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PRACTICAL BENEFITS OF USING TAKT TIME PLANNING: A CASE STUDY

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ABSTRACT

Takt time planning (TTP) aims to increase productivity by reducing waste. This is achieved by optimizing work packages and team sizes to fit the desired rate of production. Takt time planning has shown to reduce non-value adding time spent by work crews. This reduction makes workers produce more in less time, thus reducing the costs of construction. However, when performing TTP in practice, extensive plans have to be made in collaboration with subcontractors to make the process as smooth as possible. This, in combination with the time used to follow-up on the plans during the construction phase, takes time to perform and can be costly.

Little documentation exists on the benefits of using TTP and exactly what kinds of efforts are worthwhile. The purpose of this research is to examine a practical application of TTP and evaluate the usefulness of the efforts made in the planning process. By doing this one can prioritize where to spend extra time or resources to optimize projects.

This paper is a case study of a project from a major Norwegian contractor where TTP is being used. Methods used and experiences gained are compared to tried and tested methods to evaluate how TTP has affected the case project. The paper concludes that TTP has been beneficial to the case project in terms of completion time and worker comfort, but also identifies some obstacles that needs to be overcome before the true value of their method of TTP can be identified.

KEYWORDS

Takt time planning, production planning, case study

INTRODUCTION

Takt Time Planning (TTP) is a method of production planning with a focus on creating continuous flow of production at a steady rate (Frandson et al. 2013). This is achieved by managing the parade of trades to keep up with the desired takt time (Tommelein et al. 1999). TTP has been proposed as a step in the right direction to improve upon project-based production systems by maximizing the utilization of available resources (Frandson et al. 2014). Although there exists theory on how TTP should be done and its possible effects on

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a project, limited documentation on practical application of TTP exists. Previous research into applications of takt has posed questions for further research on TTP (Frandson and Tommelein 2014) and indicate a lack of empirical data to analyze and evaluate, as concluded by Frandson et al. (2015). They recommend examining projects where it has been used as to provide useful data and experiences.

One of Norway's largest construction companies has adapted several Lean Construction principles, including TTP. Up until now they have completed two projects using it. Project 1; a wing of a modern university hospital, and Project 2; a housing project consisting of several row houses. Both projects and their way of applying TTP has been studied, with a goal of understanding better how it affected them.

While examining Project 1, Smiseth (2013) found that only 32% of the scheduled work packages started when they were supposed to. This was related to the fact that just 35% of the same work packages were completed on time. The reason for this was a lack of variability control. The project was a limited success takt-wise, and the research concluded that, among other factors, efforts to reduce and control variability will be necessary to improve results.

Mordal (2014) found that in Project 2 there was a measureable reduction in construction time and costs. By comparing construction time of two identical part of the projects, one with TTP and one without, it was shown that there was a significant reduction in both time spent by the carpenters and start-to-finish time. Still, there are indications that TTP does not combine properly with Norwegian construction culture and tradition.

are improvements to be made, and while providing valuable information about TTP and the projects it was applied on, they both conclude that there is still need for more research. By examining an ongoing project and its takt plan, this paper aims to look at:

- How the takt plan was generated
- If and how it affected the project in terms of completion time and cost
- If and why the craftsmen and project administration preferred the takt plan

The analysis compares the case project to established theory and comments on any similarities or deviations. This will aid future applications of TTP in making good decisions and identify potential obstacles that needs to be overcome for future analyses and improvements.

THEORETICAL FRAMEWORK

Frandson et al. (2013) identified a process for generating a takt plan which consisted of the following six phases; (1) gather information, (2) define areas of work, (3) understand trade sequence, (4) understand individual trade durations, (5) balance the workflow and (6) establish the production plan. Through collaboration with the production team these six phases are iterated until a takt plan emerges. This production plan consists of work packages that can be completed within one takt time, and also gives the order of which they must be completed. This helps insure that only work packages that *can* and *should* be done *will* be done, which is also an important part of The Last Planner-system (Ballard 2000).

Bølviken et al. (2015) proposes a set of criteria a project can fulfil that makes different planning concepts work well with the specific project. They are divided into four categories;

the tasks, the use of time, the use of space and fit for purpose. The following are proposed as indicators that takt planning would work well.

- **The tasks:** Should be as independent as possible, and all preconditions for the tasks to become sound are identified.
- **The use of time:** The right sequence and logic should be identified, and the duration should be in compliance with the framework conditions.
- **The use of space:** The project should be able to have a good division in zones, with a suitable direction of construction where only one trade works in each zone at any given time.

