

ALIGNING LEAN PROJECT DELIVERY WITH INDUSTRIALIZED CONSTRUCTION: A PROJECT-LEVEL, REQUIREMENTS-BASED ANALYSIS

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ABSTRACT

Existing industrialized construction (IC) and lean construction research have mainly addressed IC adoption at organisational and industry levels, identifying barriers, mapping lean techniques, and proposing strategic frameworks, while offering limited insight into the project-level requirements of industrialized construction projects (ICPs) and how these relate to Lean Project Delivery (LPD). This paper develops a requirements-based perspective on ICPs and examines to what extent LPD characteristics address these requirements. A structured literature review was used to consolidate key LPD characteristics into three dimensions: project organisation, contractual relationships, and operational system. In parallel, an expert focus group in the Chilean context elicited, refined, and prioritised ICP requirements, which were clustered into nine thematic categories. Both structured sets were then cross-referenced through thematic analysis. The results indicate strong alignment between LPD and requirements related to early stakeholder integration, collaboration and organisational governance, and factory–site planning and coordination, while in other areas LPD mainly offers a collaborative platform to better address ICP requirements, particularly those linked to regulatory and contractual (RC) aspects and digitalization and information technologies (D&I).

KEYWORDS

Industrialized construction, lean project delivery, collaboration/collaborative, industrialized requirements.

INTRODUCTION

Industrialized construction (IC) has emerged as a key pathway to transform the construction sector from a fragmented, craft-based activity into a more systematic, repeatable, and productivity-oriented mode of production. Recent studies define IC as the adoption of practices that minimize project-specific work in construction from the start of the design to the end of the building's life cycle (Kauppinen et al., 2024). Off-site construction, prefabrication, pre-

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assembly, and modular construction are often considered the main approaches within IC. Through these approaches, IC has been associated with improvements in cost, time, quality, safety, and environmental performance compared to traditional, site-based construction (Durdyev & Ismail, 2019).

Despite this potential, the effective adoption of IC in practice remains challenging. Prior studies highlight barriers including fragmented and unstable supply chains, low levels of standardization, misaligned incentives, limited early involvement of key stakeholders, and limited organisational readiness for industrialization. In the Chilean context, recent research identified a set of barriers to IC adoption. It showed that they cluster around issues such as manufacturer offerings, low standardization, volatile material costs, and limited knowledge of ICs (Ortega et al., 2023). These challenges have fuelled industry interest not only in listing barriers, but in understanding how to address them through more suitable project delivery (PD) approaches (Vásquez-Hernández et al., 2023). Chile provides a relevant setting for this study because, while the industry has shown growing interest in industrialization as a response to persistent productivity and coordination challenges, its implementation remains incipient and constrained by fragmented delivery practices, making it a useful context in which to examine project-level requirements and the potential role of Lean Project Delivery.

At the industry and organisational levels, several initiatives have begun to address these challenges. Recent work has identified and classified barriers to IC adoption (Ortega et al., 2023) into common dimensions (e.g., cultural, design, regulatory), drivers and organisational readiness (Liu et al., 2017), proposed a method for industrialization potential analysis (Vásquez-Hernández et al., 2022), and frameworks to support decision-making around IC strategies (Ortega et al., 2022). These studies provide valuable guidance at the organisational and sectoral levels. However, they operate at a relatively high level and do not explicitly articulate the project-level requirements that must be satisfied within individual IC projects. Furthermore, while the lean construction literature has developed robust concepts and tools for improving project performance, there is still limited work that explicitly connects project delivery characteristics with the requirements of IC projects in a structured, requirements-oriented manner.

Lean Project Delivery (LPD) is an approach for structuring and managing construction projects. The Lean Project Delivery System (LPDS), first proposed by Ballard (2000), conceptualises the project as a project-based production system and organises delivery into interlinked phases such as project definition, lean design, lean supply, lean assembly, and use, supported by a lean operational system. In a similar vein, Mesa et al. (2019) characterized LPD as a project delivery system distinguished by its project organization, contractual relationships, and operational system. In this study, the term Lean Project Delivery (LPD) refers to LPDS and its associated principles, phases, and practices, and the LPD structure proposed by Mesa is explicitly adopted as an analytical framework.

