

Combining Takt and Deming Cycles at Operator Level—Practical Study



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Abstract Few empirical studies have previously been reported on implementation of takt planning and controlling the workflows continuously. This paper presents a case study from the offshore renewable industry, which is closely related to construction. The paper aims to develop and trial a conceptual model for combining takt planning and PDCA, also known as the Deming cycle in construction environments. The conceptual model has furthermore been modified for a visual board implementation that covers a specified process with a fixed number of technicians per performing team. The conceptual model draws on knowledge of takt planning implementation from the lean construction community and PDCA implementation from the lean production community. The main contribution of this paper is the conceptual model combining takt planning and Deming cycle in a construction environment. This conceptual model has potential implications in the construction and refurbishment industry.

Keywords Construction · Deming · Management · Offshore · Takt

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1 Introduction

1.1 Offshore Wind Turbine Construction Projects

From a turbine provider perspective, a project starts with a contract negotiation and customers choosing expected power output of the turbines. The project then formulates the design interfaces between cabling, foundation, and turbines. At the same time as the design formulations are prepared, the larger installation vessels are booked for installing foundations and turbines, as these hold a major contingency of the overall construction cost. When these parameters are defined, the turbines are set in production and later received at a designated harbor port facility. Here towers, nacelles, and blades are prepared for later offshore installation (Barlow et al. 2014) where the turbines will move into operation and start the power production. Various studies have focused on offshore wind project planning. Alla et al. (2013) focused on the overall project planning, including cabling, foundations, and turbines. Backe and Haugland (2017) investigated port and vessel configurations for the project plan, emphasizing the potential effects from the weather. Ursavas (2017) further developed the understanding of offshore wind farm installation planning and how calculations for this are highly affected by the changing weather conditions and how this is seen as a critical factor in the plans.

Wind turbine construction operates with repetitive tasks which have minor differences, similar to the case study presented by Heinonen and Seppänen (2016) from cabin refurbishment in a cruise ship. Hence, wind turbines can be perceived as standard products or modules that are manufactured and later constructed within the project-based production paradigm. In construction, modulization has had increasing attention (Peltokorpi et al. 2018) and the increased standardization makes it ideal for takt planning. The project shifts from land to offshore, which increases the importance of continuous improvements and a thorough plan. Liker and Meier (2006) described a combination of Deming cycle and takt planning within the car manufacturing industry (Liker 2004). Frandson et al. (2013) developed the understanding of takt applied in a construction setting with repetitive activities, which is also a known practice in location-based scheduling (Seppänen 2014).

Even though planning of wind farm installation is a developed topic, takt is not yet seen as it is in manufacturing (Liker 2004) or construction (Frandson and Tommelein 2014). Neither takt nor the Deming cycle (Deming 2000) had previously been introduced to the planning of offshore wind farm installation. In this study, we will present a case study of the installation processes for turbines in an offshore construction project and the implementation of takt and PDCA in a combined conceptual model. The project and the results from the implementation of the lean methods are presented. Finally, results are compared with existing takt literature, and the implication possibilities for lean construction are discussed. For academics and practitioners, this paper presents a conceptual model for takt planning and PDCA combined in a construction environment.

2 Case Study

2.1 Case Project

The case data was gathered in collaboration with an offshore wind turbine construction site, located in the British sector of the North Sea. The project organization is considered temporary, as the teams are brought together for executing this specific project for a known client to fulfill a contract as turbine supplier with a total expected power output above 400 megawatts for the complete wind farm. The project team had, prior to the construction phase, focused on planning of the construction works and generated takt workflows to understand the risks and identify improvement potentials. These initiatives and schedules are to meet contractual targets for various processes and milestones in the project. The selected process for this case study is part of the offshore installation requiring a large jack-up vessel (Barlow et al. 2014). The daily vessel charter rate is at approximately 200,000 EUR. The contractual target is 19 h of lead time per installation run throughout the project. Besides defining the takt, the vessel charter cost also motivated the project organization to continuously improve their processes. This makes the vessel and equipment the main cost drivers during the installation phase. The available number of vessel cabins limits the number of available technicians during the voyage and processes. The process studied here is considered similar to takt operations seen in manufacturing and construction. During the installation, the components are relocated to their final assembly positions by utilizing the vessel crane, and the technicians go through the product as if it were a high-rise building. The workstations are defined by the interface assembly points of the turbine: foundation—tower, tower—nacelle, nacelle—blades. The process planning and control system include the following three steps and will be described below:

- Standard installation process workflows
- Conceptual model for takt and PDCA
- Operational roles and responsibilities.

