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VALUE STREAM MAPPING IN MACHINE ALLOCATION FOR CONSTRUCTION LOGISTICS – A CASE STUDY

Franz-Ferdinand Gloser[1], Jörn Welle[2], Nico Wursthorn[3], (Paul) Christian John[4], & Shervin Haghsheno[5]

ABSTRACT

Construction projects are frequently affected by coordination problems, unreliable information flows, and logistical disruptions. In construction SMEs, these issues become particularly visible in machine allocation, where limited resource pools, cross-site competition, and incomplete visibility of machine status can create waste and reduce planning reliability. This paper investigates the machine allocation process of a medium-sized construction company through an exploratory case study that combines Value Stream Mapping (VSM), detailed process reconstruction, and a follow-up survey of those involved in the process on perceived usefulness. The analysis shows that major bottlenecks arise from fragmented availability checks, insufficient transparency of maintenance status, weak return notifications, and repeated clarification loops across process participants. Based on these findings, improvement features were developed and discussed with the core process participants interviewed. The follow-up survey indicates that time-based visibility of machine availability, stronger links to construction schedules, and improved resource transparency are perceived as particularly useful. The results are primarily beneficial to practitioners, as they provide their dispatchers and on-site employees with an improved overview of the machinery fleet. The features should be aligned with the needs of the employees in order to have a positive impact on machine utilization rates.

KEYWORDS

Construction logistics, machine allocation, value stream mapping, information flow, lean construction

INTRODUCTION

Construction projects are frequently affected by disruptions in workflow, coordination, and logistics. Empirical studies show that average construction project delays (in Germany) have risen in the last years (BBSR, 2023). One cause of these delays are inefficiencies in construction logistics, which have a direct negative impact on construction progress and project deadlines (PwC, 2025). Such construction logistics delays tend to be embedded in operational processes

[1] PhD Student, Karlsruhe Institute of Technology (KIT), Institute of Technology and Management in Construction, franz-ferdinand.gloser@kit.edu, orcid.org/0009-0006-7692-6194
[2] Site manager, Implenia AG, Germany, joern.welle@gmx.de
[3] PhD Student, Karlsruhe Institute of Technology (KIT), Institute of Technology and Management in Construction, Germany nico.wursthorn@kit.edu, orcid.org/0009-0007-4146-808X
[4] PhD Student, Karlsruhe Institute of Technology (KIT), Institute of Technology and Management in Construction, Germany, christian.john@kit.edu, orcid.org/0009-0005-0648-9331
[5] Professor, Karlsruhe Institute of Technology (KIT), Institute of Technology and Management in Construction, Germany, shervin.haghsheno@kit.edu, orcid.org/0000-0002-0602-6370

where resources, information, and responsibilities intersect. In practice, one such process is machine allocation. If machines are not available at the right time, in the right place, and in the required condition, project execution is affected through waiting times, repeated coordination loops, short-notice changes, and non-productive resource accumulation (Tariq & Shujaa Safdar Gardezi, 2023).

From a Lean Construction perspective, such problems are not merely local operational inefficiencies. They indicate interruptions in flow, unreliable commitments, and non-value-adding activities as previous research has shown (Abdallah et al., 2024). Lean Construction has long stressed that production should be understood not only as transformation but also as flow and value generation (Koskela, 1992, 2000). Consequently, construction logistics must not be reduced to transport and storage alone. Rather, it includes the coordination of people, information, plant, equipment, and materials in support of production at the workface (Mossman, 2007). Supply Chain research shows that fragmented coordination and poor articulation of commitments create waste and reduce overall process performance (Vrijhoef & Koskela, 2000; Vrijhoef et al., 2001).

This broader view is especially relevant when machines are allocated across multiple sites under changing project conditions, resulting in interfaces and conflicts of interest with regard to machine efficiency and flow on the construction site. These challenges are particularly pronounced in small and medium-sized enterprises (SMEs)

Compared with larger companies, SMEs often work with smaller internal equipment pools, tighter resource constraints, and less formalized information infrastructures. In such settings, the allocation of machines is more vulnerable to incomplete visibility of availability, maintenance status, return dates, and competing site demands (Leimböck et al., 2024).

Machines in particular, with their high overhead costs, are a significant cost factor in this regard. Kraus (2026) illustrates that machine utilization in the German construction sector has shown a declining trend since 2022 and fell again in January 2026, underlining the practical relevance of improving allocation and utilization processes.

