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NO SINGLE TAKT PLANNING METHOD FITS ALL PROJECTS

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ABSTRACT

Takt planning methods have been used to plan and control production of a variety of construction projects that have been delivered in various contexts. Recognizing that projects vary by type based on different product- and process designs as well as contextual characteristics of relevance to project production, not one but several takt planning methods have therefore emerged. This paper presents the objectives pursued in takt planning and describes projects by type and context, based on their complexity, in relation to these objectives. It outlines several takt planning methods and then matches those methods to project types and contexts. It is clear that no single takt planning method fits all projects and also that takt planning may not be a suitable method to plan some projects. This paper aims to shed light on available takt planning methods and on choosing which one to use when considering the complexity of a given project and its context.

KEYWORDS

Takt planning, takt production, work structuring, complexity, uncertainty, variability, slack.

INTRODUCTION

Projects are complex socio-technical systems. Their complexity stems in part from the fact that they comprise a large number of elements that are interconnected in various ways and to various degrees (e.g., people, materials, equipment, activities, processes, economic conditions, and legal requirements). Complexity is exacerbated by expected and unexpected variability arising from internal processes (e.g., decision-making processes or production processes) and external factors. Articulating and managing project complexity is crucial for effective project planning.

Here we focus specifically on takt planning. Takt planning methods have been used to plan and control production of a variety of construction projects that have been delivered in various contexts. Recognizing projects by type based on different product- and process designs as well as contextual characteristics of relevance to project production, various takt planning methods have therefore emerged. Our aim is to shed light on available takt planning methods and on choosing which one to use while considering the complexity of a given project type and context.

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This paper is structured as follows. We first offer a literature review on takt planning, project- and contextual complexity, and slack. Next, we introduce takt planning, present its objectives, and describe project characteristics relevant to takt planning. We then characterize and compare five projects, using data from case studies documented in the Lean Construction literature, based on their complexity and in relation to the aforementioned takt planning objectives. Subsequently, we outline four takt planning methods and match those methods to project types and contexts. We conclude the paper with recommendations for follow-on research.

LITERATURE

TAKT PLANNING

Takt planning methods set a regular "beat" for production so that work can flow in time and space, in order to match customer demand. The application of takt production in manufacturing dates to at least the early 1900s (Baudin 2012b), however the application of takt in construction has become more widespread only in this millennium. Takt planning can be applied to an entire construction project, but it is likely that different parts of a project will each have their own takt, as is the case in manufacturing where different assembly lines typically have different takts.

Quite a few instances of takted projects have been reported in the Lean Construction literature. These reports show that takt planning can be applied to projects of various types across the construction industry. Among relatively recent examples, Fiallo and Howell (2012) described the application of takt in designing the production system for an infrastructure project. Frandson et al. (2013) described the use of takt planning for the installation of a hospital's exterior cladding system, and Linnik et al. (2013) described how takt planning was used on the same project to plan non-repetitive interior work. Heinonen and Seppänen (2016) described the use of takt planning for the refurbishment of cruise ship cabins. Dlouhy et al. (2016 and 2018) applied their "three-level method of takt planning and takt control" to plan the construction of two automotive manufacturing plants. Vatne and Drevland (2016) described how takt was used to plan interior construction of a student housing complex, whereas Lehtovaara et al. (2019) used takt to plan interior construction of a residential building.

Although these reports mention the use of takt, not all takt planning methods are the same. In fact, takt planning describes a broad category of location-based planning methods, and therefore comparison with other methods in this category is warranted. Frandson et al. (2015) compared and contrasted the underlying assumptions of the Location-based Management System (LBMS) with takt planning. They identified key differences in how these methods make use of capacity-, space-, and time buffers. Formoso et al. (2022) presented a location-based approach for using takt on linear infrastructure projects, allowing for flexibility in choosing when to start work in any one of several planned work zones. Tommelein (2022) presented the Work Density Method (WDM) for takt planning, a method based on the work density concept to determine work locations and set a time limit for the completion of activities. Tommelein and Lerche (2023) compared the use of takt planning methods on projects of two different types: (1) a wind farm infrastructure project and (2) a healthcare facility project, the first paced by rather unique and expensive equipment, the second more flexible in throttling up-or-down the number of resources involved. These applications and methods may be viewed according to characteristics relevant in this production-planning context, as will be described in this paper.