Although Bølviken et al. (2015) points out that TTP works well when the project can be divided into clear zones with repetitive work it is not a requirement for takt to work; it has been used by Linnik et al. (2013) on an experiment with a non-repetitive project. One of the benefit of having repeating zones is shown by Kenley and Seppänen (2009), it gives the possibility to plan work for one zone and copy the plan to every other zone.

METHOD

The data was collected by conducting eight face-to-face semi-structured interviews. Key personnel where chosen from both the main contractor and subs, with a mixture of persons from both the project administration and craftsmen. The site manager from the main contractor was in charge of both making the takt plan and following it up. Therefore, much of the information gathered about making the takt plan is based on his experiences. Others were interviewed with a focus on uncovering how it had been to work with it, and if they had any thoughts about pros and cons compared to past experiences.

The interviews consisted of two parts. The first part established background information about the interviewees, projects they had worked on earlier and if anyone of them had experience with TTP from before. During the second part of the interviews the current takt plan was reviewed together with the interviewees. They were asked to talk about their participation in generating the plan and how it later on was to work with. This included how comfortable the project was to work in, especially regarding the predictability of their work day considering the repetition of tasks. To conclude, the last topic asked if they would be positive to using TTP in future projects.

FINDINGS

The case project, Project 3, is the contractors latest attempt at TTP. Being the largest massive wood project in Europe (Egge and Nilsen 2016), the project consists of five high rises and a kindergarten, all made of cross-laminated timber elements. The high rises each have nine floors, where all but the ground floor are student dormitories with a total of 632 dorms. These floors are more or less identical while the ground floor houses different types of public facilities in each high rise. This makes for a project with a high grade of repetitive work packages, which is ideal for TTP.

The project is being built for a student welfare organization in Norway, with a goal of completing the first three high rises and the kindergarten before school starts in august 2016. TTP was considered necessary in order to reach the deadline and has been used on

the interior of the high rises. Combined with the rapid rate of construction using massive wood elements and prefabricated bathrooms the project has progressed quickly. By studying the inception and progression of the projects takt plan and comparing it with other experiences using TTP there are some similarities and differences.

THE TAKT PLAN AND ITS DEVELOPMENT

e process of generating the takt plan started early, with the site manager leading the way. He has been trained in Porsche Takt, but with his own adaptations based on previous experiences from the two aforementioned projects. He was by far the most experienced person with TTP within the company, and had spent much time evaluating the previous projects and their takt plan. He pointed out that his method focuses on identifying trade order while minimizing the number of times each trade enters the same zone as to reduce time wasted on non-productive work. Also, it emphasizes on collaboration during the planning process. The following is a summary of what was done.

Initial plan and deadlines: According to the site manager, the main limitation for the takt plan was completing the project in time for the deadline. Initially the project had a traditional production plan, but it was discovered early on that it would not be possible to complete it on time using it. The site manager made a rough takt plan to illustrate how it could be done using TTP. This was sent over to the project owner which agreed that it was necessary to do things differently. The original plan was scrapped and work begun on a takt plan for the high rise interior based on the deadlines identified earlier.

Since the takt plan only encompassed the interior work of the high rises the original plan helped identify some deadliness the takt plan had to confine to. For instance, sealed building had to be achieved in order to start a takt planned work package involving gypsum boards. Since exterior cladding and roofing was not a part of the takt plan it was important to identify when this precondition was met.

Takt plan meetings: When the timeframe for the takt plan was set it was time to identify work packages and their sequence of completion. This was done through arranging "takt meetings". A total of three takt meetings were arranged, and in these meetings the site manager invited foremen and project managers from the different trades. The goal of these meetings were among other to identify:

Each trades required work

Order of work packages

Zone size and buffer

Takt time

During the meeting the participants divided into group consisting of representatives from each trade. While studying a floor plan they talked about what each trade had to do, and how it affected others. For instance, if the HVAC company could finish more work if the electrician had already completed certain parts of his job.

Considering the layout of the high rises, the zones were set to one floor and takt time set to one week. Initially a two day takt time was considered, which was rejected due to areas being to constricted. There was also discussion about having two week takt because

one subcontractor found it better for them. This would have made it necessary with two-floor zones, which would have been impractical. Since the work crews could end up being as small as two persons there would be too much back and forth between the floors. This meant time would be wasted doing non-productive work, which is the takt plans goal to reduce. The idea was abandoned and they got on board with the one floor/one-week plan.