In machine allocation, this becomes visible when requests are incomplete, release information is delayed, maintenance conditions are uncertain, or dispatching decisions depend on repeated clarification between several actors.

Value stream mapping (VSM) is a promising method for making such process weaknesses visible because it supports a structured representation of information and resource flows and helps identify waste.

Lean Construction is not yet as widespread among SMEs in Germany as it is among larger companies, but here too it is clear that VSM is not often used regularly (John et al., 2025).

The existing literature primarily discusses VSM in relation to production trades, supply chains, and construction workflows more broadly, while internal machine allocation processes in construction SMEs remain underexplored (Arbulu & Tommelein, 2002; Bulhões et al., 2005; Espinoza et al., 2021). The specific interaction between site demand, dispatcher coordination, maintenance-related availability, and machine returns has not yet been sufficiently discussed from a Lean Construction perspective.

Against this background, the paper addresses the following research questions:

RQ1: *How can VSM be used to identify information-related bottlenecks and waste in the machine allocation process of a construction SME?*

RQ2: *Which features can be implemented to enhance information flows in the core machine allocation process identified in the VSM?*

The paper contributes in three ways. First, it shows a way to apply VSM to an internal machine allocation process in construction logistics. Second, it analyses this process through a Lean Construction lens focused on flow, constraints, and information reliability to identify the

problems in the whole process. Third, it derives and prioritizes improvement features based on an exploratory assessment.

LITERATURE REVIEW

LEAN CONSTRUCTION LENS

Lean Construction is based on the idea that all phases of a company's production process can be understood as a flow that should contribute to value creation (Koskela, 2000). From this perspective, waste arises when activities do not contribute to value creation or when flow is interrupted by waiting, unnecessary handling, poor coordination, or unreliable information (Koskela, 1992). For construction logistics, this means that the coordination of equipment, materials, people, and information must be designed to support reliable production at the workface (Mossman, 2007).In addition, Ballard & Howell (2003) stress that reliable workflow depends on planning and control systems that support pull, handoff quality, and commitment-based coordination. Construction supply chain research reinforces this view. Vrijhoef et al. (2001) interpret coordination problems through the language perspective and stress the importance of well-structured communication.

Vrijhoef & Koskela, (2000) further shows that waste is often generated by fragmented management and insufficient coordination across organizational boundaries. These arguments are highly relevant for machine allocation because the process depends on several interconnected commitments concerning need articulation, machine release, maintenance readiness, and dispatching feasibility.

VALUE STREAM MAPPING IN CONSTRUCTION

VSM was originally developed in manufacturing as a tool for visualising the current state of a process, identifying waste, and designing an improved future state (Rother & Shook, 2018). A research in the IGLC database shows that VSM is applied in many different areas. Bulhões et al. (2005) demonstrate that manufacturing-derived VSM can be transferred to construction by combining value stream and process-level analysis, thereby enabling continuous-flow considerations in construction settings. Similarly, the method has been adapted in construction to account for more variable, fragmented, and project-based process conditions (Pasqualini & Zawislak, 2005; Espinoza et al., 2021).

Cano & Rubiano, (2020) demonstrated that VSM can be used to analyse flow and waste in infrastructure projects to identify improvement opportunities. Bizarro et al., (2023) analyses the level of value adding by methods such as VSM in Brazilian construction companies and shows it is useful. Recent research has focused on analysing the design process in modular construction in Brazil. The study shows that VSM can identify opportunities for improvement with semi-structured interviews as well. (Cunha et al., 2025)

Further IGLC studies demonstrate that VSM can be used to map construction supply logistics, support process transparency, and reveal non-value-adding activities across workflows (Arbulu & Tommelein, 2002; Björnfot et al., 2011; Simonsson et al., 2012).

At the same time, successful applications of VSM in construction require careful preparation, the involvement of relevant process actors, and an explicit follow-up logic that translates identified waste into feasible improvement actions (Björnfot et al., 2011). This is especially important in settings where the process is shaped by multiple actors and several information interfaces, as is the case in machine allocation.

STRENGTHS AND LIMITATIONS OF VSM

The strength of VSM lies in its ability to provide a shared visual representation of material and information flows and to make waiting times, rework, communication gaps, and bottlenecks

visible (Simonsson et al., 2012). For construction settings, this visual and collaborative character is particularly valuable because it supports the joint understanding of fragmented processes and helps structure improvement discussions (Pasqualini & Zawislak, 2005).

