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From Theory to Construction: Rethinking Task Complexity and Cognitive Load

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ABSTRACT: Task complexity governs human cognition, influencing decision-making, problem-solving, and performance. Behavioral science has long explored complexity from a cognitive load perspective, yet construction research often treats it as an operational obstacle rather than a structured phenomenon. In many cases, complexity is used as a generic term in construction research, lacking clear differentiation between cognitive, procedural, and systemic challenges. This broad usage oversimplifies the ways in which complexity affects human performance, limiting the potential for targeted interventions. Cognitive capacity is a finite yet critical resource that shapes how individuals process information, adapt to challenges, and execute tasks effectively. However, why do we not design tasks with a structured understanding of task complexity, considering its different dimensions and the cognitive load it imposes on workers? This paper examines task complexity from a behavioral science perspective, questions how it has been translated into construction research, and argues for a reframing of complexity not as a burden but as an essential component of a human centered task design. Finally, it challenges the field with provocative questions to reconsider how we design, measure, and engage with task complexity in construction. It highlights the need to develop a systematic assessment framework, leveraging cognitive science to create more adaptive and efficient construction workflows that align with human cognitive capabilities.

1. INTRODUCTION

The construction industry is one of the largest and most complex sectors globally, contributing nearly 13% of the world's GDP and employing over 7% of the global workforce (Barbosa et al. 2017). Despite its economic significance, the industry faces persistent challenges related to productivity, safety, and efficiency. Studies indicate that over 70% of construction projects experience delays, with cost overruns averaging 20% of the initial budget, largely due to inefficiencies in task execution and management (Aero 2020). These inefficiencies are not just procedural but cognitive. At the core of many on-site performance challenges lies task complexity—a multidimensional factor that shapes how workers perceive instructions, interpret technical drawings, prioritize tasks, and respond to evolving site conditions. In high-risk environments like construction, even routine tasks can become mentally taxing when workers are required to monitor multiple sources of information, resolve plan discrepancies, make real-time decisions, or coordinate their activities with other teams to avoid worksite conflicts. These mental challenges, collectively referred to as cognitive load, can impair concentration, slow down task execution, and increase the likelihood of errors. As such, task complexity has been identified as a key driver of performance outcomes in construction(Memarian et al. 2012; Mitropoulos and Memarian 2013; Pourrahimian et al. 2024). Task complexity governs how individuals process information, coordinate activities, and adapt to changing conditions. In construction, tasks frequently involve high levels of interdependency, dynamic site conditions, and high cognitive demands, making complexity a key determinant of performance.

Researchers have studied the impact of task demands on various aspects of worker performance, including physical strain (Anwer et al. 2021; Umer et al. 2020), and mental fatigue (Jamil Uddin et al. 2024; Li et al. 2019, 2020; Mehmood et al. 2022). Studies have shown that high task demands can lead to increased physical exertion (Zhang et al. 2023), musculoskeletal impact (Akanmu et al. 2020), mental stress, and safety risks (Choi et al. 2019; Kwon et al. 2024; Lee et al. 2021), all of which negatively affect productivity and safety in construction environments. Even though project complexity has been extensively studied in construction research (Dao et al. 2017; Luo et al. 2017a; b), task complexity remains an underexplored aspect despite its significant influence on workforce efficiency, cognitive demands, and overall task performance. Project complexity is often analyzed at a macro level, focusing on factors such as supply chain dependencies, stakeholder coordination, and regulatory challenges. However, the complexity of individual tasks into how they are structured, executed, and cognitively processed has received far less attention, despite being a fundamental driver of productivity and error rates at the execution stage. In particular, mental workload and cognitive overload have been identified as major contributors to errors, slower task execution, and decreased adaptability to unforeseen challenges. These findings highlight the critical need to design tasks that align with workers' cognitive and physical capabilities, ensuring both efficiency and long-term sustainability in the workforce.

Construction research has largely treated complexity as an operational burden to be minimized rather than as an integral component of task design. A major issue is the lack of a structured, quantifiable framework for measuring complexity, leading to generic and subjective assessments that fail to capture what truly makes a task complex. This ambiguity hinders practitioners from identifying the specific sources of complexity, making it even more difficult to develop strategies for managing or mitigating its impact effectively (Efatmaneshnik and Handley 2021). Research in this field often refers to complexity as a general challenge without distinguishing between its various forms. Construction research lacks the necessary granularity to analyze how complexity interacts with cognitive demands, task execution, and decision-making in real-world construction environments. Consequently, existing approaches fail to offer actionable strategies for designing tasks that align with human cognitive capacities.