The characteristics mentioned suggest that LPD offers a promising baseline for addressing the collaborative and integrative demands of industrialized construction at the project level. However, research examining the extent to which LPD characteristics can meet the requirements of industrialized construction projects (IC_{PS}) remains limited. Existing studies either discuss LPD conceptually, present case studies of lean and collaborative delivery, or map lean techniques to IC barriers, but do not explicitly analyse how LPD, as a project delivery approach, responds to a structured set of IC_P requirements at the project level (Costa et al., 2023).

In the context of the Chilean construction industry, this paper aims to develop a project-level, requirements-based perspective on industrialized construction and qualitatively explore its alignment with Lean Project Delivery. The following objectives guide the study: (i) identify key aspects and characteristics of Lean Project Delivery in the development of construction

projects, drawing on existing LPD/LPDS literature, *(ii)* identify project-level requirements for the effective adoption of industrialized construction and categorize them, and *(iii)* qualitatively explore the contributions of LPD characteristics to address the identified industrialized construction project requirements.

By doing so, the paper provides a baseline view of the fit between IC_P requirements and LPD characteristics, highlighting areas of strong alignment, partial coverage, and gaps. This contributes to ongoing efforts to design and adapt project delivery systems that are better suited to industrialized construction in the AEC industry.

METHODOLOGY

The study employs a theory-driven, deductive qualitative design to investigate the extent to which Lean Project Delivery (LPD) characteristics meet the requirements of Industrialized Construction Projects (IC_P s). The research methodology comprises three principal stages (**Figure 1**): *(i)* a structured literature review to identify key Lean Project Delivery (LPD) characteristics, *(ii)* identification, categorization, refinement, and validation of IC_P requirements through a content analysis and focus group supported with experienced practitioners and academics, and *(iii)* thematic analysis of the Key LPD characteristic contribution to IC_P requirements.

