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SHORT TAKT IN CONSTRUCTION: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Over the past decade, Takt planning has steadily gained ground as a production system design scheme in construction projects. The approach entails organising trades as wagons in a train and running that train through a set of designated work areas in a building, with the train making regular stops and the wagons spending a fixed amount of time – the takt – in each area. The most common takt in construction projects is weekly takt. While using a shorter takt in combination with smaller work areas yields a shorter overall execution time, there is limited research on the actual consequences and feasibility of reducing takt time in practice. This paper conducts a systematic literature review on using short takt in construction projects, seeking to consolidate existing knowledge and suggest avenues for future research. From searches in the Scopus and IGLC.net databases, the paper identifies 13 articles related to using short takt in construction projects. The articles are analysed using thematic coding, revealing seven themes: maturity, planning and preparation, production monitoring, visual management,mock-ups, logistics, and collaboration. Key insights include the importance of rigorous follow-up during production and the advantage of experience in managing short takt times. The paper concludes that the sum of existing knowledge on short takt times in construction is limited, offering minimal practical guidance for implementation. This identifies an urgent need for further research to fill this significant gap.

KEYWORDS

Lean construction, production system design, takt, short takt

INTRODUCTION

The construction industry has evolved significantly in the past few decades, with an increased focus on enhancing efficiency. This shift has seen the adoption of Lean principles to reduce waste and deliver better value. Recognised for their vital role in modernising construction processes, lean methods contribute to achieving superior outcomes (Kuenzel et al., 2016; Lohne et al., 2022). Over the past decade, one method that has gained particular traction is takt planning (Andreassen & Drevland, 2023; Halttula & Seppänen, 2022).

Takt planning is a method for planning and executing projects, strongly influenced by Lean and the Toyota Production System (TPS) (Linnik et al., 2013). Key principles in Lean and TPS include continuous improvement, elimination of waste, and optimal workflow (Power et al., 2023). Takt time is a central part of the Just In Time principle in TPS, which focuses on producing the product at the right time (Linnik et al., 2013).

A train metaphor often illustrates Takt planning (Dahlberg & Drevland, 2021; Haghsheno et al., 2016). A train comprises several wagons, each representing a trade's work (for example,

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electrical, HVAC, carpentry). In a construction project, the building is divided into work zones with an equal amount of work for each zone. The train moves through the building and stops in each zone at a specified rhythm – the takt. The most common takt time in construction projects is weekly (Binninger et al., 2018), meaning the train wagons stay in each zone for a whole week before moving on to the next zone. This cycle is repeated until all wagons have visited all zones.

By adjusting the size of work zones, it is feasible to significantly shorten the execution timeline of a takt (Binninger et al., 2018; Jabbari et al., 2020). Smaller zones necessitate reduced workloads within each, thereby permitting a decrease in takt time. This strategy can potentially lower both production times and project costs substantially. However, it also introduces new challenges, necessitating adjustments in logistics, coordination, and the frequency of work zone turnovers.

There is limited research on the actual consequences of reducing takt time in practice. Some smaller projects with limited scope have conducted such tests (Apgar et al., 2022; Binninger et al., 2018), as well as some larger construction projects (Apgar & Smith, 2023; Keskiniva et al., 2021; Riekki et al., 2023). However, the literature in this area is relatively limited, and there is a need for further research to gain more knowledge on how shorter takt time affects the practical execution of projects.

Adjusting the size of work zones offers a strategic means to significantly reduce project timelines, as smaller zones require less work per segment, thus allowing for shorter takt times. This approach can lead to notable reductions in both production times and costs, albeit introducing challenges related to logistics, coordination, and the management of work zone transitions (Binninger et al., 2018; Jabbari et al., 2020). Despite its potential benefits, there is a notable scarcity of research exploring the practical implications of reducing takt time, with limited studies focusing on both small-scale experiments and larger construction endeavours (Apgar et al., 2022; Apgar & Smith, 2023; Binninger et al., 2018; Keskiniva et al., 2021; Riekki et al., 2023). This gap highlights the necessity of exploring the impact of shorter takt times on project execution in real-world settings. Consequently, further research is essential to deepen our understanding of the effects of shorter takt times on the practical implementation of projects and to identify strategies for ensuring the successful execution of projects with short takt durations.

