Fireman, M.C.T., Binninger, M. (2025). Takt Planning: A reinterpretation of adjustment mechanisms from the perspective of slack. In O. Seppänen, L. Koskela, & K. Murata (Eds.), *Proceedings of the 33rd Annual Conference of the International Group for Lean Construction* (IGLC33) (pp. 330–340). https://doi.org/10.24928/2025/0234

TAKT PLANNING: A REINTERPRETATION OF ADJUSTMENT MECHANISMS FROM THE PERSPECTIVE OF SLACK

Marcus C. T. Fireman[1], Marco Binninger[2]

ABSTRACT

This paper offers a reinterpretation of takt planning through the lens of the slack concept, focusing on how adjustment mechanisms can address variability in construction projects. By analyzing 30 adjustment mechanisms identified in previous studies, the research evaluates how different types of slack (redundancy, flexibility, etc.) contribute to project stability. The study reveals that there is an intricate relationship between adjustment mechanisms in takt planning and the slack strategies, demonstrating that while takt planning is often criticized for its rigidity, it inherently integrates various forms of flexibility through slack strategies. The paper also highlights that there is a gap in addressing operational slack at the execution level, suggesting the need for deeper integration of micro-adjustments and day-to-day practices into formal takt planning frameworks.

KEYWORDS

Takt Planning, Slack, Flexibility, Complexity, Buffer.

INTRODUCTION

Research on Takt Planning as a production planning and control method in construction has grown significantly in recent years. This growth is driven by the benefits of the approach, including reduced non-value-adding activities, increased productivity, and shorter project lead times (Frandson et al., 2014; Haghsheno et al., 2016; Vatne & Drevland, 2016; Binninger et al., 2017a; Dlouhy et al., 2018; Dlouhy et al., 2019; Power et al., 2023). There are many approaches related, as Takt Planning and Takt Control (TPTC) (Binninger et al., 2018), Takt Time Planning (TTP) (Frandson et al. 2013), 4-Hour Takt Time (Riekki et al., 2023). The present paper uses the term Takt Planning to refer to all approach based on the concept of Takt.

Takt is a core concept in the Toyota Production System (TPS), where the term "Takt" (derived from the German word for "beat") defines the rhythm and pace of production (Haghsheno et al., 2016). This rhythmic approach ensures synchronised production processes, improving predictability and efficiency (Frandson et al., 2013).

In construction, Takt Planning establishes a defined rhythm by organizing work packages within consistent time frames, known as "Takt times." These time frames vary based on project scope and complexity, ranging from a few hours to several weeks (Tommelein et al., 2024). The visualization of the production system in Takt Planning is often compared to a train, where the "wagon" (teams responsible for groups of activities) moves through the work zones (Takt Area) of the project (Gardarsson et al., 2019). According to Tommelein et al. (2024), Takt can

1 Founding Partner at Climb Consulting Group and PhD Candidate at NORIE/UFRGS, Porto Alegre, RS, Brazil, marcus@climbgroup.com.br, orcid.org/0000-0001-5843-4715

2 Head of Lean Management at weisenburger bau GmbH, Germany, m.binninger@weisenburger.de, orcid.org/0009-0006-3274-2481

be applied to a specific phase of a project or to the entire project, as well as manufacturing, where there may be different Takt times on various production lines.

Despite the benefits and advantages of Takt adoption, there are some criticisms of the method, positioning it as rigid, or in other words, a "tightly coupled" system where a delay in one "wagons" can lead to cascading delays throughout the system (Dahlberg & Drevland, 2021). The criticism in literature highlights that Takt Planning eliminates time buffers between wagons and look to the reduction of batch sizes, making the system more vulnerable to delays (Alhava et al., 2019; Dahlberg & Drevland, 2021; Andreassen & Drevland, 2023). Although the perceived rigidity of Takt Planning may be linked to the maturity level of companies adopting the methodology, criticism suggests an implicit gap in understanding how a system can protect itself from variability. This is because only buffers are typically considered when evaluating the method's flexibility or rigidity.