Because takt can be used to plan the construction of products in different contexts—i.e., to deliver projects and phases of projects of various scope and size—the methods used on any given project may vary with time as needed to result in an efficient and effective plan. This aligns with Shenhar's (2001) assertion that "one size does not fit all projects."

Questions that come to mind are: (1) What are the essential conditions to implement takt time successfully in construction projects? (2) When all these essential conditions are met, is it still possible to fail in applying the fundamental principles of takt and find no solution? (3) When is it not appropriate to takt a process? (4) When does takt planning [and control] fail and what alternative methods can then be used?" These questions were inspired by Casey Ng's questions on LinkedIn, as quoted in Baudin (2012a). In this short paper, we begin to address these questions, but we cannot provide extensive answers.

A study of project- and contextual characteristics that affect the suitability of using takt planning and the choice of method is in order. In the following section we present such characteristics that we think are fundamental to assessing the applicability of takt planning. These characteristics may be grouped into concept categories pertaining to project- and contextual complexity and the availability of slack as a coping mechanism.

PROJECT- AND CONTEXTUAL COMPLEXITY

As it is said that construction projects are becoming more complex over time, and Baccarini (1996) stated that complexity makes a difference in the management of projects, we must first define complexity. Then we can ask: How can knowledge of what makes a particular project more (or less) complex than others be used to plan and deliver that project using takt planning?

Complexity, as defined by the Cambridge Dictionary (n.d.), is "the state of having many parts and being difficult to understand or find an answer to." The degree of complexity of an entity (e.g., a project) is, according to Klir (1985), "associated with the number of recognized parts as well as the extent of their interrelationship; in addition, complexity is […] related to the ability to understand or cope with the thing under consideration." Williams (1999) argued that in the context of project management, complexity manifests in two dimensions: (1) structural complexity and (2) uncertainty. Whereas structural complexity relates to the number of distinct elements in a project and the degree of interrelatedness between them, uncertainty relates to how well-defined the goals are and the means to achieve them.

Geraldi et al. (2011) systematically reviewed project complexities and presented a timeline of the historical development of complexity frameworks since the 1990s, showing when new understandings emerged in the literature. They identified five so-called "dimensions of complexity" in projects, namely (1) structural complexity, (2) uncertainty, (3) dynamic [complexity], (4) pace [complexity], and (5) socio-political [complexity]. In the framework presented in this paper we include an additional dimension, namely organizational complexity. Although these dimensions appear to not be mutually exclusive, we use this framework—with adjustments tailored to the context of construction and takt planning—to expand on the nature of project- and contextual complexity. Using example projects delivered with takt planning and mapping them to the complexity framework, we illustrate that some takt planning methods may be better suited for certain project types than for others.

1. Structural Complexity: 1.1. Product Complexity and 1.2. Supply Chain Complexity

Projects with a variety of numerous, interrelated elements give rise to structural complexity. Structural complexity may be attributed to product complexity and supply chain complexity. Product complexity is determined by the number of systems and their constituent elements, and the interrelationships between those systems and elements. These interrelationships can involve various degrees of tight- or loose coupling (Howell et al. 1993). In the construction context, interrelationships refer to how elements within a system fit together, and how changes in the design of one system affect the design of other systems. Supply chain complexity is determined by the quantity and variety of products, people, and organizations, and their interrelationships. Whereas Williams (2005) lumps both organizational- and supply chain complexity together under the umbrella of structural complexity, here we lump product- and supply chain complexity together and we treat organizational complexity separately. The articulation of complexity dimensions is itself rather complex and not generally agreed upon.

2. Uncertainty

The prediction and control of system performance is particularly challenging in the presence of uncertainty (Böhle et al. 2016). Uncertainty defines a state where individuals have incomplete knowledge of a situation (Saunders et al. 2015), e.g., due to measurement errors or a limited understanding of cause-and-effect relationships. Uncertainty may be viewed as "unexpected variability" (Saurin and Werle 2017). It may arise from human and social influences or organizational conditions, and it can be influenced by both internal and external factors.

