

UNDERSTAND THE RELATIONSHIPS BETWEEN COMMUNICATION BEHAVIORS AND TEAM PERFORMANCE IN LAST PLANNER SYSTEM IMPLEMENTATION

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ABSTRACT

Drawing on sociotechnical systems theory, the effective implementation of the Last Planner® System (LPS) requires the motivation and empowerment of individuals to collaborate effectively. To improve LPS implementation performance, it is necessary to examine how social mechanisms within LPS influence team performance, with particular attention to social interactions. Although prior case studies suggest that certain communication behaviors may be associated with LPS performance, their analyses often involve substantial uncertainty and limited capacity to isolate and quantify behavioral effects. To address this gap, this study conducted an immersive virtual reality (IVR) experiment, where LPS was implemented while minimizing involvement of potentially confounding factors, thereby exclusively examining the association between communication behaviors and team performance. Correlation and regression analyses indicate that frequency of formative communication was positively correlated with team performance, while negotiation and identification behavior were the two strongest predictors. These findings provide empirical grounding for improving commitment management system (CMS) and for developing behavior-based machine-learning models to predict team performance in LPS contexts.

KEYWORDS

Last Planner® System, collaboration, language action perspective, performance, immersive virtual reality.

INTRODUCTION

The Last Planner® System (LPS) is a production planning and control tool grounded in core Lean principles. It enhances the reliability and predictability of planning by reducing workflow variability, strengthening commitment management, adopting pull-based planning, and promoting continuous learning (Ballard, 2000). From the perspective of sociotechnical systems theory, the implementation of LPS inherently triggers a dual transformation in project management paradigms (Liu et al. 2025; Saurin & Rooke, 2020). First, it generates technical dynamics, including higher levels of organizational integration, decentralized decision-making

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structures, flexible and transparent communication channels, and bottom-up workflow control. Second, it induces social dynamics, stimulating the reconstruction of team cognition and the evolution of behavioral patterns (González et al., 2015). Effective LPS implementation therefore requires not only the adoption of tools and processes, but also the motivation and empowerment of individuals to collaborate effectively. To fully realize the potential of LPS, it is necessary to examine the social mechanisms that LPS engenders in project, with particular attention to how LPS emergent team interactions and psychological states contribute to enhanced teamwork and improved project outcomes (Asadian & Leicht, 2022; Liu et al., 2025). Such insights can provide valuable guidance for advancing LPS implementation performance.

One of the major social mechanisms warranting investigation is the relationship between social interactions and team performance (Castillo et al., 2018; Retamal et al., 2022). Traditional research typically examines a set of projects managed with the LPS and assesses communication behaviors and performance using questionnaires, interviews, or project documentation to determine how LPS-related behavioral indicators influence performance outcomes, such as percentage plan complete (PPC) and key performance indicators (e.g., cost, wastes, and time). (Asadian, 2023; Castillo et al., 2018; Priven & Sacks, 2015; Retamal et al., 2022). However, this case study-based approach has notable limitations for examining the relationship between communication behaviors and team performance: (1) it affords limited control over contextual factors (e.g., heterogeneous team composition) and extraneous influences (e.g., team member turnover), which may confound observed relationships, thereby reducing the robustness of the findings; and (2) it often depends on self-reported, or document-derived measures that are susceptible to recall errors and subjective biases.

Thus, there is value in employing experiments and objective data-collection approaches to quantify linkages between communication behaviors and team performance. This study addresses this gap by using immersive virtual reality (IVR)-based experiments in conjunction with objective video analyses to identify and quantify relationships between communication behaviors and performance metrics (i.e., wastes and PPC). The findings are expected to provide empirical guidance for LPS practitioners seeking to enhance implementation performance and to inform researchers developing near real-time monitoring tools for use during coordination meetings.

COMMUNICATION IN LPS-BASED COORDINATION MEETINGS

Evidence from LPS studies suggests that reliability in production planning and schedule performance can be improved when teams use coordination meetings to conduct commitment-oriented conversations (Priven and Sacks 2015; Viana et al. 2017). LPS-based coordination meetings present valuable opportunities to observe the impact of communication on team performance in a project. Therefore, rigorous analysis of communication requires a typology that separates recurrent behavioral patterns observed in coordination meetings.