This paper presents the findings from a systematic literature review focused on the use of short takt in construction projects. The review served as a preliminary step to an empirical case study examining the implementation of 1-day takt. The aim was to consolidate current knowledge and identify potential avenues for future research.

The paper starts by outlining the methodology for selecting and analysing pertinent literature, leading to the identification of twelve studies that shed light on the implementation of short takt times. The thematic analysis reveals seven themes relevant to projects with shortened takt times: maturity, planning and preparation, production monitoring, visual management,mock-ups, logistics, and collaboration. Notable findings highlight the necessity of diligent follow-up during production and the benefits of experience in short takt management. The review finds that the sum of existing documented knowledge on short takt times in construction is minimal, with little practical guidance available for implementing short takt in projects – underscoring the pressing need for additional research to address this substantial knowledge gap.

METHOD

To identify literature, Scopus and IGLC.net were selected for their extensive coverage of relevant research. Scopus provides a broad range of curated peer-reviewed literature across disciplines, including construction, offering access to journals, books, and conference papers. The IGLC.net database contains all papers published at the IGLC's annual conferences.

The search used "takt" and "construction" to encompass the literature on takt planning. Searches conducted on Scopus and IGLC.net yielded 110 and 97 hits, respectively. Scopus searches included "construction" to narrow down the scope to construction-specific literature. In contrast, IGLC.net searches used only "takt" due to its focus on the construction industry.

The article selection process, illustrated in Figure 1, involved removing duplicates and excluding articles unrelated to takt planning with shorter takt durations. This process resulted in the final selection of 12 relevant articles, primarily case studies.

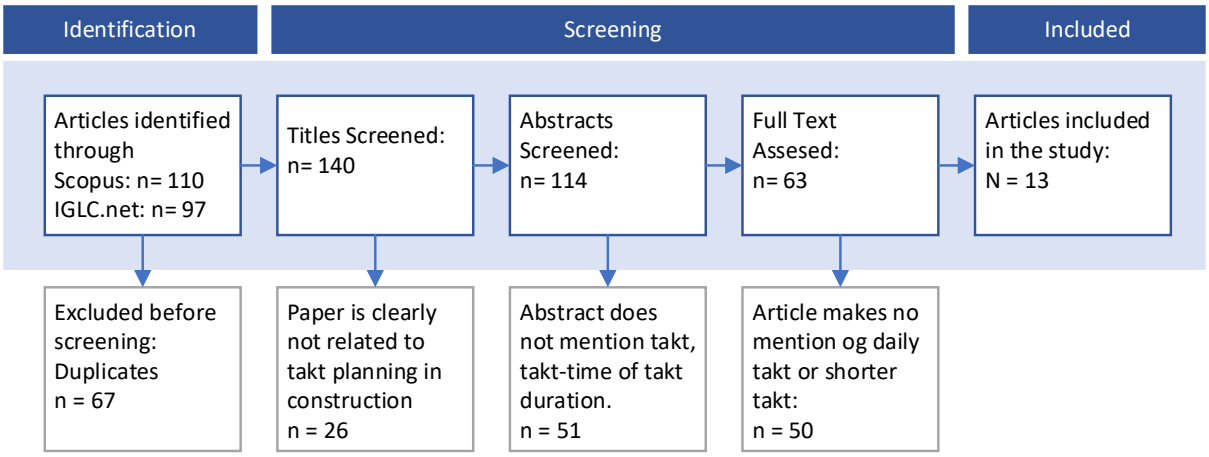

Figure 1: Flow chart for literature search and selection

The included papers were analysed using thematic analysis as described by Robson (2002), aided by an Excel sheet that organised the articles for a concise overview, including details about publication, content, and relevance. This structured approach facilitated easy identification of key points and themes across the literature.

LIMITATIONS

This review has several limitations worth noting. First, it focuses exclusively on peer-reviewed research literature. As a result, potentially valuable insights from non-peer-reviewed sources such as trade magazines, which might discuss practical applications and industry trends, have been omitted.

Secondly, the review did not include PhD dissertations. These works are often rich sources of detailed research but are challenging to integrate into a systematic review due to the lack of a unified database for global PhD theses. This makes a structured and comprehensive search challenging.

