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Complexity and Construction Management: An Integrated Analysis of Logistics, Organizational Processes, and Productivity

Walter Antonio Abujder Ochoa [1,2,*], Diego Andrés Chacón Quiroga [1], Sebastián Javier García Mendivil [1], Miguel Rivero Chavez [1], Dayler Taborga Guzmán [1], Alfredo Iarozinski Neto [2] and Oriana Palma Calabokis [3,*]

[1] Universidad Católica Boliviana San Pablo, Departamento de Ingenierías y Ciencias Exactas, Centro de Investiga-ción en Ciencias Exactas e Ingenierías (CICEI), Carrera de Ingeniería Civil, C. Márquez, Esq. Parque Jorge Trigo Andia, Tupuraya, Cochabamba 0000, Bolivia; diego.chacon@ucb.edu.bo (D.A.C.Q.); garciamendivilsebastian@gmail.com (S.J.G.M.); miguel.riv.ch@gmail.com (M.R.C.); daylertaborgaguzman@gmail.com (D.T.G.)

[2] Construction Civil Area, Construction Management and Sustainability, Graduate Program in Civil Engineering (PPGEC), Federal University of Technology of Paraná, Curitiba 81280-340, Paraná, Brazil; iarozinski@professores.utfpr.edu.br

[3] Faculty of Engineering and Basic Sciences, Fundación Universitaria Los Libertadores, Bogotá 1112211, Colombia

* Correspondence: wabujder@ucb.edu.bo (W.A.A.O.); opalmac@libertadores.edu.co (O.P.C.); Tel.: +591-79752888 (W.A.A.O.)

Abstract

Prior studies have commonly examined organizational structure, managerial processes, construction logistics, productivity, and project complexity through separate research streams, leaving limited empirical evidence on how these domains are positioned within a single multilevel construction management framework. This study develops an integrated analysis of their relationships using data from construction firms operating in Cochabamba, Bolivia, and the Metropolitan Region of Curitiba, Brazil. A quantitative, non-experimental, cross-sectional design was adopted, and 108 valid survey responses were analyzed through descriptive statistics, correlation analysis, Exploratory Factor Analysis, Principal Component Analysis, reliability assessment, regional comparison, and Relative Importance Index ranking. The results showed that formal organizational characteristics displayed comparatively limited direct associations with performance-related variables, whereas stronger relationships were concentrated among managerial, strategic–logistical, and operational processes. The project complexity analysis retained three dimensions—technical, process-stage, and planning-related complexity—which jointly explained 61.271% of the rotated variance. At the operational level, equipment and tool maintenance, schedule adherence, and material storage received the highest Relative Importance Index values, with RII = 0.776 for each item. The findings indicate that construction performance is more closely associated with the dynamic processes through which information, decisions, responsibilities, and resources are coordinated than with formal structure considered independently. The study contributes a multilevel conceptual framework in which project complexity is interpreted as increasing the coordination requirements linking organizational arrangements, managerial processes, logistics, and operational reliability.

Keywords: construction project complexity; exploratory factor analysis; Relative Importance Index; emerging economies; organizational capability; workflow reliability

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1. Introduction

The construction industry is widely recognized as a fundamental driver of economic growth and social development. However, it continues to exhibit persistent inefficiencies, including cost overruns, schedule delays, and productivity losses, particularly in emerging economies. Despite decades of research addressing these issues, improvements in project performance remain limited, suggesting that conventional analytical frameworks are insufficient to fully capture the underlying dynamics of construction processes [1].

Traditionally, research in construction management has focused on isolated dimensions such as productivity, logistics, organizational structure, and managerial practices. While these approaches have generated valuable insights, they tend to treat construction projects as decomposable systems, where performance can be explained through linear cause–effect relationships. However, empirical evidence increasingly indicates that such assumptions do not hold in real-world construction environments, where uncertainty, interdependence, and variability dominate project behavior.

Against this background, the objective of the present study is to examine how organizational structure, managerial processes, logistics, productivity-related conditions, and project complexity are positioned and associated within an integrated multilevel construction management framework. The empirical analysis draws on survey data from participating construction firms in Cochabamba, Bolivia, and the Metropolitan Region of Curitiba, Brazil.

Project complexity provides the analytical lens for this integration because construction projects involve interdependent activities, multiple participants, changing requirements, and uncertain information. In the present study, complexity is not treated as an isolated predictor of performance, but as a theory-guided condition associated with greater coordination requirements across organizational, managerial, logistical, and operational levels. The detailed theoretical foundations of this interpretation are developed in Sections 2.1–2.4.

