Dlouhy J., Oprach S.,Binninger M., and Haghsheno S. (2018). "Using Taktplanning and Taktcontrol in production projects – Comparsion of Construction and Equipment Phases" In: *Proc. 26th Annual Conference of the International. Group for Lean Construction (IGLC), González, V.A. (ed.)*, Chennai, India, pp. 890–898. DOI: doi.org/10.24928/2018/0477. Available at: www.iglc.net

USING TAKTPLANNING AND TAKTCONTROL IN PRODUCTION PROJECTS – COMPARSION OF CONSTRUCTION AND EQUIPMENT PHASES

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ABSTRACT

Takt Planning and Takt Control (TPTC) as a method for construction processes shows the potential for improving time aspects of construction sites in many practical examples. A first example of using the method of TPTC not only in construction but also in following processes such as equipment installation (production projects) indicates equal improvements. By analyzing 10 construction and seven equipment installation case studies, this paper gives an overview of similarities and differences in construction and equipment projects. Furthermore, it describes adjustments for using TPTC in the construction stage as well as in the equipment assembly stage and picturing each stage's timetable in one common Takt Plan for increased clarity. Interlinking planning phases of both stages shows not only, that further time savings in implementation phases can be realized, but also that overall project planning can benefit from considering interfaces to upstream and downstream phases.

KEYWORDS

Lean construction, lean equipment, comparison, process, work flow.

INTRODUCTION

The stages of construction projects have many interfaces to preceding and successive stages. For example, after completing a building for industrial production, assembly of

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the equipment needed for the building's end-use will begin. Thereby construction projects aim at assembling the structure of the building itself, while consecutively assembly lines and production equipment is installed in an equipment installation projects. In Dlouhy et al. (2017b) the authors use a case study project to show that the Lean Construction methods of Takt Planning and Takt Control (TPTC) (e.g. Binninger et al. 2017) are also applicable in assembly of production equipment and have similar advantages in terms of time, cost and quality compared to classical approaches (e.g. Oprach and Dlouhy 2017). In contrast to this, customers using a separate uncoupled design and execution process for the individual phases lose a large proportion of this potential. The high-level use of TPTC as an integral part of process planning and the Takt Plan as central instrument of time planning leads to an improved understanding between both stages. Experiences from planning equipment assembly projects show that using TPTC during the stage of equipment assembly is not possible without adjustments to the method and taking into account the particularities of these projects.

This paper will use data from real case study projects to show differences and particular characteristics differentiating both stages and provide a resource for preparing a common Takt Plan for both project stages.

THEORETICAL FOUNDATIONS

While TPTC is a well-known and well-established method(e.g. Frandson et al. 2013; Binninger et al. 2017; Kaiser 2013). for steadily planning and executing construction projects in the meantime, it is practically not used in equipment ventures, yet. Although a timely finish of equipment projects is crucial for the start of production and therefore decides over considerable losses of profits for principals, research rather focuses on savings through maintenance strategies instead of plannable and steady installation processes. The Takt Plan is the central scheduling tool for successful application of the Lean Construction methods of Takt Planning and Takt Control. Compared to others such as the Gantt-Chart, the Takt Plan shows more information while using less space and giving greater oversight (e.g. Oprach et al. 2018 p. 210).

Aside from information about which subcontractor executes which works at what time, the Takt Plan also shows the exact location of value creation. Figure 1 shows a typical Takt Plan, for which the additional dimension of location can also be shown in a path-time diagram.

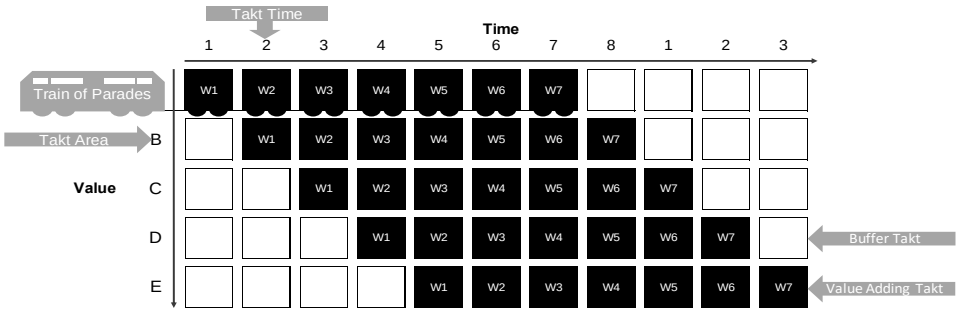

Figure 1: Example Takt Plan with typical elements (author generated image)

Using Takt Times, the x-axis shows the time dimension of the Takt Plan. Depending on the project conditions, a Takt Time can have duration from a few minutes (e.g. Dlouhy et al. 2017a) up to one week. Experience has shown that in construction projects the Takt Time generally lies between one day and one week.

