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FROM THEORY TO PRACTICE: APPLYING TIME SPAN OF DISCRETION IN LAST PLANNER SYSTEM® AND TAKT PRODUCTION TO NAVIGATE WORK COMPLEXITY

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ABSTRACT

Due to the introduction and adoption of new organizational structures and technology, the power dynamics within projects in the construction industry have shifted. This may lead to an increase in dissatisfaction and frustration among workers who are not willing to change because the emphasis is on organizational and technological change. In circumstances of change, the role extends beyond the employee's inherent comfort and proficiency, frequently resulting in discontent and unease. Prior studies indicate that if the task surpasses its inherent timespan, failure is probable; conversely, if it is shorter, the employee may experience inadequate challenges and dissatisfaction. In recent decades, the implementation of Lean Construction (LC) principles has frequently instigated such changes on construction sites. Although these production systems, such as Last Planner System® (LPS) and Takt Production (TP), are noted to enhance project performance and success, especially via collaborative and workload-balancing strategies, their implementation seldom resolves issues related to task complexity, workforce cognitive capacity, or the distinct timespan for tasks. This conceptual study explores the subject and examines, through Stratified Systems Theory (SST) theory, similarities between LC methods and the timespan of discretion (TSD) concept. Moreover, the research seeks to illustrate the importance of comprehending the potential of integrating TSD ideas with LPS and TP to enhance project outcomes. Furthermore, the study will focus on investigating how tailoring activities to align with workers' cognitive capacities and inherent timeframes may enhance situational awareness and satisfaction in construction projects.

KEYWORDS

Lean construction, time span, takt production, last planner system.

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INTRODUCTION

Construction projects are complex systems often thought to be merely governed by physics and engineering principles. However, they are driven by socio-technical dynamics on construction sites, which involves coordinating many individual actors and their needs, is a significant challenge. Managing project complexity at an individual´s task level, while considering each actor's unique skills, experience, and mental capacity, seems beyond the current capabilities of construction management practices. Collaboration among these actors further increases this complexity. As a result, individual behaviours and needs are often not fully understood, leading to one-size-fits-all approaches that result in ineffective management and decision-making (Görsch et al., 2020; Lehtovaara et al., 2020).

In the context of construction, the concept of the TSD highlights the need to successfully manage work complexity and projects based on understanding the relationship between workers' cognitive capacities, the time horizon of their tasks, and the complexity of their roles (Jaques 2006). When work falls outside a worker's TSD, their natural comfort zone, dissatisfaction, and discomfort arise. If a job exceeds this span, failure is likely; if it is shorter, the worker remains insufficiently challenged and unsatisfied. Matching tasks to each worker's TSD and translating between different spans for effective collaboration is a significant challenge in construction projects. Successful projects consist of workers with varying TSD, each operating within their natural comfort zone, ensuring that tasks are appropriately matched to their capabilities and time horizons.

LC production systems, such as LPS and TP, are repeatedly reported as contributors to improved project performance and success (Kovvuri et al. 2016; Xing et al. 2021). These systems emphasize collaborative planning, standardized work structures, and balanced workloads (Power et al. 2024), which align with TSD components such as coordinating task complexity, workers' capacities, and time spans. This alignment may not only enhance worker satisfaction and efficiency but also reduce workflow disturbances and errors. Despite the effectiveness of LPS and TP, there remains a critical gap in understanding how the TSD concept is reflected in these systems. Addressing this gap is essential, as it could uncover additional opportunities for optimization. By further exploring the integration of TSD within LPS and TP, potential enhancements can be identified to improve project outcomes further, such as increased adaptability, improved resource allocation, and more precise workflow management. This investigation is crucial for advancing the theoretical and practical applications of lean construction methodologies. Therefore, this paper adopts a conceptual approach to theory building by exploring the underlying connection between the TSD and the LC production systems, TP and LPS. Following the theory adaptation design described by Jaakkola (2020), this paper incorporates insights from human social and organizational science, including the TSD concept

The paper aims to examine how TP and LPS can be understood through the lens of TSD, by exploring the similarities between both methodologies and the concept. Managing project complexity at an individual´s task level, while considering each actor's unique skills, experience, and mental capacity, seems beyond the current capabilities of construction management practices. Ultimately, it discusses how LPS and TP can enhance workers situational awareness and satisfaction by further incorporating insights from the TSD concept.The aim is pursued by answering the following research question: What are similarities between the TSD and the LPS and TP system? Finally, the paper discusses how to open avenues for future research by suggesting further research questions.

