Dlouhy, J., Binninger, M., Oprach, S. and Haghsheno, S. (2016). “Three-level Method of Takt Planning and Takt Control – A New Approach For Designing Production System in Construction.” In: *Proc. 24th Ann. Conf. of the Int’l. Group for Lean Construction*, Boston, MA, USA, sect.2 pp. 13–22. Available at: <www.iglc.net>.

THREE-LEVEL METHOD OF TAKT PLANNING AND TAKT CONTROL – A NEW APPROACH FOR DESIGNING PRODUCTION SYSTEMS IN CONSTRUCTION

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ABSTRACT

Due to the individualized design and construction of buildings, recurring processes are often not recognized. Because of this, potential improvements are not applied to future projects. With the use of Takt Planning and Takt Control, an effective method exists for identifying recurring processes and thereby adding stability to the construction process. Until now the focus has been on the optimization of the trade sequences during project execution whereby mostly one particular construction phase is considered.

This paper describes a newly developed method for designing a Takt Planning and Takt Control system. This method is based on a model with a three level hierarchy to be used for defining Takt and the related workspace.

The effectiveness of the method developed was analysed in a case study in a large-scale project. With application of this method, the building phases could be interlinked and the construction time could be reduced from the original eleven months down to five months. Additionally it could be shown that the division into three levels provides managers with the necessary transparency, helps them to make better decisions and to simplify controlling of a construction project. Furthermore, the method enables an improvement in the interlinking of construction phases with the operating phase of a building. The implementation of standardization across different levels allows a continuous improvement of processes from a multi-project perspective. With the help of the method used, the project won the “German Project Management Award 2015”. Building on the results presented in this paper, the method and its effectiveness need to be validated in further construction projects.

KEYWORDS

Production system design, Takt planning and takt control, systematic approach, generic structure.

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INTRODUCTION

During process planning for construction projects, knowledge gained from earlier projects is rarely integrated into future project structures. Generally there is no generic structure that can be applied to multiple projects. This means the quality of processes and relevant data cannot be compared across different projects. The reason is that every construction project is completed on an individual basis. The potential offered by higher levels of standardization of process structures thereby remains unrealized.

During projects, construction phases are only optimized individually, also known as the "over the wall" approach (Ehrlenspiel 1999). After optimization is completed within one construction phase, information is passed to the next phased over "invisible walls". Networked and structured communication is not part of planning the project meaning that the interfaces between different construction phases are first defined during project execution. Therefore a transparent value-creation process binding to all project participants does not exist – the foundations for effectively leading performance delivery are missing.

Bulhões et al. (2005) consider work planning on multiple levels. A central element is value stream management, which despite being able to optimize and individual project to meet its goals, does not allow a generic approach able to be applied at a multi-project level. Takt Planning is mentioned, however is not a part of the systematic approach. In their approach to Takt Planning Frandson et al. (2013) list six steps leading to a Takted production plan. Within each level variations and associated buffer times are planned. The approaches of Takt Control and optimization across multiple construction phases are not part of the method.

The research to date shows that there is a need for a new method for designing a Takt Planning and Management System on the basis of a generic and systematic project structure for construction projects.

This contribution describes further development of Takt Planning and Takt Control Systems resulting in the integration of collaborative elements. The three-level method developed here based on a three-level hierarchy model. Every level is structured to be built upon the previous level in terms of spatial and time factors. The advancement offered to construction projects is found in the level of detail possible for project planning. The significance is the ability for independent decision-making and collaboration between project participants at the relevant levels at any time without affecting the client's wishes. The method allows for greater transparency in the construction process for all parties. Furthermore data from individual construction processes can be compared with the same processes from other projects. This allows continuous improvements across all projects.

THE THREE LEVEL METHOD FOR TAKT PLANNING AND TAKT CONTROL

FOUNDATIONS

The theoretical foundations of the method originate in network theory as well as action regulation theory.

Action regulation theory describes a network and its participants. Known proponents of this theory are Walter Volpert and Winfried Hacker. According to Volpert (1994) actions can be broken down from their global objectives hierarchically, and built up again to assess if objectives have been met. The definition of levels allows assigning of different levels of accountability. Hacker (1973) differentiates between the steps of planning, execution, controlling execution. This sequence of action is similar to the PDCA cycle of lean theory.