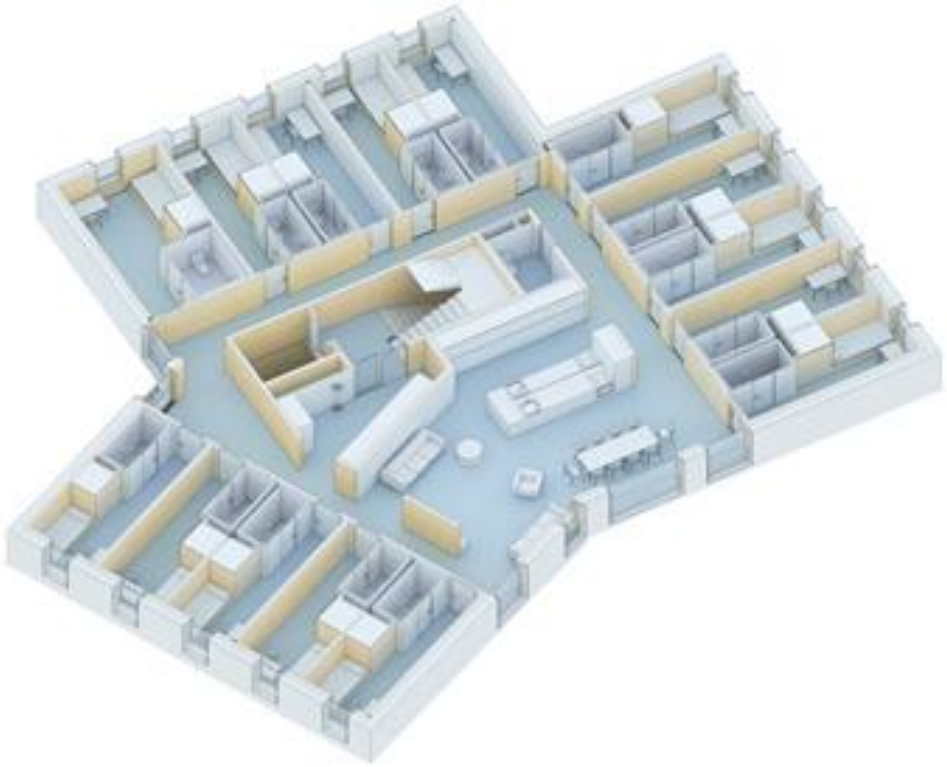

Figure 1: 3D model of one floor – the takt zone

With the previous decisions and discussions in mind, the time came for arranging the order of trades and work packages. The method used was collaboration on a post-it wall calendar. Each trade got their own color post-it-pad and wrote down the different work tasks. This was then arranged on the calendar while commenting were other trades put their notes. This method gave the trades the possibility of understanding each other's work. It also helped highlight alternatives or potential problems before locking down the takt plan. Using Porsche Takt terminology, each post-it represented one "wagon" in the takt train that moves through the zones, and by combining as many similarly colored notes into the same wagon there was less need for each trade to visit the zone many times. For labor intensive wagons it was possible to compensate by increasing its staffing.

The takt plan: After completing the three takt meetings the foundation for the takt plan was laid. The preferred trade order, takt time and zones were all discussed. The idea behind the takt plan was to progress as smooth as possible during the main parts of the production, and then including a smaller completion phase at the end. This left some room to correct

errors while not hampering subcontractors that did not need to be a part of the completion team.

Figure 2 shows a cut-out of the complete takt plan, with floors on the y-axis and weeks/takt periods on the x-axis. It includes the entire progression of high rise A and most of B and C, with a total of 26 individual wagons per high rise.