In contrast, behavioral science has long explored complexity through structured theoretical models. Cognitive Load Theory (Sweller 1988) provides a foundation for understanding how complexity interacts with cognitive demands, distinguishing between intrinsic load (task difficulty inherent to the activity), extraneous load (unnecessary complexity that hinders performance), and germane load (productive complexity that fosters learning and expertise development). Wood's (1986) task complexity framework categorized complexity based on task components, required actions, and informational cues, establishing an early foundation for complexity analysis. Later, Hærem et al. (2015) introduced a network-based model, demonstrating that task complexity grows exponentially due to interdependencies rather than in a linear fashion. More recently, Danner-Schröder and Ostermann (2020) presented a process-based approach, highlighting that task complexity is not a static attribute but rather evolves dynamically based on situational interactions and decision-making processes. These insights suggest that task complexity should be systematically structured and managed.

This paper raises fundamental questions regarding how complexity should be measured, categorized, and integrated into construction task design by critically examining how construction research currently conceptualizes and manages complexity. Instead of treating complexity as a loosely defined challenge, this study argues for a paradigm shift toward structured complexity management, where task demands are analyzed and modeled in a way that aligns with cognitive constraints and operational efficiency. Addressing these gaps is crucial for enhancing productivity, reducing errors, and ensuring that complexity is not arbitrarily addressed but instead systematically understood and optimized. By integrating insights from behavioral and cognitive sciences, this study challenges conventional construction task design approaches and calls for a new perspective that positions complexity as a structured, analyzable, and integral component of construction task execution.

2. METHODOLOGY

This study adopts a conceptual and philosophical methodology to examine task complexity through the lens of behavioral science and construction research. The methodology is structured into three key stages. Theoretical Exploration: A conceptual analysis of task complexity is conducted based on behavioral science theories to establish a foundation for understanding complexity in human cognition and decision-making. Comparative Analysis: Construction research literature is critically reviewed to evaluate how task complexity is conceptualized, measured, and managed in the industry. This review was conducted using academic databases such as Scopus, Google Scholar, and ASCE Library, focusing on peer-reviewed publications from the last 15 years. Search terms included combinations of "task complexity," "construction productivity," "cognitive load," and "human performance in construction". The study identifies gaps and misalignments between behavioral science perspectives and construction research methodologies. Critical Reflection & Synthesis: A philosophical reflection is applied to challenge the conventional reductionist approach to complexity in construction. Finally, open-ended questions are formulated to provoke new research directions, encouraging a shift towards a human-centered complexity framework in construction task design.

3. TASK COMPLEXITY IN BEHAVIORAL SCIENCE

Task complexity is fundamentally defined by three key components: products, required actions, and information cues (Wood 1986). The primary objective of task design is to improve outcomes while reducing cognitive load on workers by deconstructing tasks into smaller, more manageable components (Campbell 1988; Zhou 2013). As a result, tasks are designed to sustain an "optimal" level of complexity, since excessive complexity can impair performance (Wood 1986). To avoid overload and performance decline, task complexity is often minimized where possible. Hærem et al. (2015) proposed a conceptual model of task complexity, asserting that "anything influencing how a task is performed can potentially affect its complexity." Their model represents tasks as networks of interconnected events, where the sequences of events leading to task completion are termed paths. By structuring tasks as networks with multiple paths linking various events, task complexity can be systematically quantified and analyzed. Older models, like Wood (1986) assumed complexity was additive as each additional action or decision made a task slightly more complex in a linear fashion. However, Hærem et al. (2015) argue that task complexity grows exponentially because interdependencies between actors and events create multiplicative effects on complexity. Once a task is represented as a network, its complexity can be quantified by identifying all possible pathways leading to each goal and summing the number of interconnections within these paths, as shown in equation 1 (Hærem et al. 2015) as inspired by the structural role theory method described by (Oeser and O'Brien 1967). This approach captures the real-world complexity of tasks that involve multiple actors responding to dynamic situations. This approach retains fundamental insights from Wood (1986) regarding component and coordinative complexity while integrating them into a unified calculation that yields a nonlinear measure of task complexity.

$$Task\ Complexity\ =\ \sum_g \sum_p ties_{g,p}\ \ldots\ldots\ldots\ldots equation\ (1)$$

Where:
*   Goals (g) = Task goals (end states)*
*   Paths (p)= Routes to particular goal*
*   Ties= The number of ties (dependencies) between events in path*

While Hærem et al. (2015) provide a quantitative, network-based model of complexity, Danner-Schröder and Ostermann (2020) contribute a process-based perspective, emphasizing the evolution of complexity through situated action. Unlike traditional models that treat task complexity as a fixed attribute of a given task, their work highlights how complexity emerges, transforms, and dissolves dynamically based on real-time interactions, decisions, and environmental factors.