Tommelein et al. (2024) suggest that the concept of slack can be an asset for Takt Planning, as it is widely used in complex socio-technical systems to manage variability from different sources. According to Bourgeois (1981), slack is a cushion of resources, either available or potential, that a system can use to mitigate the effects of variability. Recent studies argue that slack is a broader concept than the term buffer, encompassing redundancy and flexibility (Formoso et al., 2021; Fireman et al. 2022; Saurin et al., 2021). Moreover, slack can be either designed or opportunistic: in the former, the system's resilience is demonstrated through pre-conceived planning, while in the latter, operational resilience is shown through production teams' ability to adapt and apply resources opportunistically (Saurin & Werle, 2017).

Research on slack in construction is still emerging, with no explicit practical studies examining its integration with Takt Planning. The closest study, by Binninger et al. (2017b), emphasized the important role of adjustment mechanisms, often used in a planned or ad hoc manner during the Takt Planning implementation to address disruptions. These mechanisms were evaluated in over 40 projects and introduced a more flexible nature to Takt Planning, though within certain limits (Binninger et al., 2019). Some of these mechanisms, such as 'jumpers' - multi-skilled workers who can be redeployed to adjust task performance during demand peaks or mitigate flow interruptions – implicitly serve as examples of slack strategies.

This study aims to contribute to Takt Planning research by providing a theoretical analysis of how Takt Planning deal with variability from different sources. To this purpose, a reinterpretation through the lens of the slack concept is proposed to the adjustment mechanisms presented by Binninger et al. (2017b). By exploring these practices, we aim to explore how slack contributes to Takt Planning, offering new insights into managing variability and project stability in construction.

LITERATURE REVIEW

THE FLEXIBILITY INCLUDED IN TAKT PLANNING

The method Takt Planning is often criticized for being a rigid, fixed-schedule method with little to no flexibility. Work packages are meticulously planned to minimize buffers between activities, resulting in a tightly coupled system with less room to prevent delays (Dahlberg & Drevland, 2021). Indeed, the core objective of Takt Planning is to create a consistent and stable workflow through repetitive scheduling.

However, while the overarching framework appears rigid, it does not enforce rigidity on every aspect of project execution, flexibility exists at the micro-level. The method offers flexibility within the work packages ("coloured boxes"), between task handovers, and through the strategic use of buffers. This structured flexibility allows Takt Planning to adapt to the dynamic realities of construction projects while maintaining the overarching goal of achieving stable, continuous flow (Frandson et al., 2015). Lehtovaara et al. (2021) pointed out that flexibility is achieved although the takt planning parameters: flexible locations (takt areas); flexible sequence - work packages which contain several activities without interference between them (takt wagons); and the flexible time, the time in which the work package should be done at a location (takt time)

Effective buffer and variability management is integral to the success of Takt Planning (Tommelein, 2020). Although the takt schedule aims to minimize buffers, the reality of construction necessitates some degree of flexibility. Buffers are strategically embedded within individual work packages and detailed subprocesses. The goal is not to eliminate buffers entirely but to manage them transparently and effectively, enabling teams to identify, manage, and resolve issues proactively without jeopardizing the entire schedule. For example, each work package is rarely filled to 100% capacity, as this would be unrealistic given human and process variability (Frandson, 2019; Haghsheno et al., 2016; Binninger et al., 2016). Beyond capacity, there are other three main types of buffers applied in takt planning (Frandson et al., 2015): space; workable backlog and time.

Another way that flexibility can arise is related to the adjustment mechanism present in the control dimension of takt planning (Tommelein et al., 2024). The adjustment mechanism was first presented by Binninger et al. (2017b), and represent practices developed by planners and managers to absorb disruptions or changes in the framework conditions (Binninger et al. 2017b; Tommelein & Lerche, 2023; Dahlberg & Drevland, 2021). These practices offer the flexibility to react to problems that were surfaced during production (Riekki et al., 2023) and represents the system´s resilience (Tommelein et al., 2024). According to Binninger et al. (2017a; 2019) the adoption of the adjustment mechanisms can generate different effects on the system, so it is necessary to understanding the relationships between various factors before select the appropriate strategy to response (Table 1). The numbers preceding each mechanism correspond to the ID numbers in Table 1, indicating their relative frequency of use (with 1 being the most common mechanism).

