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THE BEAUTY OF A PHASE-OVERLAPPING LAST PLANNER® SYSTEM WITH INCORPORATED TAKT

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ABSTRACT

The purpose of methods and tools is to serve the project team and add value within the project delivery. Therefore, the implemented production system should support the interaction of the project team, enabling team members to develop a common understanding, and to reach the required quality and production performance when carrying out their daily activities. This research concludes that the Last Planner® System (LPS) aligns to the Toyota Production System (TPS) and its recognized management theory, which is a vehicle to integrate the minds + hands philosophy within projects from early design phase till handover. Our findings show that adopting the LPS as a production system helps to align and integrate the project participants. Takt is a work structuring tool that can be integrated into the LPS, if the product allows (repeatable areas). Thus, we recommend that the production system be designed based on the team's needs and the product requests.

KEYWORDS

Lean Construction, Last Planner System, Minds + Hands, Takt, Toyota Production System.

INTRODUCTION

Although a large number of papers have been published regarding the Last Planner® System (LPS) in the International Group for Lean Construction (IGLC) community, few papers have been published regarding takt time – only some regarding the combination of LPS and Takt-time planning. The LPS has been the major method used to implement Lean within construction projects for decades. Formerly introduced by Ballard and Howell more than 25 years ago as a system for production planning and control (Ballard 1993), its application has been reported for all kinds of projects within the Owner, Architectural, Engineering and Construction (OAEC) fields in the construction phase and for a few

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projects within the design phase. However, no study has explored how the LPS as an overall production system, from early design phase until handover, defines the applied management philosophy whilst also incorporating the work structuring method takt time planning in dedicated areas. To explain the LPS from a production system context, this study uses the TPS and its management theory and philosophy. Therefore, the research questions the paper seeks to answer are:

- How does LPS function as a production system across the whole project and which role does takt play in the LPS?
- How to design a production system for all project phases?

The paper is structured as follows: First, the literature is reviewed for production systems, specifically the Toyota Production System (TPS) as management theory and the LPS together with the element of takt. Then the research methodology utilized to analyze the case study will be introduced, followed by the case study findings and the discussion of these findings in accordance to the literature. Finally, we will draw our conclusion and answer the research questions.

BACKGROUND BASED ON LITERATURE

TOYOTA PRODUCTION SYSTEM

The Toyota Production System (TPS) has been acknowledged to be truly remarkable in generating more value for the company's customers and employees than alternative management systems (Spear 1999). Krafcik (1998) highlighted a distinctive difference between the TPS and the Fordist Production System in the way that Toyota was the innovator, taking the minds + hands philosophy of the craftsmen era and merging it with work standardization and assembly line. The TPS thus showed that, if workers are given responsibility and a variety of tasks, they effectively engage their minds + hands within the production system. This was added through commitment, teamwork, empowerment and training of the shop floor workers to give them responsibility to steadily improve quality and performance (Krafcik 1998). The simple act of asking and integrating the people who carry out the work in order to identify what they needed to handle the variety in the production line made the difference (Seddon 2007). Johnston and Brennan (1996) underlined that the TPS stands for more than just a superior production system. Based on their work, Koskela (2001) found out that TPS is the better management theory, because it involves the following four functions: (1) Management as-organizing, (2) Management as-planning, (3) Management as-adhering and (4) Management as-learning. Seddon (2007) aligns with Koskela (2001) and summarizes that TPS is based on systems thinking that handles both the design and management of the work to have products with no defects and the best possible flow. This recognition is closely related to the application of collaborative production planning systems within the construction industry like the major lean construction (LC) method LPS.

LAST PLANNER SYSTEM AND TAKT TIME

The LPS is a production planning and control system that is based on the development of a network of commitments; it aims to improve workflow, reliability and predictability between different trades in the various phases of a construction project (Ballard and Howell, 1998; Ballard, 2000). This network of commitment is created through the conversation for action loop, also named the promise cycle, defined by Flores (2013) and is an important connection between TPS and LPS. This mind + hands philosophy empowers foremen/forewomen to make their own commitment regarding their daily and weekly tasks in order to deliver and improve their performance continuously (Shang and Low 2014). To do so, the LPS consists of seven key principles: (1) use pull planning to develop the different scheduling levels, (2) engage the Last Planners early on in the different scheduling phases to reduce uncertainty, (3) activities are planned and made-ready collaboratively by the Last Planners, (4) commitments are given by the Last Planners, (5) do not detail too far in the future, (6) the opportunity to say 'no' to attain a transparent and trustfully production plan, and (7) learn from mistakes by having short-cycle evaluation and planning meetings (see for example Ballard and Tommelein 2016).