Reijswoud and Dietz (1999) distinguished two primary modes of interaction: performative actions and informative actions. Performative actions are speech acts that are oriented towards initiating or advancing action (Reijswoud & Dietz, 1999). Beyond transmitting task-related content, they also function relationally: even a simple request can signal underlying intentions and mutual social expectations among the interacting parties (Goldkuhl, 2006). From this perspective, coordination talk can be represented using a commitment-loop structure in which two roles—typically a client and a performer—engage in paired obligations, as so-called language action perspective (Flores & Ludlow, 1980). Medina-Mora et al. (Medina-Mora et al., 1992) described this loop as a sequence of four phases: (i) request, (ii) negotiation, (iii) execution, and (iv) evaluation. The process begins when the client articulates the requirement

to the responsible party. The negotiation phase comprises dialogue that settles the conditions of satisfaction and the schedule under which delivery is expected. The execution phase covers the implementation of the agreed requirement and the performer's declaration that it has been completed (Searle, 1969). The loop culminates in evaluation, where the client reviews the delivered work, signals acceptance (or non-acceptance), and provides feedback; this judgement is made by comparing the outcome against the pre-specified conditions of satisfaction and the client's initial expectations (Searle, 1969). Informative actions, by comparison, prioritize informational content and are not primarily concerned with the motivational or commitment aspects of action (Goldkuhl, 2006). In this category, Viana et al. (2017) further delineated three interaction forms: information sharing among meeting participants, recommendations about how tasks should be performed, and identification of practices that workers should adopt or avoid.

A considerable body of literature have employed in-situ observations and multi-case comparative analyses to explore the relationship between communication behaviors and project performance. For instance, Castillo et al. (Castillo et al., 2018) adopted social network analysis to analyze the communication patterns in nine construction projects and found that the network average degree of total interaction and information sharing were associated with improved PPC and reduced accident severity. Retamal et al. (2020) investigated four construction projects and reported correlations between the ratio of negotiation and request with PPC. Similarly, Salazar et al. (2022) developed a Commitment Management System (CMS) to monitor Language action perspective-based indicators (e.g., percentage of fulfillment of request) and observed increasing trends in these indicators alongside decreased delays across two projects. Building on this work, Retamal et al. (Retamal et al., 2022) implemented this system across four projects and found that increases in compliance with negotiations and fulfilment of requests were positively associated with PPC metrics. Asadian (2023) compared information sharing behaviors and PPC data in weekly work plan (WWP) meetings in three LPS-based projects, suggesting that teams with higher PPC value exhibited a lower number of information sharing behaviors.

These studies underscore a growing consensus that communication and collaboration are integral to effective LPS implementation and project performance. However, this body of work was centered on the project as a whole, with variables typically measured at the project level, limiting fine-grained insight into team-level behaviors. The effects of performative and informative actions on team performance in LPS-based project still remain unclear. This gap likely stems from the prevailing reliance on case study methods. Firstly, the case study approach, while rich in contextual detail, typically lacks the static rigor necessary for examining the relationship between behaviors and team performance. Many studies, including those by Asadian (2023) and Viana et al. (2017), the absence of control groups or random assignment limits the comparability and repeatability of findings. Secondly, confounding factors—such as differing LPS maturity levels, team compositions, or team member turnover—were rarely controlled, making it difficult to interpret the associations between specific team behaviors and performance metrics. Thirdly, these studies majorly relied on project documents, interviews, and interviews, which might have retrospective and subjective biases in collecting behavior and performance data.

As a response to these limitations, there is a compelling need to explore alternative research designs that enable more robust methods to examine the relationships between communication behaviors and team performance. One such approach is the use of experiments and video analysis, which allow for objectively measure the communication behavior and control key variables while maintaining external and internal validity. This method enables researchers to more rigorously assess the relationship between specific team behaviors and team performance outcomes.

Immersive virtual reality (IVR) has been increasingly adopted in construction engineering and management (CEM) to support controlled experimental investigations. A common methodological approach is to combine IVR with video recording, enabling researchers to capture participants' observable actions and task performance in a standardized and reviewable manner (Li et al., 2022). These IVR-based research has focused primarily on (1) investigating evacuation behavior in indoor earthquake and post-earthquake evacuation (Feng et al., 2022); (2) assessing workers' safety behavior in construction site (Gao et al., 2021); (3) predicting worker's inattentive behaviors during a construction task (Kim et al., 2021). However, much of the existing IVR-based work has primarily examined behavioral responses at the individual level, while comparatively limited attention has been paid to measuring and analyzing team or group-level social behaviors.