The y-axis shows the spatial dimension of the Takt Plan through division of the construction site into Takt Areas (A to E in figure 1). Dividing the project into smaller entities allows more detailed planning of the works to be completed as well as simplified progress monitoring during execution. Planning of equipment assembly projects has shown that the Takt Areas are not limited by the spatial dimension, but rather other logistical factors of the construction site such as machine components or functions.

With the wagons (W1 to W7 in Figure 1) of a work train, the information about the work to be completed (who) and the applicable activities (what) are recorded in the Takt Plan. Using a legend, it is simple to show which works are part of which wagons. The associated subcontractor can either be recorded in the legend or through color-coding of the wagons.

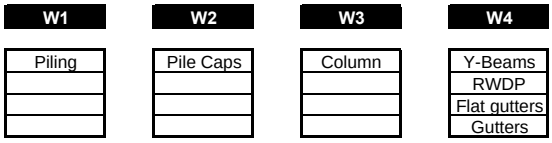

Figure 2: Legend with example of information on works to be completed in each wagon (Author generated image based onDlouhy et al. (2016))

The exact method for preparing a Takt Plan is described step by step by Binninger et al. (2017) for construction projects and by Dlouhy et al. (2017b)for equipment assembly projects. Both publications show the project planning process is different for both project stages. The exact nature of these differences will be described in this paper based on their characteristics and data from real projects.

While construction projects can usually be divided into the three phases of shell construction, fit-out and commissioning, equipment assembly projects are divided into the phases of mechanical installation, electrical installation and final phase of commissioning. For time-efficient design of a building and equipment assembly plant, seamless integration of the three phases of each project stage is necessary. In terms of the overall planning of the complete project, a uniform direction of construction and principles should be used in both sectors. A uniform direction of construction allows time to be used effectively. Using uniform principles such as fluid working groups, takt principles, needs-based supply of materials and short-cycled defects inspections creates security and understanding on both sides.

Comparison of 17 case study projects – 10 construction projects and seven equipment assembly projects – shows the differences between the two project types due to their own specific values. In some cases, equipment assembly projects are projects which followed directly after construction projects which are also part of this study. This allows comparison in terms of identical conditions in terms of surface area as well as in terms of cultural and climatic factors.

There is a large difference between the project categories in terms of costs. For example the cost of production facilities in automobile plants is many times more expensive than the cost of the building (e.g. Wiendahl et al. 2014 p. 528).

METHODICAL APPROACH

In the construction industry Takt Planning and Takt Control are established process planning methods and have been used to successfully complete many projects for varying types of customers. The potential for their use in equipment assembly has also been proven in a number of projects(e.g. Dlouhy et al. 2017b; Oprach and Dlouhy 2017).In this research, focus lies on comparing data to investigate differences in how TPTC is applied. This will show advantages of construction industry according to hard as well as soft factors which can be applied to equipment assembly projects. Apart from measurable savings in construction time while using the same materials and therefore constant costs, quality of completed works is at least equal. Moreover, using TPTC in construction projects also improves construction process by increasing stability and providing greater certainty in planning. The main reason for this is the detailed planning of works and easily understandable display of information using the Takt Plan. A basic condition for successful implementation of TPTC in equipment assembly is therefore to adapt the Takt Plan to the needs of these works.

Underlying Projects are all realized by an industrial principal in several different countries in Europe, North- and South-America, as well as Africa. While some of them were already terminated, others were in the process of construction or not yet started by the time of data acquisition. Table 1 shows a selection of TPTC-specific data gathered from the projects' Takt Plans in their latest version, respectively. By understanding the characteristics of each project stage first, commonalities and differences are being derived to find a possibility for representing both stages in one common Takt Plan.