Three levels are often used when allocating levels of accountability (Best and Weth 2005). This allows the most efficient knowledge transfer between all parties. The simplified standardization of products and processes improves existing systems.
Network theory also describes a system with participants divided across three levels: at the macro level the environment of the production system and its associated relationships can be considered from a multi-project perspective. The middle level shows all resource and information flows within the organization and its internal groups. The micro level, with the highest level of detail, shows individual roles, competencies, workstations and dependencies between roles (Zundel 2013; Sultanow 2010).

THE NEW METHOD

In stationary industry processes the product (object) flows between workstations with the labour (subject). Conversely, in the construction industry the labour (subject) and its services flow through the construction project (object) (Ballard und Howell 1998; Friedrich et al. 2013). Therefore labour in the construction industry must be completed at a specific time in a specific place. In construction processes time and space are linked and co-dependent. The new method divides these into three levels: the 'macro level', 'norm level' and 'micro level'.

MACRO LEVEL: PROCESS ANALYSIS

The macro level incorporates preparing a milestone plan for the different functional areas. The objective is to compete a systematic process analysis at an early stage to define priorities from the perspective of value to the customer. This places greater value on collaboration between project participants, and those at interface points. Clashes can be detected and dependencies defined. The result is a common vision for completing the future construction project.

Building upon this, the interface points and sequencing of works for the construction phases can be defined and optimized. Existing data from earlier projects can be utilized in different functional areas. Through escaping time and product related project constraints, a generic project structure emerges.

NORM LEVEL: TAKT PLANNING

At the norm level Takt planning reflects the customer's spatial prioritization. The value-adding process is therefore defined according to customer (user) requirements across all levels of the hierarchy. The time and spatial divisions are built up according to the macro level structure.

To be able to plan an equalized and stable construction process, the functional areas must be divided into standard space units (SSU). Under the defined work sequence these cannot be further subdivided, and can be finished independent of one another. Through division into small spatial units, there is a detailed dataset as a basis for harmonizing performance factors. Moreover different combinations of SSUs into different Takt areas are possible. These Takt areas are to be defined according to the customer's spatial prioritization.

For every work package in the work sequence, the process steps involved are identified and the work required is documented. As shown in Figure 1 the three levers of subjects, objects and machines can be used for harmonizing workloads (Engström 1987).

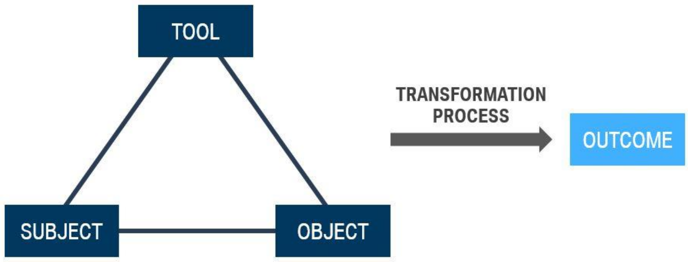

Figure 1: Factors influencing the transformation process (according to Engström 1987)

- Subjects are the workers: by defining the number of people working in each trade, the workloads can be equalized.
- Objects are the SSUs: through combining SSUs into Takt
- The type and number of machines also influences the workload.

The teams for completing the individual work packages are metaphorically grouped as wagons of a work train passing through the different Takt areas. The sequence of construction follows the spatial prioritization of the Takt areas, and therefore the customer's requirements. The generic elements of the macro and micro levels are fit to an individual project.

The Takt plan prepared in a production layout and named "WIP" by Faloughi et al. (2015) includes the dimensions of space and time. The definition of parameters leads to replicable work packages and early stage planning of material flows and machine use. Using workable backlogs (Sepannen 2014; Hamzeh 2008) for non-replicable work packages in prioritized surfaces is also possible. Knowledge gained and variations at the norm level are directly transferable to the macro level.

MICRO LEVEL: TAKT CONTROLLING

The micro level encompasses the detailing of the process packages of the norm level and management during execution of construction. The generic connection to the macro level remains through the work steps of the process packages.