3. Dynamic Complexity

Dynamic complexity refers to changes over time, so it indicates a certain kind of variability. Hopp and Spearman (2011) characterized variability as the attribute of non-uniformity within a class of entities. Process variability emerges from variations and randomness in work procedures, setups, random interruptions, and quality issues. Flow variability results from the way in which work is released to the system or transferred between locations.

4. Pace Complexity, i.e., Pace of Project Delivery

Pace is related to speed and urgency associated with performance and completion of project activities, reflecting deadlines and pressure to deliver results (Geraldi et al. 2011). "Fast" projects require numerous resources and overlapping activities (i.e., work taking place in many locations simultaneously), increasing activity interdependence and making them more tightly coupled, and consequently increasing the complexity related to planning. Lindkvist et al. (1998) suggested that the use of deadlines, milestones, and other time-based controls not only helps to pace projects in relation to overall time limits, but also supports parallel (simultaneous) work by encouraging communication and reflection. Takt time is a time-based method of control (Hall 1998) that helps to pace projects and indeed provides such support.

5. Socio-political Complexity

Socio-political complexity pertains to the network of interactions between people, power dynamics, stakeholder relationships, and political influences within and around the project environment (Geraldi et al. 2011). This dimension of complexity is related to the alignment of interests among stakeholders and their negotiation of project objectives.

6. Organizational Complexity

Organizational complexity encompasses technical elements (e.g., skill- and tool specialization) and human elements such as decision making, interactions among individuals (employees) at different levels of the organizational hierarchy (e.g., teams, departments, and divisions), as well as factors such as organizational size, culture, expertise, and risk tolerance (Peñaloza et al. 2020). In contrast to supply chain complexity that relates to elements and interactions between companies, and socio-political complexity that relates to elements and interactions both within and around a project, organizational complexity focuses on internal project team dynamics.

Takt planners, and planners in general, will recognize these dimensions of complexity in their projects and the contexts in which their projects unfold. To manage complexity, they can use certain coping mechanisms, which we present next under the broad category called "slack."

SLACK

Slack refers to the use of resources in a planned or opportunistic way to cope with complexity (Formoso et al. 2021, Saurin et al. 2021). Here, resources refer to not only people, materials, tools, and equipment, but also time, information, production strategies and, more generally, the flexibility people have in devising new approaches and creative solutions. Slack does not necessarily imply the use of extra or idle resources: existing resources can be readapted in order to protect systems from uncertainty and variability. Bourgeois (1981) described three roles for slack: (1) spare resources to prevent ruptures in the face of a surge of activity; (2) resources that allow an organization to adjust to external changes; and (3) resources that allow an organization to experiment with new products or innovations in management.

Formoso et al. (2021) and Saurin et al. (2021) advocated for two uses of slack in construction: (1) to have enough resources for fulfilling demands or carrying our strategic actions, and (2) to manage complexity as projects are complex socio-technical systems. Although it is (generally) desirable to reduce complexity rather than manage it, it is prudent to devise management strategies—e.g., strategically plan the use of slack—to cope with existing complexity that is difficult to remove or reduce. Slack resources should be planned and deployed judiciously so as to add flexibility or redundancy to systems while ensuring that they will have positive impacts. These impacts can be measured in terms of system resilience, reliability, robustness, innovativeness, and output flexibility. When the use of slack is mostly opportunistic or not well-defined, it can impact the system negatively and generate waste.

The provision and use of slack resources in the context of takt planning can be realized through various approaches. One approach is to develop alternative takt plans, so that the most suitable one can be used when uncertainties in the project diminish. Another approach is to determine what aspects of the work (e.g., work zones, work instructions, process sequence) should be standardized in a takt plan and what should be left for qualified workers to figure out. This poses strategic questions: (1) What level of specificity is appropriate for takt plans at different levels of planning? and (2) How detailed should takt plans be at various points of a project's construction timeline?