Recently, Liu et al. (2024) developed the multiuser immersive virtual reality-based LPS simulation game (MILPS), a IVR platform designed to simulate LPS implementation in construction project planning and control. Following that, their experimental study compared social interactions in traditional (non-lean) planning condition and an LPS-based condition using Bales' interaction process analysis. The findings indicate that MILPS can capture salient group-level social interactions observed in real-world coordination meeting while maintaining internal and external validity (Liu et al. 2024, 2025a). They also noted that the Language action perspective-based coding framework could offer a richer behavioral taxonomy for MILPS, enabling a more comprehensive representation of team interaction processes during coordination meetings. Although prior work suggested that the performative and informative actions may associated with team performance (Liu et al., 2024), these linkages were not empirically tested in the MILPS experiments. This gap motivates the present research. By integrating MILPS-based experimentation with systematic video-based behavior coding, this study aims to examine the impact of communication behaviors on team performance in LPS-based coordination meetings.

RESEARCH METHODS

IVR ENVIRONMENT

The environment in MILPS simulates a sidewalk construction project, which required participants to complete a sidewalk consisting of three different zones as soon as possible, with the highest accuracy and maximum level of PPC. The MILPS simplifies practical construction working and planning tasks. It supports at least three participants to collaboratively make a plan, order materials and arrange delivery, and construction. The prototype consists of three characters: the manager, subcontractor, and supplier, with each character having specific responsibilities. In general, the manager is responsible for creating the plan and ensuring that construction works are completed as planned. The subcontractor is responsible for ordering materials and carrying out the construction tasks, following the provided designs and planning details from the manager. The supplier's role is to produce and deliver materials to the subcontractor based on the manager's plan. Figure 1 presents layout of four areas in the MILPS environment. The construction area has a sidewalk and stock where subcontractor can perform paving tasks. The meeting area has planning and progress boards, which are used to make plans and review the construction progress during meetings. The production area incorporates a workstation, which allows the supplier to order materials. The delivery area has a delivery machine enabling the supplier to deliver materials in batches.



Figure 1: Layout of the MILPS environment

EXPERIMENT SETUP

The experiment was designed to include groups of three participants, each of whom participated simultaneously. The MILPS was accessed using the Meta Quest 3, and a desktop. The graphics output of the Meta Quest 3 was casted to the desktop screen, enabling researchers to observe and record participants' behavior. The OBS studio (<https://obsproject.com>) was installed on each desktop to record the Meta Quest 3's screen and voice.

Participants were organized into groups of three, with each group being randomly assigned. To maximize the sample size and facilitate the coordination of group experiments, this experiment exclusively recruited university students (Arnett, 2008; Saucier et al., 2015). To ensure the sample reflects real-world scenarios, only students from construction management, civil engineering, or related disciplines were recruited, as other students may lack relevant knowledge and experience in construction (Comu et al., 2014; Du et al., 2018, 2019). As a result, a total of 90 participants (51 females, 39 males) were recruited. The survey results show that while some participants have limited industry experience, a significant number across various disciplines possess substantial work experience. Participants' prior Lean knowledge was assessed using a 5-point scale, revealing substantial variability: 26% reported very low knowledge, 37% low knowledge, and 34% moderate to very high knowledge. Experience with video games and IVR was also measured on a 5-point scale; the mean score of 1.35 indicates that most participants had limited prior exposure to these technologies.

Once the demographic survey was complete, participants were randomly assigned into 30 groups. To prevent confusion, the researchers provided a comprehensive explanation of the environment and procedures, encouraging participants to ask questions before beginning. While participants were told they would see their performance results, they were also informed that facilitators would not offer any strategic advice or hints during the trial. This ensured that participants relied solely on their own understanding of the simulation.

The experiment followed a four-step structure: (1) Briefing: A standardized video introduction ensured every group received identical information. (2) VR trial: A 15-minute individual session allowed participants to adjust to the headsets and virtual environment. (3) Group training: Teams practiced on a simplified version of the task to learn the controls and

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identify any issues with motion sickness. (4) Formal experiment: After a 10-minute review of the rules, participants completed the 21-minute experiments.

The duration of the game was limited to 21 min and was broken down into a “three-week” construction simulation, each lasting 7 min. Except for the first week, each “week” contained a 2-min weekly work plan stage, followed by a 3-min construction stage, where participants could complete their tasks as planned. Lastly, all participants were required to start a 2-min review meeting to check their work and start the next “week.” A typical 1-week simulation storyline is outlined in Figure 2. The MILPS were designed to allow for observation of behaviors in these stages. Participants could make any decisions and behave as saw fit.