Work steps for Takt areas are taken from the process packages at the norm level. They are planned according to the Takt timeframe within the framework of a collaborative procedure between the project manager and subcontractors. Managing execution of construction occurs through daily short-cycled Takt status meetings lasting approximately 15 minutes. All site workers thereby meet with the accountable foreman. These meetings are inspired by shopfloor management of the stationary industries (Hofacker et al. 2010). For purposes of visualization and documentation, information is gathered during status meetings and recorded on a takt control board.

The Takt status meetings and takt control board are made up of two essential parts: firstly documentation of the actual status. Secondly the resultant measures to fulfil the requirements of the norm level.

OVERVIEW OF THE THREE-LEVEL METHOD

Figure 2 summarizes the three hierarchical levels, which show the different levels of detail from the perspective of value to the customer. The components of the micro and macro levels are project-independent and therefore suited for application to different projects. The three-level method developed here is a flexible system. The knowledge gained at the micro level is automatically transferred to the norm level, and will influence planning in future. By harmonizing workloads, the norm level can react to findings at the micro level.

The following lists significant points defining the components of the developed three-level method:

- Process package: defined at the macro level and part of the process chain of the sequence of works of a particular functional area.
- Process plan: describes the macro level and its milestones and functional areas
- Work package: defines the works, which can be completed within each Takt and Takt area at the norm level. It is compiled during harmonization.
- Takt plan: is a structured construction plan with a complete overview of the construction process according to the spatial construction and time Takt.
- SSU (Standard space unit): is a small spatial and independent unit according to structural and manufacturing characteristics.
- Performance factor: is the average needed time for one work step.
- Work step: defined at the micro level for every SSU. They are allocated a performance factor.
- Dashboard/Takt Control board: incorporates the short-cycled inspection of building progress and operations at the location of value creation to ensure the takted construction process is followed.

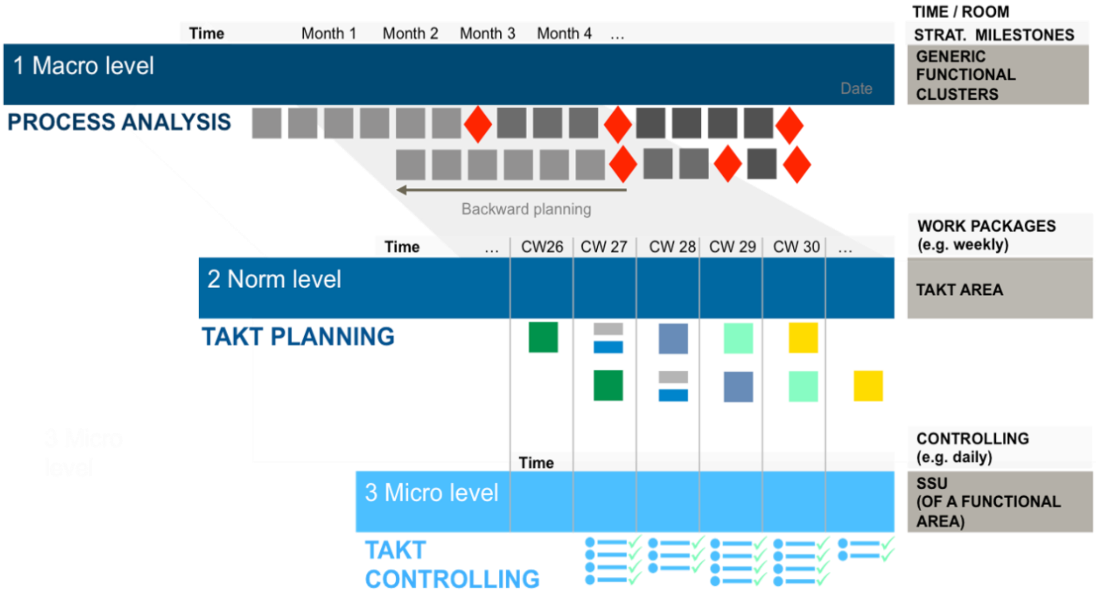

Figure 2: Overview of the three-level method

The effectiveness of the three-level method will be analyzed within the framework of a large-scale Greenfield construction project carried out by BMW AG. The building serves as a facility for storing parts, and their assembly into vehicles.