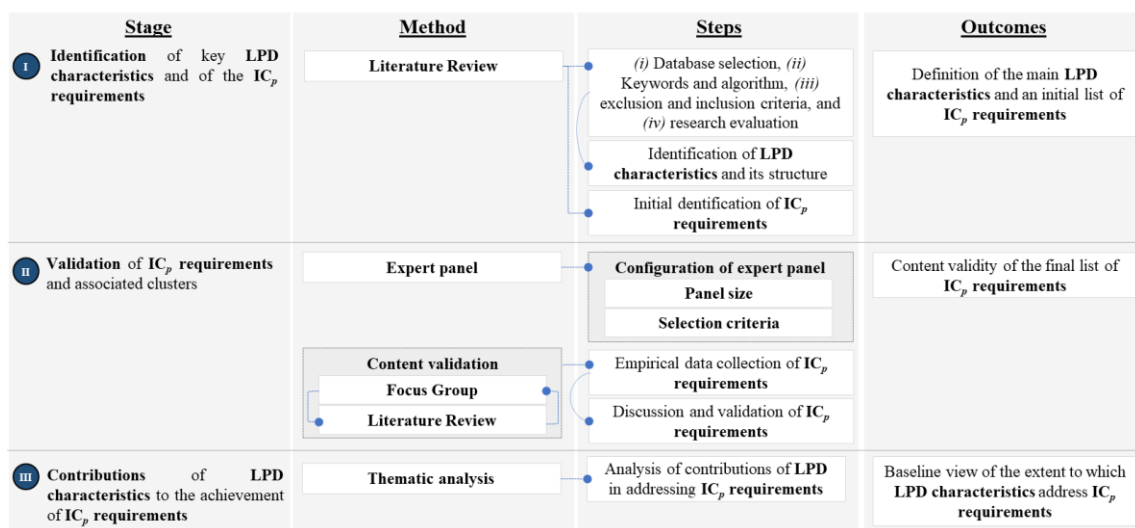


Figure 1: Research Methodology

STAGE I

The authors conducted a literature review to identify the principal characteristics of LPD. This research method is essential across all research disciplines; it is conducted to evaluate the state of knowledge on a particular topic, identify research gaps, and discuss a particular matter (Snyder, 2019). A literature review is not only a background activity. Still, it can be used as a systematic research method when it follows explicit procedures for database selection, search strategies, inclusion and exclusion criteria, and research evaluation. According to these procedures, the authors performed a literature review to identify updated information and organize it around key characteristics of LPD that define it as a project delivery system (PDS) in construction, and to ground the content for subsequent analysis that would allow understanding of the LPD's contribution to addressing IC_P requirements. Regarding IC_P requirements, the barriers identified by Ortega et al. (2023) served as a basis for Stage II, in which the requirements will be refined and validated with practitioners and academics.

Database Selection and Search Strategies

For this research, the authors selected Scopus as the database due to recommendations from other studies in the field of Industrialized Construction and its recognition as a research engine that covers a wider range of journals than any other database (Wuni & Shen, 2020). Next, a list of keywords was identified under the topic of “Lean Project Delivery System” and “Core characteristics of LPD.” Based on the list of keywords and the Boolean operators ‘OR & AND’, the authors developed the search algorithm and applied it to the database search engine's functionality (title/abstract/keyword). The search algorithm contained the following: (“Lean Project Delivery” OR “Lean Project Delivery system” OR “Lean Project Delivery method”) AND (“Construction Industry” OR “AEC Industry”) AND LIMIT-TO (LANGUAGE, “English”). The authors restricted the search to papers published between 2015 and 2025. This search yielded **45** documents.

Inclusion and Exclusion Criteria

The selection of articles was based on inclusion/exclusion criteria. The main inclusion criteria involved (i) documents that explicitly discuss the topic in the construction environment implementation (e.g., case studies, pilots) or systematically discuss LPD application; (ii) articles that are published in a peer-reviewed journal or conference papers; (iii) Books and industry reports developed by recognized research or industry entities.

Research Evaluation: Full-article Revision

Based on previous criteria, the authors screened the titles and abstracts, resulting in **9** documents. This relatively high exclusion rate is explained by the specificity of the review focus mentioned in the previous section. Then, with the full set of documents, the research team conducted a full-text evaluation. To reduce the risk of omitting relevant studies, the structured database search was complemented by snowballing to enhance the literature coverage. In line with established guidelines, snowballing was applied as an iterative process of examining the reference lists of included papers (backward snowballing) and identifying articles that cite these papers (forward snowballing), using the initially selected studies as a “start set” (Wohlin, 2014). Finally, data were examined using a qualitative content analysis to describe, categorize, and code-frame the key LPD characteristics into a PD definition.

STAGE II

The second stage aimed to identify, categorize, refine, and validate the IC requirements for the effective development of industrialized projects. To this end, an expert panel configured as a focus group was convened. Focus group discussions are a well-established qualitative method for exploring collective meanings and for generating feedback on frameworks or constructs; they enable interaction among participants and the co-construction of interpretations (Hennink & Leavy, 2014).

Expert Panel Configuration and Focus Group

The expert panel was configured to meet predefined criteria, and participants were required to have a minimum level of professional experience. The experts' selection criteria included the following: (i) more than **5** years of experience in the Construction Sector, (ii) hold a leadership position in their organizations, and (iii) active participation in private or public entities that promote Industrialized construction. Regarding the focus group, the session lasted approximately **60–90** minutes, and two of the authors served as moderators to facilitate clear identification of experts' views. To promote understanding of the focus group agenda, the authors began with a brief introduction to the project stages and an explanation of the specific subjects that would be addressed during the focus group. The expert panel was divided into two equal groups, which then interacted with each other on separate occasions to reach consensus

on the findings. This facilitated management and promoted greater participation by the experts. The structure of the expert panel and focus group followed the recommendations in the literature (Hallowell & Gambatese, 2010; Hennink & Leavy, 2014).