THEORETICAL BACKGROUND

STRATIFIED SYSTEMS THEORY

Jaques (2006) proposed in his research that a correlation exists between the general management layer that underpins the management hierarchy and the intricacy of psychological processes. His observation indicates that the hierarchy of a management organization mirrors the varying levels of individuals' capabilities; specifically, distinct levels of competence and decision-making skills are necessary for different tasks, as evidenced by the organizational structure. This is illustrated in Figure 1, which is known as *stratified systems theory* (SST).

Table 1: Stratified system theory (Jaques 2006)

Individual Maturation Bands	Levels of Task Complexity	Organizational Strata	Time Horizon
Mode I	Overcome Obstacles, Practical Judgement	Shop & Office Floor (frontline worker)	1 day – 3 months
Mode II	Diagnostic Accumulation	First Line Manager (supervising mode I)	3 months – 1 year
Mode III	Create Alternative Pathways	Unit Manager (continuous improvement)	1 - 2 years
Mode IV	Parallel Process, Multiple Pathways	General Manager (executive, radical change)	2 - 5 years
Mode V	Judge Downstream Consequences	Business Unit President	5 - 10 years
Mode VI	Oversee Complex Systems	EVP	10 - 20 years
Mode VII	Construct Complex Systems	CEO, COO	20 - 50 years

In the construction sector, this may imply that in strategic management roles, such as CEO or managing director, the duration could range from 7 to 15 years and include, for instance, new market expansion or the formulation and execution of a new business model. For a project manager or construction manager, it may be 3-7 years, encompassing the design and execution of a significant infrastructure project from start to completion, such as a road project or port terminal. For a design manager or technical director, the time span is typically 1 to 5 years, shown by the comprehensive design of a new residential development and its associated infrastructure. A site manager generally oversees multiple construction sites for a duration of 1-3 years, whereas a site supervisor is responsible for a single building site for 6-18 months, encompassing all stages from foundations to final inspection. For professionals, including HVAC and electrical managers, the project duration generally ranges from 3 to 12 months, encompassing the design, implementation, and commissioning of systems. The employment period for workers and installers often spans from 1 to 6 months, encompassing tasks such as the construction of wall structures or the installation of piping systems in accordance with contractual specifications. Jaques' (2006) SST theory sums this up: The longer the time span of a role, the more complex is the work, the heavier are the felt uncertainty and the felt weight of responsibility of that work.

LEAN CONSTRUCTION METHODS NAVIGATING WORK COMPLEXITY

LC production systems, such as the Last Planner System® (LPS) and takt production (TP), enhance project performance by aligning task complexity, workers' capacities, and time spans, which improves worker satisfaction and reduces errors (Kovvuri et al. 2016; Xing et al. 2021; Power et al. 2024). Understanding how the TSD concept integrates into LPS and TP is crucial for optimizing project outcomes.

LPS is a widely studied approach in LC that offers effective strategies for navigating the complexities of construction work (Ballard and Tommelein, 2021). The approach involves planning and controlling tasks by converging task spans as the work progresses, fostering close collaboration with the workforce, identifying and eliminating obstacles, making dependable commitments by adhering to agreements, ensuring seamless handoffs, and continuously improving by learning from encountered issues. (Ballard et al. 2009). LPS emphasizes tight collaboration and communication among all stakeholders, including those who execute the work. This collaboration helps in understanding the complexity of each worker's role and ensures that tasks are assigned based on their capabilities and expertise. By involving workers in the planning process, LPS ensures that their roles are clearly defined and that they have a say in how tasks are executed. This collaborative approach allows workers to understand tasks in their own way, based on their mental models and cognitive capacities. Furthermore, the LPS aligns tasks with workers' cognitive capacities by breaking down complex tasks into manageable chunks. This is achieved through lookahead planning and weekly planning, which ensure that tasks are prepared, and constraints are removed before they are assigned to workers. By doing so, LPS reduces cognitive overload and allows workers to focus on their tasks without being overwhelmed by uncertainty and complexity.