In theory and practice there is an ongoing discussion about whether to implement LPS or Takt time. Frandson et al. (2014) point out that takt time is a work structuring method to simplify the lookahead process by focusing on standardization and clear batch size in order to "create a more stable environment for the LPS" (Frandson et al. 2014, p. 573). In comparison, the LPS "facilitates irregular work variances" (Frandson et al. 2014, p. 577) such as areas with non-repetitive work. Takt-time planning can be processed in six steps: (1) data gathering, (2) zone definition, (3) trade sequence generation, (4) individual trade duration, (5) workflow balancing and (6) production schedule finalization (Frandson et al. 2013). The development of a Milestone & Phase Plan (MPP) requires similar steps. The main difference exists in the granularity. In Takt Planning the degree of detailing the time duration is more intense in order to harmonize the resources through repetition. The MPP is based on the approach that, the further away the future is, the more unrealistic the plan (e.g. Mossmann 2013). Therefore, the MPP that builds the guideline for the six week lookahead (6WL) and the weekly workplan (WWP) is based on weekly durations and only done for a few months. Last Planners then detail and optimize their activities based on the MPP in the 6WL and the WWP during the LP meeting. This links back to the theory of management within the TPS and the mind + hands approach which is evident within the TPS too. Furthermore, there is a great opportunity in integrating takt time in the LPS for repetitive work.

RESEARCH METHOD

The authors used case study and action research to analyze the research questions. Case study research was used to investigate the particular issues in depth (Yin 2014). Therefore, 21 structured interviews were collected from design and construction teams across different trades and positions. Questions were asked regarding production system, Lean knowledge, target and milestone definition, decision-making, honesty and transparency, challenges, the working relationships, and degree of diffusion. The interviews were transcribed and, based

on Mayring (2010), analyzed using the MAXQDA software package. Additionally, in a close-out workshop the project team did a reflection on the implemented production system in February 2019. Action research was used during the project to support the project team and act when issues occurred based on investigation (Dickens and Watkins, 1999). The authors were part of the project team and responsible for Lean implementation in the design and construction phases. The second author supported the design team for the first six months. The first author took over in June 2017, shortly before construction started, and supported the design team until December 2017 and the construction team until December 2018 (see Figure 1). The support included the facilitation of the weekly Last Planner meetings, called production evaluation and planning (PEP), and pull planning sessions for the MPP, as well as onboarding and training workshops. Thus, the action research during the project was based on discussions, meeting evaluation, plus delta evaluation, observation and findings during workshops.

