

SEMANTIC BLINDNESS IN DIGITAL LPS SYSTEMS

Raquel H. Reck¹, & Eduardo L. Isatto²

ABSTRACT

Digital tools supporting the Last Planner System (LPS) have expanded rapidly over the past years, encompassing BIM-based planning platforms and constraint ontologies. Although the LPS has demonstrated improvements in production reliability and coordination, evidence of sustained and comparable performance across projects remains limited. Rather than attributing this gap to insufficient data or computational capability, this study suggests it is also associated with how production information is structured and maintained across planning cycles. The study presents a qualitative comparative analysis of 12 digital LPS-related systems reported in the literature between 1999 and 2025. Four representational dimensions are examined: work package definition; representation of location, process, and scope; capture of progress and constraints; and recording of deviations and their causes. The results show that these systems effectively represent operational aspects of production, such as tasks, quantities, timestamps, and execution states, but provide limited support for preserving the contextual and decision-related information required to reuse and compare commitments across planning levels. This paper identifies a structural representational limitation in digital LPS systems — termed semantic blindness — defined as the inability to maintain and reuse contextual and decision-related information across planning levels.

KEYWORDS

Last Planner® System, semantic representation, work package, data reuse.

INTRODUCTION

Since its early development, the Last Planner System (LPS) has been closely intertwined with digital technologies. Initial efforts focused on basic forms of digitalization to support planning and control routines (Choo et al., 1999). Over time, this relationship has expanded into a diverse ecosystem of digital solutions, including BIM-based planning platforms (Heigermoser et al., 2019; Lin; Golparvar-Fard, 2021; Schimanski et al., 2021; Sbiti et al., 2022) and ontology-driven constraint management tools (Mao et al., 2025). Together, these developments signal a decisive shift toward digitally mediated Lean production control.

Despite this technological expansion, evidence of sustained and comparable performance improvement remains limited. A systematic review of 1,351 IGLC papers (2013–2024) found that only 52 studies (3.8%) explicitly addressed performance improvement, with few providing consistent and comparable metrics across projects (Asmone et al., 2025). The literature remains dominated by short-term indicators (e.g., Percent Plan Complete) and lacks standardized measures for cross-project or longitudinal assessment (Asmone et al., 2025). These challenges are particularly relevant to aspects of performance related to production reliability, coordination,

¹ PhD and Lean Consultant at Climb Consulting Group, Porto Alegre, RS, Brazil, +55 51 998711561, raquel@climbgroupp.com.br, orcid.org/0000-0003-1928-3461.

² Associate Professor, School of Engineering, Building Innovation Research Unit (NORIE), Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, Brazil, isatto@ufrgs.br, orcid.org/0000-0002-0851-8790

and learning across projects, which are central to the LPS. This suggests that the growing volume of digital production data has not translated into robust empirical evidence of Lean's promised benefits.

Although data generation and analytics capabilities have expanded, the construction industry continues to struggle to leverage data for decision-making and performance improvement (Munawar et al., 2022). Most digital LPS systems represent activities, resources, geometry, quantities, and execution status, but not the meaning of work packages as units of commitment and control. Ontologies formalize specific domains (Mao et al., 2025), and BIM platforms structure models and schedules (Heigermoser et al., 2019; Lin; Golparvar-Fard, 2021; Schimanski et al., 2021; Sbiti et al., 2022). What remains largely unaddressed is how the semantic content of a work package is maintained, why it exists, under which conditions it was defined, and what assumptions it embodies. In particular, digital systems rarely preserve structured information about constraints, assumptions, and execution conditions in a form that can be reused across planning cycles.

This paper argues that this condition can be understood as semantic blindness in digital LPS systems: a systematic inability to maintain meaning across planning levels despite the availability of digital data, representing a structural limitation that contributes to the observed difficulties in capturing and reusing production knowledge across planning levels. Despite advances in digital LPS tools, there remains a lack of understanding of how production information is represented in ways that support the preservation and reuse of meaning across planning levels.

Accordingly, this study addresses the following research question: how do digital LPS systems represent work packages and their associated information across planning levels, and to what extent do these representations support the preservation of meaning?