Data Collection and Judgment Expert's Process

A structured approach inspired by the early phases of Design Thinking, namely Empathize, Define, and Ideate, was employed to guide the core of the focus and the data collection process. Design Thinking is understood as a human-centered and iterative approach to problem-solving that integrates users' needs, multidisciplinary collaboration, and continuous learning to address complex challenges (Brown, 2008; Lo et al., 2019). This approach supported the process of eliciting and reaching consensus on the key IC_P requirements currently faced by the Chilean construction industry in the development of IC projects.

Empirical data collection was structured into three (3) sequential rounds: First, with the input of the barriers identified by Ortega et al. (2023), an individual brainstorming round allowed participants to independently articulate perceived key requirements based on their professional experience, reducing early group bias. Second, a collaborative clustering round enabled the socialization and consolidation of individual inputs into shared requirement categories. Finally, the third round was comprised of two moments, (i) a collective agreement round to classify the identified requirements into four levels of severity, critical, emerging, latent, and strategic, based on their perceived urgency and impact per group, and (ii) a collective agreement round between the groups to merge the categories and IC_P requirements level of severity. The authors planned the third round this way because they expected the requirements' categories and severity levels to be similar. Therefore, it would facilitate the grouping and final definition of the requirements. Finally, the severity levels were assigned by requirements categories.

The (I) critical level is related to IC_P requirements that must be addressed immediately, (II) emerging level corresponded to the IC_P requirements with low current impact, but high urgency due to ongoing trends or changes, (III) Latent level is comprised of those IC_P requirements with low impact and low urgency, they are not a priority, and (IV) strategic level is related to the IC_P requirements with high impact, but low urgency. This level requires medium-term planning. This process resulted in a validated and collectively agreed set of requirements, that provides a structured foundation for subsequent analysis and the development of collaborative and integrative mechanisms for Industrialized Construction projects.

STAGE III

The third stage investigates the extent to which LPD characteristics address the validated IC_P requirements. Conceptually, this stage builds on previous work that has mapped lean techniques to industrialized construction barriers and benefits, but extends it by focusing specifically on LPD characteristics and a structured set of IC_P requirements at the project level. The relationships between these two sets were examined using thematic analysis, a flexible method for analysing qualitative data and identifying patterns of meaning (themes) within it (Braun & Clarke, 2006). To this end, in a collaborative manner, the authors used the structured representation of LPD characteristics (set A) and IC_P requirements (set B) as a coding framework to systematically and qualitatively cross-reference characteristics in A with requirements in B, interpreting and highlighting the most salient contributions of LPD characteristics to addressing the IC_P requirements based on conceptual alignment. Given the exploratory nature of this stage, no formal member checking was conducted; however, the IC_P requirements used in the analysis had been previously validated through the expert focus group in Stage II, providing an indirect level of empirical grounding for the alignment.

RESULTS

KEY LPD CHARACTERISTICS

The literature review yielded **17** key characteristics of LPD. These characteristics were organized using the structure proposed by Mesa et al. (2019) as a baseline (Project Organization, Contractual Relationships, and Operational System). **Table 1** shows the dimensions, their associated characteristics, the authors who mention them, and the frequency of citations.

Table 1: Key LPD characteristics in project development

Dimension	ID	LPD Characteristics	Reference	Fr.
Project Organization (PO)	PO-1	Integrated governance: core group	[1,10,11]	3
	PO-2	Cluster groups & interdisciplinary and cross-functional groups	[2,3,12,13]	4
	PO-3	Early involvement of key participants	[4,5,6,10,12,14-15]	7
	PO-4	Co-location of the team project	[10,16-17]	3
Contractual Relationships (CR)	CR-1	Relational multi-party agreement	[2,4,5,10,11,15,17-18]	8
	CR-2	Reward/Risk Sharing Mechanism	[2,4,5,10,11,15,17-18]	8
	CR-3	Open Book	[4,5,15]	3
	CR-4	Incentive structure aligned with project-level performance	[15,18]	2
	CR-5	LPD principles in commercial terms	[10,19]	2
Operational System (OS)	OS-1	Flow-based approach to project production	[12-14]	3
	OS-2	Predictable and rapid workflow	[6,10,12-14]	5
	OS-3	Target Value Design	[10,11,13,17,20]	5
	OS-4	Last Planner System	[7,8,10,11,12,14]	6
	OS-5	Set-Based Design	[10-14]	5
	OS-6	A3 reports	[10]	1
	OS-7	Value Stream Mapping	[7,10]	2
	OS-8	BIM	[6,7,10,11]	4