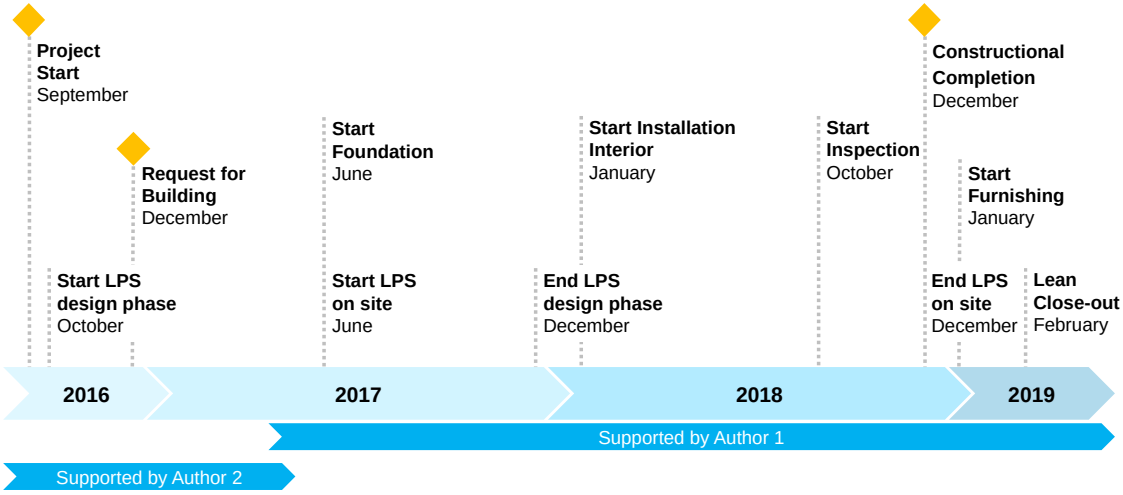

Figure 1: Project timeline with illustration of the Lean support

CASE STUDY

PROJECT INFORMATION

BMW Freimann is an office building of around 75,000 m^2 in the north of Munich that will accommodate 3,500 employees. The building has a length of 248 m and a width of 96 m (see Figure 2) and contains, besides the office facilities, a restaurant with 1,000 seats, a cafeteria, fitness centre and a shop.

The design team started in October 2016 and submitted the building permit in December 2016 (see Figure 1). The project team was contractually required to submit the building request within six weeks to achieve the permit on time. Furthermore, because of the short timeline until construction started and due to the request, the design team had to produce the preliminary design, detailed design and construction documents in parallel. The design team started detailing the design in January 2017. The construction phase was contractually fixed to 18 months and started with foundation work in June 2017. The shell

contained prefabrications and was finished in May 2018. Installation of the interior started in January 2018. Inspection of the first office area started in October 2018. Constructional completion was finished in December 2018 and commissioning and inspection were completed in February 2019. The occupation of the building started in March 2019.

Figure 2: Project BMW Freimann (PORR Design & Engineering GmbH)

IMPLEMENTATION OF THE PRODUCTION SYSTEM

The LPS was applied from project start throughout the commissioning and handover phases. In the design phase, the main goal was to achieve the permit and produce the construction documents for the site on time. Construction documents were produced while construction was already ongoing. The design team was collocated in Vienna, while the site was in Munich. Thus, two weekly PEP meetings were carried out to coordinate the design and construction phases. Therefore, an Obeya-Room with all the visual management, trade sequence, MPP, 6WL and area overview was set up in Vienna and Munich. During the overlapping design and construction phases, the site pulled construction documents using milestones which the LP consultancies integrated in the 6WL of the design phase. With the start of the interior installation, the MPP was split into two major areas. Areas which contained specific functional areas like the basement and the first floor were developed in a usual LP pull scheduling session. Levels one to three consist of repeatable office space. Therefore, a sequence of the trades for a smallest common area was developed to integrate a takt into the MPP of the LPS (see Figure 3 and Table 1). To achieve a common understanding and to make them aware of the need for transparency and teamwork, new team members were systematically onboarded through a workshop and on-site explanation. It has to be noted that a project delivery with such a Lean approach and a consequent use of this from design and construction was new for all of the participants involved.