At the same time, VSM has limitations. It is a static representation and cannot fully capture dynamic interactions, feedback effects, or process variability. Cano & Rubiano (2020) show that VSM can reveal workflow obstructions but benefits from complementary modelling when the causal interactions of waste are more dynamic. Similar limitations are noted in the broader VSM literature, which points to restricted detail, limited simulation capability, and challenges in analyzing complex future state scenarios (Braglia et al., 2009; Forno et al., 2014; Schmidtke et al., 2014).

For this reason, the present study uses VSM as the main analytical frame but complements it with more detailed process reconstruction for sub-processes and actor interfaces.

ANALYTICAL POSITIONING OF THE STUDY

Although the construction literature demonstrates that VSM can be adapted to project workflows, supply chains, and specific trade processes, there is still limited evidence on how it can be used to analyse internal machine allocation processes in construction SMEs. In particular, the interaction between site-based demand articulation, dispatcher decision making, maintenance related availability, and return logistics has not been sufficiently discussed. This paper addresses that gap by combining VSM with detailed process mapping and a user-oriented assessment of proposed improvements.

METHODOLOGY

A three-stage process was carried out in an iterative procedure. The study follows an exploratory case study design with a predominantly qualitative core and a complementary quantitative follow-up survey. This design was chosen because the machine allocation process had not yet been formalised in the company we analysed in a way that would allow direct measurement of all relevant information flows and bottlenecks. Exploratory case studies are well suited to such settings because they enable an in-depth understanding of complex process interactions within a real organisational context.

This methodological choice is consistent with IGLC-related case study work that combines interviews, process analysis, and visual documentation to investigate lean practices in context (Tezel et al., 2013; Kemmer & Marin, 2024). In addition, previous VSM applications in construction show the importance of close practitioner interaction and iterative development of current-state representations (Pasqualini & Zawislak, 2005; Björnfot et al., 2011; Espinoza et al., 2021). Before data collection, the relevant resource types within the supply chain were systematically identified and categorized. These include construction machinery, vehicles, and larger immovable materials such as container systems. The following three subsections describe the three-stage process that was used.

STAGE 1: QUALITATIVE PROCESS CAPTURE AND VALUE STREAM MAPPING

In the first stage, the machine allocation process was examined through semi-structured expert interviews with 13 participants from management, operational functions, and supporting units, including site managers, foremen, machine dispatching staff, warehouse or depot management, and additional stakeholders involved in procurement and administration. The company is an SME general contractor with approximately 100 employees that operates in the building construction sector. The purpose of this stage was to reconstruct the relevant information flows, resource flows, responsibilities, and recurring coordination problems across the process.

All participants in the process were involved in order to provide an accurate and comprehensive representation of the company-specific machine allocation process. The

interview data collected was used to create a shared representation of the current state of the process. To help illustrate and categorize the entire process, sub-processes were mapped out during the interview and visual tools like Post-its were used to highlight issues. VSM was used as the primary visualisation and analysis tool, supplemented by more detailed process descriptions for sub-processes that could not be adequately represented in the overarching diagram. These qualitative process descriptions were subdivided into management, core and support processes in accordance with DIN EN ISO 9241-210 (2020) in order to derive a detailed process architecture. This approach follows the construction-specific adaptation logic suggested by Pasqualini & Zawislak (2005) and Espinoza et al. (2021),who both highlight the need to tailor VSM to the characteristics of construction processes.

STAGE 2: IDENTIFICATION OF WASTE, BOTTLENECKS AND DEVELOPMENT OF IMPROVEMENT OPTIONS

In the second stage, the VSM and the detailed process descriptions were analysed to identify waste, information gaps, contradictory process perceptions, and bottlenecks. Particular attention was paid to the availability check, maintenance-related information, return notifications, and cross-site competition for machines. Based on these findings, improvement ideas were developed together with practitioners in and after the interviews in order to ensure practical relevance and organisational feasibility. This participatory development of improvement options reflects the logic of VSM as not merely a descriptive tool but as a basis for collaborative process improvement and future-state design (Björnfot et al., 2011; Rother & Shook, 2018).

STAGE 3: FOLLOW-UP SURVEY

In the third stage, the proposed process features were assessed through a follow-up survey with 10 core process participants, focusing on site managers and foremen. The aim of this stage was not to measure actual performance effects, but to obtain an initial assessment and prioritisation of the proposed functions from the perspective of the intended users. The functions represent ideas and variants that address the problems identified in the first interview.