Finally, the literature screening process also presents limitations. Relying on skimming full texts to identify mentions of short takt times may result in oversight. This method depends heavily on the authors' ability to detect relevant details, which can be subjective and potentially inconsistent.

RESULTS

This section presents the results from a thematic analysis of the identified literature pertaining to using short takt in construction projects. The study defines *short takt* as any schedule tighter than a weekly cycle, including daily and hourly takt. The main goal was to pinpoint key factors influencing project outcomes when takt times are shorter than the commonly used weekly takt.

Out of the 13 identified and included articles, only one specifically explored the effects of reducing takt time (Binninger et al., 2018). However, 11 of the remaining 21 articles were case studies from projects – with short takt times – that investigated different issues. For instance, examining the general implementation of takt production (Lehtovaara et al., 2019), research on

logistics handling during takt production (Heinonen & Seppänen, 2016), and comparing projects with varying takt times to assess effective implementation of takt production (Lehtovaara et al., 2021).

The studies reviewed reported takt times ranging from 25 minutes to 2 days, with many projects opting for a 1-day takt. Short takts were mainly used in the finishing stages of highly repetitive projects, like residential and hotel constructions. Most of the research came from Finland, with additional studies from Norway, Germany, Ireland, and the USA. Table 3 summarises each study's focus.

Table 1 Overview of included studies

Reference	Country	Case Projects	Takt Time	Project Type
Apgar and Smith (2023) [Conference paper]	USA	1	1-day takt	Data centers
Apgar et al. (2022) [Conference paper]	USA	1	1-day takt	Roofing system
Binninger et al. (2018) [Conference paper]	Germany	1	1-hour takt	Retail space
Frandson and Tommelein (2014) [Conference paper]	USA	1	2-day takt	Health care facility retrofit
Gardarsson et al. (2019) [Conference paper]	Norway	None (Literature review)	Varying, discusses shorter takt	Not applicable
Heinonen & Seppänen (2016) [Conference paper]	Finland	1	25-minute takt	Boat cabins
Keskiniva et al. (2021) [Journal paper]	Finland	1	2-day takt	Residential renovation
Kujansuu et al. (2019) [Conference paper]	Finland and USA	4	From 1-day to weekly takt	Residential
Lehtovaara et al. (2021) [Journal paper]	Finland	6	Varying takt. From 1-day to weekly takt	Hotel and residential
Lehtovaara et al. (2020) [Conference paper]	Finland	24	Varying takt. One project with 1-day takt	Residential
Lehtovaara et al. (2019) [Conference paper]	Finland	1	Varying takt. From 1-day to weekly takt	Residential
Riekki et al. (2023) [Conference paper]	Finland	1	4-hour takt	Hotel
Tetik et al. (2019) [Conference paper]	Finland	2	1-day takt and 40-minute takt	Boat cabins

The thematic analysis of the articles revealed seven themes related to effectively implementing shorter takt times in construction projects: 1) Maturity, 2) Planning and preparation, 3) Production monitoring, 4) Visual management, 5) Use of Mock-up, 6) Logistics, and 7)

Collaboration. The following sections explore each of these areas in detail, shedding light on their significance and the role they play in the success of projects utilising short takt times:

MATURITY (EXPERIENCE)

The literature often emphasises maturity in the context of implementing shorter takt times, referring to organisations with extensive experience and advanced practices in takt production. While several Finnish studies explicitly mentioning 'maturity'(Lehtovaara et al., 2021; Lehtovaara et al., 2020; Tetik et al., 2019; Kujansuu et al., 2019), other studies hint at maturity issues, such as overestimating work capacity (Binninger et al., 2018) or a lack of preparation for takt production's pace (Lehtovaara et al.(2019), without directly mentioning the term. Maturity is often associated with experience in these discussions, though this perspective may overlook other important aspects, such as organisational culture and leadership.

Lehtovaara et al. (2021) emphasise maturity's role in managing short takt times and work zones, noting challenges in projects with low maturity levels due to inexperience with takt production. Despite planned efforts, these projects struggled with workflow efficiency, contrasting with higher maturity ones, which saw benefits from longer, weekly takt times. Lehtovaara et al. (2020) introduced a maturity model for takt production, identifying three maturity levels from basic takt planning to advanced, socially integrated practices.