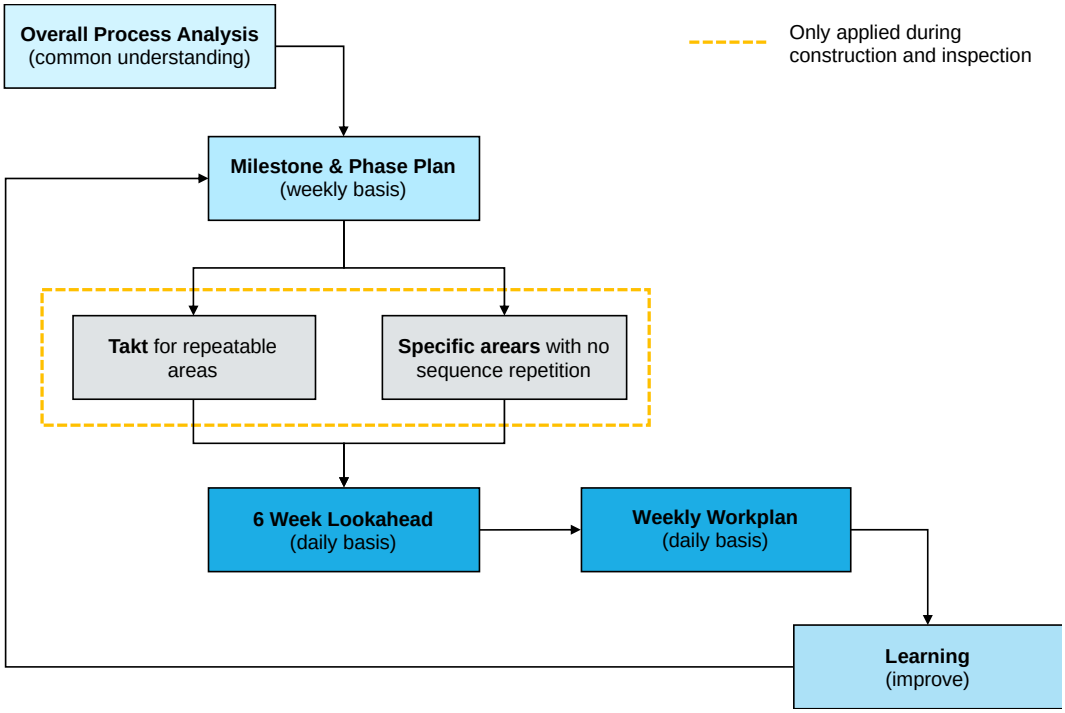

Figure 3: Integration of a Takt Plan for repeatable areas in the LPS

Table 1: Overview of the MPP during construction, commissioning, and inspection

Unique sequence	Takt
− Ground floor	− Shell
− Basement	− Interior office space 1. – 3. floor
− Roof	− Interior core area 1. – 3. floor
− Outside facilities	− Exterior (partly)
− Commissioning	− Inspection 1. – 3. floor

FINDINGS FROM THE INTERVIEWS AND OBSERVATIONS

To understand the implementation of the production system, it is important to be aware of the challenges the project team had to face. During the interviews the following main challenges were reported: aggressive project schedule, the new way of working regarding the executed project delivery system and the implementation of LPS and Building Information Modelling (BIM), coordination of interfaces especially during installation and completion, the cultural differences between Austria and Germany including the difference in wording, norms and regulations, and missing support from their own company. Additionally, with the start of the construction site in Munich, a natural break in the communication within the project team occurred due to the geographical distance and the non-reciprocal participation of the other PEP. The issue was solved by basing one person from the design team on site to answer questions quickly.

The analysis showed that the LPS and its structure and transparency as well as the disciplined execution of the weekly PEP meetings had improved communication and the common understanding within the project team. Furthermore, it was generally acknowledged that the clearly visualized production areas and the colour-coded sticky notes with the activities of the upcoming six weeks made it easy to coordinate, as long as people were honest and had all the information regarding their resources such as material and labour. This is evidence that the Obeya-Room delivers a great advantage to identify the issues and discuss problems effectively. Furthermore, the PEP meetings were received as a great element to connect everyone and enable a clear view of the activities of other team members as well as the overall process and the impact of changes. One interviewee mentioned that, without all this information, the communication among the trades would not have been engaged as deeply as required.

The production plan was continuously prioritized, adjusted and optimized. This was regularly performed as part of the self-organized collaboration of the LP within the PEP meetings and MPP sessions. Both LPS steps have been characterized as profound. It was not always possible to execute the takt that was integrated into the LPS as planned. With a focus on the MPP, there is clear evidence in the findings that a regular re-planning or adjustment is a requirement for both the specific areas and the takt areas. There were different reasons that triggered a re-planning as, for instance, that team needed to react to the difficulties in achieving the targeted milestones, so there was a need to optimize the production sequences of the areas or trades. One interviewee stated, *"There have been relatively many such kinds of improvisational needs and changes used against the original commitment, but, in the end, they have proved to be right."* Reasons for not keeping commitments were mainly the missing check of preliminary work, a lack of coordination between the trades, not having the right people in the meeting along with the lack of fully understanding the system, and missing information from their own company. Somewhat difficult were the shortage of resources, changes and additional requests for work.