Their study was conducted in an Intensive Care Unit (ICU) which illustrate how task complexity is not predetermined, but rather constructed and reconstructed through ongoing social interactions. This means that complexity does not exist independently of the actors engaging with the task—it is shaped by their experience, adaptation, and situational context. For example, a medical emergency in an ICU involves a constantly shifting interplay of information, team coordination, and evolving patient conditions, making complexity fluid rather than static.

Their concept of narrative networks challenges conventional task complexity models, such as Wood (1986), by reframing complexity as an interactive process rather than a sum of task elements. Rather than viewing complexity as a fixed challenge to be reduced, they argue that complexity should be contextually managed—sometimes simplified for efficiency, but in other cases preserved to support adaptability and learning.

The insights from Hærem et al. (2015) and Danner-Schröder & Ostermann (2020) suggest that task design must account for both structural and emergent complexity. A task is not simply a set of predefined steps; it is an interactive system influenced by worker expertise, cognitive demands, environmental uncertainty, and evolving dependencies. This means that effective task design requires a balance between reducing unnecessary complexity and preserving beneficial complexity that fosters skill development and decision-making agility. Hamzeh et al. (2018, 2019) heighted that in dynamic construction environments, workers frequently deviate from predefined plans due to time pressure, resource unavailability, or unforeseen site conditions which necessitates adaptive behaviours and decision making. These findings reinforce the argument that task complexity should not merely be reduced but rather structured to account for the dynamic changes in construction sites. Together, these perspectives challenge the simplistic view of complexity as a burden and encourage researchers and practitioners to rethink how tasks are structured, measured, and managed across dynamic work environments.

4. CONSTRUCTION RESEARCH: A GENERIC VIEW OF COMPLEXITY?

Despite significant advancements in behavioral science and cognitive research on task complexity, construction research has yet to fully integrate these insights. Instead, it often treats complexity as a generalized obstacle rather than a structured, multifaceted aspect of task design. Researchers frequently suggest that reducing task complexity leads to fewer errors, improved productivity, and enhanced worker efficiency (Hasan et al., 2018; Mitropoulos et al., 2005; Mitropoulos & Memarian, 2013; Pourrahimian et al., 2024). However, this raises several critical questions:

> *What is task complexity?*
> *What specific aspects of a task contribute to poor performance?*
> *How does task design influence complexity?*
> *How does task complexity relate to cognitive load?*

Without addressing these questions, the recommendation to "reduce complexity" remains a broad and oversimplified directive rather than an actionable strategy grounded in a structured understanding of complexity.

4.1 What is Task Complexity?

Task complexity has been established as a factor impacting productivity in construction research (Kedir and Fayek 2023; Nasirzadeh and Nojedehi 2013; Raoufi and Robinson Fayek 2018). However, its meaning can vary depending on the time and nature of the task at hand. A task that appears simple in one phase of a project may become highly complex in another due to evolving dependencies, changing site conditions, or cognitive demands placed on workers. One of the shortcomings in construction research is the lack of a precise and structured definition of task complexity. Studies often refer to complexity in generalized terms, failing to differentiate between distinct types of complexity that affect performance. Task complexity is not a singular concept, but rather a multidimensional phenomenon influenced by multiple factors, which could include coordinative complexity which is the number and interdependencies between tasks, and workers. Processing Complexity which could reflect the cognitive demands required to interpret, assess, and apply relevant information. Dynamic Complexity which reflect the extent to which tasks change in real-time due to unpredictable conditions, different conditions than assumed in planning (Hamzeh et al. 2018), environmental factors, or emergent challenges. Temporal Complexity which is the impact of time constraints and task sequencing on workflow efficiency and decision-making. Hamzeh et al. (2019) show that time pressure is an antecedent of improvisation, where workers frequently make on the spot adjustments to keep projects on schedule. For example, during structural steel installation, a worker may need to interpret

an ambiguous drawing while coordinating with a crane operator and working under tight time constraints to avoid delaying subsequent trades. In this situation, the mental load of interpreting information, making rapid on-the-spot decisions, and managing real-time coordination all contribute to the overall complexity of the task. These are just examples of the multidimensional nature of task complexity, which cannot be fully understood without identifying and analyzing its specific components. By failing to differentiate between these distinct aspects among others, construction research treats task complexity as a uniform burden. This often results in blanket recommendations to reduce complexity without first understanding which specific elements are responsible for inefficiencies.