Additionally, LPS uses a hierarchical planning approach that includes master planning, phase planning, lookahead planning, and weekly planning (Ballard, 2000). This approach ensures that tasks are planned and executed within the appropriate time horizons. Lookahead planning, for example, connects master and phase planning with weekly planning, breaking down long-term objectives into production-ready tasks within a time horizon of two to six weeks (Hamzeh et al. 2008). This method ensures that tasks are prepared, and constraints are removed well in advance, allowing for smooth execution. In summary, the LPS effectively addresses the time span of discretion concept by aligning tasks with workers' cognitive capacities, defining the complexity of their roles, and planning tasks within appropriate time horizons. This approach ensures that work is executed smoothly, with reliable handoffs and continuous improvement through learning from problems.

Another LC production planning and control method is TP, built on top of the location-based management principles (Kenley & Seppänen, 2010) for planning, controlling, and continuously improving construction production systems (Lehtovaara et al. 2021). It has gained significant attention in recent years for its focus on maintaining a consistent production beat and continuously improving the system as issues arise (e.g., Frandson et al. 2013). Studies have shown that TP can decrease production durations (Binninger et al. 2018), increase transparency and stability (Frandson et al. 2014), and promote proactive problem-solving (Linnik et al. 2013). TP simplifies the complexity of workers' roles through standardized tasks and predictable workflows, which also reduces cognitive load and allows workers to develop expertise, leading to increased efficiency and fewer errors (Lehtovaara et al. 2020). Furthermore, TP aligns tasks with workers' cognitive capacities by providing clear, structured workflows and emphasizing continuous improvement and learning, which can enhance productivity and job satisfaction and reduces stress (Frandson et al. 2014). Additionally, TP carefully plans the time span of tasks to match the takt time, ensuring tasks are completed within a predictable timeframe, reducing uncertainty and enabling better planning and resource allocation (Tommelein and Lerche, 2023).

These LPS and TP aspects not only enhance productivity and efficiency but also contribute to a more stable and transparent production environment. While LPS and TP have demonstrated improvements in productivity and project success, on-site construction remains inherently complex. Because construction tasks are complicated and workers have different time horizons and cognitive capacities, task coordination is still difficult. Understanding and addressing these challenges is crucial for optimizing project outcomes further. The following discussion explores how TP and LPS can be understood in more detail through the lens of TSD, by exploring the similarities between both methodologies and the concept.

METHOD

This study adopts a conceptual approach, which does not include empirical data (Malvik, 2022). However, it provides an analysis of chosen theories and concepts. Conceptual papers aim to bridge existing theories, connect work across disciplines, provide multi-level insights, and broaden the scope of thinking (Gilson & Goldberg, 2015). This approach is particularly effective for developing theories without relying on empirical data (Cropanzano, 2009). Jaakkola (2020) identifies four types of research designs for conceptual papers: theory synthesis, theory adaptation, typology, and model development. This study employs the theory adaptation approach, which involves expanding the scope or perspective of an existing theory by integrating insights from other theories or viewpoints to enhance its applicability to new contexts. Specifically, this paper focuses on understanding and further developing Lean Construction by incorporating literature on TSD. The aim is to explore how TP and LPS can be understood through the lens of TSD, by exploring the similarities between them. .

A literature review was conducted by searching books, journals, and conference papers available through university libraries and online search engines. The primary source for understanding TSD has been the book Requisite Organization: A Total System for Effective Managerial Organization and Managerial Leadership for the 21st Century by Jaques (2006). Regarding Lean Construction literature, the conference proceedings archive for the Annual Conference of the International Group for Lean Construction (IGLC) has been particularly useful.

