgeable about planning than the sub-contractors. According to the informants, it can then be a good idea for them to help the trades in their planning. Some informants revealed that they sometimes had sat down with single trades and, for example, made very detailed logistic plans to maintain site workflow.

To prevent delays related to deliveries, we found it beneficial to ensure orders are placed before the takt production starts. With takt, every trade knows what and where to produce when and can easily convert the takt plan into a delivery plan. Some informants said that fewer delivery related problems occurred when they had made sure that the trades in the takt had made their orders before the production started. They also said that any changes to the deliveries after order placement, was often no problem for the supplier as long they were made in sufficient time before the delivery. Also, with occurrences of delays, they had experienced few issues related to postponing deliveries from the supplier.

DISCUSSION

CAUSES FOR DELAYS

The causes for delays found in this paper are arguably not only related to takt production but construction in general. They align with earlier findings in the literature, especially, findings related to delays in LBMS. There are many similarities between the two work structuring methods – takt production and LBMS. Therefore, it is not surprising that the methods face similar challenges to maintain production. However, a unique factor for takt production is the tight coupling between activities and little or no time buffers to absorb variability. Therefore, we would argue takt is the more fragile production system of the two, with less room to implement necessary measures to prevent delays before handovers between trades, leading to unfinished takt areas being handed over.

According to our findings, handing over unfinished takt areas tends to lead to more delays later because of irrational work sequences and correctional work – i.e., it leads to what we would call a *parade of delays.* The parade of delays is similar to Seppänen's cascading delay chains in LBMS. However, a parade of delays in takt production is more likely to affect the overall delay in the project due to the differences between the work structuring methods previously discussed. Once a delay has occurred in takt production, it requires taking measures straight away to not delay the overall schedule in the project. For example, the literature points to train stoppage as a solution to prevent these handovers of unfinished takt areas. However, train stoppage cannot fully prevent a parade of delays. A train stoppage will cause an overall delay. It delays the takt plan one takt period, a delay which will not be made up without other measures.

Both cascading delays and the parade of delays relates to the principle of jidoka, in the sense of not letting a deficient product pass through the production line – it causes more waste than just fixing the problem straight away. Therefore, it is crucial to strive to prevent delays instead of reacting to them when they occur.

PREVENTING DELAYS

The literature suggests that the key to flow in production is to design a production system that spans from the design phase to the handover to the client. The 16-12-8-4-1 meeting series aims to deal with the transition between the design and production phases by gradually involving the trades in production. This gradual transition helps the trades familiarize themselves with the design and quality assure it, making production plans – e.g. the takt plan – more reliably. In particular, the meeting series can help prevent delays such as building errors and incorrect estimation.

Planning the logistic on site is key to keeping the flow in the takt production. The takt plan makes it easier to make visible where the different trades will be working at specific times but need to be complemented by additional planning of non-value creating activities such as transportation of materials and supplies. From the case study, one of the most challenging parts of logistics was handling takt areas that are also transport areas such as hallways and stairs. The challenge was to maintain progress in the area and, at the same time, not cut the supply to other takt areas. A key idea of takt is to let every car work undisrupted in the takt area. Any transport through the area will interfere with this. While transport through production areas is a well-known challenge in construction, it has been poorly covered in previous studies on takt and is an area that warrants more research.

The control work of the takt production through Weekly Meetings and Daily Huddles harmonizes well with the Last Planner System's mechanisms. Our findings are in concurrence with previous studies. Weekly Meetings and Daily Huddles are effective tools in combination with takt production. We found that the Daily Huddle is a tool that can deal with disruptions at a very early stage and solve the day-to-day challenges at the site. Our findings underline that it is crucial to involve people with the necessary overview and mandate to make the Daily Huddle effective. Setting aside time for key roles – such as the site supervisor – to deal with minor issues every day can be time-saving in the long run because it prevents parades of delays. Prioritizing the Daily Huddle made the Weekly Meetings superfluous.

A finding in this paper is that the necessary commitment and ownership in the project for the trades can be created through the takt planning process. However, doing so requires the trades to be involved in the process. Among the approaches described in the literature, TTP will serve this purpose better than TPTC.

CONCLUSION AND FURTHER RESEARCH

The purpose of this paper was to look at how managers on site can prevent delays proactively in executing the takt. To achieve this purpose, we conducted a case study of Consto - a major Norwegian contractor.

This paper confirms findings from previous studies that the key to smooth takt production is the takt planning process. The takt planning process is where the takt production participants build ownership and commitment. A good process is crucial for establishing good communication in the execution phase. Good communication enables detecting and dealing with potential issues before they cause takt delays. Also, the handover from design to production is essential to prevent delays. The 16-12-8-4-1 meeting series is an effective tool for quality assuring the design and making the trades familiar with it.

The consequences of a parade of delays in takt production can be significant. Instead of reacting to delays, delays should be prevented. Even with a healthy takt planning process, we found frequent trade involvement throughout the execution phase necessary to prevent delays. Daily Huddles and Weekly Meetings are tools that improve information distribution, logistics and ensure all preconditions are met for carrying out the takt production on site. We found that it is crucial to involve people who have an overview perspective of the project and decision-making mandate to make these meetings effective. It is also beneficial to set aside enough time after these meetings to solve any needs or issues brought up.

This paper has identified several causes for delays in takt, and approaches for preventing them. Having used a qualitative case study strategy, we have no quantitative data on how often these delays occur or how effective the various approaches prevent these delays. Based on this paper's limitations, more research is needed on how to prevent takt production delays effectively. We suggest further investigation to measure the effect the Weekly Meetings and Daily Huddles have on preventing delays in takt production.

We have in this paper looked at only one Norwegian contractor. Other proactive measures by management on site in other companies should be identified. Also, there is a need to investigate if the delay causes and the prevention approaches are culturally dependent.

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