Note: Fr= Frequency; [1] Umstot (2023) [2] Paulsen et al. (2023) [3] Garcés & Peña (2023) [4] Moradi et al. (2022) [5] Kim et al. (2016) [6] Plugge et al. (2023) [7] Saradara et al. (2024) [8] Vaagen & Ballard (2021) [9] Mesa et al. (2019) [10] Mossman et al. (2010) [11] Kim & Dossick (2011) [12] Ballard (2000) [13] Howell (2011) [14] Ballard & Howell (2003) [15] NASFA et al. (2010) [16] Dave et al. (2015) [17] Ballard (2008) [18] Lichtig (2006) [19] Sodal et al. (2014) [20] Zimina et al. (2012)

IC_P REQUIREMENTS AND CATEGORIES

Based on the expert panel's criteria, a total of 15 experts were invited to participate, and **12** accepted. Table 2. Provides a demographic information. The expert panel that participated in the study belongs to national private and public Chilean entities, such as the Industrialized Construction Council of Chile (CCI), the Technology Development Corporation (CDT), the Chilean Chamber of Construction (CChC), and the Association of Real Estate Developers (ADI). All the experts have at least 10 years of experience and are active members of entities that promote industrialized construction.

Table 2: Expert demographic information

ID	Discipline	Occupation	Locality	ID	Discipline	Occupation	Locality
1	Civil Engineer	PM	RM	7	Civil Engineer	CEO	RM
2	Architect	Consultant	RM	8	Engineer in MI&C	PM	RM
3	Civil Engineer	PM	RM	9	Industrial Engineer	CEO	RM
4	Architect	PM	LL	10	Civil Engineer	CEO	RM
5	Industrial Engineer	PM	RM	11	Civil Engineer	PM	RM
6	Civil Construction	PM	VA	12	Architect	CEO	RM

PM= Project Manager ; RM= Region Metropolitana, Chile; Engineer in MI&C= Engineer in Management Information and Control; LL= Region de los Lagos, Chile; VA= Region de Valparaiso, Chile.

In the first round, the authors provided a set of requirements extracted from Ortega et al. (2023). **Table 3** shows the initial list of IC_P requirements. From this input, the two groups generated

approximately **72** requirements among them. **Figure 2** shows the requirements identified by the experts, transcribed onto sticky notes.

Table 3: Initial list of ICP requirements

ID	IC _P requirement	ID	IC _P requirement
R1	Involve key players in the value chain early on.	R8	Define the complete design in the early project phases
R2	Encourage collaboration among the project's players.	R9	Adapt the regulations to the IC _P requirements
R3	Promote an organizational culture that is open to innovation and change.	R10	Integrate and coordinate the supply chain efficiently.
R4	Establish long-term business relationships that favor innovation.	R11	Strengthen the production capacity of specialized suppliers.
R5	Develop internal capabilities to incorporate technology and innovation.	R12	Implement planning methodologies appropriate for industrialized systems.
R6	Adapt the traditional risk transfer model.	R13	Build capacity to coordinate between the factory and the construction site.
R7	Standardize components and processes during design.	R14	Increase the adoption of information technologies in construction processes.

Next, in the second round, these requirements were clustered into **7** categories by Group-1 and **9** categories by Group-2. **Figure 3** shows the requirements grouped by category for each group.



Figure 2: ICP Requirements (Round 1)



Figure 3: Categories pre-define (Round 2)

Note: Group-1, right side and Group-2, left side, in each figure.