The questionnaire design was based on the construct of perceived usefulness from the Technology Acceptance Model (Davis, 1989). As the proposed improvements included digitally supported planning and transparency functions, perceived usefulness was regarded as a suitable construct for an exploratory initial assessment. This choice is also consistent with later construction-related technology acceptance research (Sorce & Issa, 2021).

The survey comprised 18 items that could specifically address the identified problems across the entire information flow. These were rated on a five-point Likert scale ranging from 1 (‘strongly disagree’) to 5 (‘strongly agree’). Mean and median values were calculated as descriptive indicators. In addition, a ranking system was used to prioritise selected functions in alphanumeric order.

RESULTS

CURRENT-STATE PROCESS AND KEY BOTTLENECKS (STAGE 1)

The qualitative analysis shows that machine allocation is shaped by a dense network of interactions between site managers, foremen, dispatchers, workshops, depots, and supporting units. A coherent overall representation of these processes proves challenging due to the diverse personnel relationships and the complex information and decision-making structures involved. By combining the statements and descriptions collected, the machine allocation process can be represented using a VSM, as illustrated in Figure 1. In this process, the dispatcher occupies a central coordinating position because requests, availability checks, return information, and

maintenance-related status updates converge in this position. At the same time, the dispatcher's decisions depend on information that is distributed across several actors and is not always available in a timely or reliable form.

The findings indicate that the availability check is the most critical process stage. To allocate a machine reliably, the dispatcher requires up-to-date information on stock, current deployment, technical condition, maintenance status, and expected release times. In practice, this information often has to be gathered repeated contacts, telephone calls, list checks, or ad hoc clarifications. This creates repeated coordination loops within the organizational units and extends the effort required before an allocation decision can be made. A second major bottleneck concerns maintenance and inspection status. In several cases, the condition of a machine only becomes fully clear when checks or repairs begin, meaning that apparent availability may later prove unreliable. A third recurring bottleneck is related to return and release information from sites. If a machine is not reported as released or if the expected release date is uncertain, subsequent allocation decisions are based on incomplete assumptions. In addition, machines may remain on sites longer than necessary, reducing transparency and flexibility for reallocation.

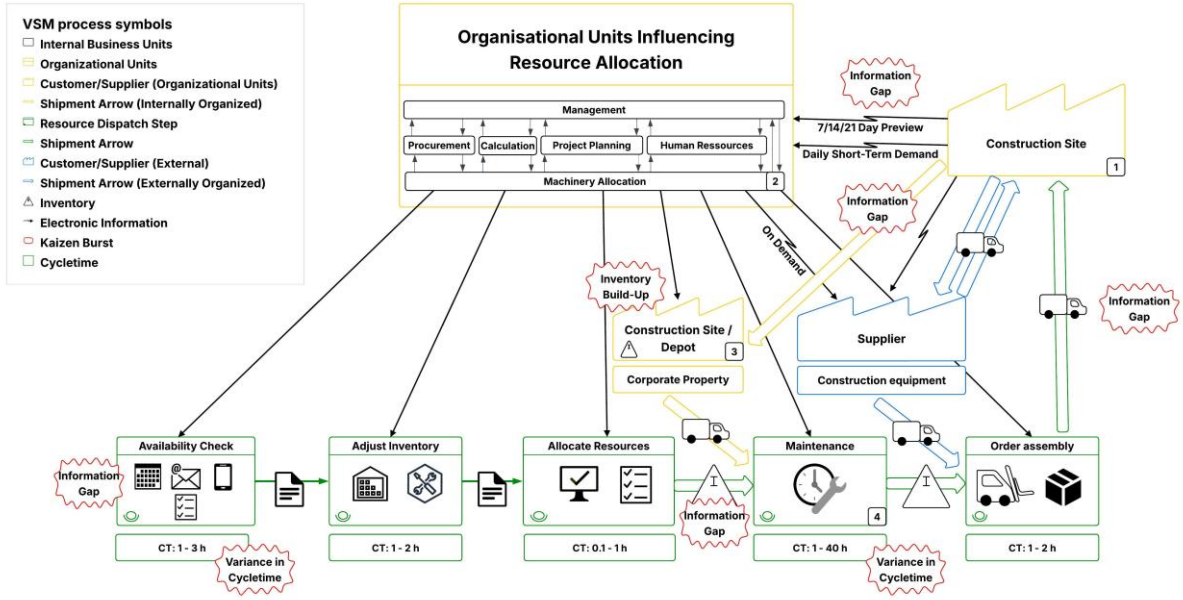

Figure 1: Value Stream Map of machine allocation

From a Lean Construction perspective, these findings point to a combination of flow interruptions, weak information reliability, and constraint-related uncertainty. They also echo earlier arguments that fragmented coordination across interfaces leads to waste and reduced reliability (Vrijhoef & Koskela, 2000; Vrijhoef et al., 2001). The present case further shows that such coordination problems are not only inter-organisational supply chain issues but can also appear within internal construction logistics processes when information quality is insufficient.