In the present study, organizational processes are operationalized through the managerial mechanisms by which formal organizational arrangements are enacted during project execution. These processes include planning, communication, information management, stakeholder coordination, supplier evaluation, allocation of responsibilities, conflict resolution, monitoring, and decision-making. They differ conceptually from organizational structure: structure defines the formal distribution of authority, roles, hierarchy, and reporting relationships, whereas organizational processes describe how participants actually coordinate information, decisions, and activities across firm and project boundaries.

Construction logistics refers to the coordinated management of procurement, suppliers, materials, equipment, storage, transportation, information, and timing required to sustain project execution. It is therefore treated not merely as an operational support function, but as an interface connecting managerial decisions with site-level resource and workflow conditions. Planning priorities, information exchanges, supplier decisions, and responsibility assignments become operationally relevant when they are translated through logistics into the timely availability and movement of the resources required by construction activities [2].

Construction productivity is interpreted as an operational outcome reflecting the continuity and reliability of these organizational and logistical arrangements. It is not understood solely as the result of labor effort, equipment capacity, or material availability considered independently. Rather, productivity reflects the combined conditions created by planning reliability, communication, maintenance, material flows, workforce continuity, supplier performance, and coordination among interdependent activities [3–5]. The connection among the three concepts is therefore relational: organizational processes coordinate decisions and responsibilities; logistics translates those decisions into resource and

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workflow conditions; and productivity reflects how reliably those conditions support site execution [6,7]. Under increasing project complexity, the coordination requirements linking these levels also increase.

Despite these advances, three related gaps remain insufficiently resolved. First, project complexity, organizational structure, managerial processes, logistics, and construction productivity continue to be examined predominantly through separate research streams. Consequently, the literature provides extensive knowledge about the relevance of individual variables but comparatively limited empirical evidence regarding how these dimensions are connected across the organizational, managerial, logistical, and operational levels of the construction management system.

Second, previous studies have not sufficiently established where the strongest performance-relevant relationships are located within this system. Formal organizational characteristics—such as hierarchy, centralization, role definition, and formalization—are frequently assumed to provide the organizational basis for improved performance. However, it remains unclear whether project outcomes are more closely associated with these relatively static structural attributes or with the dynamic processes through which information, decisions, resources, and responsibilities circulate among organizational functions and project participants.

Third, recent research has made important progress in the multidimensional measurement of project complexity, but complexity is still frequently analyzed separately from organizational capability, logistical coordination, and site-level operational reliability. There remains limited evidence explaining how technical, process-stage, and planning-related complexity may increase the coordination requirements placed on managerial, logistical, and operational processes, particularly in construction markets characterized by organizational variability and resource constraints.

The point of departure of the present study is that it does not examine organizational processes, logistics, productivity, or project complexity as isolated explanatory domains. Previous studies have generated substantial knowledge within each of these areas, but their variables are commonly analyzed at one organizational or project level and are not positioned according to the different functions they perform within the construction management system. The present study instead distinguishes formal structural capacity from enacted managerial capability, positions logistics as the intermediate interface through which managerial decisions become resource and workflow conditions, and interprets productivity as an operational expression of the reliability of those coordinated conditions.

The theoretical significance of this departure lies in shifting the analytical focus from the independent importance of individual variables toward their relative position and connection across organizational, managerial, logistical, and operational levels. Project complexity is consequently not treated only as an additional project characteristic or as a directly estimated predictor of performance. It is interpreted as a theory-guided condition that increases the coordination requirements placed on the relationships among these levels. This multilevel positioning provides the basis for the integrated framework and research propositions developed in Sections 2.8 and 2.9.

The central theoretical proposition is that performance-related outcomes are associated not only with formal organizational characteristics or the availability of individual resources, but also with the managerial, logistical, and operational processes through which information, decisions, responsibilities, and resources are coordinated during project execution. Project complexity is interpreted as increasing the coordination requirements placed on these relationships.

Accordingly, the study compares the relative empirical position of structural characteristics and cross-functional processes within the construction management system. Its contribution lies in identifying whether stronger relationships are concentrated in formal organizational attributes or in the managerial, strategic–logistical, and operational interfaces connecting organizational arrangements with project execution. These relationships are examined through an exploratory, cross-sectional, and module-based analytical design and are not presented as statistically confirmed causal, mediation, or moderation effects.

2. Literature Review

2.1. From Systems Theory to Complexity in Construction

Early treatments of complexity in engineering distinguished between complicated and complex systems. Complicated systems contain many components and subsystems, but their structure and behavior can, at least in principle, be decomposed, modeled and controlled through deterministic rules; they tend to be closed, bounded and weakly influenced by context [8]. By contrast, complex systems are open, strongly context-dependent and characterized by dense webs of interactions among their elements. Small variations in local interactions can trigger disproportionate changes at the system level, and emergent properties arise that cannot be explained by analyzing components in isolation [1,9,10].