PROJECT CHARACTERISTICS RELEVANT TO TAKT PLANNING

With this understanding of takt planning, characteristics of project complexity, and slack as a means for coping with complexity, we now focus on project characteristics relevant to identifying a suitable takt planning method. The success of applying a takt planning method depends on the ability of the planner (i.e., the person or team responsible for developing and maintaining plans) to structure the work of a project, or a phase of a project. Here, "ability" encompasses not only personal- and team competence, but also the degree of flexibility granted to the planner. This flexibility can arise from the manifestation of resilience of the planning method, when the method enables the planner to define and fine-tune various production system design elements to their desire. The following are examples of "throttles" or "adjusting mechanisms" (Binninger et al. 2017) that can be manipulated to shape a takt plan.

1. Use alternative breakdowns of the scope of work.

One throttle is to study alternative breakdowns of the scope of work. Takt planning requires a breakdown of work into "chunks" that can be done concurrently, creating process modularity, allowing for fast feedback, and ultimately aiming to reduce lead time. Work breakdown relates to product complexity, i.e., how tightly- or loosely coupled project physical elements (building elements, assemblies thereof, and systems) are. On the one hand, when they are loosely coupled, planners have more flexibility, e.g., to structure work into small (in scope and duration) process steps and divide work space into more zones to reduce cycle time. On the other hand, when projects are less flexible, i.e., when elements and systems are tightly coupled and process steps are larger (in scope and duration), planners may not be able to divide work space into so many zones but instead have to rely on other takt planning throttles to realize shorter cycle times.

2. Re-sequence work or add/remove work from a process step.

A second throttle involves the possibility of re-sequencing work or shifting work content from one process step to another, essentially redistributing the workload between steps in order to achieve more evenness (workload leveling or "heijunka"). This helps to reduce cycle time and work fragmentation, and it results in a reduction in the workload of one process step and possibly a corresponding increase in another process step. The feasibility of resequencing work or shifting work content may depend on trade jurisdictions (e.g., whether a trade contractor can perform the work initially assigned to another trade), specialty equipment requirements, personnel training needs, etc.

3. Define the resources that can be assigned to perform work.

A third throttle is to adjust resources in terms of their type, quantity, or capacity (e.g., augmenting capacity by providing skill training). When all constraints for a task have been removed, the pace at which work happens is dictated by the nature of the resources involved.

For example, operations such as percussive- and rotary drilling are equipment-paced, i.e., the operation is inherently tied to the capability of the equipment being used. Reducing cycle time would require allocating additional- or alternative equipment, i.e., equipment that gets work done faster. However, such equipment can be expensive, difficult to obtain, and logistically challenging to mobilize on site. Furthermore, even when under ideal conditions a certain level of predictability in equipment performance may be anticipated, that performance will be impacted by uncertainties stemming from the surrounding environment—known unknowns.

In contrast, for example, operations such as those involving interior work (e.g., painting, tile installation, window installation) are worker-paced. Provided that there is some kind of slack (e.g., capacity buffers, multi-skilled labor, or financial resources to hire additional workers), it is relatively speaking more straightforward and affordable to adjust the number of workers. Although the pace of work is dictated mainly by worker skills and speed of construction, the surrounding context can also introduce uncertainty. For example, retrofit work tends to have more known unknowns compared to new construction (e.g., "Does the ceiling have asbestos or not?"), in which case the additional complexity must be considered during planning.

4. Exploit flexibility in the use of space.

Spatial features and flexibility in the use of space influence the flexibility afforded to planners. In some projects, most of the work must be performed in situ, and this need for location-specific work may limit how much work can be scheduled concurrently using takt planning while avoiding trade stacking. Conversely, other projects may allow some or several elements or assemblies to be produced ex situ, with only the final installation taking place in situ. The possibility of working ex situ provides planners with flexibility in structuring in-situ work. By reducing the time needed to perform in-situ work (i.e., reducing the work density), the corresponding process cycle times can be reduced, ultimately shortening the overall project duration. Furthermore, defining larger zones for takted work can allow several crews to work shoulder-to-shoulder, requiring them to figure out who works where and when, while at the same time offering the flexibility of choice.