IMPLICATIONS FOR PROCESS IMPROVEMENT (STAGE 2)

Based on the identified bottlenecks, the future-state considerations focused on improving information transparency at the points where allocation decisions are made. Three improvement directions emerged as particularly relevant.

First, the process requires a transparent overview of available resources across sites and storage locations. Second, allocation decisions would benefit from time-based visibility of availability, including current use, expected release, and maintenance status. Third, the process

should be linked more closely to construction schedules and short-term site requirements in order to improve planning reliability.

From a process architecture perspective, the findings suggest that machine allocation should be structured as a core process supported by clearly defined information interfaces with management and support functions. This interpretation is consistent with the literature on process-oriented VSM use in construction and with the need to align information and resource flows across organisational boundaries (Pasqualini & Zawislak, 2005; Björnfot et al., 2011).

FOLLOW-UP SURVEY FINDINGS (STAGE 3)

The follow-up survey indicates broad support for the proposed process features. Among the fundamental functions of machine allocation, feedback on approved resources and the relevance of delivery time received the highest ratings, as shown in Table 1. These were described by the survey participants as fundamentally essential, so no ranking is provided here. This suggests that process participants primarily value functions that reduce uncertainty in ongoing coordination.

For functions supporting the determination of resource requirements, the visualisation of the construction schedule and the visualisation of bill of quantities related needs were ranked highest, both with an average rank of 1.7. This indicates that process participants see the strongest benefit in functions that connect machine allocation more closely to planned site execution.

Table 1: Results of the proposed process feature

Proposed Process Features	**Rating 1 (Low) to 5 (High)**		**Ranking 5 (Low) to 1 (High)**
	Mean	Median	Average rank
Fundamental functions of resource allocation			
Calendrical visualisation to support the planning	4	4	
Catalogue-based view on the resources to collect and order	3.7	4	
Feedback of the approved resources	4.5	4.5	
Information of the delivered resource	4	4	
Relevance of the delivery time	4.5	5	
View of the actual resources on the construction site	3.6	3.5	
Functions to support the determination of resource requirements			
Visualisation of the construction schedule	3.2	3	1.7
Visualisation for the bill of quantities as a bar in the timetable over the requested resources	3.4	4	1.7
Visualisation of the subcontractor services	3.8	4	2.8
Visualisation of the authorised change orders	3.5	4	3.8
Functions for visualisation of factors influencing availability			
Overview of the entire resources inventory	3.2	3.5	2.4
Visualisation of the stock with a time-based availability	3.5	4	2.8
Estimated duration of use at other construction site	3.7	4	3.3
Insight into the technical specifications, such as datasheets	3.3	3.5	5.1
View on the currently not available resources due to maintenance and repairs	3.8	4	5.3
Actual construction site of the currently not available resources	3.3	4	5.4
Information for the next maintenance appointment	3.8	4	5.5
information about other construction site had requested the same resource	3.3	3.5	6.2

For functions visualising factors that influence availability, the best average rank was assigned to the overview of the entire resource inventory (average rank 2.4), followed by the visualisation of stock with time-based availability (average rank 2.8). This finding is significant because it shows that users value a general static overview of available resources, and that real-time transparency regarding machine availability is only marginally less relevant, particularly when it comes to allocation decisions.

Taken together, the survey results suggest that the proposed features are perceived as useful mainly because they reduce information uncertainty in the early allocation steps. This does not yet demonstrate actual performance improvements, but it does indicate where implementation efforts are most likely to be accepted by intended users. In this respect, the findings support previous construction VSM studies that use visual transparency as a lever for improvement while also pointing to the need for later implementation-based evaluation (Björnfot et al., 2011; Espinoza et al., 2021).

DISCUSSION OF CONTRIBUTION

The study contributes to Lean Construction in three ways. Firstly, it applies VSM to an internal machine allocation process in construction logistics, thereby extending its scope beyond the more commonly studied workflows within trades or external supply chains. Secondly, it demonstrates that information-related waste plays a central role in the internal coordination of machinery. In this case, waste arises not only from physical flow problems, but also from incomplete availability information, uncertain maintenance statuses and inadequate feedback. Thirdly, the study demonstrates how an analysis of the current state can be translated into practical improvement priorities through an exploratory follow-up assessment.