FINDINGS

The following discussion explains how TP and LPS components can be understood through the lens of TSD, by exploring the similarities between both methodologies and the concept. Thus, the chapter follows three factors which TSD consider needed for effective organizational structures and processes: task complexity, workers' capacities, and time spans. Despite the separation of these factors in TPS, they cannot always be understood in separation in the context of LPS and TP, due to their interconnectedness within certain LPS and TP components.

COORDINATING TASK COMPLEXITY

One of the distinct features in LPS is to provide a converging structure (Ballard et al. 2009) that describes different time horizons in which teams and individuals are involved in planning and controlling production to reduce process variability and complexity. Thus, LPS inherently aligns with the idea of reducing task complexity based on adequate time spans for different roles. The various periods are a critical element in the realm of continuous development, integral to both LPS and TP systems. LPS incorporates a weekly framework for recording deviations from the plan, wherein deviations are analysed and understood using root cause analysis. Similar methods can be customized to the organizational structure, aided by TP. SST theory highlights the importance of ongoing improvement, which involves learning from deviations and takes longer than quick problem-solving. Both management and workers tend to prioritise immediate issues over long-term project improvements. As a result, longer-term issues may remain unresolved, leading to neglecting learning and opting for solutions that address task complexity's root causes.

Usually used TP times are well within mode I or, at most, mode II (see Table 1). However, the takt time directly impacts the nature of the low end of time spans, because takt times set the pace for the control cycles. Longer takt times are usually associated with higher variability and uncertainty, greater decentralized decision making and more autonomous work crews. Shorter takt times, on the other hand, are associated with situations of lower variability, since greater effort is put into planning and preparation. A hypothesis could be the shorter the takt time, the more complexity is handled by production planning, which should lead to less variability in task performance and shorter time spans of production control. Conversely, the longer the takt time, the less complexity is handled upfront in production planning, leading to more variability and greater efforts needed in the production control (longer time spans). TP´s success builds on the premise that establishing a consistent rhythm for executing tasks across various trades and time spans ensures stakeholders' alignment, fostering cohesion and synchronized thinking in a silo-driven industry. TP has shown to be contribute to lower shares of non-value-adding activities and disturbances in the trade flow, enhancing overall efficiency (Görsch et al. 2024), and potentially reducing workers´ cognitive load and improve work satisfaction. However, effectively matching tasks to each worker's TSD and translating between different spans for collaboration remains a significant challenge in construction projects. Evidence of correlations between shorter takt times and its benefits for reduced complexity, decreased cognitive loads and improved work satisfaction have not been presented in literature. Another emerging aspect of creating a consistent rhythm for all trades, is if TP can provide adequate time spans for different roles and tasks or if this means crews and workers may work out of their comfort zone to align with the takt time.

COORDINATING WORKERS' CAPACITIES

The length of the time span (or takt time) also affects the cognitive load of all roles. Although short takt time allows the detection of issues and steer production in much higher granularity, it also requires – especially from the roles that operate with wagon and handoff-specific tasks – an increased capacity or experience to handle tasks and problems in shorter intervals, with shorter reaction times. This might result in higher levels of experienced stressed and exhaustion, potentially impacting task performance. Here, the production system should find adequate support structures by implementing capacity buffers or slack as needed (Formoso et al. 2021). Currently, many smart wearable devices can track, analyse and provide insights of physical fatigue and stress levels. However, to provide more holistic real-time guidance and contributing to reducing mental strain and consistent task performance they also need to consider mental capacities such as skills and experience (Eltahan et al., 2024). Additionally, another path towards reduced cognitive loads and mental strain can be access to real-time and all-time relevant as well as easy to understand information through visual management Koskela et al. (2018) approaches based on smart and digital technologies used to provide a digital situation picture Seppänen (2022).These approaches are designed to manage cognitive load and stress, ensuring that workers can operate within their cognitive capacities and time spans.