To address this question, the study examines how digital LPS-related systems reported in the literature represent work packages, context, progress, and deviations. The main contribution of this paper is the identification and conceptualization of semantic blindness as a structural representational limitation in digital LPS systems. To support this contribution, the analysis identifies recurring representational patterns and examines how these patterns affect the preservation of meaning across planning levels. Rather than evaluating software performance or usability, the analysis focuses on whether these systems are semantically equipped to support coherent production control within the Last Planner System. This study does not question the effectiveness of the LPS, but examines how its logic is represented in digital systems.

THEORETICAL BACKGROUND

LPS AS A COMMITMENT-BASED CONTROL SYSTEM

The LPS was conceived as a production planning and control system designed to manage uncertainty through flow structuring rather than schedule optimization (Ballard, 2000). Instead of fixed activity sequences, it organizes production around cycles of planning, execution, checking, and learning, with control exercised through continuous feedback (Ballard, 2000).

At its core, the system defines the work package as a unit of control (Ballard, 2000). These are bounded units of production integrating scope, sequence, constraints, and responsibility within a planning horizon, ensuring that only ready and coordinated work is released (Ballard; Howell, 1998). Control is therefore based on assessing readiness and reliability rather than enforcing plan compliance.

This logic is operationalized through recurring control cycles across planning levels. Constraints are identified and removed to protect short-term commitments (Ballard; Howell, 1998), while short-term planning compares planned and completed work to support learning

and adjustment (Ballard, 2000). The LPS thus embeds a PDCA-like logic in which planning, control, and learning are inseparable.

Within this structure, the LPS operates as a commitment-based control system. Work packages represent negotiated promises made under real conditions of capacity and constraints (Ballard, 2000). Planning meetings function as arenas for alignment, where commitments are formed, assessed, and revised (Viana et al., 2017). Production reliability depends on the quality of these commitments and the system's ability to monitor and renegotiate them over time (Viana et al., 2017).

The effectiveness of the LPS therefore depends on the quality of work packages as meaningful units of control. Learning requires that causes identified in plan-do-check cycles inform how work packages are defined, sized, sequenced, and released in subsequent cycles. Commitment reliability depends on attributes such as scope clarity, appropriate sizing, readiness, and logical sequencing (Ballard & Howell, 1998; Ballard, 2000). When these criteria are not updated, root causes may be documented without influencing future decisions, limiting continuous improvement. Work packages therefore embed not only operational attributes but also semantic content essential for commitment-based control, including planning assumptions, conditions of satisfaction, negotiation outcomes, and contextual constraints that define when and how work can be reliably executed. These attributes support coordination, accountability, and learning across planning cycles.

DIGITAL REPRESENTATION IN CONSTRUCTION PLANNING

Parallel to the development of the LPS, construction planning has undergone extensive digitalization. Building Information Modelling (BIM) has become the dominant paradigm for representing construction products and processes in digital form, enabling the explicit modelling of geometry, quantities, spatial relationships, and object attributes (Sacks et al, 2018). BIM-based systems have significantly improved the coordination of design and construction information, particularly when integrated with schedules and cost data.

Beyond BIM, ontology-based approaches have been proposed to formalize specific domains of construction knowledge, such as space, resources, or constraints. Ontologies define explicit specifications of shared conceptualizations, establishing a formal vocabulary of concepts, relationships, and constraints within a given domain to support clarity, consistency, and reuse across systems (Uschold; Grüninger, 1996). In Lean Construction, such approaches have been used to structure constraint-related information and support planning routines, particularly at the lookahead level (Mao et al., 2025). These developments demonstrate the capacity of digital systems to represent complex information structures when concepts are explicitly defined.

Digital representation in BIM-based systems is inherently selective, as only information explicitly defined within formal data structures can be represented and processed. BIM environments rely on predefined schemas to model objects, attributes, and relationships; consequently, meaning, behaviour, or intent are not captured unless deliberately formalized (Borrmann et al., 2018). As a result, representations tend to emphasize structured elements (such as geometry, quantities, properties, and predefined states), while aspects dependent on interpretation, rationale, or situational context require additional modelling effort or remain external to the model (Borrmann et al., 2018). This selectivity reflects the underlying logic of formal data models, which prioritize elements that can be explicitly structured and standardized. As a result, aspects of production that depend on interpretation, negotiation, and situational judgment — central to commitment-based planning — are not systematically represented unless deliberately encoded. This creates a structural misalignment between what digital systems are designed to capture and what the LPS requires to sustain learning across planning levels.

