

HISTORY AND THEORETICAL FOUNDATIONS OF TAKT PLANNING AND TAKT CONTROL

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ABSTRACT

The use of Takt is one of the key methods applied in Lean Production. With the implementation of Takt into processes overproduction is prevented, lead times are reduced, and work processes are stabilized. Inventory and waiting times between work steps are reduced, transport is optimized through continuous flow and a higher production capacity is enabled.

In Germany the method of Takt Planning and Takt Control for use in construction was developed approximately ten years ago in practice. In the last years these methods have also been discussed in the international lean construction research community.

This paper brings together the development of the theoretical foundations for the use of Takt Planning and Takt Control on the basis of a literature review. Hereby the existing knowledge from the stationary production industries can be applied to the construction sector. Furthermore, practical experience gained by the authors from the application of Takt Planning and Takt Control has been incorporated. Along with the historical development of the use of Takt in production, the fundamental principles for implementation of Takt in construction processes are described. The theoretical foundations developed here provide a basis for future research to investigate the effectiveness of the use of Takt Planning and Takt Control systems.

INTRODUCTION

SCOPE OF APPLICATION OF TAKT

Takt plays an important role in music, traffic, information technology and technical procedures. Takt processes are applied in many areas of today's everyday life, and Takt is a central part of their coordination. Takt is generally the basis of musical compositions and lyrics, the march of an army and also indispensable for the crew of a row boat. Transportation systems function through takt route timetables, phone calls are invoiced based on takt and motors run on a defined basis of takt combustion. The pulse of a heart is also a form of Takt, which defines the frequency and amplitude of a heartbeat.

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Takt plays an especially important role in industrial production. When it is necessary for different fields or people to work together to an agreed speed, Takt serves as the basis of this speed.

DEFINITION OF TAKT

The origin of the term “Takt” is from the Latin “tactus” meaning “touch, sense of touch, feeling”. From this the term “to have Takt” can be derived. In the 16th century a Takt was defined in German as “durch regelmäßige Berührung ausgelöster Schlag” (EN: “beats applied through regular contact”) (www.wissen.de 2015a, 2015b). The first meaningful translation of Takt is the English term “beat”. Frandson et al. (2013) further defines that the German word ‘Takt’ refers to ‘rhythm’ or ‘cadence,’ that is, to the regularity with which something gets done. A Takt can be understood as an impulse generator, which triggers an action in uniformly sized time intervals. The application of a Takt to a process is described as taktung. The timespan between two beats of a Takt is termed as Takt time. According to Frandson et al. (2013) “Takt-time is ‘the unit of time within which a product must be produced (supply rate) in order to match the rate at which that product is needed (demand) rate’”.

Alongside Takt there is also rhythm. In music the rhythm (Greek: *rhythmós* = flow) determines the arrangement of time progression. Expressed another way, rhythm leads to a time structure, a pattern or a sequence of tones and pauses. Unlike Takt, which has a predetermined repetition of processes with the same duration, the rhythm can vary within individual Takts. In production the scope of a Takt is also defined by the product. In construction this is also the case due to the spatial aspects of a structure. Takt times are generally determined by the categorization of the structure into different spatial areas. The work content of the areas can therefore be varied. Through this a specific rhythm will occur according to the Takt and work content.

HISTORY OF TAKT IN PRODUCTION

Takt processes already played an important role in production before the industrial revolution. Records from a 16th century shipyard of an arsenal in Venice describe a stable and taktung production of merchant ships and warships. Due to the high demand for ships from the Venetian state a system of continuous production was developed which was unique for its time (Das Arsenal von Venedig, 1)

At the beginning of the 20th century Takt was increasingly used in industrial operations. One of the most well-known users of Takt-based production was the automobile pioneer Henry Ford. Fascinated by the “disassembly lines” of Chicago slaughterhouses, in Detroit in 1913, Ford was the first company to introduce mass production of automobiles using production lines. Through using the production line, production capacity was increased on the one hand, and on the other hand it was possible to use unskilled labor rather than a specialized workforce. Built this way, the Model T Ford was able to be assembled faster and cheaper than similar cars built at this time. (3sat 2014).