Table 1: Comparison of selected attributes of construction and equipment assembly projects

Attribute	Construction Projects			Equipment Assembly Projects		
	Avg.	Min.	Max.	Avg.	Min.	Max.
Takt Time [d]	4.4	0.5	6.0	1.7	1.0	3.0
SSU [m^2]	302.4	9.0	360.0	47.9	14.0	100.0
SSU [#]	93.9	10.0	289.0	119.1	14.0	600.0
Takt Area [m^2]	1200.0	35.0	3000.0	128.1	36.0	350.0
Takt Area [#]	16.3	3.0	34.0	22.4	9.0	36.0
Wagons [#]	15.3	7.0	29.0	16.0	6.0	33.0
Trains [#]	1.5	1.0	3.0	5.9	1.0	15.0
Work Packages [#]	38.6	7.0	116.0	22.6	16.0	36.0

Function Areas [#]	2.5	1.0	5.0	1.7	1.0	5.0
Partial Handover [#]	0.9	0.0	3.0	0.0	0.0	0.0
Work Takts [#]	239.3	19.0	719.0	642.4	165.0	2092.0
Buffer Takts [#]	328.7	8.0	1253.0	1239.7	20.0	4462.0

Table 1 shows the average values of typical TPTC attributes recorded for the selected construction and equipment assembly projects. A short Takt Time as well as many Takt Areas, Wagons and Trains in both project parts mean a high level of planning and coordination effort for the construction manager. This generally requires comprehensive pre-considerations during planning to consider all dependencies. This usually leads to complicated schedules preventing potential time savings and reductions in complexity.

Through dividing the construction site into Takt Areas, and planning on this basis, dependencies must only be considered in smaller entities which can later be synchronized between the Takt Areas. When considering an entire project, synchronization between the dependencies of individual phases and between the two project stages also occurs.

As was shown in Table 1, the two project parts have different characteristics. Therefore, it is necessary to better understand the different characteristics of the two project types in greater detail:

- While the Takt Time of construction projects is 4.4 days on average, at 1.7 days it is less than half as long in equipment assembly projects.
- The smallest replicable unit (Standard Space Unit SSU see (Binninger et al. 2017)) of equipment assembly projects is many times smaller than in construction projects. This influences the dimensioning of Takt Areas.
- Equipment assembly projects therefore have more SSUs within each phase than construction projects.
- The Takt Areas of equipment assembly projects cover less space than construction projects. A phase of equipment assembly is on average made up of a higher number of Takt Areas than the equivalent phase of construction. This means that a simple construction project quickly results in a complex equipment assembly project which requires greater coordination effort. This is demonstrated in Figure 3.
- The average number of wagons is comparable in both types of project.
- An average equipment assembly project has almost four times as many trains as an average construction project.
- On average construction projects have 38.6 work packages, which is more than the average of 22.6 work packages in equipment assembly projects. Therefore, the smaller Takt Areas have less work packages per area.
- The construction projects investigated were divided into more functional areas than the equipment assembly projects.

- After completion, the equipment assembly projects were handed over in full, or no partial handovers were recorded. According to the analysis, partial handovers of parts of the project took place in the construction projects
- Equipment assembly projects are made up of many different Takts. In both types of project the number of Buffer Takts is higher than the number of Work Takts. However, the proportion of Work Takts is greater in construction projects.

The random sample used for this research is relatively small with 10 and seven projects for construction and equipment assembly projects respectively. This means it is not possible to make generalizations from the available data. Nevertheless, possible tendencies do appear. The difference in time and value dimensions is particularly noteworthy. This makes showing all works in the same Takt Plan difficult.

Time can be shown in a common Takt Plan provided that the different Takt Times are shown to scale and the spread of the Takts along the y-axis is differentiated by project stage.

Showing the Takt Areas is considerably more difficult as the Takt Areas do not necessarily align between the project types. In the analyzed projects these differ from one another. While the Takt Areas in construction projects are usually defined by building characteristics such as storeys or walls, in equipment assembly they are frequently defined by steps in the production sequence. Allocating these is less defined by spatial areas and more by steps in value creation during production. Figure 3 compares the Takt Areas of both project types according to the study by Dlouhy et al. (2017b).