This limitation is particularly relevant for production control systems based on the LPS. Although digital tools increasingly support the visualization and monitoring of production status, these representations are typically centered on observable execution data, such as task completion and workflow states. The semantic content embedded in planning decisions — including the rationale behind commitments, negotiations, and trade-offs — tends to remain outside the digital model, residing instead in planning meetings or informal documentation. This limitation exposes a fundamental tension between the semantic requirements of the LPS and the representational logic of digital planning systems. While the LPS depends on work packages as carriers of meaning — including assumptions, commitments, and contextual conditions — digital representations predominantly capture operational states detached from the decision context in which commitments are formed.

PLANNING LEVELS AND SEMANTIC REQUIREMENTS IN THE LPS

The LPS is structured around multiple planning levels (master planning, phase planning, lookahead planning, and weekly work planning), each addressing different decision scopes and time horizons (Ballard, 2000). These levels are not independent layers of detail, but interconnected decision spaces in which upstream planning frames the conditions under which downstream commitments can be reliably made.

Within this structure, work packages evolve across planning levels. At higher levels, they are defined in broader terms, emphasizing scope, sequencing logic, and strategic constraints. As planning advances toward execution, these packages are progressively refined through constraint analysis and negotiation until they are released for execution. While their level of detail increases, their role as units of control remains unchanged. For the LPS to support reliable production and continuous improvement, the meaning embedded in work packages must be preserved as they are refined across planning cycles.

The literature emphasizes coordination mechanisms such as constraint removal, shielding, and the evaluation of commitment reliability (Ballard & Howell, 1998; Ballard, 2000). However, less attention has been given to how the assumptions, conditions, and decisions embedded in work packages are maintained when planning information is represented and exchanged digitally. Digital tools effectively propagate schedules, quantities, and status indicators across planning horizons (Choo et al., 1999), but provide limited support for representing the semantic content that underpins commitments.

This limitation exposes a tension between the requirements of the LPS as a system oriented toward learning and continuous improvement and the representational logic of digital planning systems. As a result, the mechanisms that sustain meaning across planning levels often remain external to the digital system, relying on informal coordination practices and tacit knowledge.

RESEARCH METHOD

This study adopts a qualitative analytical narrative review to examine how digital systems associated with the LPS represent production information and how such representations influence the potential for semantic coherence across planning levels. Rather than aiming for exhaustive coverage, the review focuses on developing an interpretative understanding of representational patterns and their implications for production control. This approach aligns with narrative review methodologies, which prioritize interpretation and theory-building over aggregation of evidence (Greenhalgh et al., 2018). Semantic coherence is operationalized as the ability of a system to maintain the identity, structure, and associations of production information across successive planning cycles, such as commitments, execution outcomes, constraints, and contextual conditions.

The selection of studies followed a purposive strategy, focusing on academic publications that explicitly describe digital systems designed to support LPS practices. Only studies

providing sufficient detail regarding how production information is structured, stored, and used within the system were included. Papers lacking explicit descriptions of their information models, data structures, or representational mechanisms were excluded. The objective was not to achieve completeness, but to capture representative examples of different approaches to digital representation within the LPS domain. The analysis includes studies from different periods to identify recurring representational patterns rather than to evaluate the current state-of-the-art.

Each system was analyzed individually based solely on information explicitly stated in the text, figures, or tables of the respective publications. No assumptions or external interpretations were introduced. The analysis was guided by a structured analytical protocol comprising four descriptive dimensions:

- (a) how work packages are defined and identified;
- (b) how location, process, and scope are represented;
- (c) how progress and constraints are captured; and
- (d) how deviations and their causes are recorded.

These dimensions were selected because they capture key aspects of how production information is defined, structured, and updated across planning cycles, providing a consistent basis for assessing the preservation and reuse of information required for commitment-based control. By comparing how these dimensions are implemented across the selected systems, the study identifies recurring representational patterns and examines their implications for how production information is structured and maintained across planning levels. Rather than evaluating these dimensions independently, they were interpreted jointly to assess the role assigned to status information within each system's information model. Particular attention was given to whether status operates as the primary object of representation or as an attribute associated with a structured work package, as well as to how information related to constraints, causes, and context remains linked to identifiable production entities across planning cycles.