Nevertheless, these concepts raise questions regarding how to achieve real-time tracking aligned with GDPR regulations while providing relevant insights for task performance. There is also a need for approaches and technologies that can deliver information not only in real-time but also in contextually relevant ways, customized to the physical and mental conditions of individuals.

COORDINATING TIME SPANS

LPS and TP have very similar organisational structures (Frandson et al. 2014; Pancholi & Devkar, 2023). At the highest level, both systems rely on a CEO or management team, who decides how to use them as part of the company's production system. Construction managers or site managers, depending on the structure of the company, supervise the use of the systems. In both systems, foremen are responsible for workflow and problem anticipation. The role of site supervisors is to keep several tasks running simultaneously. In both systems, workers and foremen, lower down the hierarchy, create alternative routes to adapt to changing conditions. Foremen collect diagnostic data to help refine and adapt plans based on real-time conditions. A key operational difference is that in LPS, the "last planner"—who may occupy various roles—is tasked with addressing challenges and making practical decisions. Within TP, this responsibility is assigned to frontline workers and team leaders. As the takt time reduces, there is a greater need for front-line workers to communicate issues effectively due to the dynamic and brief operation cycles on site. This helps to address these issues in higher-level planning and coordination both in advance and continuously during task performance. Thus, TP provides distinct structures on the construction crew and worker level that advocate the boundaries between different tasks and time spans. TP (as location-based systems in general) support tangible and visual understanding of when and where workers´ tasks should be carried out, enabling clarity in daily goal setting and flow of work (Tommelein et al. 2022).

TP distinguishes explicitly two perspectives of production flow: (1) the trade flow and (2) the location flow (Sacks, 2016). These perspectives view time spans slightly differently. Workers and foremen are concerned with the trade flow; they try to make sure that their scope of work can progress through the sequence of upcoming takt areas. While the workers align with mode I, that is, immediate work at hand, the trade foremen should make work ready for the subsequent areas—that is, be concerned with mode II. The time span of the trade foremen therefore spans across several areas. In contrast to the trades, the general contractor's foremen should be concerned with the location flow in addition to the trade flows; they try to make sure work is made ready for each subsequent trade in each takt area. The time span of the trade foremen also aligns with mode II but covers the succession of trades in each area in addition to the trades progressing through the sequence of areas. Due to this difference in the production flow perspective, arguably the complexity related to the time spans of the trade and GC foremen are also different.

In detail, TP helps to distinguish between three boundaries of wagon-specific, handoff-specific, and train-specific tasks that have distinct time spans (Lehtovaara et al. 2022a) and makes stakeholders aware of them. Takt wagon-specific tasks, including construction activities such as painting and pipe installation, are executed in takt wagons and represent a significant portion of everyday operations in takt areas. The primary responsibilities are assumed by frontline workers and team leaders, with the duration of these tasks corresponding to the takt time, for example, typically ranging from 4 hours to 5 days (Riekki et al., 2023). Takt train-specific tasks, which encompass production-wide activities impacting several takt wagons, including logistics systems management and planning, are executed at an elevated level and are essential for undertaking larger-scale operations. The primary roles here are site and project (or equivalent, such as design) managers. Such roles necessitate an extended decision-making process and are typically executed infrequently, resulting in a prolonged duration, spanning from weeks to months. The transfer of takt wagon and takt train responsibilities, encompassing post-construction and pre-construction activities such as cleaning and quality control, occurs between or at the conclusion of the takt wagons, establishing a foundation for subsequent duties and quality assurance. The principal roles are fulfilled not just by frontline workers and team leaders, but also by site managers. Delegations often require team collaboration and joint problem-solving to ensure all stakeholders have situational understanding, due to translating between different time horizons. The timing corresponds to that of takt wagon-specific assignments and aligns with the established takt time.