2.2 Existing Workflow

The workflows define the planned durations for the team of technicians executing the construction process together. Each complete run-through would then be considered an actual duration and here referred to as a lead time. The formalized workflows are based on the takt planning methodology and had previously been mapped and organized. But they are based on the team of multiskilled technicians working together, in contradiction to how Frandson et al. (2013) organized it per trade. The takt system here is developed on a team level in similarity with the structure described by Frandson et al. (2014). The turbine installation processes have a low variation and

complexity, which enables organizing activities among specialists, assuring the processes are commenced systematically in the various locations. The locations here are defined by the vessel deck or main components—foundation, tower, nacelle, and blades—but these are not directly reflected in the individual workflows. Each row is divided between the team roles and gives a clear illustration of the tasks and the structure which must be performed. The role could potentially be exchanged with locations. If locations would be more applicable to the overall project planning methods such as location-based scheduling (Kenley and Seppänen 2010), this would require considerations of the operational level and trades. The columns in Fig. 1 display the timeline at top and then give the time stamps for when the activities are organized to be performed by each individual technician. The task headlines and durations are directly marked in the schedule, and if multiple technicians are required for individual activities, this would be reflected by similar task descriptions. Color segregation could also be used to create an easy overview of the processes for the technicians and managers. The project teams are familiarized with this way of working, enabling further development of a conceptual model.

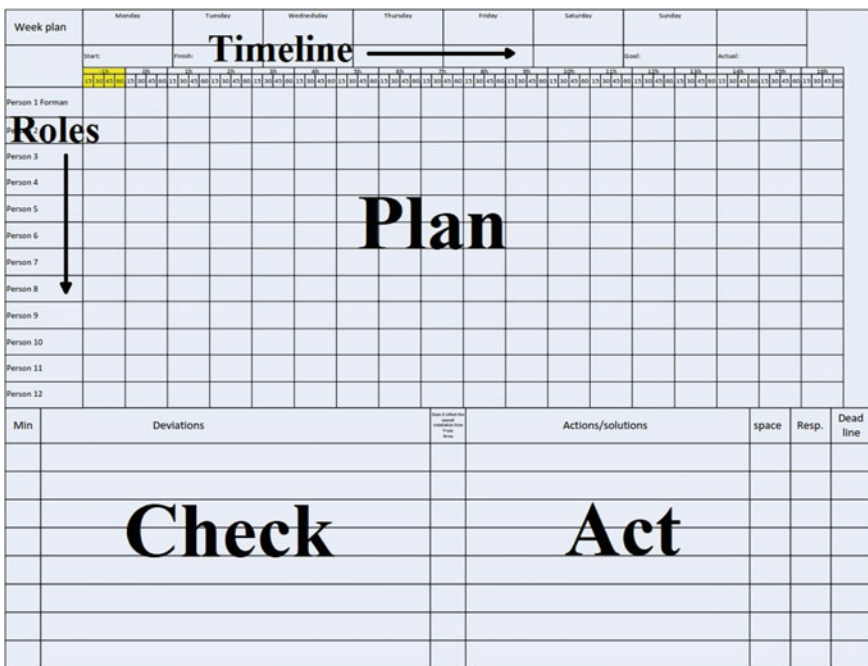


Fig. 1 Takt table design with the PCA

2.3 Conceptual Model Development

The following section shows the findings and development of the conceptual model for combining takt planning and Deming cycle in a visual board solution intended for the team levels. This was initiated with understanding of the activities and structuring these between the individual roles as described above. The Deming cycle (Deming 2000), also commonly known as the Plan-Do-Check-Act (PDCA) cycle, has been widely utilized in industry standards and management systems (ISO 2018; Liker 2004).

- Plan—Describing *how* and *what* and ensuring processes are aligned with the objectives.
- Do—Performing the processes or tasks according to the plan.
- Check—Measuring the performance, deviations and results of the processes compared to planned.
- Act—Acting to eliminate deviations or improvements to the existing processes.

PDCA has been a method for improving work processes, handling issues, and improving the business or organization. The four steps have also been presented by Liker and Meier (2006) as a driver of continuous improvements and key element in a learning culture (Frandsen et al. 2014). The utilization of the PDCA in this case was motivated by the continuous improvement potentials and understanding how or if this could affect the workflow durations. Teams could use it as a communication method and structure for meetings concerning deviations or corrections in the flow. This streamlined the decision process. A workshop in collaboration with the operational team was organized to uncover the potentials and to further understand how the workflows in combination with PDCA could be displayed for the teams.

The case owner agreed to create a visual and adjustable solution for the daily interactions within the team that could assist them in their decision making. During the workshop, visual management was discussed in the construction context, referring to “why” manufacturing had chosen to utilize visual management (VM) through years. Koskela et al. (2018) argued that “Mental operations, such as communication and decision-making are strictly seen waste in production; they are not adding value to the customer. Through VM, communication and decision-making can be sped up.” The operational team agreed to develop the conceptual model around their existing workflows and with a systematic way to handle deviations or improvements. The product of the workshop is described here and illustrated in Fig. 1. The fields are as shown in Fig. 1 and marked as “check” and “act,” which both relate to the PDCA cycle (Liker 2004; Deming 2000). These inputs are then used for adapting the workflow if required and reducing the waste in the daily operations by making deviations visible for operators. Figure 1 is then illustrated in Fig. 2, which comes from the case project. Here the tasks are organized for the operators. The visual display of the workflow is then as illustrated in Fig. 1, combined with rows for deviations marked “check” on the left and actions marked “act” on the right. Between check and act there is a column for whether the deviations affect the lead time, indicated by “Y” for yes and