APPLICATION OF THE NEW METHOD ON A CASE EXAMPLE

KEY FACTS OF THE PROJECT BMW BRAZIL

The following lists the main actors and frame of reference for the project:

- Location: Joinville Region, Brazil
- Planned production capacity: 30,000 vehicles / year, 1,300 new jobs (Bimmertoday 2012)
- Project Size: Total Area 1.5 million sqm, 500.000 sqm surface area (Bimmertoday 2012)
- Project timeline: December 2012 – September 2014 (22 months total); with six months for execution of construction for the following case example
- BMW's organizational structure comprised of a project leader, multiple project managers and external project controllers
- As end-user, BMW AG produces vehicles on the surface area. After handover of the building the end-user installed production facilities.
- The general contractor Perville Engenharia e Empreendimentos S.A is a multidisciplinary engineering team (comprising a project manager, project controller, specialist engineers, HS&E, purchasers and subcontractors).

MAKRO LEVEL: PROCESS ANALYSIS

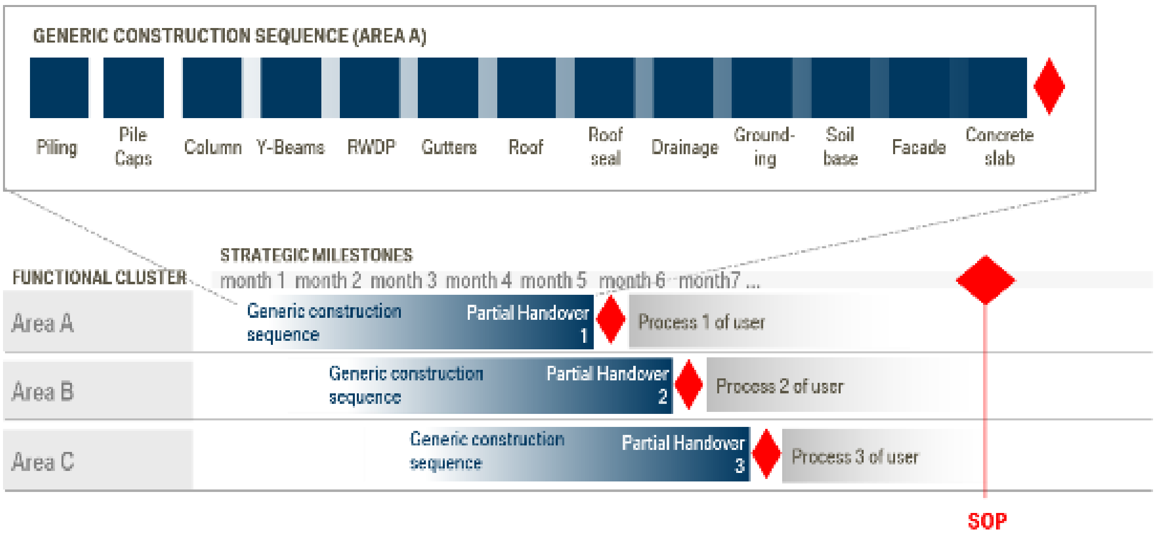

Figure 3: Milestone plan at the macro level with a generic sequence of works

In the case study, preparing the work sequence for the installation and construction processes began from "SOP" (Start of Production). The sequencing for the shell construction and milestones of the construction project are shown in Figure 3. By showing the nature and complexity of the process, individual spatial areas within the production hall can be identified and prioritized.

After the process analysis, the structure was divided into three areas according to the perspective of the customer wishes (Area A, Area B (B1 + B2), Area C) (see Figure 4). For partial handover of building areas the following conditions had to be met: the façade must be predominantly closed-in, the roof watertight and the floor prepared for assembly works.