In other industries Takt was used for the first time in the German aviation industry. Takt was used as a precise time interval to synchronize the movement of airframes

through a production facility. At the end of every Takt the airframes were moved to the next step in the assembly (Womack 2015). Technical cooperation between the German aviation industry and Mitsubishi brought this idea to Japan where Toyota took Takt and incorporated this approach into the Toyota Production System (TPS) (www.lean.org 2015).

James P. Womack and Daniel T. Jones described the TPS and significant approaches of other low-waste production systems in their books “The Machine that changed the world“ (1990) and “Lean Thinking“ (1996). Through these works they introduced the term “Lean”. Takt time was mentioned by Womack and Jones (1996) and brought into connection with the principles flow and pull. The significance of this in TPS was however not mentioned. Takt was considered as a tool aiding the reaching the basic principles of lean thinking. However in practical applications takt is a central element of production systems. The Toyota Production System and most other production systems for automotive assembly state takt as one of the integral parts of their system.

THE ROLE OF TAKT IN PRODUCTION SYTEMS

In the meantime almost every large enterprise in the automotive industry has based their own production system on lean principles. In most cases the production system is visually represented with sketches or diagrams. In many production systems, for example Porsche, BMW, Daimler and Toyota, Takt plays an important role and is shown in these representations. Figure 1 shows a representation of the Toyota Production System, the most well-known example of this system.

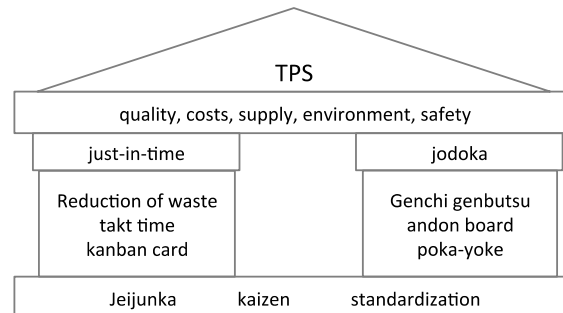


Figure 1: The Toyota Production System (Toyota 2010, 5)

Takt time is a central element of the just-in-time pillar of this production system. In industry Takt time is commonly defined in minutes. For example Porsche sets a Takt of approximately five minutes as the market on average absorbs one car every five minutes (Friedrich 2013, 48). The potential influence Takt can have on a production system is highlighted in the example of the Wolfensberger foundry in Germany. The introduction of one piece flow led to implementation of takt and equalization of the duration of the working steps. The new takt enabled throughput times to be reduced by 50% (Reusser 2013).

From a company perspective, the selection of a Takt time is dependent on the product. From a lean perspective the customer stands at the center. Hopp and Spearman (2008,

495) define this approach as the demand rate. The Takt and the batch size selected define the output. This means Takt is a means of satisfying customer demand.

CALCULATING A TAKT IN THE STATIONARY INDUSTRY

Takt has the goal of fully meeting customer demand. It is the time interval in which a quantity is produced and thereby also defines the procurement and purchase rates (Frandsen et al. 2013). In this way the market influences the Takt.

$$\text{customer takt} * \text{batch size} = \text{Output}$$

Therefore takt is defined as the time interval in which the quantity of a product variant is produced with regard to the available process time (Lean Production Expert 2012). The customer takt is the time to produce one batch:

$$\text{Customer takt (production)} = \frac{\text{available net working time}}{\text{average customer demand}}$$

THE ROLE OF TAKT IN CONSTRUCTION

DEVELOPMENT IN CONSTRUCTION

In the construction of buildings the first recorded use of Takt time for construction was during erection of the Empire State Building in New York in 1930. In this case location-dependent time plans were prepared in which multiple time-defined work steps were planned (Willis and Friedman, 1998). In the field of bridge construction from 1857 the Grandfey-Viaduct in Freiburg, Switzerland was produced using Takt. (Marti et al. 2001, 108)

Today Takt is also used in various construction processes. Examples include bridge construction (incremental launching method), underground construction (slotted walls using pilger rolling), tunnel construction (tunnel boring machines using lining segments) and excavation (digger-truck traffic coordination). What all of these construction methods have in common is that the product is completed repetitive. The use of a Takt is highly relevant in frequently repeated (nearly) identical procedures. As soon as the content of a Takt is planned, it can be continuously repeated. Hereby economies of scale can be used.