4.2 Which Aspects of Complexity Lead to Poor Performance?

Many construction studies associate high task complexity with reduced performance, yet does not specify what aspect of complexity is responsible for this decline. Complexity may become problematic for several reasons which could include the following among others.

High Cognitive Load: Workers may experience elevated cognitive load—possibly due to factors such as large volumes of information processing, unclear instructions, time pressure, or poor task design.
Overwhelming Interdependencies: Too many interconnected tasks create bottlenecks in workflow coordination.
Environmental Uncertainties: External factors make task execution unpredictable and inefficient.
Worker Skill Gap: Insufficient training or expertise leaves workers unable to manage the level of complexity inherent in the task.
Time Pressure and Urgent Decision Making: Construction projects often operate under tight deadlines which forces workers to make real time decision making under highly stressful conditions.
Variability in Actual Site Conditions: Variability in actual site conditions compared to planned assumptions creates discrepancies that require immediate adaptation.

Without identifying the specific aspects of complexity that contribute to poor performance, any attempt to reduce complexity remains imprecise and potentially counterproductive. Simplifying tasks without understanding the underlying causes of inefficiency may result in oversimplification, which can hinder skill development, reduce adaptability, and create inefficiencies when unexpected challenges arise. Instead of treating complexity reduction as a universal solution, research must first analyze which elements of complexity negatively impact performance and which are essential for learning, decision-making, and problem-solving. Without this structured understanding, efforts to manage complexity risk removing necessary cognitive challenges or failing to address the true sources of inefficiency.

4.3 The Role of Task Design in Shaping Complexity and Cognitive Load

A major gap in construction research is the lack of a human-centered approach to task design that considers cognitive load and the dynamic nature of complexity. Unlike fields such as aviation (Androulakis et al. 2023; Di Stasi et al. 2015) or healthcare (Hysong et al. 2016), where tasks are deliberately designed to improve cognitive efficiency, construction tasks are rarely structured with cognitive demands in mind. Instead, task design in construction is often driven by operational constraints, productivity targets, and physical sequencing, with little consideration for how workers process information, coordinate tasks, or adapt to evolving complexities on-site. This oversight results in tasks that impose unnecessary cognitive burdens, leading to errors, inefficiencies, and reduced adaptability to dynamic work conditions.

Cognitive Load Theory (Sweller 1988) offers a framework for understanding how task complexity affects human performance by distinguishing between Intrinsic Load (the inherent difficulty of a task), Extraneous Load (unnecessary complexity that hinders performance), and Germane Load (productive cognitive effort that enhances learning and expertise). The core principles of CLT emphasize reducing intrinsic and extraneous load where possible, in order to free up cognitive capacity for germane load. However, construction research has yet to apply CLT principles in a systematic way to measure and reduce cognitive load in task design. As a result, construction tasks often contain high levels of extraneous load, such as unstructured workflows, excessive information processing, and poorly sequenced activities. For example,

in structural steel assembly, workers frequently receive fragmented instructions, forcing them to interpret plans and resolve inconsistencies mid-task, increasing cognitive strain. Similarly, in electrical installations, lack of standardization in technical drawings leads to high information-processing complexity, slowing down execution and increasing the likelihood of errors.

Despite the clear impact of cognitive overload on performance, construction research has yet to develop methods for systematically measuring cognitive load in task execution or designing tasks to improve cognitive efficiency. The absence of a dynamic approach to task complexity that accounts for real-time decision-making, adaptability, and cognitive effort further compounds inefficiencies. Without these insights, complexity is either left unmanaged, leading to cognitive overload, or simplified arbitrarily, potentially reducing opportunities for skill development. Moving forward, construction research must shift toward a human-centered approach to task design, integrating cognitive load measurement to balance efficiency, learning, and adaptability in dynamic work environments.