Table 1- The adjustment Mechanism of Binninger et al.(2017b)

Id	Adjustment Mechanism	Description	Effect
1	Decoupling of Takt Areas	Reorganizing the sequence for completing Takt Areas	Change in the order completed
2	Empty Wagon	Planning of buffer times (slack); for example drying-out periods	Visualization of the required buffer; lengthening of the construction time
3	Phase Interlinking	Different process phases require different sizes of Takt areas	Optimization of the construction process
4	Soft Start	Delaying following trains, if more than one train is used. This allows learning from the starting train	Lengthening of the construction time, stabilization of site processes
5	Train Stoppage	Stopping the construction process due to a problem	Longer duration of construction
6	Combining handover times	Arranging the handover by combining takt areas to larger areas	Bundling of takt areas for handover
7	Coupling into and onto	Adding or removing wagons to change the process sequence	Lengthening of the construction time
8	Jumpers	Using flexible labour to deal with peaks in required work	Harmonization of the process

9	Split of train orders	Splitting the construction sequence, because conditions demand for extended process durations	Lengthening of the construction time
10	Takt time reduction	Reducing the takt time	Harmonization of the process sequence; shortening of the throughput time
11	Takt time increase	Extending the Takt time	Harmonization of the process sequence; lengthening of the throughput time
12	Trains split	Paralleling multiple trains with similar sequences to pass the construction site	Shortening of the construction time
13	Wagon acceleration	Ensuring a stable Takt time by optimizing a wagon in detail	Harmonization of the process sequence (Levelling); shortening of construction time
14	Wagon overlapping	Following wagons start before the preceding wagon is completed	Optimization of the process sequence
15	Wagon parallelization	Completing wagons in parallel	Optimization of the process sequence
16	Hard start	Starting multiple wagons at the same time	Shortening of the construction time
17	Inserting fixed buffers	Planning slack at the end of a sequence/train	Slack is built in to stabilize the construction process
18	KIT Move	Combining multiple work packages to use the full takt time in a wagon	Harmonization of the process sequence; shortening of the construction time
19	Shunting yard	Utilizing available process sequences	Changing construction site process
20	Splitting Takt areas	Reducing the size of Takt areas	Harmonization of the process sequence
21	Takt area enlargement	Increasing the size of Takt areas	Harmonization of the process sequence; lengthening of the throughput time
22	Wagon subcontracting	Completing individual wagons with subcontractors	Stabilisation of construction site processes
23	Multiple train levelling	Using multiple trains to increase efficiency within workers and trades	Stabilization and optimization of the construction process
24	Train station	Re-planning the process sequence	Changing construction site processes
25	Use of fixed buffers	Making use of buffers (slack) at the end of a sequence/train	Slack is used-up, the construction process is stabilized

26	Work package acceleration	Targeting optimization of work packages within a wagon	Optimization of the process sequence at the micro level
27	Work package shift	Reallocation of a work package to another wagon;	Optimization of the process sequence
28	Wagon switch	Swapping the position of at least two wagons in the process sequence	Optimization of the process sequence
29	Division of materials/logistics	Decoupling of value creating and logistical tasks	Focus on the value chain
30	Wagon shift	Moving a wagon to a different position in the process sequence	Optimisation of the process sequence
31	Work package switch	Swapping work packages between wagons	Optimisation of the process sequence

THE SLACK CONCEPT

Safayene & Purdy (1991) pointed out slack as a mechanism able to reduce interdependences and minimizing the possibility of one process affecting another. Slack is a reserve of resources that exceed or not the minimal necessary and that can be reallocated to support organizations to support organizations to deal with disruption in the face of expected or unexpected events (Fireman et al, 2022; Saurin, 2017). The term is not limited to any specific type of resource, for example perspectives to solve a problem, redundant equipment's, degrees of freedom in standard operating procedures (Saurin & Werle, 2017) or even prearranged contractual agreement with subcontractor (Fireman et al., 2022).