Tetik et al. (2019) compared takt production maturity in shipbuilding and construction, finding ship cabin production more advanced in integrating takt and logistics solutions. However, it did not explicitly define maturity, viewing it as developing efficient takt and logistics practices in construction.

PLANNING AND PREPARATION

The literature emphasises the necessity of thorough planning for the success of construction projects employing shorter takt times (Apgar & Smith, 2023; Apgar et al., 2022; Binninger et al., 2018; Frandson & Tommelein, 2014; Lehtovaara et al., 2021; Lehtovaara et al., 2020; Lehtovaara et al. 2019; Riekki et al., 2023; Tetik et al. 2019). A study by Riekki et al. (2023) on converting an office building into a hotel with a four-hour takt highlighted how advanced and detailed planning, including a preparatory workshop, dedicated management efforts, and logistics coordination, was critical for project efficiency. Their findings align with the findings of Lehtovaara et al. (2019), which pointed to the importance of detailed planning, takt principle training, and careful production startup.

Additionally, the research notes the common issue of inadequate project definition prior to construction commencement, as seen in Tetik et al. (2019), where plan maturity affected procurement and delivery planning. Lehtovaara et al. (2021) and (2020) further discussed the benefits of early obstacle identification and integrating takt requirements in the design phase for enhanced collaboration and smoother production. They also warned against the pitfalls of minimal buffer areas, highlighting the balance needed to manage delays and unforeseen events in projects with tight schedules and high process variability.

PRODUCTION MONITORING AND CONTROL

The literature underscores the crucial role of rigorous production monitoring, including active management and daily coordination meetings, to adhere to takt times once construction starts. Studies reveal that effective workflow supervision, especially with shorter takt times, is key to maintaining efficiency (Apgar & Smith, 2023; Frandson & Tommelein, 2014; Riekki et al., 2023; Lehtovaara et al., 2021; Gardarsson et al., 2019). In cases like Riekki et al. (2023), where a project adopted a four-hour takt, the intensive monitoring required by management proved essential for project success, offering flexibility and control. Similarly, Binninger et al. (2018) demonstrated that close oversight and proactive management support were vital, particularly

after startup challenges in a project with an hourly takt, leading to significant improvements in coordination, efficiency, and project duration reduction from ten to three days.

Several studies highlight the need for additional resources, as well as active production management and daily follow-up in managing projects with short takt times (Keskiniva et al., 2021; Lehtovaara et al., 2019; Apgar & Smith, 2003). With short takt times, limited time is available to address production disruptions. Lehtovaara et al. (2021) point out the need for more resources, particularly in site management and among technical leaders during the planning and startup phases. This increased resource requirement is mainly due to the need for more frequent coordination and management of takt production.

Daily Coordination Meetings

Daily meetings are deemed essential for the day-to-day management of short-take projects. According to Riekki et al. (2023), such meetings help create a shared situational understanding and enable quick responses to work challenges. Other studies support this. Kujansuu et al. (2019) found daily meetings an effective way to start the workday, share information, and evaluate progress from the previous day. Lehtovaara et al. (2019) made a similar observation, highlighting it as a learning point due to the absence of good routines and daily meetings.

Buffers and Plan Adjustments

Buffer management is an approach in production or project management that uses reserves or buffers to handle uncertainty and variations in the workflow (Gonzalez et al., 2008). It involves allocating extra time, resources, or materials to manage unforeseen events without disrupting progress.

Gardarsson et al. (2019) point out that shorter takt times limit the time available to handle delays or unexpected project challenges. Dividing into smaller work zones may reduce total production time and costs but increase the risk of delays. Keskiniva et al. (2021) support this, noting that takt planning with shorter takt times can be rigid, making it challenging to adapt to changes and maintain the pace. Keskiniva et al. (2021), therefore, emphasise the necessity of daily monitoring and adjustments to avoid delays.

Lehtovaara et al. (2021) highlight that short takt times demand a more proactive role from tradespeople in managing capacity and resources, deviating from the buffer of extra time and materials often available in longer takt projects. Effective coordination and resource planning become essential skills for tradespeople to navigate the constraints of shorter tasks successfully.

Riekki et al. (2023) demonstrate that projects with short takts, such as one with a 4-hour takt, can maintain flexibility and manage adjustments effectively with careful planning, including adjustments in work steps, wagon sequence, the addition of new steps, and buffer wagons.