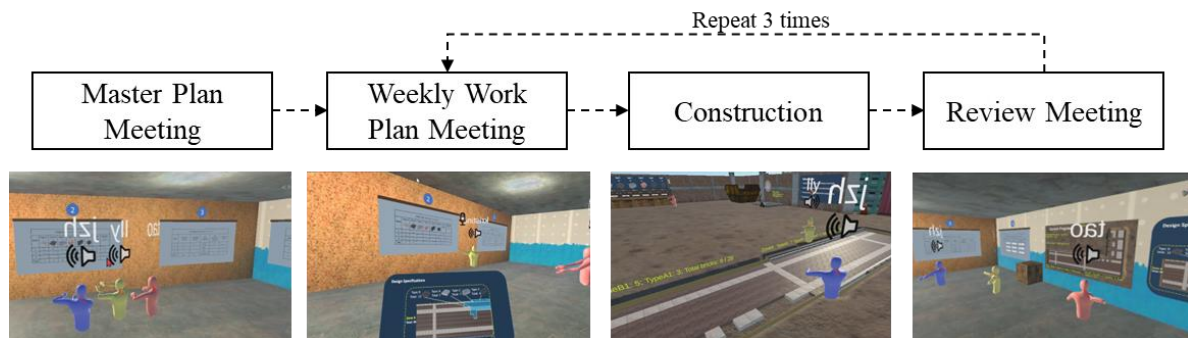


Figure 2: The typical storyline of MILPS

MEASURES

To monitor the team performance, MILPS system automatically logged idle time, resource waste, and average PPC. In addition, the OBS studio recorded communication behaviors among participants during master plan meeting, weekly work plan meeting, and review meetings. The performances and behavior measures with their definitions are presented in Table 1 and 2.

Table 1: Communication variables for the experiments

Categories	Variables	Description
Performative action	Request	The number of coded instances in which a performer requests an action according to a condition of satisfaction.
	Negotiation	The number of coded instances in which participants intended to establish the conditions of satisfaction for performing an action.
	Evaluation	The number of coded instances in which a performer declares the completion of an action and the requester evaluates that action.
Informative action	Recommendation	The number of coded instances in which participants provide advice or suggestions regarding how an action should be performed.
	Information sharing	The number of coded instances in which participants exchange information without proposing the performance of an action.

Identification	The number of coded instances in which participants identify good or bad practices in project execution.
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Table 2: Performance variables for the experiments

Categories	Variables	Description
Waste	Idle time	The subtraction of actual working time from the total duration of the construction stage.
	Resource waste	The number of bricks produced but not used.
PPC	Average PPC value	The ratio of completed tasks to planned tasks, divided by three.

To provide a fine-grained account of team communication, we performed individual-level coding using each individual's video record as a separate analytic unit. Only segments from the coordination meeting were included—specifically the master planning, WWP, and review meeting stage. We designed a coding framework to describe salient features of the observed communication behaviors (Table 1). Specifically, each discrete speech act that aligned with a defined category was coded as one instance, and all instances were treated equally regardless of their conversational depth or duration. This frequency-based approach was selected because the simulated coordination meetings were highly time-constrained (e.g., 4-minute meetings per week), which typically elicited rapid, discrete exchanges rather than prolonged and deep discussions, making frequency a reliable indicator for examining the relationship between communication behavior and performance in the MILPS setting (Liu et al. 2025). The framework comprised three performative action codes (request, negotiation, evaluation) and three informative action codes (information sharing, identification, recommendations). We did not code the execution because construction activities were not enacted within the meeting context. Two research assistants, trained in the protocol and aligned through discussion of the coding rules, independently coded the selected video data. To evaluate coding consistency, we calculated inter-rater reliability on a random subset of five teams; Cohen's kappa values demonstrated satisfactory agreement across categories ($\kappa \geq 0.70$).

The average PPC value, resource waste, and idling time were three measures of team performance. In this paper, every activity represents the completion of one brick slot on the pavement place. To calculate the weekly PPC value, this actual number of completed slots was divided by the planned number of brick slots to be completed that week. The average PPC value for each group was obtained at the end of the third week. Resource waste was quantified as the number of bricks produced that were not incorporated into construction. In this simulation, idling typically occurs when a subcontractor is waiting for materials delivery, referring it to waste as this is a nonvalue-added activity. The idling time was determined by subtracting the subcontractor's actual working time from the total duration of the construction stage.