WHAT DIGITAL LPS SYSTEMS ACTUALLY REPRESENT

WORK PACKAGE DEFINITION AND IDENTIFICATION

Across the analyzed systems, work packages are defined as units supporting planning and execution control, although their level of structuring varies. In KanBIM, they are composed of task groups filtered by maturity and readiness (Sacks et al., 2009; 2010; 2011). In VisiLean, tasks and operations are defined across phase, lookahead, and weekly planning levels (Dave et al., 2011; 2013; 2016). In the Excel-based LPS database, they correspond to individual Weekly Work Plan assignments represented as spreadsheet entries (Zaeri et al., 2017). Other systems define work packages as structured production entities linked to quantities, resources, and spatial units. WorkPlan defines them as quantified work associated with specific areas and prerequisites (Choo et al., 1999). IPS links activities to resource and information requirements (Chua et al., 1999; 2003), while LEWIS associates tasks with spatial, material, and resource data through classification systems (Sriprasert; Dawood, 2003). More recent systems, such as vPlanner (Emdanat et al., 2016), BIM-based LPS tools (Heigermoser et al., 2019; Schimanski et al., 2021; Lin; Golparvar-Fard, 2021; Sbiti et al., 2022), and ontology-based approaches (Mao et al., 2025), reinforce this structuring by mapping work packages to BIM entities, WBS structures, or ontologies. Despite these differences, work packages are predominantly defined as operational units linked to execution control, with limited explicit representation of the decision context in which they are created.

REPRESENTATION OF LOCATION, PROCESS, AND SCOPE

Location, process, and scope are represented across systems to support the organization and visualization of production activities. KanBIM combines process–location matrices with 3D BIM models to display work progression (Sacks et al., 2009; 2010; 2011), while VisiLean uses BIM models and visual boards to communicate production status (Dave et al., 2011; 2013; 2016). In spreadsheet-based systems, location is represented through work-area fields, and process information is embedded in task descriptions (Zaeri et al., 2017). In other systems, these dimensions are more explicitly structured. WorkPlan and IPS represent scope and process through activity definitions, hierarchical structures, and precedence relationships (Choo et al., 1999; Chua et al., 1999; 2003). LEWIS and BIM-based systems associate spatial and process information with tasks using classification systems, 4D models, or zoning approaches (Sriprasert; Dawood, 2003; Heigermoser et al., 2019; Lin; Golparvar-Fard, 2021; Schimanski et al., 2021; Sbiti et al., 2022). Ontology-based approaches formalize spatial relationships and constraints (Mao et al., 2025). Across systems, however, these dimensions are primarily used to organize and situate production activities rather than to preserve structured, reusable representations of work packages across planning cycles.

CAPTURE OF PROGRESS AND CONSTRAINTS

All analyzed systems capture progress and constraints as part of production control. KanBIM and VisiLean support continuous updates of task status, including indicators for readiness, execution, and stoppages (Sacks et al., 2011; Dave et al., 2014). The Excel-based LPS database records progress through binary completion status and manually listed constraints (Zaeri et al., 2017). Other systems use more structured data. WorkPlan records completion status, labor hours, and cost-to-date (Choo et al., 1999), while IPS monitors resource and information availability during scheduling (Chua et al., 1999; 2003). In LEWIS and vPlanner, progress is updated through reported quantities or simulation outputs, and constraints related to space, resources, and flow are analyzed using stored data (Sriprasert; Dawood, 2003; Emdanat et al., 2016). BIM-based systems capture progress through planned-versus-actual comparisons or automated field reporting linked to models (Heigermoser et al., 2019; Lin; Golparvar-Fard, 2021). Despite this variability, progress and constraints are predominantly represented as attributes of execution status, focusing on monitoring and control rather than on preserving the conditions under which work was planned.