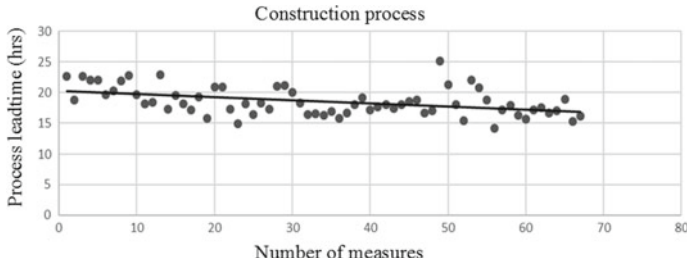


Fig. 3 Registered process lead times and trendline

ensures visual overview and traceability for the on-signing shift, reducing decision making time for them as they have a clear overview of the situation and performed.

3 Achieved Results

The case owner agreed to implement the conceptual model, with continuous performance measures afterward. These performance measures were conducted by operational managers taking pictures (Fig. 2) of the visual board after each run-through. The process lead times include preparations, lifting operations, assembly of main components, and ensuring the turbine is at a certain stage for the commissioning teams that follows.

Each process run-through for the installation was cleaned for adverse weather delay registrations, as these were not contractually included. The data are presented here in a scatter diagram with a trendline. Figure 3 illustrates the multiple lead times for the installation processes registered during the case study. The trendline illustrates a downward tendency. The trendline illustrates a trend from 20 to 16 h lead time, giving a 20% reduction by utilizing this conceptual model with takt time planning of the activities. This reduction was generated through stabilization of the workflow, by continuously adapting minor improvement adjustments and removing obstacles in the flow. Every deviation was registered on the board and transferred to an Excel register for later follow up and potential analysis of occurring errors. These data registration could be used to improve future project executions.

4 Discussion

4.1 Workflow Comparison

Wind turbine construction is similar to construction in multiple aspects: the project-based production, pre-fab elements, and fixed position manufacturing. This is also

reflected in the external conditions of the turbine construction sites being subject to weather conditions (Alla et al. 2013; Ursavas 2017), which is also seen within regular construction (Koskela 1999). These flow conditions enable the workflows and performance of the teams if they are prepared, no matter if constructing wind turbines or pre-fab buildings. Trades are organized and move through the products (Tommelein and Riley 1999). The foundation for the wind turbine construction here was the formalized workflow illustrated in Fig. 2, which defined the movements through the products. Tommelein and Riley (1999) described the deviations in the workflows as variabilities which in construction have registered implications. The lack of possibilities for protecting the flow with buffering and potential deviations emphasizes the importance for workflow readiness prior to each turbine installation.

4.2 Combined Takt and PDCA in Comparison

The conceptual model has implications as a method for visually displaying PDCA with different forms of plan. This could apply to process meetings like week plans and lookaheads (Ballard 2000). The check areas could potentially be adapted further with the flow conditions for planning and control purposes. The control of the flow allows technicians and site management to increase focus on deviations or variabilities that affect the workflow. It could also be argued that the registration of deviations gives the technicians a voice when or if the takt time is not realized, allowing them to be part of the solution for stabilizing the flow. A similar voice is heard when the foremen, as part of the Last Planner System (Ballard 1999), coordinate and together formulate their process plan across trades based on the master and phase plan. Obstacles and challenges are brought to surface, easing the decision making for managers and peers during repetitive planning sessions. Besides this, a combination of takt and PDCA can be used as a continuous method for improving the parade of trades through workflow improvements, encouraging the teams to reconsider approach and methods.

4.3 Takt Results in Comparison to Construction Takt Results

Chauhan et al. (2018) argues for prefabrication and takt as way of industrializing the construction industry. This could be argued to support takt applied in offshore wind construction with its multiple identical products in each project. Heinonen and Seppänen (2016) achieved a 73% cycle time reduction during the refurbishment of 126 identical cruise ship cabins. This indicates that the potential is greater than the presented results here, which could be related to learning curves as presented by Thomas et al. (1986) for construction productivity. Frandson et al. (2013) showed how takt and daily management led to 5 months completion instead of the original 11 months planned.

5 Conclusion

This case revealed a potential positive relation between takt and PDCA in a construction environment. Furthermore, measures illustrated a downward tendency in the process lead times for the teams. The 20% reduction of lead time is perceived as a substantial reduction. The impact on decision-making was not registered, and neither was the time from a deviation occurred until a solution had been implemented. The conceptual model presented can potentially be further developed for various levels of site management, using the planning and control as an opportunity for learning. Furthermore, the case illustrates a potential for further development or adaption into the construction domain.

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