However, Lehtovaara et al. (2019) caution against a “hard start” without a gradual pace increase, as it can lead to subcontractor disengagement and a lack of thorough error inspection. This underscores the importance of a balanced pace and resource allocation from the project’s outset to mitigate potential issues and fully leverage the benefits of shorter takt times.

VISUAL MANAGEMENT

Visual management, utilising digital tools and physical markers, is reported by several studies as beneficial when implementing shorter takt times, enhancing workflow and communication (Lehtovaara et al., 2021; Lehtovaara et al., 2019; Riekki et al., 2023). Digital aids like Building Information Modeling (BIM) are crucial in reporting progress and managing discrepancies. Digital tools help keep schedules aligned with production, support accurate work tracking, and facilitate real-time updates, making them critical for efficient takt management (Riekki et al., 2023; Lehtovaara et al., 2019). However, adjusting takt plans can be challenging and time-

consuming, indicating the need for more automated solutions to enhance adjustment efficiency (Lehtovaara et al., 2021).

In addition to digital tools, physical visual aids such as printed takt plans and floor markings significantly improve on-site management and teamwork, as demonstrated in a hotel project employing a 4-hour takt (Riekki et al., 2023). These strategies foster a collective understanding and ease the integration of personnel, underlining the combined value of digital and physical visual management methods in optimizing construction processes.

MOCK-UPS

The hotel project detailed by Riekki et al. (2023) included efforts to create a mock-up of a hotel room outside the actual construction site as part of its planning phase. This initiative aimed to gain early insights into potential work process challenges and opportunities. Unfortunately, the mock-up was not finished before construction commenced, significantly restricting the learning opportunities it could have provided. The study highlights that such attempts can provide valuable insights into potential challenges and opportunities for details in work processes; however, it stresses that such mock-ups need to be completed to benefit from potential advantages during the planning and project phases.

LOGISTICS MANAGEMENT

Logistics management, especially in conjunction with shorter takt times, is crucial for maintaining project momentum, as evidenced by various studies. Riekki et al. (2023) emphasize the necessity of synchronizing material deliveries with the takt plan to ensure smooth progress. The study details a project using a four-hour takt in a city centre, where logistics strategies for different materials—external storage for large items and on-site storage for smaller items—helped maintain low inventory levels and streamlined material flow.

Tetik et al. (2019) and Heinonen & Seppänen (2016) discuss adopting industrialized logistics strategies from the shipyard industry, such as material sequencing and Just-In-Time (JIT) deliveries, to enhance takt production in construction. These approaches – including organizing materials on trolleys for specific cabins and ensuring daily delivery schedules – minimized inventory and optimized logistics management.

COLLABORATION

Two main areas of collaboration recur in several studies as crucial for the successful implementation of projects with short takt times. The first is collaborative planning among design teams, main contractors, subcontractors, and suppliers related to both the takt plan and the logistics management (Apgar et al., 2022; Heinonen & Seppänen, 2016; Riekki et al., 2023). The second concerns the importance of contract models that effectively support takt implementation and facilitate good collaboration. A greater focus on collaboration in contract models is essential to address challenges related to tight deadlines and complex work methods (Heinonen & Seppänen, 2016).

Studies by Kujansuu et al. (2019) and Lehtovaara et al. (2019) highlight the challenges of conflicting contract models and the negative impact of non-collaborative contract terms on project trust and efficiency. These findings suggest a need for contracts that promote openness, manage changes effectively, and support Lean management principles. Moreover, adopting new contract forms that encourage collaboration and innovation could address these challenges, aligning project stakeholders towards common goals and facilitating the successful execution of projects with short takt times.

SUMMARY OF FINDINGS

This literature review has systematically explored the existing knowledge on implementing short takt times in construction projects, identifying seven key themes: maturity, planning,

monitoring, visual management, mock-ups, logistics, and collaboration. Table 2 summarises the insights from each of these themes.