According to Fireman et al. (2022), buffer is always slack, but slack is not always a buffer. Differently of buffer, slack is viewed in two main dimensions: (i) resources, which type of resources will be applied as slack; (ii) strategies, how the resources will be applied. In the buffer literature, these two dimensions is not clear, and the term buffer is used in an interchangeable form to reference both. For example, Ingvaldsen & Benders (2016) discuss the role of supervisors in lean production, they defend that the supervisory hierarchy is a flexible buffer of manpower since the supervisors can perform direct work on the line when workers are absent or more manpower are needed. Righi & Saurin (2015) highlights other difference between the concepts, the authors realize that, differently of buffer, slack is not necessarily designed. There are spare of resources whose quantity, place of storage or use and nature are decided by group and supported by managers based on historical data (designed slack), on the other hand there are opportunistic slack, which refers to isolated and informal initiatives by staff who in time of need adapt resources into slack (Saurin & Werle, 2017).

The literature of slack presents four types of strategies (Formoso et al, 2021; Saurin et al., 2021):

- Redundancy- the resource is provided above the minimum amount necessary (Nonaka, 1990) or when more than one resource performs the same function (Azadeh et al., 2016). Some examples of this category are: (i) spare of capacity; (ii) time buffer; (iii) stock of material; (iv) double check or other type of redundant procedures. An example of the double check is present into look-ahead routines of last planner, since redundant checks can be made to ensure that any constrains will be removed before the start of activity (Fireman et al., 2022);
- Work in progress- It is a specific type of redundancy, and reflects the number of simultaneous work zones in a construction site (Fireman et al., 2022);
- Flexibility- the use of resources in diverse and adaptable way (Formoso et al., 2021), as for example (Pereira & Fireman, 2022): (i) multiple sourcing; (ii) flexible contracts; (iii)

multi-modal logistic; (iv) postponement; (v) multiskilled worker or multi-purpose machine; (vi) alternative sequence of production routes; (vii) flexible layout, and (viii) operational or process flexibility.

- Margins of manoeuvre- creation or maintenance of margins and additional resource that allow the system to deal with variability (Saurin & Werle, 2017). It could be defensive, which restrict actions of a unit or borrow margins from another unit; autonomous, that consider local reorganization or adaptation of resources; coordinated, creation of features that can be shared two or more units. For example, a strategy to release capacity in projects where the crane dictates the pace of work is to try to remove steps that require the use of crane to alleviate its workload (Tommelein & Lerche, 2023).

METHOD OF INVESTIGATION

The research is based on an extensive literature review on Takt and Slack. This paper adopts as a research method a thematic analysis, which is a type of qualitative analysis used to examine classifications and identify themes or patterns in the data (Alhojailan, 2012). In this research, the author did a critical reinterpretation of the adjustment mechanism in Takt Planning described by Binninger et al. (2017b). This approach offers a more comprehensive understanding of how slack is applied within the context of Takt Planning.

The relationship between adjustment mechanisms and slack was analyzed by the authors, who then classified the mechanisms according to the type of slack strategy (e.g., redundancy, flexibility) and the type of resource used (e.g., material, information, time, space, equipment). The analysis unfolded in two main steps. First, each author independently conducted a categorization. Because the two authors have substantial expertise in both slack and takt, a second step involved an online workshop session. During this session, each author addressed their particular area of expertise, leading to a substantive discourse on the categorization process.

In this classification scheme (Table 2), green denotes an adjustment mechanism that is directly related to a slack strategy, whereas blue indicates mechanisms that depend on the prior presence of slack resources. All other mechanisms are categorized as having no relation (orange color).

The discussion session provided insights into how slack relates to takt planning, while also highlighting the limitations of takt planning in fully integrating the slack concept.

RESULTS

The analysis of the relationship between slack and the adjustment mechanisms revealed that only 7 out of the list of 31 adjustment mechanism identified by Binninger et al. (2017b) could be classified as slack strategies, representing 22,5% of the sample. Additionally, 13 adjustment mechanisms (42,5%) were found to depend on the prior presence of slack within the system. Therefore, the analysis showed that nearly 65% of the adjustment mechanisms have some degree of connection to slack. These relationships have been found to be positive, offering benefits for Takt Planning, and providing new perspectives and possibilities for the use of Takt.