5. Acknowledge the distinction between operable takt vs. customer takt.

Projects must be delivered to meet the customer's takt, but approval processes and externalities can introduce uncertainty into the delivery process. For example, projects situated in seismically active areas require rigorous inspections of both structural- and non-structural elements during construction. Takt plans must make explicit the handoffs from upstream- to downstream process steps, including those required for inspections, and include decoupling buffers where needed. Slack can be used to mitigate some variability, e.g., from delays in inspections or rework resulting from failed inspections. Other projects, such as those in the realm of infrastructure, may encounter unknown underground and site access conditions. A takt plan can help to delineate different zones where work can take place simultaneously, limiting the propagation of variability (Formoso et al. 2022).

The flexibility to adjust these throttles derives from the characteristics and constraints of each project. Understanding the general characteristics of the type of project being evaluated can guide the identification of the most suitable takt planning method(s). For example, planning the construction of a multi-family building or a hotel may be simpler in some regards than in others when compared to planning the construction of an offshore wind farm.

SELECTION OF PROJECTS FOR COMPARISON

To compare construction projects in terms of their dimensions of complexity and rationalize the takt planning methods used to deliver them, we looked at data from five case studies documented in the Lean Construction literature. These case studies—some of which conducted by the authors of this paper—describe a variety of projects, namely:

[1] Multi-family residential building (Barth et al. 2020)
[2] Cruise ship cabin refurbishment (Heinonen & Seppänen 2016, Makinen 2021)
[3] Overhead MEP work in a healthcare facility (Frandson & Tommelein 2014a, 2014b)
[4] Offshore wind farm construction (Lerche 2020, Tommelein & Lerche 2023)
[5] Underground linear infrastructure projects (e.g., sewer lines, fiber-optic cables) (Yassine et al. 2014, Formoso et al. 2022)

PROJECTS COMPARED ALONG DIMENSIONS OF COMPLEXITY

By adapting Geraldi et al.'s (2011) framework to the context of construction—here specifically takt planning—we illustrate how one might evaluate projects based on their complexity. Although their framework presented five dimensions of complexity, we present seven as we not only added organizational complexity but we also split structural complexity into product- and supply chain complexity.

Based on group discussions among the authors and our expertise in takt planning, we scored each project along each dimension of complexity, assigning the full range of integer values from 1 to 5 (Table 1). Admittedly this is a very crude way of assessing complexity but, as we were wondering if an approach like this might be promising in any way, it offered an initial attempt at categorization. To add: scores assigned to complexity in one dimension are not to be summed up with scores assigned to complexity in another dimension, as these dimensions are qualitatively rather different and overlap to some degree, as previously mentioned. Clearly, follow-on research must include selection of an assessment method that is more fit-for-purpose, comprehensive, and superior to what is presented here. Methods matter! For choice problems, for example, we have argued that Choosing by Advantages (CBA) is superior to Weighting-Rating-Calculating (WRC) and to the Analytic Hierarchy Process (AHP) (Arroyo et al. 2014a, 2014b).

Table 1: Projects Scored According to their Dimensions of Complexity

Type of Project	PRODUCT	SUPPLY CHAIN	UNCERTAINTY	DYNAMIC	PACE	SOCIO-POLITICAL	ORGANIZA-TIONAL
[1] Multi-family building	4	3	1	3	1	2	2
[2] Cruise ship cabin refurbishment	3	2	2	1	2	1	1
[3] Hospital overhead MEP work	5	4	3	5	4	4	5
[4] Offshore wind farm	2	5	5	2	5	3	4
[5] Linear infrastructure	1	1	4	4	3	5	3

Product complexity assesses the interconnectivity of physical elements (e.g., building elements, assemblies thereof, and systems). A score of 1 indicates low complexity due to loose interconnectivity, whereas a score of 5 indicates high complexity due to tight interconnectivity. We scored case [5] the lowest, considering that it has relatively few, simple parts, connected one-to-one linearly and therefore is the least complex of all 5 cases, and we scored case [3] the highest, considering that many parts of different shapes and sizes make up the mechanical, electrical, and plumbing (MEP) systems, all routed and tightly packed in the same overhead space. Table 1 reflects these scores and the scores given to the three other cases, but due to the 12-page restriction of this paper we could not spell out all our rationale in this write-up.