ANALYSES

As an initial step of the data analyses, we computed Pearson product-moment correlation coefficients among all pairs of the variables described above. Following the correlation exploration, we conducted multiple linear regression analyses to predict performance metrics from communication behaviors. Following that, we built separate regression models for each of the four performance outcomes as the dependent variable (DV): (1) Model A: idle time (DV) regressed on all six communication variables; (2) Model B: resource waste (DV) regressed on all six communication variables; (3) Model C: averaged PPC (DV) regressed on all six

communication variables. Variance inflation factors (VIFs) were examined, suggesting no severe multicollinearity.

By using multiple regression, we can estimate the unique contribution of each communication behavior to the performance outcome while controlling for the influence of other behaviors. This helps us understand which specific aspects of team communication have significant predictive power for project performance, beyond simple pairwise correlations.

RESULTS AND DISCUSSION

As shown on Table 3, the correlation pattern indicates that most informative actions were positively correlated with average PPC ($r_{\text{recommendation}} = 0.60, p < 0.05$; $r_{\text{identification}} = 0.58, p < 0.05$) and negatively correlated with idle time ($r_{\text{recommendation}} = -0.35, p < 0.05$; $r_{\text{identification}} = -0.30, p < 0.05$). A possible interpretation is that high performance teams engaged more actively in diagnosing reasons for non-completion, identifying and learning from effective or ineffective practices, and offering suggestions for continuous improvement. Notably, information sharing was not correlated with average PPC. This may reflect the fact that information sharing is the dominant communication behavior in coordination meetings (Liu et al., 2024), and can encompass both value-adding exchanges that enhance transparency and redundant or negatively framed information that does not translate into improved planning reliability.

In contrast, most performative actions exhibited consistently weak correlations and non-significant regression effects (with the exception of negotiation). One interpretation is that performative actions represent essential, routinised communication required to complete planning tasks (Liu et al., 2024). Many teams followed similar structured communication patterns. These statements (e.g., request and evaluation) may occur as procedural or ceremonial confirmations rather than information that improves coordination. This pattern underscores the potential importance of less structured, informative communication for enhancing team performance. Interestingly, negotiation, although categorized as a performative action, showed a positive association with average PPC ($r_{\text{negotiation}} = 0.55, p < 0.05$) and a strong negative association with idle time ($r_{\text{negotiation}} = -0.78, p < 0.05$). A plausible explanation is that negotiation carried more consequential content than other performative actions, supporting teams in aligning constraints, clarifying commitments, and establishing executable plans.

Regarding resource waste, only identification was negatively correlated with this outcome ($r_{\text{identification}} = -0.25, p < 0.05$). One explanation is the limited variability in waste across the 30 groups ($M = 2.39, SD = \pm 2.12$), which reduced statistical power and made it more difficult to detect reliable associations with behavioral measures.

Table 3: Pearson correlation coefficients among communication and performance metrics

Categories	Variables	Idle time	Resource waste	Average PPC value
Performative action	Request	-0.45	-0.23	+0.30
	Negotiation	-0.78*	-0.44	+0.55*
	Evaluation	-0.19	+0.25	+0.24
Informative action	Recommendations	-0.35*	-0.24	+0.60*
	Information Sharing	-0.22	-0.30	+0.51
	Identification	-0.30*	-0.25*	+0.58*

* Significant at $p < 0.05$

The regression models for idle time (Model A) and resource waste (Model B) show weak model fit and limited statistical significance, suggesting that communication frequencies alone were

insufficient to explain variance in these waste-related outcomes. A possible reason is that idle time and resource waste were often driven strongly by more complex team interactions that were not fully captured by frequency measures. Future study might involve communication pattern measures such as network centrality and density into analyses (Herrera et al., 2020).

As shown in Table 4, the regression model predicting average PPC performed satisfactorily, indicating that team communication behaviors provided meaningful explanatory and predictive power for planning reliability. Performative and informative actions jointly provided substantial explanatory power for averaged PPC, accounting for 58% of the variance ($R^2 = 0.58$) and remaining strong after adjustment ($Adjusted R^2 = 0.47$). Negotiation ($coefficient = +0.032$) and identification ($coefficient = +0.045$) were the most significant predictors of high PPC. From a practical perspective, project managers may encourage both informative and performative actions (perhaps via development of blame-free and psychologically safe environment) to boost reliability in task completion. Given that existing commitment management systems predominantly relies on performative-action indicators to operationalize “best practice” in LPS, future systems could be strengthened by incorporating informative-action indicators (e.g., explicit identification statements) as complementary indicators of effective coordination.