Table 2- Relation between Adjustment Mechanism and Slack (from the authors)

No Relation with Slack	Adjustment Mechanism depends of the prior presence of slack	Adjustment Mechanism is a Slack Strategy
04. Soft Start	01. Decoupling of Takt Areas	02. Empty Wagon
06. Combining handover times	03. Phase Interlinking	07. Coupling into and onto
05. Train Stoppage	14. Wagon overlapping	08. Jumpers
10. Takt time reduction	15. Wagon parallelization	09. Split of train orders
11. Takt time Increase	18. Kit Move	17. Inserting fixed buffers
12. Trains split	19. Shunting yard	25. Use of fixed buffers
13. Wagon acceleration	20. Splitting Takt areas	29. Division of material/logistics
16. Hard start	21. Takt area enlargement	
23. Multiple train leveling	22. Wagon subcontrating	
24. Train station	27. Work Package shift	
26. Work Package acceleration	28. Wagon switch	
	30. Wagon shift	
	31. Work Package switch	

ADJUSTMENT MECHANISM AS A SLACK STRATEGY

When analysing the adjustment mechanisms classified as slack strategies, four can be identified as forms of redundancy: (i)Empty Wagon; (ii)Inserting Fixed Buffer; (iii)Use Fixed Buffers; (iv) Coupling Into and Onto. The first three function as redundancy strategies by incorporating time reserves to protect the system, while the Coupling Into introduces a time and space buffer at a critical point to maintain workflow stability.

The Jumper mechanism involves multi-skilled tradespeople who intervene when issues arise, such delays, absenteeism, or unexpected disruptions. So, the Jumper is a flexibility strategy of slack, ensuring workflows stability, preventing bottlenecks, and supporting Lean Construction principles.

According to the Split of Train Orders exemplifies work in progress. By splitting sequence, unaffected areas can continue operations when a major disruption occurs, creating simultaneous work zones.

Finally, the Division of Material/Logistics involves outsourcing logistical tasks - considered non-value-adding – to specialists. So, this adjustment category could be classified as a defensive margin of manoeuvre, freeing up capacity and allowing workers to focus more on core value-adding tasks.

ADJUSTMENT MECHANISM EXIST DUE THE PRIOR PRESENCE OF SLACK

The adjustment mechanisms that rely on the prior presence of slack resources are closely linked to the flexibility dimension of slack strategies. For example, practices such as Phase Interlinking, Shunting Yard, Wagon Shift, Wagon Switch, Work Package Shift and Work Package Switch, represent various types of process changes. These practices are only feasible because alternatives sequences (paths) exist for completing a plan process (Hutchinson & Pflughoeft, 1994). This type of flexibility is normally found in loosely coupled systems, where some processes and operations exhibit a higher degree of independence from each other, or in other words, follow a variant sequence (Perrow, 1984), allowing for changes in the other of execution.

The practices of Decoupling of Takt Area, Splitting Takt Area, Takt Area Enlargement have a strong connection to the initial presence of a margin of manoeuvre in the sizing of the Takt Area. In other words, these practices are possible because the Takt Area initially selected is not the smallest possible spatial unit. Similarly, Wagon Overlapping and Wagon Parallelization are feasible due to the existence of a space margin within the Takt Area, allowing two wagons to be executed simultaneously. Additionally, there may be redundancy in the temporary installations, further enabling the concurrent execution of two wagons.

The practice of Kit Move is tied to need for "combining multiple work packages to use in a wagon" (Binninger et al., 2017b), which sometimes requires either a multifunctional team or a cross-training of the team members.

On the other hand, the effectiveness of Wagon Subcontracting relies on having a prearranged contractual agreement with the subcontractor or offering a bonus for standby availability, in case subcontractors are required for individual wagon.