Supply chain complexity gauges the level of customization of construction materials. A score of 1 represents a project using mostly made-to-stock materials (not customized, simple, and readily available), whereas a score of 5 represents use of engineered-to-order materials (highly customized, complex, and procured with long lead times). We scored case [5] the lowest, considering that many of its parts are commodities and made-to-stock, and we scored case [4] the highest, considering that its parts are engineered-to-order to reflect the latest technological advancements, and that they are being supplied by geographically dispersed companies.

Uncertainty here measures, for example, the unpredictable nature of approval processes (e.g., permitting) and workers' ability to ascertain where (work locations) work can be performed in the short term (e.g., influenced by weather or other unforeseen subsurface conditions). A score of 1 indicates the least amount of uncertainty, whereas a score of 5 indicates the highest amount of uncertainty. We scored case [1] the lowest, considering the more routine nature of the work involved, and we scored case [4] the highest, considering the potential impact of weather and sea conditions on the project.

Dynamic complexity (often tied to uncertainty) relates to the flexibility planners have—based on project characteristics—to break down work into smaller chunks, divide work space into zones, and rearrange process steps. A score of 1 indicates planners have a high degree of flexibility in work structuring, whereas a score of 5 indicates minimal to no such flexibility. We scored case [2] the lowest, considering that work zones (cruise cabins) are independent from one another, and process steps can be rearranged to some extent, and we scored case [3] the highest, considering the interconnectedness and density of parts in MEP systems, which impose limits on how work can be broken down and what zones can be defined.

Pace (or speed) complexity evaluates the difficulty of adjusting the number of resources in a project, considering factors such as cost, availability, and required worker skills or equipment capabilities. A score of 1 indicates that it is relatively easy to adjust the number of resources, whereas a score of 5 indicates that it is challenging to do so. We scored case [1] the lowest and case [4] the highest.

Socio-political complexity refers to the context and environment surrounding the project, characterized by the influence of the voices of stakeholders and power dynamics among them, that ultimately impact the project. A score of 1 indicates a weak impact, whereas a score of 5 indicates a strong influence of stakeholders on the project and strong stakeholder interactions. We scored case [2] the lowest and case [5] the highest.

Organizational complexity measures the experience, skills, behaviors, and knowledge levels required for performing work within organizations involved in the project team. A score of 1 implies that work is relatively straightforward, whereas a score of 5 indicates that work requires more experience, skills, behaviors, and knowledge, as well as specialized processes and tools or equipment as needed to perform more demanding work. We scored case [2] the lowest and case [3] the highest.

Of note is that our discussions that resulted in these scores were based on comparing specifics of individual projects, rather than only their project type. Being specific is important because numerous flavors of complexity can be discerned among projects, even among those of the same project type.

To visually capture the assigned scores and use the complexity framework, we drew a radar diagram (Figure 1). The aim is to provide planners with insights into the diverse complexity profiles of different projects, informing the selection of what may be the most appropriate takt planning method for their project.