Table 4: Multiple regression predicting averaged PPC from communication behaviors

Predictor	B (Unstd.)	SE(B)	t (df=23)	p-value
Intercept	+0.315	0.096	3.276	0.003
Request	−0.011	0.006	−1.943	0.064
Negotiation	+0.032	0.013	2.522	0.019
Evaluation	−0.004	0.008	−0.512	0.614
Recommendations	+0.009	0.005	1.725	0.098
Information Sharing	+0.011	0.005	2.031	0.054
Identification	+0.045	0.016	2.839	0.009
Model Fit: $R^2 = 0.58$, $Adjusted R^2 = 0.47$, $F(6,23) = 5.29$, $p = 0.002$.				

The model was statistically significant, indicating that communication behaviors, considered jointly, were meaningfully associated with average PPC. Theoretically, this pattern is consistent with the view that both informative actions (e.g., identification) and performative actions (e.g., negotiation) are proximal determinants of team performance, potentially by strengthening situational awareness and a shared team mental model.

Recent work by Lagos et al. (2025) developed a machine-learning model to predict schedule performance using social network indicators. However, because the input features were derived from project documents and questionnaires, the approach limits its suitability for objective assessment. In contrast, the present study identified team-level behavioral variables that can be captured objectively during coordination meetings, thereby providing a pathway to predicting LPS implementation performance from micro-level team dynamics. Collectively, these findings offer empirical guidance for developing machine-learning models that leverage implementation communication data to generate more timely and actionable performance forecasts.

CONCLUSION

This study aimed to advance understanding of how communication behaviors impact team performance in LPS-based coordination meetings, thereby informing more effective Lean management practice. An experimental study was conducted using the MILPS platform and video recording to examine correlations between both performative and informative actions with team performance. The results show that teams engaging in richer identification,

recommendation and negotiation behaviors achieved significantly higher PPC. In fact, informative actions and performative actions jointly explained a substantial portion of the variance in PPC (around 58%), with negotiation and identification emerging as the strongest predictors of high planning reliability.

This study contributes to the body of knowledge by two folds. First, the identification of the communication-performance relationship provides in-depth insights into the social mechanisms that LPS engenders in projects. Second, the findings could inspire LPS facilitators and project managers. Unlike prior studies have often emphasized the general importance of performative actions for supporting project performance, the present results specify the roles of negotiation and identification in improving team performance. This suggests that facilitators should not only encourage adherence to the structured commitment loop but also cultivate an environment in which team members actively negotiate commitments and openly identify best and bad practices. Such communication can strengthen shared understanding and trust. These are well-established foundations of high-performing teams and can improve planning reliability and reduce delays.

Still, this research has several limitations. First, only frequency-based measures were used to quantify communication behavior. While frequency provides a foundational indicator of team interaction patterns within time-bound meetings, it treats all communication instances equally and fails to account for the depth, quality, or true effectiveness of the communication. As a result, discussing an issue multiple times might indicate proactive problem-solving, but it could equally imply that the issue was not addressed effectively in previous attempts. Therefore, frequency alone cannot capture the full spectrum of communication processes or the ultimate efficacy of team interactions. Future research could incorporate temporal and sequential features (e.g., how negotiation and identification episodes unfold over time) as well as interaction-structure indicators (e.g., network patterns) into analysis. Integrating network and sequential metrics may offer a more comprehensive account of how team communication supports continuous improvement and enables more effective, timely planning interventions.

Second, relatively low task complexity and difficulty may not have been sufficient to reveal relationships between communication behaviors and waste-related performance indicators. Future research should introduce realistic project variability—such as unexpected material delivery delays, sudden design modifications, or overlapping trade workflows—into experimental scenarios. Elevating task complexity in this manner is expected to generate a wider variance in waste outcomes, providing a more robust environment to investigate how specific communication strategies can effectively identify and mitigate non-value-adding activities.

Third, although the experiment included three distinct roles to represent essential project functions, the simplified nature of the MILPS tasks required each team to comprise only three participants. This is notably smaller than the team size typically found in real-world LPS meetings, which usually involve more than 10 members. Consequently, the findings may be more transferable to small project teams than to larger project settings. This may constrain the external validity of the study, as communication dynamics are likely to vary with team size. Future research should increase group size by assigning multiple participants to each role, thereby better approximating real-world project team conditions and enabling validation of the findings obtained in this study.

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