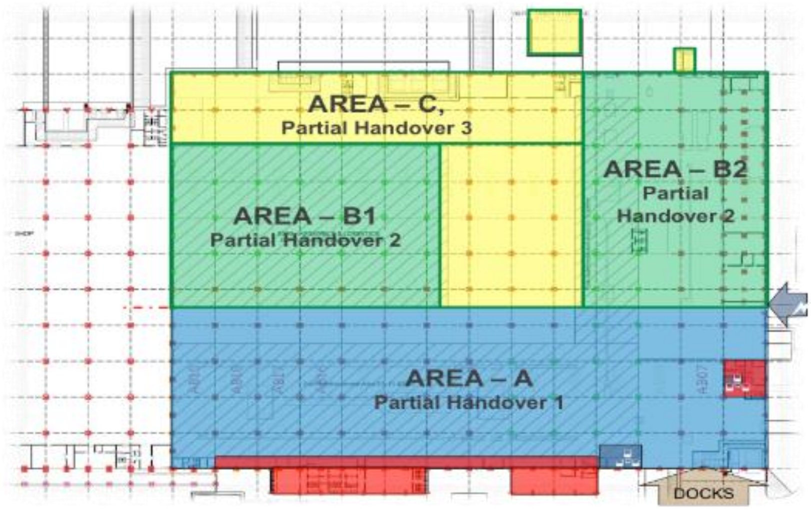

Figure 4: Categorization of customer's spatial area prioritization

NORM LEVEL: TAKT PLANNING

Trade Sequence	SSU	Performance factor / SSU	Man-power	Duration / SSU	Takt area	Performance factor (total)	Levelling (Takt time = 5 days)
Piling	5 piece	5*160 min.	4	40 min.	60 pieces (with 2 Takt areas)	5 days	W1
Pile Caps	2 piece	2*480 min.	4	120 min.	13 pieces	3.25 days	W2
Column	1 piece	1200 min.	5	240 min.	7 pieces	3.5 days	W3
Y-Beams	1 piece	800 min.	5	160 min.	5 pieces	1.67 days	W4
RWDP	1 piece	320 min.	2	160 min.	6 pieces	2 days	
Flat gutters	2 piece	2*80 min.	5	16 min.	30 pieces	1 day	
Gutters	3 piece	3*300 min.	5	60 min.	16 pieces	2 days	
Roof	1 grid	3840 min.	8	480 min.	5 grids	5 days	W5
Roof seal	1 grid	1920 min.	4	480 min.	5 grids	5 days	W6
Drainage	18 m	18*149.33 min.	7	21.33 min.	90 m	4 days	
Grounding	18 m	18*10.67 min.	2	5.33 min.	90 m	1 day	
Soil base	324 m^2	324*10.37 min.	7	1.48 min.	1.620 m^2	5 days	W7
Facade	2 piece	2*240 min.	5	48 min.	10 pieces	1 day	
Concrete	360 m^2	360*20 min.	15	1.33 min.	1800 m^2	5 days	W8

Figure 5: Example of a harmonization table

For developing the Takt plan (production plan) a SSU was defined for all functional areas during shell construction. Furthermore by arranging the performance factors to the individual process packages, the work sequence was harmonized by balancing the size of teams and machine capacities. The result was one Takt made up of five work stages, and one Takt area made up of six SSUs. When defining the Takt areas, safety regulations had to be considered meaning that mobile cranes could not be used in adjacent SSUs. The work packages making up one Takt and Takt area together comprise one “wagon”. In the following harmonization table, the wagons studied are labelled as W1, W2, W3 etc. (Figure 5).

One work train was calculated to contain 28 Takt areas. These, and one SSU are shown in Figure 6. Also figure 6 shows the completed Takt plan. After implementation less Takts were needed after adjusting to the norm level. For example, construction management changed the workload from five to six Y-beams per Takt area. The Takt plan also served as the basis of communication with external partners.