DISCUSSION AND CONCLUSIONS

The Time Span of Discretion (TSD) concept is grounded in empirical research, notably within the organizational and social sciences, and has been implemented across various industries

(Jaques, 2006). Despite its effectiveness, TSD has not been extensively utilized within the construction sector. To integrate TSD insights into construction and on-site operations successfully, further adaptations and studies are required. *Future research should revisit Jaques' findings in the context of the construction industry, aiming to develop a more concise approach that aligns with current technological advancements, societal changes, and prevailing practices.*

The implementation of SST in construction presents a potential interaction between the LPS and the TP system. SST relies on hierarchical frameworks and suggests that well-defined roles and decision-making procedures are essential for organizational effectiveness. LPS and TP systems aim to move away from traditional hierarchical top-down models, focusing on decentralized decision-making, collaboration, and flexibility among teams (Lehtovaara et al. 2022b) through leveraging smart and digital technologies (Gonzalez et al. 2024). On the one side, the incorporation of SST principles into LPS and TP systems may prompt discussions regarding the feasibility of flexible and decentralized production systems, as SST is based on an ideology that recognizes a natural hierarchy within human-based organizations. Conversely, smart and digital technologies may challenge whether the "natural hierarchy" is crucial for organizational effectiveness or if it can be bypassed. *Future research should examine what role smart and digital technologies can play in strengthening planning and control systems in construction by balancing hierarchical and decentralized approaches.*

Additionally, construction projects possess intrinsic uncertainty, and flexible methodologies like LPS and TP systems capitalize on this characteristic. SST presents a contradiction in that it presupposes a stable and predictable environment, amenable to precise organization and planning, which is never achievable in actual construction. The intricacy of construction arises from reasons such as unique projects, site-specific production, and varying organizational systems from one project to another. These characteristics induce variability and lack of transparency, as well documented in the construction management literature, including Koskela (2000). While SST offers a systematic framework for decision-making, its inflexibility may result in sub-optimization (Koskela et al., 2019), foster excessive bureaucracy, and diminish the agility that LPS and TP seek to enhance. *Consequently, how can smart and digital technologies bypass hierarchical and static practices and improve dynamic and autonomous decision making at operational levels, without violating* GDPR regulations.

Notwithstanding these potential concerns, SST may still provide value in enhancing decision-making frameworks inside LPS and takt organizations. It aids in visualizing decision-making timelines and defining roles, facilitating proper allocation of duties and enhancing operational efficiency. SST could also enhance TP by offering more defined role specifications and ensuring effective information processing within a synchronized workflow. Furthermore, SST can mitigate overlapping duties, thus enhancing the clarity of roles in LPS and TP. This systematic method may enhance organization in intricate projects, particularly by synchronizing decision-making authority across various levels of the organization. *Future research considering SST could focus more on individual needs and demonstrate the dynamics at operational levels.* These aspects are currently not extensively studied in construction (Görsch, 2024; Liinasuo et al., 2023).

TP's success seems to stem from aligned time horizons across trades and tasks, whereas TSD notes that each task has its own time frame and comfort level. Both perspectives examine the possibility of decentralizing time horizons for trades and workers, while maintaining a consistent rhythm as in takt. Additionally, *they can lead to question whether ideal takt times per trade and task exist for effective decision-making and resource efficiency*. Optimal intervals may depend on project, trade and task complexity as well as dynamic site conditions and workers cognitive capacities. The duration of the takt timeframe in TP affects role allocation and cognitive demands. A one-week takt time can be inefficient, while 15-30 minutes is too short and overwhelming (Binninger et al. 2018). According to the literature, shorter takt times result in increased demands on management and workers, as well as greater efforts required for planning and controlling production (Riekki et al., 2023). *In this context future research should investigate these dynamics further and examine if matching takt times and workers cognitive capacities can improve production from the location and trade flow*.

This paper examined the relationship between TP and LPS through TSD. By exploring their similarities, it highlighted how integrating TSD can enhance project outcomes in construction. Applying TSD principles within TP and LPS helps manage work complexity, align tasks with workers' cognitive capacities, and improve situational awareness and satisfaction. This approach addresses socio-technical dynamics in construction, identifying barriers and potential solutions to enhance construction management practices. However, TSD's application in construction often lacks explicit recognition, necessitating further research on its practical implications. Future studies should further explore integrating TSD principles with LC methodologies as well as to drive innovation and improve project performance.

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