At the same time, the study's significance could be further improved. This study does not provide before-and-after performance data on key metrics such as the lead time for availability checks, the number of contacts per enquiry, the lead time for allocation, or the frequency of conflicts. Such metrics would be of great value for future research and would enable a more robust assessment of whether the proposed improvement measures actually reduce process waste and improve reliability.

Beyond the immediate case, the findings are discussion-worthy because they suggest that machine allocation problems in construction should not be understood only as scheduling or dispatching issues. Rather, they represent a coordination problem at the intersection of logistics, information reliability, and operational decision-making. In Lean Construction terms, the observed waste is therefore not limited to physical waiting or unnecessary transport. It also appears in the form of repeated clarification loops, uncertain commitments, delayed release signals, and missing status transparency. This widens the discussion on construction logistics by showing that internal information interfaces can be just as critical for flow reliability as external supply interfaces.

The study also highlights an important methodological tension. VSM was highly useful for creating a shared current-state representation and for making hidden coordination problems visible. However, the case also shows the limits of VSM when the process is shaped by dynamic availability changes, informal workarounds, and distributed responsibilities. A static map can reveal bottlenecks, but it cannot fully represent the temporal volatility of requests, changing site priorities, or the organisational negotiation that often precedes allocation decisions. For this reason, the additional detailed process reconstruction was not only a supplement but a necessary extension of the VSM logic. This can be relevant for future IGLC-related studies that aim to analyse internal logistics processes with high variability.

A further point concerns implementation. The survey indicates that greater transparency is perceived as useful, but usefulness should not automatically be equated with feasibility or actual improvement. Functions such as time-based availability, maintenance visibility, or stronger

links to construction schedules may only create value if the underlying data are updated reliably, responsibilities for data entry are clear, and process participants trust the system sufficiently to use it in everyday coordination. Otherwise, digital features may add another layer of administrative effort without reducing the original uncertainty. Especially in SMEs, the practical challenge is therefore not only to identify useful features, but to implement a level of process formalisation that improves decision quality without overcomplicating routine work.

The transferability of the findings should also be discussed critically. The identified bottlenecks are plausible for many construction settings in which resources are shared across sites, maintenance status is uncertain, and planning horizons are short. However, their exact configuration is likely to depend on company size, degree of digitalisation, fleet structure, centralisation of dispatching, and the stability of project planning. The case points to recurring categories of waste and coordination problems, but not to a universal solution design. This is why future comparative work across several companies would be particularly valuable. It could show which problems are structurally typical for machine allocation in construction logistics and which are shaped primarily by company-specific routines.

CONCLUSION

This paper analysed the machine allocation process of a medium-sized construction company in Germany through an exploratory case study combining semi-structured interviews, value stream mapping, detailed process reconstruction, and an exploratory follow-up survey on perceived usefulness. The findings show that major sources of waste are related to fragmented information transfer, insufficient visibility of machine status and availability, and weak feedback loops between construction sites, dispatching, maintenance, and depot functions.

The study further indicates that process improvements should focus particularly on transparent resource overviews, time-based availability information, maintenance visibility, and stronger links between allocation decisions and construction schedules. The follow-up survey suggests that such features are perceived as useful by core process participants and are therefore promising candidates for implementation.

In this respect, the paper's main contribution is the structured demonstration that internal machine allocation can be analysed as a Lean Construction problem of flow, information quality, and coordination reliability. By combining VSM with detailed process reconstruction, the study shows how fragmented operational knowledge can be translated into a shared understanding of the current state and into a focused set of improvement priorities. This is particularly relevant for SMEs, where even comparatively small deficits in transparency can have disproportionate operational effects because resource buffers are limited.

The findings should, however, be interpreted considering the study's limitations. The research is based on a single case study. The qualitative process reconstruction depends on the perspectives of the interviewed participants, and the follow-up survey involved only 10 respondents. In addition, the survey measured perceived usefulness rather than actual performance effects. Thus, the results should be interpreted as exploratory and should not be generalized without further validation.

Future research could test the proposed features in practice and assess their effects using defined process indicators such as availability-check cycle time, number of contacts per request, allocation lead time, incomplete request frequency, and conflict frequency caused by missing or unreliable information. Comparative case studies across further company settings would also help clarify which bottlenecks are context-specific and which represent recurring patterns of machine allocation in construction logistics.

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