RECORDING OF DEVIATIONS AND THEIR CAUSES

Deviations are commonly recorded across systems as differences between planned and actual performance. In several systems, such as WorkPlan, vPlanner, the Visual and Virtual Production Management System, BeaM!, and BIM-based integrations, deviations are documented alongside associated causes linked to work packages (Choo et al., 1999; Emdanat et al., 2016; Lin; Golparvar-Fard, 2021; Schimanski et al., 2021; Sbiti et al., 2022). Other systems capture deviations without fully formalizing causal information within the same data structure. IPS identifies uncertainties through screening and shielding mechanisms (Chua et al., 1999; 2003), while ontology-based approaches verify constraint violations without explicitly linking them to causal explanations (Mao et al., 2025). In systems such as KanBIM, VisiLean, and spreadsheet-based implementations, causes are recorded as annotations, predefined categories, or notes associated with task status (Sacks et al., 2011; Dave et al., 2014; Zaeri et al., 2017). Across systems, deviations and causes are primarily recorded as discrete events linked to execution outcomes, with limited support for maintaining structured relationships between causes, decisions, and subsequent planning actions.

Table 2: data-centric LPS systems

System	Work package definition	Location / process / scope representation	Progress & constraint capture	Deviation & cause recording
WorkPlan (Choo <i>et al.</i> , 1999)	Work packages defined as quantified amounts of similar work, associated with specific areas, resources, and prerequisites	Scope and process represented through package IDs, descriptions, and hierarchical planning structure; spatial logic supported in WorkMovePlan	Progress captured via completion status, labor hours, and cost-to-date; constraints explicitly listed and checked before release	Variance between planned and actual recorded; reasons for plan failure collected
Integrated Production Scheduler (Chua <i>et al.</i> , 1999; 2003)	Activities defined in lookahead planning with associated resource and information requirements	Process relationships explicitly represented through precedence logic; scope linked to activity definitions	Availability of resources and information monitored; constraints pulled into activities during scheduling	Uncertainties identified through screening and shielding mechanisms
LEWIS (Sriprasert; Dawood, 2003)	Tasks defined and classified using Uniclass; work associated with spatial and resource requirements	Location, materials, drawings, and suppliers linked to tasks; 4D visualization used to represent space and sequence	Constraints related to space, resources, and congestion analyzed through simulation	Deviations addressed through simulation outcomes; causes not explicitly formalized
KanBIM (Sacks <i>et al.</i> , 2009; 2010; 2011)	Work packages defined as groups of task types; tasks assigned and filtered by readiness and maturity	Location and process represented through a 2D matrix (process $\times$ location) and 3D BIM model	Task and work package status updated through Kanban states (e.g., ready, started, stopped, completed) via touch screens	Interruption reasons and stop events recorded and linked to task status
VisiLean (Dave <i>et al.</i> , 2011; 2013; 2016)	Tasks and operations defined at phase, lookahead, and weekly planning levels	BIM model used to represent spatial context; process flow supported by digital and physical visual boards	Task status updated in real time; constraints captured through predefined LPS flow categories and mobile inputs	Deviations and causes registered as task-level notes, stop symbols, and annotations
vPlanner Production Tracker (Emdanat <i>et al.</i> , 2016)	Labor production activities linked to subcontractors	Work locations associated with labor hours and quantities	Progress automatically updated based on reported quantities	Go-back work explicitly recorded
Excel-based LPS database (Zaeri <i>et al.</i> , 2017)	Weekly Work Plan tasks defined as individual assignments	Location represented through work area fields; process embedded in task descriptions	Progress recorded as binary status (done / not done); constraints listed manually	Causes of non-completion selected from predefined categories
BIM-based LPS prototype (Heigermoser <i>et al.</i> , 2019)	Activities decomposed from phase planning to weekly work planning	Zones, levels, and types represented via BIM attributes	Progress captured through PDCA-based planned vs. as-built comparison	Daily deviations between plan and execution recorded
Visual and Virtual Production Management System (Lin; Golparvar-Fard, 2021)	Work packages mapped from WBS and schedule activities	Spatial context represented through 4D BIM and reality capture models	Progress captured via field reporting and automated quantity tracking	Root causes of delays recorded
BeaM! (Schimanski <i>et al.</i> , 2021)	Processes transformed into assignable operations	Digital Kanban board linked to BIM viewer	Constraints captured during make-ready planning sessions	Root cause analysis integrated into planning stage

Table 2: data-centric LPS systems (continued)