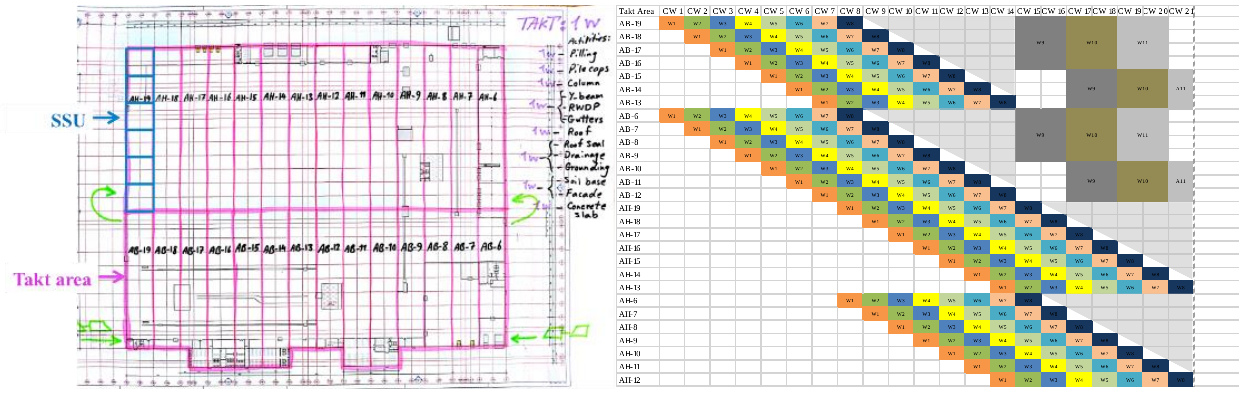

Figure 6: Defined Takt areas with SSUs and the Takt plan

MICRO LEVEL: TAKT CONTROLLING

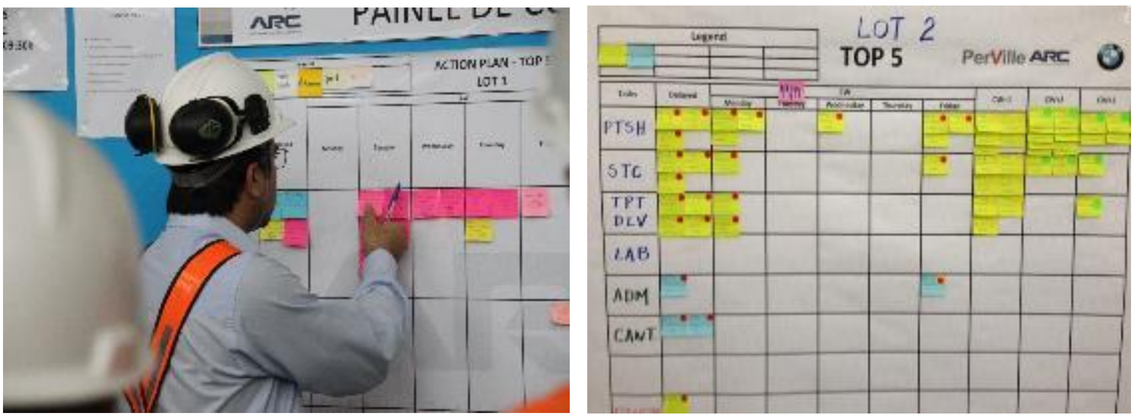

Figure 8: Images of Takt meetings and dashboard

The micro level divides the work packages from the norm level into detailed working steps. The contractors executing construction cooperatively plan these working steps for the applicable Takt from the norm level.

As shown in Figure 8, the current and three upcoming Takts are visualized on the dashboard at the norm level. During daily Takt meetings construction progress is documented on the dashboard at micro level

RESULTS

In the case study using the three-level method generated generic processes, which can be reused in future projects. Moreover the standardization across the three levels results in continuous improvement.

Construction phases were determined in a commonly optimized flow according to the client's requirements. A side effect was that critical spatial areas such as Area could be handed over earlier as it was prioritized in an early stage of planning (see Figure 4). Dividing into three levels showed an improved visualization of the overall construction process. Both decision making for the project team and controlling the construction process were simplified. This meant no delays were recorded.

Using modular prefabrication, collaboration between PerVille and BMW, as well as Takt planning and Takt Control, allowed the construction time in the case study to be reduced by five months.

The project described in this paper was awarded the "German Project Management Award 2015".

Based on the results of this paper, the method and its effectiveness should be verified in future construction projects.

CONCLUSIONS

The three-level method described in this paper shows a system that can be used generically and from a multi-level perspective. It is possible to use work sequences at the macro level and performance factors of individual work steps at the micro level in multiple ways. The norm Takt comprises the total added value of the construction site making them transparent and available to all project participants. Processes are adjusted to a concrete project through the top-down approach of the macro level, and the bottom-up approach of the micro level. The macro, norm, and micro levels divide the project both in terms of space and time, so that the customer's requirements can be structured and followed at all levels. Interfaces between the construction phases can be transparently stated, and optimized according to the customer's batch size.

This case study shows that data for further development in subsequent projects is possible, that it is possible to commonly optimize according to the customer's requirements and that the construction process becomes more efficient.

Further development of the three-level method would be based on data from various construction projects. These data could be used for deviations from standardizations, which through continuous improvement can generate noticeable efficiencies in construction processes.

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