Table 2 Summary of findings

Maturity	• Project organizations with higher takt maturity navigate shorter takt times more effectively.
Planning and Preparation	• Thorough planning and preparation are crucial for projects to succeed with shorter takt time – including detailed planning, early integration of takt production requirements, and training in takt principles. • Proactive planning is important to avoid obstacles, reduce the risk of quality errors, and minimize the need for rework.
Production Monitoring and Control	• Short takt requires more active follow-up in the production phase. • Daily coordination meetings are crucial. • The startup phase should facilitate learning and adjustment to shorter takt times. • Continuous plan adjustments and buffer management are essential.
Visual Management	• Digital tools like BIM simplify workflow and communication • Visual tools such as paper takt plans and floor markings enhance on-site management and communication.
Mock-up	• Development and testing in a mock-up can provide valuable insights for planing and executing the takt plan.
Logistics	• Aligning deliveries with takt schedules is crucial for material flow and project progress. • Efficient strategies include systematic planning, material sequencing, Just-In-Time deliveries, and supplier integration. • Advanced inventory management systems minimize time loss.
Collaboration	• Collaborative planning among design teams, main contractors, subcontractors, and suppliers is crucial for short-take-time projects, impacting both takt plans and logistics management. • Conflicting contract models can hinder collaboration, affecting project trust and efficiency. • Contracts should foster openness, effectively manage changes, and adhere to Lean management principles.

DISCUSSION AND CONCLUSION

This paper delivered a systematic literature review focused on using short takt times in construction projects, aiming to synthesize the current body of knowledge and highlight areas for future investigation. A notable discovery is the scarcity of detailed research on short takt times, with just 13 articles addressing the topic. Among these, only one explicitly delves into short takt times, with the rest incorporating short takt cases in their studies, without short takt being the focus of the research. This scarcity raises questions about the specificity of findings to short takt times versus general takt production in construction.

Nevertheless, certain insights emerged distinctly related to short takt times, such as the need for intensified follow-up during production and the observation that organisations with greater experience in takt planning are better equipped to manage short takt times. These points serve as foundational insights for understanding other findings. For instance, while visual management tools are beneficial across takt projects, their value is likely accentuated in projects with short takts. Their use fosters greater transparency and should thereby reduce reliance on managerial oversight.

The study highlighted seven key themes relevant to executing short-take time projects, suggesting these areas as fruitful directions for future research. Although not exclusive to short-take-time projects, they underscore critical considerations in execution, revealing a more complex relationship among them that warrants deeper exploration.

While the themes were presented separately in the results, it is important to recognise the overlap and inherent connections between them. For example, *Maturity*, *Planning and Preparation*, and *Production Monitoring and Control* are closely interrelated. Mature organisations, i.e., those with expertise in takt production,, often have planning processes that anticipate issues and provide early solutions. Mature organisations are better at production monitoring and control, which helps them efficiently manage short takt times, leading to improved workflow and resource utilisation through effective daily coordination and supervision. Thorough planning, including logistics coordination, is essential for managing short takt times. Without it, production monitoring becomes difficult, leading to frequent adjustments that complicate project execution.

The uneven geographical distribution of the studies, with two-thirds originating from Finland, warrants discussion. Why is this the case? There are several reasons. Firstly, the Finnish construction industry has seen a significant rise in the use of takt construction, and Finland has been quicker to adopt shorter takts than other regions. Industry sources indicate that a takt of 2.5 days is now the norm for Finnish projects. Secondly, Finland's research community is very active in takt production research. Over the past five years, Finnish researchers have contributed 30% of all construction-related takt studies, underscoring their significant influence in this area.

Although these factors explain the Finnish dominance in the study, they raise questions about the generalizability of the findings to other regions. While none of the seven themes don't seem directly influenced by cultural factors, future research should consider this aspect.

A notable limitation in the current literature is the lack of in-depth case studies on using short takt times in construction projects. To address this gap, future research should delve into these case studies to better understand how the themes identified in this paper manifest across different regions and project types. This will provide a clearer, more nuanced understanding of the challenges and best practices of implementing short takt times in diverse construction environments.

In conclusion, this paper aimed to consolidate existing knowledge on short takt times in construction through a review of the literature. However, it became evident that the available information is limited. As a result, there isn't enough evidence to offer comprehensive, practical guidance on effectively implementing short takt times in construction projects. Nevertheless, the identified themes serve as a valuable foundation for future empirical research to address this gap, offering insights to guide the development of best practices and strategies in the construction industry.

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