System	Work package definition	Location / process / scope representation	Progress & constraint capture	Deviation & cause recording
Quantity surveying data and BIM (Sbiti <i>et al.</i> , 2022)	Processes and operations decomposed into planning units	BIM-based micro-zoning and integration with LPS routines	Progress and constraints captured via field application	Plan failures explicitly recorded
Space Constraint Management Ontology (SCMO) (Mao <i>et al.</i> , 2025)	Relationships between tasks and spatial constraints defined ontologically	Location represented via coordinates (X, Y, Z) and spatial topology	Spatial constraints dynamically verified	Deviations and causes not explicitly recorded

LIMITS OF SEMANTIC COHERENCE ACROSS PLANNING LEVELS

This analysis focuses on the representational capabilities of digital LPS systems, rather than on the ways in which organizations enact planning and control practices. While the reviewed systems differ in how they represent and store production information, none fully support the preservation of meaning associated with work packages as they move across planning levels. This section examines which types of information survive across planning cycles and which do not, thereby exposing the limits of semantic coherence in current digital LPS implementations.

Across the reviewed systems, the information that consistently traverses planning levels is limited to operational descriptors of production performance. Status values, planned and actual dates, and aggregated performance indicators are maintained and reused as signals of execution reliability. While these data support coordination and control across planning cycles, they do not convey the assumptions, decisions, or rationales that shaped the definition of work packages.

However, the ability of these systems to retain operational data does not extend to the preservation of the meaning underlying work packages. Information related to planning assumptions, decision rationales, and contextual judgments made during lookahead and commitment formation is rarely structured, stored, or reused across planning levels. Even when deviations and their causes are recorded, they are typically treated as event-level annotations, remaining attached to execution outcomes rather than informing the redefinition of future work.

Across the analyzed systems, interruption reasons, stop events, and causes of non-completion are recorded to explain execution outcomes, but are not described as inputs for revising work package definitions or planning logic in subsequent cycles (e.g., Sacks *et al.*, 2011; Dave *et al.*, 2014; Zaeri *et al.*, 2017). In other systems, variances, quantities, and failure reasons are stored at the work package level, yet similarly lack explicit mechanisms through which such information is reintegrated into higher-level planning constructs (e.g., Choo *et al.*, 1999; Emdanat *et al.*, 2016; Heigermoser *et al.*, 2019; Lin & Golparvar-Fard, 2021). As a result, causes are documented but do not alter the criteria used to define, size, sequence, or release work packages in subsequent planning cycles.

Ontology-based approaches further illustrate this limitation. The SCMO formalizes relationships between tasks and spatial constraints and enables the verification of constraint violations through explicit representations of space and topology (Mao *et al.*, 2025). While this improves the structuring of constraint-related data, it does not address how planning decisions, assumptions, or trade-offs associated with those constraints are captured or reused across planning levels. Semantic structure is thus applied to specific data domains, but not to the decision-making processes that give meaning to work packages within the LPS.

These findings indicate that differences across systems lie primarily in how production information is structured and stored, not in whether meaning is preserved across planning levels. Across all cases, the information that survives remains predominantly descriptive rather than

interpretive. Status, dates, and performance indicators are retained, whereas planning assumptions and decision rationales are not systematically represented.

Consequently, digital LPS systems fall short of achieving semantic coherence across planning levels. Although work packages are explicitly defined and enriched with associated data, the absence of mechanisms to structure and reuse decision-related information reveals a fundamental gap in current digital LPS systems: the lack of explicit representational structures capable of maintaining the meaning of work packages as units of control throughout long-, medium-, and short-term planning.

WHY DIGITAL LPS SYSTEMS REMAIN SEMANTICALLY BLIND

The findings presented in the previous sections indicate that the limitations observed in current digital LPS systems are not related to a lack of data, computational capacity, or analytical sophistication. On the contrary, these systems demonstrate a high level of maturity in capturing, storing, and visualizing production information. The issue lies elsewhere: in what these systems are able to represent and, more importantly, in what they systematically fail to represent.

The analysis shows that digital LPS systems are highly effective at representing elements that are operationally measurable and easily standardized. They excel at handling geometry, quantities, production status, and timestamps. These elements are consistently structured, stored, and reused across planning levels, supporting transparency, coordination, and control of production activities.