For the design phase as well as for the overall project, it was incredibly relevant that people of all key trades such as: facade, MEP, dry construction and building automation and the general contractor had been involved early on within the design phase. Although it was not contractually recognized (no rewarding system, no multi-party agreement) and the tendering was carried out traditionally, the project can be classified as IPDisch, because of the early contractor involvement and the behavioural characteristics such as trust and open communication of an IPD project. It became clear that a Lean approach for project delivery can bridge traditional contracts towards the Lean philosophy and the level of collaboration connected to this. Some statements from the design team that support this view are:

> *"All in all, of course, including the construction site, this coordination, this regular one, which was now taking place intensively over the six weeks' lookahead, has helped the whole project and the whole team, construction site, planning, pretty well."*
>
> *"[Because we] were transparent to the construction site, and so was the construction site to us, we were able to react very well to [their sequence changes during building the shell] and we were also able to tell the construction site realistically if we could do it or not."*

Almost every interviewee (20 out of 21) felt that the overall production system was helpful. Most of the reported reasons for this are: reduced coordination effort, deep content, reducing the project managers' workload, as a basic medium for communication, a better thinking through the lookahead, transparency and open communication. Only one interviewee did not find the system helpful, mentioning that his project manager was setting unrealistic targets and did not listen to the Last Planners on site. A majority of the interviewees had used the production system not only within the project, but also for their own needs within the project and their company. The overall result of the project was, in the view of most interviewees, not possible without the LPS from design to commissioning.

DISCUSSION

From the production system view, the most important finding is the necessity to adjust and improve production schedules to meet the project targets. Although a takt is developed for repeatable areas, due to the issues listed below it might not always be possible to follow the takt as planned:

- No error-free and no on-time delivery of construction documents
- Limited availability of resources in the market
- Lack of timely involvement of trades
- Shortage of subcontractor availability
- Shortage of labour
- Variable performance by the different work crews of a trade
- No availability or late delivery of material
- Late change orders by the client
- Delayed decision-making by the client

For example, because of the existing market constraints and the named challenges the MP system could not follow the takt at the beginning. The team then decided to change the sequence of the area and the installation moved forward. This proves that flexibility within the production system is mandatory. Thus, the LPS fulfils this requirement by enabling the project team to continuously adjust.

Additionally, all production systems need to consider the human factor (Seddon 2007). It is important to understand that project teams contain a highly psychological side, because a team consists of members with: (1) different personalities, (2) different attitudes and behaviours, (3) different languages, (4) different experience, (5) different learning speeds and (6) different expectations. Therefore, implementing the LPS is a cultural change and the diffusion degree might be low if the team members are using the system for the first time, because often the Last Planners are not empowered to make decisions and therefore not able to act in the project's best interests. Nevertheless, having a project team that is using Lean for the first time does not prevent you from achieving the set project targets successfully.

So, our research question, 'How does LPS function as a production system across the whole project and which role does takt plays in the LPS?', must be answered as follows:

the LPS functioned very well as an overall production system across the whole project, because it was customized through every project phase based on the team's needs. The LPS helps to align and integrate the different project participants in creating a common production plan. Thus, LPS is a production system which triggers minds + hands thinking and a management theory to combine those TPS thoughts such as management as-organizing, management as-planning, management as-adhering and management as-learning (Seddon 2007). The element of takt did not really matter, since most of the people from the construction phase have used takt for their work for many years. Nevertheless, it is a good tool to structure the work of repeatable areas, if it is kept flexible and the sequence can be adjusted through learning. The second question, 'How to design a production system for all project phases?', has to be answered as follows: the production system has to be designed based on the team's needs and product request. It is crucial to have a production system that is able to engage people easily to collaborate within the team through visuals and structured communication. Therefore, the system requires flexibility for improvements, to achieve the geographical proximity of design and construction teams, supporting a common language and a common understanding, because "language is our primary for coordinating our activities" (Flores 2013, p. 20). Furthermore, it could be questioned if categorizing Lean into Lean Design and Construction could result in a mental break, especially when people are using a production system such as the LPS for the first time. This is a perception, but it could help to use one term to align the design and construction phases after decades of separation.

CONCLUSIONS

This research showed that, for a project to succeed, the most relevant aspect is not what type of relational contract has been used, nor what kind of production planning system someone uses in design and in production, but it is important to design a production system which does span from design till handover and is serving as the marketplace for information, planning, re-planning, and communication. Moreover, the production system must serve as a link to create and foster team cohesiveness by understanding different perspectives. Overall, the study stressed that the most important factor for success is to achieve a production flow by integrating the knowledge of the LP in every phase. The production system needs to be flexible for improvements and to react if breakdowns occur. Furthermore, the engagement of people, the support from their company and honest conversations are relevant for success, and thus need to be considered. Finally, the team's openness to new ways of working is also important.

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