The outcome of the third round was the identification of **thirty** (30) IC_P requirements, which are clustering into **nine** (9) final categories (Table 4): Early integration and stakeholder involvement (**ES**), Collaboration and organisational governance (**CO**), Culture of innovation and organizational change (**CIO**), Standardization, design, and constructability (**SC**), Adapted regulatory and contractual framework (**RC**), Supply chain management and logistics (**ScM**), Digitalization and information technologies (**D&I**), Performance and knowledge management (**PKm**) and Financial approach (**FI**). Regarding severity level, the groups were socialized to assign quadrant I (categories ES, CO, ScM, and FI); quadrant II (category RC); quadrant III (no categories assigned); and quadrant IV (categories CIO, SC, PKm, and D&I).

Table 4: ICP requirements validated, along with their corresponding categories.

ID _c	Categories	ID _r	IC _P requirement
ES	Early integration and stakeholder involvement	ES-1	Involve key players in the value chain early.
		ES-2	Identify stakeholder needs early in the development of industrialized projects.
		ES-3	Define integration routes, required data, and project entry times early on.
		ES-4	Define responsibilities and boundary conditions for stakeholder participation early on for the IC _P development.
		ES-5	Encourage informed and participatory involvement of the project initiator(s)
CO	Collaboration and organisational governance	CO-1	Promote a collaborative work culture among the different project stakeholders.
		CO-2	Promote vertical and horizontal permeability (e.g., director-operator and construction company-industrializer) to develop industrialized solutions.
		CO-3	Promote transparency among stakeholders regarding capabilities and production processes.
CIO	Culture of	CIO-1	Promote an organizational culture that is open to innovation and change.

ID _c	Categories	ID _r	IC _P requirement
	innovation and organizational change	CIO-2	Establish long-term business relationships that promote innovation.
		CIO-3	Develop internal capabilities to incorporate technology and innovation.
		CIO-4	Incorporate strategies that provide greater flexibility (e.g., multipurpose, interchangeable batch production) for problem-solving in industrialized project development.
SC	Standardization, design, and constructability	SC-1	Define component and production-process standardization in the design stages.
		SC-2	Define the complete design in the early stages of the project.
		SC-3	Establish mechanisms to iterate on industrialized solutions and assess their feasibility for application in the project at an early stage (e.g., through iterative constructability assessments and compliance with approvals).
RC	Adapted regulatory and contractual framework	RC-1	Adapting the regulatory framework to the requirements of industrialized construction
		RC-2	Establish collaborative contractual frameworks that include clauses on organizational teams (e.g., collaborative organizational structures), decision-making, coordination and communication (protocols and tools), and conflict resolution (DB).
		RC-3	Incorporate commercial agreements that include guarantees for industrialized solutions in the short, medium, and long term.
		RC-4	Formally define standardized and expedited approval processes (e.g., technical, regulatory, and quality) for industrialized solutions at an early stage.
		RC-5	Adapt the traditional risk transfer model to the industrialized project development model.
ScM	Supply chain management and logistics	ScM-1	Implement planning methodologies appropriate for industrialized systems.
		ScM-2	Incorporate strategies to strengthen the productive capacity of specialized suppliers.
		ScM-3	Build capacity to coordinate between the factory and the construction site.
		ScM-4	Establish mechanisms that allow industrialized solutions to be adapted to the development and execution capabilities of each organization, project team, supplier, and/or specialist.
		ScM-6	Enable integrated logistics management of stakeholders for monitoring and control (e.g., supervision, quality, change management) of the manufacturing and assembly of industrialized solutions.
D&I	Digitalization and information technologies	D&I-1	Increase the adoption of information technologies in construction processes (e.g., BIM 3D, 4D, and 5D).
PKm	Performance and knowledge management	PKm-1	Integrate continuous measurement of KPIs for ad hoc objectives into the management system for industrialized project development.
		PKm-2	Promote the dissemination and documentation of successful contractual and technical practices applied in the development of industrialized projects.
		PKm-3	Establish accessible, practical knowledge management that clarifies language and reduces knowledge gaps among stakeholders.
FI	Financial approach	FI-1	Establish vertical and horizontal integration mechanisms to develop and analyze ad hoc financial flows for industrialized projects.
Note: ID _c = Identification of each category; ID _r =Identification of each requirement			

DISCUSSION

After presenting the results of the Literature Review, which describe key LPD characteristics and the focus group's application to validate and categorize the IC_P requirements, this section, based on thematic analysis, provides a baseline view of the extent to which LPD addresses the IC_P requirements. The analysis focused on the most salient and theoretically grounded relationships, with particular emphasis on the IC_P requirements identified as more critical by the expert focus group.