However, the same systems remain largely blind to the semantic dimensions of work packages. They do not explicitly represent why a package exists, how it was defined, or which assumptions supported its release. Decisions made during lookahead planning, trade-offs between alternatives, and contextual judgments that shape commitments are rarely structured as information that can be revisited or reused. As a result, when a work package moves across planning levels, its operational attributes are preserved, but its meaning is not.

This blindness is not accidental, nor a consequence of insufficient data collection. Rather, it reflects a representational choice embedded in current digital LPS implementations. By prioritizing transparency of production states and the structuring of operational data, these systems implicitly treat meaning and rationale as external to the information model. What is not explicitly represented cannot be systematically stored, queried, or reused.

This finding aligns with broader observations in the literature on digital systems in construction. As noted by Asmone et al. (2025), data-rich and evidence-poor systems do not suffer from measurement problems, but from representational ones. The results of this study reinforce that diagnosis in the context of the LPS: digital systems capture abundant data about what happened, but provide limited support for representing why it happened and how that information should inform future planning. While alternative interpretations may relate to procedural or organizational choices, this study focuses specifically on the representational capabilities of digital LPS systems as described in the literature.

IMPLICATIONS FOR DIGITAL LEAN AND RESEARCH

The results of this study do not point to incremental improvements in existing digital LPS tools, but to a structural gap with implications for both LPS practice and future research. The observed semantic blindness of current systems suggests that advancing digital support for the LPS requires a shift in representational focus, rather than additional layers of automation, visualization, or data collection.

First, digital LPS systems need to treat work packages as semantic units of control, not merely as containers for execution status or performance data. While current tools effectively

represent when work is planned, executed, or delayed, they provide limited support for representing why work is defined in a certain way and under which assumptions it is released. Without explicitly modelling these elements, digital systems remain confined to monitoring execution reliability, without preserving meaning as work packages move across planning levels. Second, the integration of BIM and LPS requires more than mapping objects to tasks or schedules. Although BIM-based systems enrich work packages with geometric, spatial, and quantity-related information, this integration mainly strengthens the representation of what is built and where it is executed. Object-to-task mappings alone do not capture planning rationale, decision logic, or contextual judgments embedded in LPS routines. As a result, BIM–LPS integration often increases data richness without improving semantic coherence across planning cycles. Third, the growing adoption of artificial intelligence and data-driven methods in construction planning reinforces the relevance of semantic structure. While recent studies highlight the use of machine learning and analytics to support prediction and decision-making, they also emphasize their dependence on data quality, consistency, and structure (Munawar et al., 2022). When applied to LPS environments in which work packages are weakly specified or represented mainly through status indicators, AI models risk reproducing patterns without access to the assumptions and decisions that give those patterns meaning. This aligns with broader evidence that data-driven technologies in construction struggle to deliver value when data are fragmented or poorly contextualized (Munawar et al., 2022), suggesting that investments in AI should be preceded by efforts to structure production information semantically. From a research perspective, these findings point to the need for representational frameworks that explicitly model work packages as carriers of meaning across planning levels. Rather than focusing solely on enhanced data capture or computational techniques, future studies should examine how planning assumptions and decision logic can be formally represented and maintained within digital LPS systems. This shifts digital LPS research beyond tool adoption and performance metrics toward a deeper understanding of how digital representations shape production control through their treatment of meaning.

CONCLUSION

This study examined how digital LPS systems represent production information and whether these representations support semantic coherence across planning levels. The results show that current systems effectively represent operational aspects of production, supporting transparency and execution control, but fail to preserve the meaning associated with work packages across planning levels. Information about planning assumptions, decision rationales, and contextual conditions is rarely represented in a way that can be reused. These findings suggest that semantic blindness in digital LPS systems is primarily associated with how production information is represented, rather than with limitations in data availability or computational capacity. Advancing digital support for the LPS therefore requires representational frameworks that explicitly treat work packages as semantic units of control across planning levels. However, the implications of those conclusions must take into account some important limitations of this study. It is based on a qualitative narrative review and does not aim for exhaustive coverage. The analysis relies on information explicitly reported in the literature and may not reflect how systems are implemented in practice, excluding tools without sufficient documentation. Future research should focus on empirical studies of how decision-related information is generated and reused in practice, as well as on developing representational frameworks that integrate planning assumptions and decision logic within digital LPS systems.

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