Conversely the approach of Takt is rarely used in the construction of buildings. Often not all levels of a building and the room layout are designed identically. These conditions make greater preparation and planning necessary in order to integrate the different areas into a common Takt. If the structure is more precisely considered, divided and detailed, repetitions become recognizable. In Germany there has been a noticeable increasing spread of the approach of taktung the construction of buildings. Various projects currently using this method are known to the authors. For some years the approach has also been included in university teaching and research. In the IGLC community the term Takt was used and defined for the first time in 2005 in Bulhões et al. (2005, 100). Further articles from Frandsen et al. (2013, 2014), Seppänen (2014) und Yassine et al. (2014) make use of the method. The approach to Takt planning of Frandsen et al. (2013) states six steps to

a takt production plan. Variations with associated buffer times are taken into consideration. The approach to control takt construction processes has so far not been considered so far.

Through using the Takt principle a construction project is divided into small time segments and spatial areas. The work in each area is determined and structured. The duration of the work packages for each trade can be better calculated or estimated using performance factors for each Takt area. If all trades agree upon these work packages with the goal of a nearly identical Takt effort (for example one week), a consistent production speed can be achieved (Friedrich 2013, 43). This leads to a stable construction process with less constraints. At the end of a Takt every trade must ideally have completed the required works.

TAKT PLANNING AND CONTROL IN CONSTRUCTION

INTRODUCTION

The opinion that construction projects are one-off projects, which are seldom repeated, is a widely held view in the construction industry. However if the composition of a building is viewed in greater detail, similarities can be recognized. For example a residential building living space is divided according to apartments, which generally have at least one bathroom. Through these identifiable repetitions, standardized processes on the construction site become beneficial. Takt and Takt planning aids in the implementation of these.

PROCESS ANALYSIS

In the process analysis, as a upstream step, the structure of the project is divided in different work areas and the ideal trade sequence is defined. The steps of the process analysis are comparable to the first three steps of Frandson et al. (2013). This step is then further developed through including more participants. As soon as the team has a common vision for execution and the trade sequence, the input of the client is included. The customer determines milestones based on the division into functional clusters. Following this the project-pulled Takt planning can begin.

TAKT PLANNING

The Takt and Takt areas of a construction project are determined and these shape specific projects as a definite entity. This spatial entity/time slot must be filled using the content of the detailed value creation process determined during the process analysis.

The basis of the content is the sequence of works from the process analysis which divided the process into detailed working steps (see Work steps in Table 1). On the basis of these individual steps and the standard room unit (SSU), effort values can be determined and allocated (see method in Table 1). SSU is the smallest replicable space area. It should be noted, that all kind of adjusting has limits and dependencies. This means that for example a particular amount of manpower is required to complete a particular working step, or the size of a team results a minimum size of a Takt area.

Table 1: Leveling of the work packages

Work package	Work step	Performance factor	Mass of a SSU	Man-power	Duration for 1 SSU	Duration for a Takt area (3xSSU)	Total duration with a Takt of 5 days
A	1	0.5 h / m ²	25 m ²	2	6.25 h	18.75 h	4.785 h
	2	0.33 h / m	3 m	2	0.51 h	1.53 h	
	3	0.2 h / m	30 m	2	3.0 h	9.0 h	
B	4	1 h / pc.	1 pc.	1	0.5 h	1.5 h	
	5	2.5 h / m	12 m	1	2.5 h	7.5 h	
C	6	

Adding the time required for individual working steps to the time required (performance factors) for the work packages results in a sequence of works. This sequence must then be aligned to the project structure of Takt areas and Takts again. This is referred to as Takt Harmonization. The planned time cycle and floating buffer results in the required time for a Takt area. The time required for a work package must not exceed the duration of one Takt. The aim is for the best possible usage of the planned cycle. The most challenging part of the Takt planning is to derive a common production speed for the individual trades. The clear advantages of using this method are increased economic viability, better quality and timely completion. Takt planning is comparable to the three further steps of Frandson et al. (2013).