5. A NEW PERSPECTIVE: EMBRACING COMPLEXITY FOR HUMAN-CENTERED TASK DESIGN

Given these limitations, there is a pressing need for a structured framework that integrates cognitive load principles into task complexity assessment and design within construction contexts. Current approaches lack a systematic method for measuring and categorizing task complexity, often treating it as a simplistic variable rather than a structured and measurable construct. A well-defined framework should:

1. Differentiate between types of complexity.
2. Incorporate cognitive load metrics to understand the mental demands imposed by construction tasks.
3. Develop a network-based complexity model (Hærem et al., 2015) to map out interdependencies within construction workflows.
4. Integrate process-based complexity approaches (Danner-Schröder and Ostermann 2020; Hamzeh et al. 2019) to account for how complexity dynamically evolves during a project.

Such a framework would not only allow construction researchers to analyze complexity with greater precision but also enable industry practitioners to design tasks that improve cognitive load, enhance worker adaptability, and improve overall performance. Rather than treating complexity as an obstacle to be reduced, this study aims to reframe complexity as an integral component of construction task design, aligning task demands with cognitive capabilities and operational efficiency. Cognitive load theory (Sweller 1988) suggests that optimizing tasks by balancing intrinsic, extraneous, and germane loads can significantly improve task execution. Adopting such a perspective in construction could lead to structured task design strategies that account for human cognitive constraints, ultimately reducing errors and increasing productivity.
Figure 1 illustrates this approach by mapping out the relationships between Human-Centered Task Design, Task Complexity, Cognitive Load, and Performance Outcomes. At the core of this framework is Human-Centered Task Design, which recognizes that complexity should be structured, not eliminated. This perspective diverges from traditional complexity reduction by considering how task complexity interacts with cognitive load. Task Complexity and Cognitive Load both contribute to Performance Outcome, which determines whether task execution is optimized or hindered by inefficiencies. This outcome then branches into two possibilities optimized performance where complexity is structured appropriately, cognitive load is managed effectively, leading to improved efficiency, adaptability, and resilience. However, even when performance is improved, continuous monitoring of cognitive load remains essential to reassess and adjust task structures, ensuring alignment with the dynamic nature of tasks. The second possibility is overload and inefficiencies which happens when complexity is either excessive or unstructured, cognitive overload can lead to errors, inefficiencies, and decreased productivity. Task redesign highlights the importance of continuously refining task structures to align with the dynamic task complexity and cognitive load. Human-centered approaches ensure that complexity is continuously managed and improved, creating an adaptable and skilled workforce.
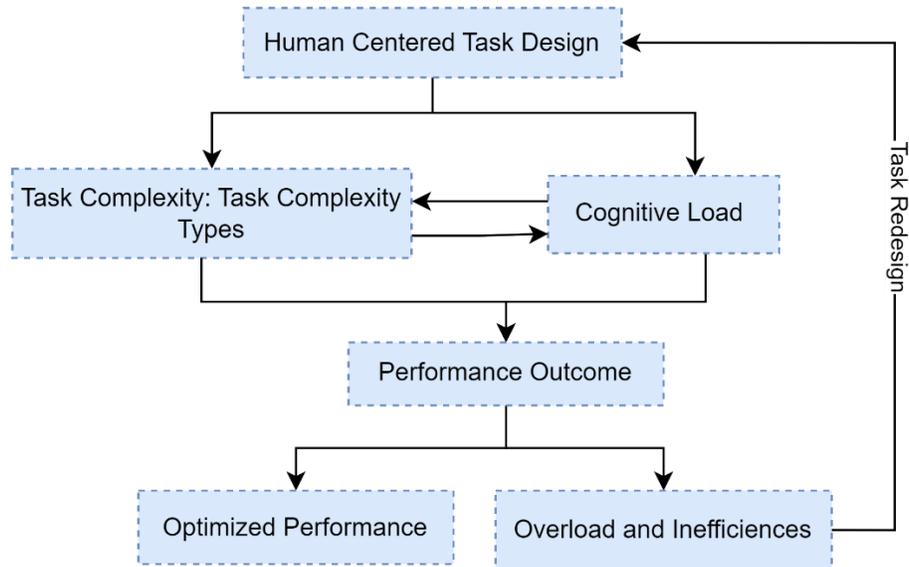
Figure 1. Conceptual Diagram of Human-Centered Task Design

Table 1 compares Traditional Complexity Reduction with Human-Centered Complexity Management, highlighting the differences in how task complexity is perceived, and addressed in construction task design. Traditional complexity reduction views complexity as a burden that should be minimized to prevent inefficiencies, assuming that simpler tasks lead to fewer errors. In contrast, human-centered complexity management recognizes complexity as a resource that should be structured, understanding that certain levels of complexity are necessary for skill development, decision-making, and adaptability. The traditional approach focuses primarily on reducing task difficulty, often by breaking tasks into smaller steps or eliminating challenging elements. However, this can lead to oversimplification, where workers are not sufficiently challenged, limiting their problem-solving abilities. Additionally, under traditional complexity reduction, there is often a lack of quantification or structured assessment of what specifically contributes to high complexity. Without clear insights into the root causes, it becomes difficult to implement targeted improvements, leading to reactive rather than strategic task design.