DISCUSSION

The results demonstrate that slack is closely linked with the adjustment mechanisms used to mitigate disruptions and process variations. The use of redundancy strategies, such as Empty Wagons, Fixed Buffers, and the flexibility of Jumper practice, indicates that slack is not eliminated but strategically distributed to preserve workflow stability. Furthermore, the ability to adjust the takt plan through mechanisms that rely on pre-existing slack (eg. Shunting Yard or Phase Interlinking) reveals a degree of manoeuvrability, enabling resource reallocation and sequence changes when necessary. This finding is significant, as it reinforces that while Takt Planning has often been criticised for its supposed rigidity, many of these critiques overlook the diversity of slack types embedded within the system. Thus, to define Takt Planning as a flexible system, one must first evaluate the levels of slack, not merely the buffer levels, which offer more limited resources and strategies.

Another key reflection from this analysis is the gap in the adjustment mechanism, as the original focus was mainly on addressing process-level variability in Takt Planning. The adoption of Jumpers is one the few examples addressing operational level variability within the listed of adjustment mechanisms. This means that many slack strategies used to deal with micro-variabilities at the operational level, especially in the day-to-day on-site activities, are undervalued or not formally considered. For example, typical operational practices, such as sizing power generators to address power shortages in construction projects (Vieira et al., 2024), or strategies adopted during the Empire State Building construction, such as staggered working hours for crews to align with elevator capacities, or the guides at elevator relay stations to direct workers, both presented by Partouche et al. (2008), illustrate this disconnect. These examples, highlight how process-level slack and operational slack are frequently disconnected, potentially limiting the system´s capacity to respond quickly and effectively to smaller, yet critical variabilities that arise at the execution level.

Therefore, Takt Planning could be improved by incorporating operational slack strategies and micro-adjustments that occur at the execution level. These adjustments, often invisible in formal planning, are essential for dealing with the micro-variabilities that affect daily productivity and increasing its resilience to the common uncertainties in construction projects.

CONCLUSIONS

The research demonstrates that, despite criticisms of rigidity, Takt Planning incorporates slack strategies for system flexibility and resilience. By leveraging adjustment mechanisms such as redundancy, flexibility, and margins of manoeuvre, Takt Planning can effectively manage variability and maintain workflow stability.

However, a gap remains in addressing operational slack at the execution level, highlighting the need for deeper integration of micro-adjustments and day-to-day practices into formal Takt Planning frameworks. In this respect, inadequate management of micro-variability can cause fluctuations at higher levels, compromising stability and predictability (Brodetskaia & Sacks, 2007). Thus, integrating more operational-level slack strategies would further improve the system's ability to manage microvariabilities, thereby increasing flexibility and productivity in dynamic construction environments.

The paper suggests that the flexibility of Takt Planning relies heavily on the presence and effective management of different forms of slack, which should be explored and expanded to enhance the overall resilience of the method.

REFERENCES

Alhava, O., Rinne, V., Laine, E., & Koskela, L. (2019). Can a Takt Plan Ever Survive Beyond the First Contact With the Trades On-Site?, *Proc. 27th Annual Conference of the International Group for Lean Construction* (IGLC) , 453-464. doi.org/10.24928/2019/0261

Alhojailan, M. I. (2012). Thematic analysis: a critical review ofits process and evaluation. In *WEI international European academic conference proceedings, Zagreb, Croatia*.

Andreassen, M., & Drevland, F. (2023). Handoffs Between Takt Train Wagons: a Systematic Literature Review, *Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31)* , 1487-1497. doi.org/10.24928/2023/0130

Azadeh, A., Hasannia Kolaee, M., & Salehi, V. (2016). The impact of redundancy on resilience engineering in a petrochemical plant by data envelopment analysis. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, *230*(3), 285-296.