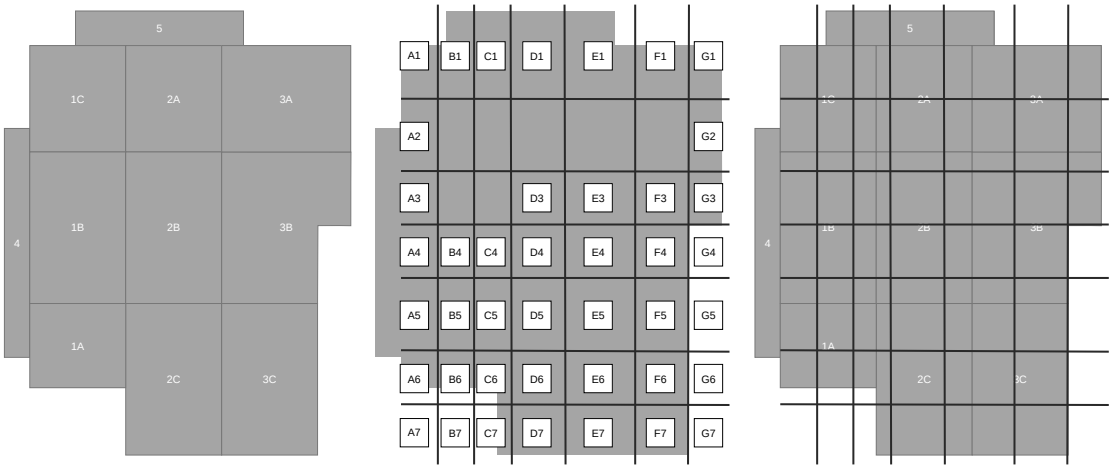

Figure 3: representation of the different Takt Areas of Lean Construction (left) and Lean Equipment (middle) and an overlay of both Takt Area boundaries (right) in the same project (author generated image)

A Takt Plan which is able to provide a common overview of the different project stages must be able to show these both in terms of time as well as in relation to value creation from different parts of the plan. Figure 4 gives an example of such a Takt Plan. Due to dependencies, the two project stages cannot work on the same parts of the project

area at the same time. For this reason, it is possible to modify the time scale of the y-axis between the two project stages. However, this is not recommended as this compromises readability and simplicity. From the example in Figure 4 it is immediately recognizable that the Takt Time of equipment assembly is exactly half that of the Takt Time for construction. This connection is easily visible, but as per the data collected, it is not the norm. Other relationships to the Takt Time are more difficult to show. Using uniform horizontal sizing of Takts despite different Takt Times must be avoided, so as not to distort the time dimension of the Takt Plan.

On the x-axis, the Takt Areas of the succeeding project area is simply added as additional Takt Areas and the list is updated accordingly. In the ideal case, the Takt Areas of each project part are also uniform to give greater readability, so that the progress of works is easily visible and can be read without additional effort. However as was shown in Figure 3 and discussed above, this is seldom the case in reality.

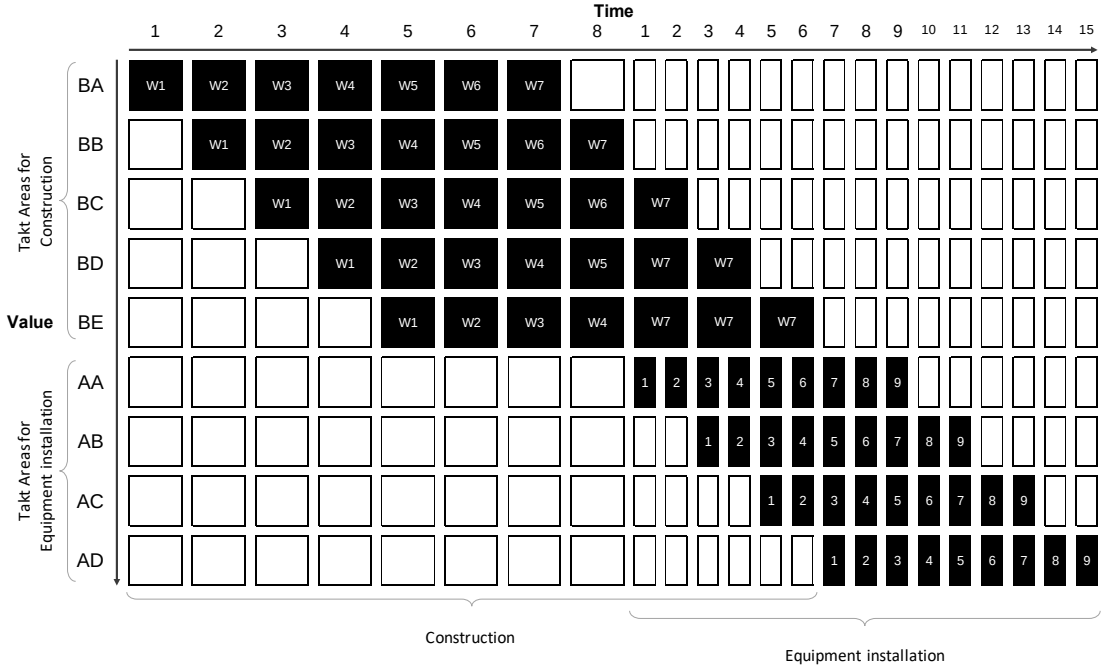

Figure 4: uniform representation of the two project stages in a higher level Takt Plan. There is a small buffer between stages due to different Takt Areas being used for each stage (author generated image)

Planning of both construction and equipment assembly projects can be completed individually for each stage. Additionally, the two Takt Plans can be joined to give an overview of the entire project and possible conflicts can be resolved.