EARLY INTEGRATION AND STAKEHOLDER INVOLVEMENT

In LPD, downstream key participants (owner, contractor, suppliers) are involved from the outset during project definition and lean design, which is related to (R/t) ES-1, so that needs, data requirements, interfaces, and responsibilities can be defined early and collaboratively (R/t ES-2, ES-3, and ES-4). In other words, an integrated governance approach that aligns the core group and teams early in project development is a central feature of an LPD environment (R/t PO-1, PO-2, and PO-3). This distinguishing organisational feature contributes to meeting the

IC_P requirements of the ES category, without limiting oneself, which calls for early integration and clear stakeholder participation.

COLLABORATION AND ORGANISATIONAL GOVERNANCE

LPD contracts are typically multi-party relational agreements (CR-1) that formalise collaboration, shared goals, and joint decision-making, reducing organisational silos and enabling vertical/horizontal permeability across firms, which is R/t CO-1 and CO-2. It is also recognized in the construction literature as a key enabler of collaborative governance (R/t CO-1). In the same line, shared risk/reward mechanisms and open-book accounting create aligned incentives and transparency regarding costs and performance (R/t CR-2, CR-3, and CR-4), which help develop a collaborative culture and openness about capabilities and production processes (R/t CO-1 and CO-3).

CULTURE OF INNOVATION AND ORGANIZATIONAL CHANGE

A3 thinking (OS-6) structures problem identification, root-cause analysis, and countermeasures (R/t CIO-3), fostering systematic experimentation and learning (R/t CIO-1) (Shahroudi & Aarabi, 2021). While A3 is primarily an operational problem-solving tool, its emphasis on structured reflection and continuous improvement can contribute to learning-oriented practices that underpin an innovation-friendly culture.. Similarly, VSM makes processes visible and highlights waste and improvement opportunities across design and production (R/t CIO-1), supporting iterative improvement and organizational learning, which underpin innovation (R/t CIO-4). Furthermore, in terms of contractual relationships, LPD commercial terms (CR-5) promote the adoption of relational contracts that explicitly reward joint improvement and continuous learning; they support long-term relationships oriented to innovation rather than short-term transactional optimization (Mossman et al., 2010b), which directly address the CIO-1 and CIO-2.

STANDARDIZATION, DESIGN, AND CONSTRUCTABILITY

TVD (OS-3) is explicitly defined as a management practice that drives design to deliver customer value within project constraints. Additionally, SBD (OS-5) allows exploration of multiple design alternatives within constraints and gradually narrows options as knowledge increases. Combined, these methods are key to addressing the SC category requirements. TVD serves as a mechanism to explicitly achieve the value targets early in the design processes, and SBD is well-suited to iteratively industrialize solutions and evaluate standardized components and solutions before locking in decisions, thereby finding the optimal solution (R/t address SC-1, SC-2, and SC-3). Moreover, in terms of project organization, PO-2 and PO-3 are the drivers in establishing an environment that enables early contractor, fabricator, and key specialist involvement during the design process to ensure that standardization and constructability are feasible and aligned with production capabilities.

ADAPTED REGULATORY AND CONTRACTUAL FRAMEWORK

Similar to category CO, this category highlights the use of multi-party relational contracts by LPD that define joint governance and risk/reward pooling that moves the risk transfer model away from adversarial allocation towards shared risk aligned with project outcomes (R/t RC-5), offering a collaborative framework more consistent with IC projects (R/t RC-2). This is conducive to a clearer picture of commercial agreements (R/t RC-3) for the project development. However, some issues, such as regulatory approvals, product homologation, and detailed public-law adaptations under RC-1 and RC-4, are not explicitly covered by LPD; LPD primarily provides a collaborative contractual platform on which such IC-specific provisions can be negotiated. This interpretation is consistent with insights from the expert focus group, where participants emphasized that regulatory constraints are largely external to project delivery

systems and must be addressed through institutional or normative changes, while LPD can facilitate coordination among stakeholders to navigate these constraints more effectively.