Binninger, M., Dlouhy, J., Oprach, S., & Haghsheno, S. (2016). Methods for Production Leveling – Transfer From Lean Production to Lean Construction, *24th Annual Conference of the International Group for Lean Construction* , -. doi.org/

Binninger, M., Dlouhy, J., & Haghsheno, S. (2017a). Technical Takt Planning and Takt Control in Construction., *25th Annual Conference of the International Group for Lean Construction* , 605-612. doi.org/10.24928/2017/0297

Binninger, M., Dlouhy, J., Steuer, D., & Haghsheno, S. (2017b). Adjustment Mechanisms for Demand Oriented Optimisation in Takt Planning and Takt Control , *25th Annual Conference of the International Group for Lean Construction* , 613-620. doi.org/10.24928/2017/0086

Binninger, M., Dlouhy, J., Müller, M., Schattmann, M., & Haghsheno, S. (2018). Short Takt Time in Construction – a Practical Study, *26th Annual Conference of the International Group for Lean Construction* , 1133-1143. doi.org/10.24928/2018/0472

Binninger, M., Dlouhy, J., & Haghsheno, S. (2019). Flow in Takted Projects – A Practical Analysis of Flow and Resource Efficiency, *Proc. 27th Annual Conference of the International Group for Lean Construction (IGLC)* , 1271-1282. doi.org/10.24928/2019/0228

Bourgeois III, L. J. (1981). On the measurement of organizational slack. *Academy of Management review*, *6*(1), 29-39.

Brodetskaia, I., & Sacks, R. (2007). Understanding Flow and Micro-Variability in Construction: Theory and Practice, *15th Annual Conference of the International Group for Lean Construction* , 488-497.

Dahlberg, T. Ø., & Drevland, F. (2021). Preventing the Parade of Delays in Takt Production, *Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC)* , 777-786. doi.org/10.24928/2021/0175

Dlouhy, J., Binninger, M., Oprach, S., & Haghshzeno, S. (2018). Mastering Complexity in Takt Planning and Takt Control - Using the Three Level Model to Increase Efficiency and Performance in Construction Projects, *26th Annual Conference of the International Group for Lean Construction* , 1365-1374. doi.org/10.24928/2018/0476

Dlouhy, J., Binninger, M., & Haghsheno, S. (2019). Buffer Management in Takt Planning – An Overview of Buffers in Takt Systems, *Proc. 27th Annual Conference of the International Group for Lean Construction (IGLC)* , 429-440. doi.org/10.24928/2019/0226
Fireman, M. C., Saurin, T. A., Formoso, C. T., Koskela, L., & Tommelein, I. D. (2022). Slack in production planning and control: a study in the construction industry. *Construction Management and Economics*, *41*(3), 256-276.
Formoso, C., Tommelein, I. D., Saurin, T. A., Koskela, L., Fireman, M., Barth, K., Bataglin, F., Viana, D., Coelho, R., Singh, V., Zani, C., Ransolin, N., & Disconzi, C. (2021). Slack in Construction - Part 1: Core Concepts, *Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC)* , 187-196. doi.org/10.24928/2021/0183
Frandson, A., Berghede, K., & Tommelein, I. D. (2013). Takt Time Planning for Construction of Exterior Cladding, *21th Annual Conference of the International Group for Lean Construction* , 527-536.
Frandson, A., Berghede, K., & Tommelein, I. D. (2014). Takt-Time Planning and the Last Planner, *22nd Annual Conference of the International Group for Lean Construction* , 571-580
Frandson, A. G., Seppänen, O. & Tommelein, I. D. (2015). Comparison Between Location Based Management and Takt Time Planning, *23rd Annual Conference of the International Group for Lean Construction* , 3-12.
Frandson, A. (2019). *Takt time planning as a work structuring method to improve construction work flow*. University of California, Berkeley.
Gardarsson, M. H., Lædre, O., & Svalestuen, F. (2019). Takt Time Planning in Porsche Consulting, the Boldt Company and Veidekke, *Proc. 27th Annual Conference of the International Group for Lean Construction (IGLC)* , 551-562. doi.org/10.24928/2019/0232
Haghsheno, S., Binninger, M., Dlouhy, J., & Sterlike, S. (2016). History and Theoretical Foundations of Takt Planning and Takt Control, *24th Annual Conference of the International Group for Lean Construction* , 53-62.
Hutchinson, G.K., & Pflughoeft, K.A., (1994). Flexible process plans: their value in flexible automation systems. *International Journal of Production Research* 32 3 , 707–719
Ingvaldsen, J. A., & Benders, J. (2016). Lost in translation? The role of supervisors in lean production. *German Journal of Human Resource Management / Zeitschrift Für Personalforschung*, *30*(1), 35–52. https://www.jstor.org/stable/26905316
Lehtovaara, J., Seppänen, O., Peltokorpi, A., Kujansuu, P., & Grönvall, M. (2021). How takt production contributes to construction production flow: A theoretical model. Construction Management and Economics, 39(1), 73–95. https://doi.org/10.1080/01446193.2020.1824295
Nonaka, I. (1990). Redundant, overlapping organizations: a Japanese approach to managing the innovation process. *California management review*, 32 (3), 27–38.
Partouche, R., Sacks, R., & Bertelsen, S. (2008). Craft Construction, Mass Construction, Lean Construction: Lessons From the Empire State Building, *16th Annual Conference of the International Group for Lean Construction* , 183-194.
Pereira, F., Fireman, M., & Etges, B. (2023). Slack: What Is Lacking on Supply Chain Resilience Strategies?, *Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31)* , 1686-1697. doi.org/10.24928/2023/0181
Perrow, C. (1984). Normal Accidents: Living with High-risk Technologies. Basic Books, New York, NY
Power, W., Sinnott, D., & Lynch, P. (2023). An Examination of IGLC Takt Literature - Learnings & Opportunities, *Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31)* , 1557-1569. doi.org/10.24928/2023/0218