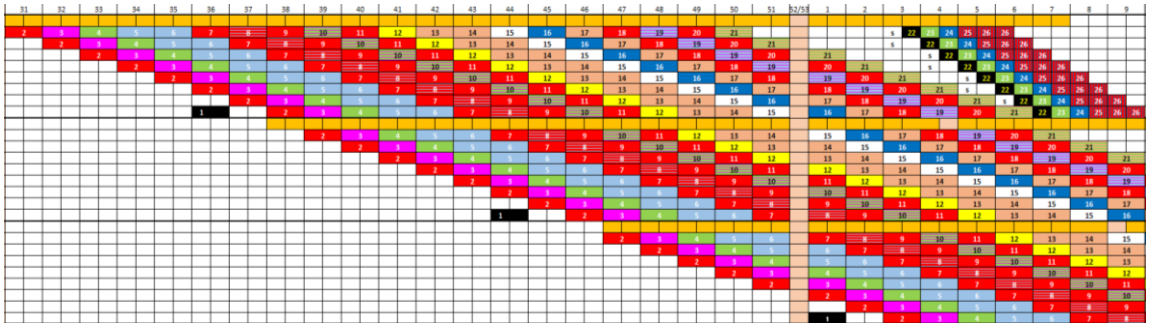

Figure 2: Takt plan of Project 3

Each wagon got an associated color which indicates what trade has work to do. For instance, red is carpenter, pink is plumber, green is HVAC and blue is electrician. Some wagons required two trades to cooperate, and these are marked with a combination of the trades colors. This made the takt plan easy to understand. The orange floor is the ground floor and due to being unique and non-repetitive it was set as a task buffer and is not included in the takt plan in other way.

THE TAKT PLAN IN USE

At the time of writing this paper the takt plan has been executed on the first high rise and well into the second. Interviewing those involved in the production shed some light into how the takt plan had been performing so far. Both employees of the main contractor and subs were interviewed, from craftsmen to administrators, and careers spanning from 10 to 30+ years. Since TTP is not that common, at least in Norway, the focus of the interviews was to compare how this project had compared to their past experiences. Some of them had never worked with a takt plan before, while others had worked on Project 1 or Project 2.

Past experiences:

Those that worked on Project 1 all agreed that, due to the complexity of the project, it was a difficult project for their first attempt at TTP. This project had little repetition and, due to being a hospital, demanded a lot from the technical utilities and the subcontractors installing them. This made it difficult to proceed with a single parade of trades, and it was often necessary to move back and forth between zones. The lack of repetition as found in Project 3 required tighter control of variability through a more flexible work force and more follow-up. Considering the low percentage of work packages completed on time, this was said to be one of the reasons. Most agreed that it would have been easier now that they have more experience. One positive outcome was that when something went wrong, the takt plan made it easy to spot. Due to the nature of a takt plan, when one work package

fails to complete on time it indicates that something is not working and measures can be taken at once. Using a more traditional approach, there might not be an indication until it is too late.

On Project 2 the takt plan worked much better. As indicated by Mordal (2014) there was a clear increase in productivity, which reduced both total time of the project and costs. This was in compliance with the interviews, where it was pointed out that Project 2 was a much simpler project with a much higher grade of repetitive work. The project consisted of several two story row houses where all but the last row was built without using TTP. By logging hours spent during construction and the increase in productivity from house to house, it was quite clear that TTP affected productivity positively, both in terms of construction time and costs. The site manager had used much of his spare time to evaluate the experiences gained from Project 1 and applied his findings to Project 2. This was of great use, and even though the project did not go without any hiccups, the takt plan was robust enough to cope with it.

Working with TTP on Project 3:

When asked about how the takt plan had worked on their current project the answers were unanimously positive. Logistics were pointed out as a key aspect for the takt plan to succeed, and so far it had worked well with just minor complications. Considering the small amount of on-site storage in this project, more problems could have been expected. With a large amount of repetitive work, many of the crews had experience an increase in productivity. Some work packages that started out with as much as five craftsmen were reduced to as little as two before completing the first high rise. This was somewhat expected, and past experience told the site manager to ask for larger crews to begin with so they could be reduced over time.

There were some that pointed out that there had been some problems with work packages not completing on time. This lead to delays as the next trade had to wait. The reason for this was explained as a problem with delivery of doors from the manufacturer. The solution here was to install temporary doors and having the manufacturer install the correct doors later. Otherwise the work packages were completed on time, and the site manager pointed out that there had been a significant reduction in wasted time due to waiting. This resulted in more time doing productive work, and due to the piece pay system it made for good salaries for the craftsmen. The system works by giving each element of the building (meters of wall, square feet of floor or roof, etc.) a price from the work that goes into them, and then calculating hourly rates out of what has actually been produced. When converted to hourly rates they reached as high as 325 NOK/hour. Other projects without TTP is usually expected to be in the area of 270-280 NOK/hour, giving Project 3 an ~18% increase. The result being that using a takt plan did not reduce the projects costs that much in terms of the production unit. The site manager pointed out that he would recommended paying by the hour, and that a revision of the salary system is in order to get the most out of TTP. In terms of costs due to the on-site project administration, there was a possibility of a cost reduction since they had a fixed salary. This was something they did not experience, since this project demanded a larger project administration compared to other projects they had experienced.