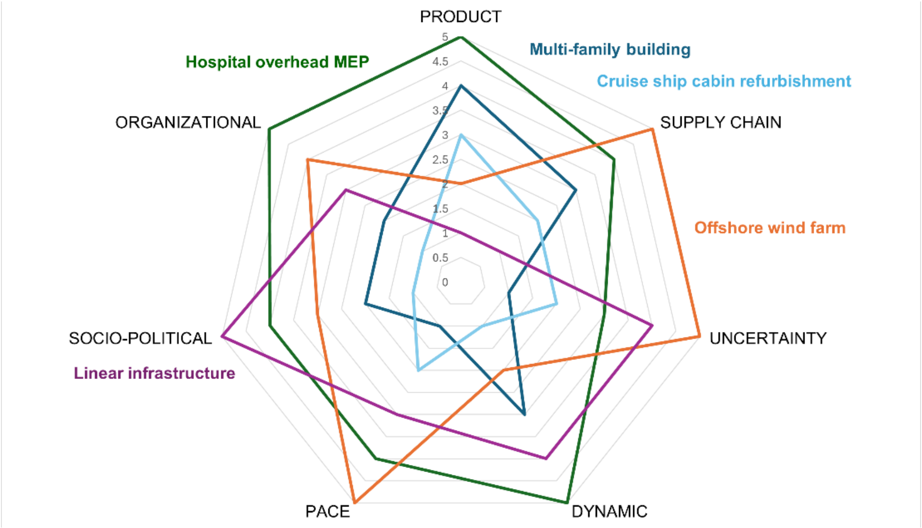

Figure 1: Radar Diagram Depicting Projects by their Dimensions of Complexity

TAKT PLANNING METHODS

The takt planning methods in use on projects around the world may be categorized as Methods A, B, C, and D. Method A is to define sequences of process steps and work zones a priori (i.e., before hiring trade specialists), typically based on some repetition in the physical product (e.g., rooms), and then use existing production data to compute the takt. An early promoter of a version of this method was Porsche Consulting (Gardarsson et al. 2019); Dlouhy et al. (2016, 2018) and Binninger et al. (2017) describe their own versions. This method of managing variability at the highest level of planning by creating a takt plan and then freezing it, while managing adaptations as needed at lower planning levels, applies to cases [1] and [2].

Method B is the Work Density Method (WDM) (Tommelein 2022). The method is to consider alternative work structures and develop work density maps showing how much time will be needed to perform certain scopes of work in different areas on site. It requires collaboration of the trades involved to decide on process steps, sequencing, and then zoning based on leveling of workloads (cumulative work density). This method applies to case [3].

Method C is to specify takt(s) and zones, but to defer deciding when to work in each zone until certain project uncertainties get resolved. This method is to define a hierarchy of locations, and exercise certain project control at each hierarchical level. It applies to case [5].

Method D stems from recognizing that certain resources have capacity constraints, i.e., they are bottleneck(s) in the system. The method therefore is to maximize the bottleneck’s utilization and pace other work based on that (as is done in the Theory of Constraints). The other work can then be structured with its own takt (perhaps using one of the other methods mentioned), informed by the required pace. This method applies to case [4].

Looking at cases [1] and [2] in Figure 1 we see patterns of complexity that appear to be similar and we note that both projects used some version of Method A. This is also the method that we (based on our considerable expertise in takt planning) would recommend using for these projects. Similar analyses were conducted for Methods B, C, and D.

DISCUSSION

Takt planning enforces clarity and simplicity by defining small chunks of work, clearly delineating what is to be done where, when, and by whom and what the expectations are for the handoff to the next trade. However, different methods achieve these objectives in different ways. Based on our scoring of five projects using seven dimensions of complexity and the four takt planning methods as described, we see alignment between a project's scores according to these dimensions of complexity and the takt planning method selected.

Our findings are highly speculative at this time. However, further research may indicate that the proposed characterization of project attributes, thought to be relevant to takt planning according to certain dimensions of complexity, may help choose which takt planning method to deploy for a particular project or phase of a project. It may also become clearer in which circumstances it is appropriate to use location-based planning and control, yet not takt planning in full, or when takt planning is not a suitable method at all.

CONCLUSIONS

Various takt planning methods can be identified in the Lean Construction literature. No single method appears to be universally applicable to all projects. Our premise was that deciding which method to use requires consideration of the complexity and context of the project to be planned with takt. This paper started by describing the objectives pursued in takt planning and it listed references to illustrate the use of takt to plan projects of various types. The section that followed shed light on different dimensions of project- and contextual complexity, and outlined various project characteristics that are relevant to takt planning.

The extension of Geraldi et al.'s (2011) complexity framework to the context of construction- and takt planning offered a practical approach to assess project complexity based on seven dimensions. The authors scored different projects based on their product- and supply chain complexity, uncertainty, dynamic complexity, pace complexity, socio-political complexity, and organizational complexity. The scores depicted in a radar diagram indicated differences between projects that helped to rationalize why one takt planning method or another might have been used on a certain project. This rationalization can inform planners when choosing a suitable takt planning method, considering the unique characteristics and challenges posed by each project. Follow-on research will describe each project in more detail regarding its dimensions of complexity and how the takt planning method was formulated, so that the matching of complexity with the appropriate takt planning method can be refined.

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