Takt planning is ideally prepared collaboratively by the entire project team. Through this use of a high level of specialist technical knowledge, execution of construction and process duration is greatly improved. The goal is for workloads to be as evenly matched as possible across the various trades and thereby to achieve a stable construction process. The Takt time can be calculated according to the following formula:

$$Takt\ time = \frac{Content\ Taktarea\ [entity = m2] * Effort\ Value\ [Time/Entity = h/m2]}{Selected\ Manpower}$$

The calculated takt time according to the perspective of the contractor must be compared with the demands of the client. If necessary, the Takt time can be adjusted through reduction of buffer times or through optimization and acceleration to adjust the demands of the customer.

As the work packages are rarely automatically suited to the planned duration of one Takt cycle, the harmonization operation shown in Figure 2 is carried out.

1. The time required can be increased or decreased by using more or less workers (see figure 2; No. 2: improving)
2. Work packages can be joined together to make up a single time slot (see figure 2; No. 3: levelling).

3. Working steps can be changed, optimized or replaced using products or processes

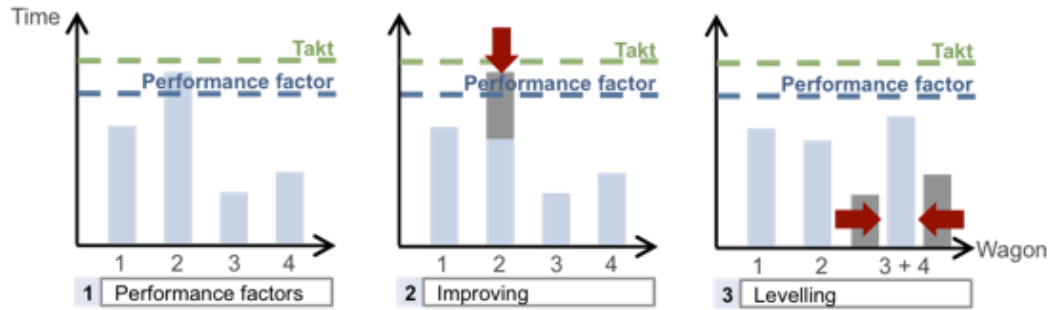


Figure 2: Ways of levelling the work packages (Lean Production Expert 2012)

In addition to the use of floating buffers, also calculation of fixed buffers at the end of every Takt is possible (e.g. weekend as buffer). The selection and use of buffers is essential for an efficient output.

After all work packages are divided into a Takt/time cycle, the individual slots are closed. This creates a continuous connection. This connection within a Takt is referred to as a 'wagon' or 'container'. If a wagon is made up of one or more work packages, it is to be defined. The sum of all wagons in a line, or sequence of works is defined as the so called 'work train'.

To prepare a production plan as can be seen in Figure 3, the work trains are carried over to the production plan according to their level of priority. The work trains cover the complete replicable sequence of value creation. Nonreplicable working areas must also be part of the production to ensure transparent production planning. These nonreplicable work areas include both time dependent and time independent work packages. The time independent work packages are in practice defined as 'workable tasks' Hamzeh et al. (2008, 641) and serve to balance the work packages.

According to the experience of the authors, the preparation of the production plan is a deciding factor. A classic Gantt chart should not be referred to in this case, as this form generally does not include spatial entities, or cannot be systematically incorporated. The authors recommend a diagram type including time and space be used where the place is defined in the form of a room, and therefore the value adding object is brought to the foreground (see Figure 3). From the customer's perspective the construction status of Takt area 1, and whether the task is being completed at the right time can immediately be recognized. This point is especially significant for project control.