Riekki, J., Rannisto, J., Lehtovaara, J., Seppänen, O., & Peltokorpi, A. (2023). Achieving a 4-Hour Takt Time – and Driving Change With It , *Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31)* , 1184-1195. doi.org/10.24928/2023/0146

Righi, A.W., & Saurin, T.A. (2015). Complex sociotechnical systems: characterization and management guidelines. *Applied ergonomics*, 50, 19–30.

Safayeni, F., & Purdy, L. (1991). A behavioral case study of just-in-time implementation. *Journal of Operations Management*, 10 (2), 213-228.

Saurin, T. A., Viana, D. D., Formoso, C. T., Tommelein, I. D., Koskela, L., Fireman, M., Barth, K., Bataglin, F., Coelho, R., Singh, V., Zani, C., Ransolin, N., & Disconzi, C. G. (2021). Slack in Construction - Part 2: Practical Applications, *Proc. 29th Annual Conference of the International Group for Lean Construction (IGLC)*, 197-206. doi.org/10.24928/2021/0178

Saurin, T. A. (2017). Removing Waste While Preserving Slack: The Lean and Complexity Perspectives , *25th Annual Conference of the International Group for Lean Construction* , 209-216. doi.org/10.24928/2017/0099

Saurin, T.A., & Werle, N.B. (2017). A framework for the analysis of slack in socio-technical systems. *Reliability engineering and systems safety*, 167, 439–451.

Tommelein, I. D. (2020). Takting the Parade of Trades: Use of Capacity Buffers to Gain Work Flow Reliability, *Proc. 28th Annual Conference of the International Group for Lean Construction (IGLC)* , 421-432. doi.org/10.24928/2020/0076

Tommelein, I. D., & Lerche, J. (2023). Comparison of Takt Planning Methods Used on Projects of Different Types, *Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31)* , 1605-1616. doi.org/10.24928/2023/0255

Tommelein, I. D., Coelho, R. V., Formoso, C. T., Barth, K. B. & Vargas, F. B. (2024). No Single Takt Planning Method Fits All Projects, *Proceedings of the 32nd Annual Conference of the International Group for Lean Construction (IGLC 32)* , 202-213. doi.org/10.24928/2024/0151

Vatne, M. E., & Drevland, F. (2016). Practical Benefits of Using Takt Time Planning: A Case Study, *24th Annual Conference of the International Group for Lean Construction*

Vieira, J. P. P., Etges, B. M. B. S., Vasconcelos, F. P., Bellaver, G. B., & Nogueira, H. R. C. (2024). Synergy Between LPS and Slack: A Case Study in Brazilian Horizontal Housing Developments, *Proceedings of the 32nd Annual Conference of the International Group for Lean Construction (IGLC 32)* , 428-441. doi.org/10.24928/2024/0176