SUPPLY CHAIN MANAGEMENT AND LOGISTICS

LPDS views projects as production systems and emphasises continuous flow and reliable workflow (R/t OS-1 and OS-2); this logic, plus other key LPD characteristics such as LPS and VSM (R/t OS-4 and OS-7), underpins planning methods that synchronise design, fabrication, logistics, and site assembly in industrialised projects (R/t address ScM-1, ScM-3, and ScM-6). Furthermore, PO-2, which involves specialised suppliers in cluster teams, builds their capabilities (R/t ScM-3) and enables integrated logistics management among stakeholders (R/t ScM-6), which is crucial for industrialised supply chains.

DIGITALIZATION AND INFORMATION TECHNOLOGIES

BIM is frequently cited in LPD/IPD case studies as a core enabler for integrated design, clash detection, and visual planning, including 4D scheduling, thereby improving coordination and information flow in complex projects. This aligns directly with the requirement D&I-1 to increase the adoption of digital tools, such as BIM 3D/4D/5D, in IC projects. Nevertheless, LPD itself does not define the full digital ecosystem, including ERP, configurators, and IoT tracking, but it provides the collaborative context in which these tools can be used jointly.

PERFORMANCE AND KNOWLEDGE MANAGEMENT

For this category, LPS (OS-4) and VSM (OS-7) play an important role. Both produce performance indicators, such as percent plan complete, reasons for failure, and cycle times, inventories and process performance, respectively, which are used to monitor and improve production performance in construction projects and can be adapted as IC-specific performance measures (PKm-1).

FINANCIAL APPROACH

Risk/reward pools (CR-2) and open-book accounting (CR-3) align the financial interests of the owner, designer, contractor, and key trades around project outcomes, facilitating project-level financial integration needed when industrialised solutions require coordinated investments (R/t FI-1). In complement, OS-3 and CR-4 work together with previous characteristics: one as a method to align incentives during the design process with IC project value targets, and the other as a mechanism to formalize incentives.

CONCLUSIONS

At the project level, this study developed a requirements-based perspective on industrialized construction and examined its alignment with Lean Project Delivery (LPD). Drawing on a structured literature review, 17 LPD characteristics were consolidated into three dimensions: project organisation, contractual relationships, and operational system. In parallel, an expert focus group produced and validated a set of IC_P requirements, clustered into nine thematic categories. The subsequent qualitative thematic analysis showed that LPD characteristics address most IC_P requirements, not as isolated mechanisms but as interdependent elements that operate across different lifecycle phases and dimensions (organisational, contractual, and operational) of IC project delivery.

The main contribution of the paper is to provide, at the project level, requirements-oriented analysis between IC and LPD, moving beyond general barriers toward a more explicit understanding of what LPD can offer to industrialized projects. In addition, the study contributes with the first structured set of IC_P requirements at the project level in the Chilean context, which can be considered a standalone contribution to support future research and

practices. Conceptually, it clarifies that LPD strongly supports IC_P requirements for early stakeholder integration, collaboration and governance, and planning and coordination between the factory and the site. In other cases, LPD primarily provides a collaborative ecosystem or platform within which ICP requirements can be more fully addressed, such as regulatory and contractual (RC) needs and digitalization and information technologies (D&I).

The study is limited by its reliance on a single expert focus group in the Chilean context and on a selected corpus of LPD literature; both the requirements and the mapping should therefore be interpreted as an informed baseline rather than exhaustive or universally generalisable. Future research should broaden the empirical base through additional focus groups and case studies across different contexts, refine and quantify the identified relationships, and translate them into tactical and operational solutions that facilitate the IC project's development.

ACKNOWLEDGEMENT

The authors would like to acknowledge the support provided by the CDT, the CChC, and *Centro Nacional de Excelencia para la Industria de la Madera* (ANID BASAL FB210015 CENAMAD) for facilitating this study.

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