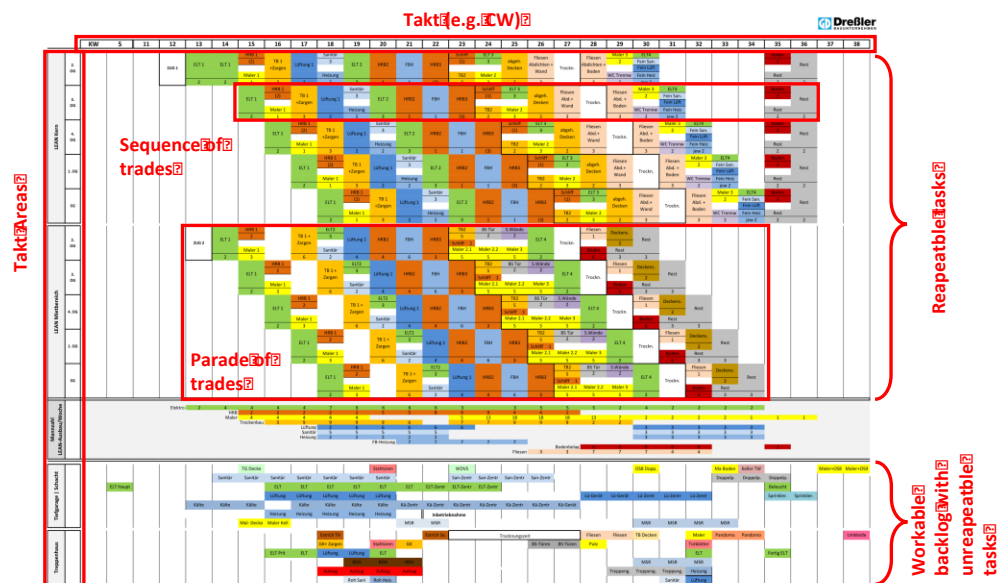


Figure 3: Preparation of a Takt plan of a general contractor

TAKT CONTROL

The use of Takt allows accurate and short-cycled control of individual works. Due to the short Takt times, the following Takt will be affected immediately, in case variations to the planned works occur. Potential disruptions are thereby visible at an early stage. The goal at the end of a Takt is, that all work is being carried out according the plan. A completed Takt plan is a not fixed concept. Rather it is an execution plan that is constantly evolving. Short-cycled adjustment of a Takt plan is important. This means for example if there is a disruption to a ‘station’ in the work train, an empty Takt (‘buffer wagons’) can be built in, individual work packages and wagons can be shifted to form a ‘catch up plan’. This can be considered an indicator of stability in comparison to PPC from the Last Planner System. Therefore reason short-cycled observations and control of the individual work packages is essential. Only through this the proportion of reactionary and costly control measures can be reduced. For the overall project this procedure leads to reduced risk due to the achieved stability of processes. Takt Control is responsible for maintaining the necessary stability. Systematic and short-cycled construction control is a significant success factor in the process of construction projects. However in construction practice this type of control is rarely used. All individual contractors are part of the management process to achieve a continual improvement process. In the stationary industries this is known as Shopfloor Management. In construction practice Takt meetings are held at the so-called construction control site office or the Takt Control Board. This board documents various information, figures and recommended actions. During daily Takt meetings, led by the site manager, the current working step displayed on the planning board is incorporated and adjusted. The foremen of the different trades participate in that meeting. Thereby this adjustment between the planned working step and the current status is completed for every Takt which allows for short-cycled implementation of the required measures (Kenley und Seppänen 2010, 44-54).

The required records and documentation should ideally be undertaken daily together with the subcontractors. Kenley und Seppänen (2010) further recommend that workers collect data on man hours spent between two takt meetings, and present these at each meeting.

This type of construction control also puts the location of value creation in focus and is also defined as Gemba. This is confirmed by a survey of 68 construction and project managers from mid-sized construction contractors questioned on the actual state of construction site management. When using a short-cycled control the employees of the contractors use an average of 46.6 per cent of their working hours for controlling of construction sites, whereas those following traditional processes used 27.8 per cent of their time for this. (Binninger et al. 2015)

CONCLUSION

When many people or production units are required to work directly with one another, coordination is necessary. As continuous comparison is rarely possible and 100 per cent uniform speed cannot be achieved in most systems, comparison must be undertaken at particular intervals. For this the use of a production Takt is a decisive factor. For every Takt beat the production must have reached the planned status so that the closely linked works can continue without disruption. Carried over to the field of construction, the required works of every trade must be completed in the allocated Takt beat. Within the Takt time, the trades are flexible and can divide the work content. The more short-cycled the Takt time is selected, the more effective the production system can be run. This effect was registered by the author's in their own projects. The deciding factor in keeping to a Takt is good planning and fine-grained management. A Takt plan is not a fixed concept, but rather should be changed according to the results of short-cycled meetings. The weekly work packages are determined on the basis of milestones which are agreed with the client during process analysis. The daily works are managed during the short-cycled meetings so that the work packages can be completed smoothly, and thereby the time schedule will be met. The use of Takt offers excellent possibilities to increase the stability of a production system and thereby improve long-term effectiveness.

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