Human-centered complexity management, on the other hand, prioritizes optimizing cognitive load, ensuring that tasks are structured in a way that enhances efficiency while maintaining an appropriate level of challenge. Structured task design considers the cognitive demands of a task, optimizing workflows, information delivery, and coordination strategies. While reducing complexity can lower error rates, it may also create inefficiencies when unexpected challenges arise. Human-centered complexity management ensures that complexity is structured, not eliminated, leading to greater adaptability, efficiency, and resilience in dynamic work environments. Traditional approaches tend to be vague, treating complexity as a general issue without differentiating between its various forms. Human-centered management takes a granular approach, identifying and managing different types of complexity, such as coordinative, informational, and dynamic complexity, ensuring that each is addressed appropriately for improved performance.

Table 1: Comparison of Traditional Complexity Reduction vs. Human-Centered Complexity Management

	Traditional Complexity Reduction	Human-Centered Complexity Management
Complexity Perception	Burden to be reduced	Resource to be structured

Focus	Reducing task difficulty	Reducing cognitive load and improving performance
Primary Method	Simplification	Improved task design
Impact on Performance	Reduces errors, but may create inefficiencies	Increases efficiency and resilience
Vagueness vs. Granularity	Vague approach with minimal differentiation between types of complexity	Granular approach, distinguishing between different types of complexity and their impact
Evidence	Existing productivity-focused construction research (Kedir and Fayek 2023; Nasirzadeh and Nojedehi 2013; Raoufi and Robinson Fayek 2018; Hasan et al., 2018; Mitropoulos et al., 2005; Mitropoulos & Memarian, 2013; Pourrahimian et al., 2024).	Supported by CLT, Wood's framework, behavioral science models (Danner-Schröder and Ostermann 2020; Hærem et al. 2015; Sweller 1988; Wood 1986)

A robust framework for construction task complexity should address the following questions:

- ***What are the different dimensions of complexity in construction tasks?***
- ***How does complexity influence cognitive load, and when should it be reduced or maintained?***
- ***How can task complexity be systematically measured beyond subjective perceptions of difficulty?***
- ***How can construction task design incorporate complexity and cognitive load in a way that improves decision-making, and mitigation strategies?***

By reframing complexity as an integral component of construction task design, rather than merely a barrier to efficiency, research can contribute to more adaptive, resilient, and cognitively efficient task structures. Future studies must move beyond the simplistic view of complexity as a hindrance and develop models that optimize task complexity. While behavioral science provides a strong theoretical foundation for task complexity analysis, construction research often lacks systematic frameworks for evaluating and mitigating task complexity. Bridging this gap through cognitive science-informed methodologies can significantly enhance task design, worker efficiency, and overall productivity in the construction industry.

6. CONCLUSION

This paper challenges the conventional perception of task complexity in construction, arguing that it should not be viewed solely as a burden to be minimized but as an integral component of task design that shapes performance. While construction research has largely treated complexity as an operational inefficiency, behavioral science offers structured models such as Cognitive Load Theory and network-based complexity analysis that reveal how complexity interacts with cognitive demands and decision-making. By categorizing task complexity into distinct dimensions, researchers and practitioners can move beyond vague, oversimplified recommendations and develop targeted strategies for optimizing complexity. A human-centered approach to complexity management ensures that tasks are designed to balance cognitive load, fostering both efficiency and long-term expertise development.

Future research must establish systematic methods for measuring task complexity in construction, integrating cognitive science principles to refine task design and enhance worker performance. Additionally, emerging technologies such as artificial intelligence and simulation modeling offer promising avenues for analyzing and optimizing task complexity in dynamic construction environments. Rather than reducing complexity indiscriminately, the field must shift towards structured complexity management where complexity is analyzed, understood, and leveraged to enhance productivity and resilience. By embracing complexity as a structured phenomenon rather than an obstacle, construction research can redefine how tasks are designed, measured, and executed, ultimately fostering a more adaptive and skilled workforce.

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