When asked about buffers one common answer was that it did not work correctly. The site manager planned to use the ground floors as off-takt buffers, which to begin with did not get much support from the rest. Since the ground floors required trades to complete their work in a specific order just as much as the rest there were some problems regarding available work. When one trade had extra craftsmen they wanted send to the buffers there might not be anything for them to do yet. It was suggested to include the ground floors in the takt plan, but due to their lack of similarity from the remainder of the floors it would require significant changes to the entire takt plan. The site manager said that if this was going to work they might have had to go for 2-days takt instead of one week.

Future use of TTP:

Most of the interviewees had little to no experience with takt planning from before. When asked about being interested in using it in the future they were unanimously positive, and wanted to contribute to making it work better. They realized that in order for TTP to work it is essential that everyone got on board with it, even though there were some that always blamed failures on others.

Some of the things pointed out as possible improvements on future projects was to start the planning process earlier, at least involving the craftsmen earlier. This was in order to get better feedback on the order of work packages, and also identifying everything that need to be done. If something is missed and has to be included into the takt plan there might not be enough time to complete it, since the plan is already optimized to a high degree. Still, when everything went according to the plan it was a comfortable way of working, especially when they got into the groove. Since the work was defined in such a detailed way they always knew what todays work was going to be, and there was little hesitation about what to do next.

There was some skepticism about other projects lacking the degree of repetition found in Project 3. Though TTP is not depending on repetitive work it makes it much easier. They pointed out that this was the reason Project 1 did not work as intended, but that because of the experience they now had gained it would have done better if they were to do that project again.

DISCUSSION

The method used for creating the takt plan has clear resemblances to the six phase process identified by Frandson et al. (2013). While not following the process step by step, the iterative takt meetings seems to be quite efficient in establishing the foundation of the takt plan. By using the post-it calendar like a reverse phase schedule, a lot of work was done in a short time. Still, generating the actual takt plan involved a lot of manual labor. One example is the use of Microsoft Excel as the tool for visualizing the takt plan as a line-of-balance view. This could be done more efficiently in software like Vico Control as a flow line view.

From the interviews conducted there is an indication that the takt plan worked much better in the case project than previous attempts, but there are still improvements to be made. At Project 1 they experienced problems with controlling variability. This was not a problem in Project 3, though much of this can be attributed to the lower complexity in the

project. In Project 2 they managed to reduce both total completion time and costs, but the success was limited by the effect experienced when combining TTP and piece pay. This effect was also seen at Project 3.

By design, the project has properties that meets many of the proposed criteria for takt-suitability. Additionally, the process by which the site manager chose to generate the takt plan helped enforce these properties.

The tasks: Due to low complexity of the building there were few tasks that required trades to cooperate directly. This was highlighted by the site manager as he wanted each trade to perform as much as possible before having to move on. Even though a task buffer was not one of the criteria for takt it has still been put to good use here.

The use of time: Much of the work performed could not be completed without the previous trade finishing their work. Therefore, the right trade sequence and correct logic was easily identified and resulted in very little setbacks.

The use of space: The project was very well suited for dividing into zones, and while some trades had to be in some zones simultaneously they rarely had to work on top of each other.

There are clear benefits from using TTP. Regarding completion time this proved essential for this project to even be able to finish on time. Having a shorter start-to-finish time can potentially reduce project costs by reducing overhead costs, but more research on this has to be conducted in order to identify how it can be utilized. A potential reduction in direct costs can be expected by switching from piece pay to hourly rates. This is may be the most attractive benefit from using TTP, and a recommendation would be to attempt at using TTP with hourly rates in parallel with piece pay so that they might be compared directly. Hopefully this might not impact worker comfort as their rates will return to the previously expected level. Even so, the other benefits to worker comfort gained by using TTP would be a welcome addition in any project since most were happy having a predictable work day.

CONCLUSION

The takt time planning method in Project 3 has been reviewed and compared to previous projects and experiences. Even though there has been a positive development during the three projects completed by the contractor there are still improvements to be made, especially when considering the benefits. There are incentives to use TTP regarding construction time, costs and worker comfort, but due to the piece pay salary system there is little change in costs. It would be interesting to do trails runs with TTP and other salary systems, for instance hourly rates.

Future research should focus on identifying indicators that could be used to replace piece pay with hourly rates without hampering the positive effects TTP contributes. To identify the true cost of performing TTP it would be necessary to gather data on overhead costs attributed to it and ways to reduce it. This can then be balanced out with the gains.

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