As can be seen in Figure 5 (left image), conventional planning considers each project stage and phase in isolation. The direction of construction and principles used differ for each. Overlaying the Takt Areas, as was seen in Figure 3, supports greater understanding of the spatial layout and questions: what is the direction of construction? Which areas are handed over first? For equipment assembly, it can be determined which construction Takt

Areas can be used for early delivery and storage of tools and materials, or where the first equipment assembly works can take place. Conversely, participants in construction projects can use the equipment assembly Takt Plan to determine which areas should be prioritized, and which areas only need to be handed over for equipment assembly at a later point in time. The definition of construction direction can be standardized by overlaying the Takt Areas (see Figure 5, middle image). The Takt Plan can use the knowledge gained from the overlaid Takt Areas to form a standardized schedule. Through the complete depiction of all activities broken down according to space and time, the same principles can be applied to each project phase (right image).

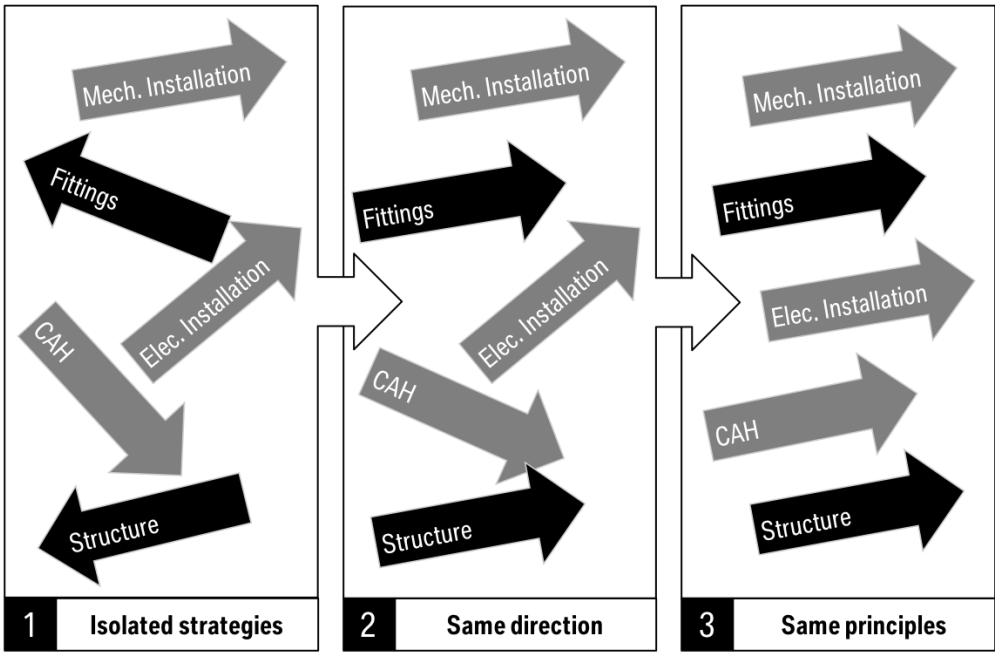

Figure 5: Advantages of a common understanding between construction and equipment assembly activities (author generated image)

DISCUSSION AND CONCLUSION

Investigation of the 10 construction projects and seven equipment assembly projects has shown the similarities and differences between the two project types. However, due to the small sample size no generalizations can be made. Despite this, the investigation shows that while joint planning of construction and equipment assembly works does not require synchronization of Takt Areas and Takt Time, it strongly simplifies planning and execution. Dialog between planners from both project stages is important to provide a common understanding of the sequence of works, and to guarantee measures with positive effects on the overall project such as earlier access to prioritized Takt Areas will occur. Apart from this, the knowledge gained could be used to prepare a new method for visualizing project information. Its use is considered a combined approach for Takt Planning and Takt Control in project planning to enable the project stages of construction and machine assembly to be shown together. As the companies involved are usually not

active in both areas, this form of planning is mainly interesting for customers and their designers. With the help of a higher level Takt Plan, the construction direction as well as the use of common principles is possible. Hereby execution can be completed seamlessly with virtually no unexpected surprises. For TPTC to be applied as profitably as possible for all subcontractors involved in a project, the methodical approach must be developed which applies not only to construction phases, but also those that precede it.

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