Within this theoretical lineage, complexity theory extends systems thinking by shifting emphasis from static structures to dynamic patterns of interaction and adaptation. It investigates how feedback loops, self-organization and path dependence shape system trajectories over time. In complex systems, prediction based solely on initial conditions and linear cause–effect chains becomes unreliable, and control must be reframed as continuous adaptation under uncertainty. This epistemological shift is particularly relevant for the construction industry, where projects unfold in changing environments, involve heterogeneous actors and are exposed to technological, regulatory and socio-economic contingencies [11,12].

From an epistemological perspective, Morin [13] argues that complexity requires preserving the relationships, reciprocal dependencies, and contextual connections among the parts and the whole rather than reducing system behavior to isolated components. This perspective supports the interpretation adopted in the present study, in which organizational structure, managerial processes, logistics, productivity-related conditions, and project complexity are examined as interconnected analytical levels rather than as independent explanatory domains.

Construction has been repeatedly described as one of the most complex industrial operations. The construction process aggregates a large number of interdependent activities and stakeholders, whose decisions and interactions generate system-level behavior that is non-linear and frequently counter-intuitive. Fernández-Solís characterizes construction as a systemic process in which a very large number of stakeholders participate, operating through non-linear organizational arrangements; outputs are not proportional to inputs, and the final product differs qualitatively from the sum of its parts. This supports the characterization of construction as an open social system with intense interoperability within firms and extra-operability between firms, which aligns closely with the defining attributes of complex systems in complexity theory [14,15].

2.2. Project Management and the Limits of Linear Approaches

Traditional project management frameworks, as codified in bodies of knowledge such as PMBOK, are based on an implicit view of the project as a relatively ordered and decomposable phenomenon [3,16,17]. The project is segmented into phases, work packages and activities, which are assumed to be planned and controlled through detailed schedules, budgets and allocation of responsibilities. Under this paradigm, the project is treated as a predominantly linear and sequential process, comparable to an assembly line, where sufficient planning effort is expected to ensure execution according to plan [12].

However, empirical evidence indicates that construction projects systematically underperform in terms of cost, time and quality. Classic performance indicators reveal persistent overruns and frequent failures to meet client expectations. Several authors argue that this chronic underperformance is not merely the result of poor planning or execution, but a symptom of a deeper mismatch between linear management tools and the intrinsically complex nature of construction projects. If processes are non-linear, path-dependent and sensitive to local perturbations, then tools designed for stable, predictable systems will be structurally insufficient [12].

From the perspective of complexity theory, project management must therefore move beyond first-order approaches that assume stability and decomposability, towards second-order approaches that acknowledge uncertainty, emergent behavior and the co-evolution between project and context. This implies considering projects not only as technical endeavors but also as adaptive social systems, where learning, negotiation and feedback among stakeholders are central mechanisms for managing complexity.

2.3. Dimensions of Complexity in Construction Projects

The seminal contribution of Baccarini conceptualized project complexity through differentiation and interdependence among project elements [18]. Differentiation refers to the number and diversity of components, tasks, organizational units, technologies, and participants, whereas interdependence concerns the intensity and configuration of the relationships among them [18,19]. This definition remains foundational because it distinguishes complexity from project size alone and directs attention toward the structure of interactions within the project system.

Subsequent construction management research expanded this understanding by incorporating uncertainty, technical novelty, workflow variability, stakeholder diversity, information instability, and environmental exposure [19]. Complexity is therefore no longer interpreted exclusively as the number of elements within a project. It also concerns the degree to which those elements interact, depend on one another, change during execution, and produce effects that are difficult to predict through linear cause–effect relationships [20].

Recent empirical studies reinforce the multidimensional character of project complexity [14]. Contractor-oriented research has grouped complexity characteristics into several categories reflecting project objectives, organizational arrangements, technical requirements, environmental conditions, stakeholders, resources, and execution processes [15,16]. Other survey-based studies have operationalized project complexity through dimensions such as context, size, diversity, autonomy, connectivity, emergence, and belonging, showing that project complexity comprises structural, relational, and contextual properties rather than one homogeneous attribute [11,20].

Recent construction-specific measurement approaches have also adopted technical–organizational–environmental frameworks. In international engineering projects, complexity has been evaluated through organizational, technological, and environmental indicators, allowing both the sources and overall degree of complexity to be assessed [11,16,20]. Meta-analytic evidence likewise indicates that technical, organizational, environmental, and integrational forms of complexity may have different relationships with project success and project-management success [21,22].

Systematic reviews published in recent years show that there is still no complete consensus concerning one universally applicable set of complexity dimensions. Frequently identified criteria include stakeholder number and diversity, project scope and objectives, management structure, technological novelty, task interdependence, information uncertainty, regulatory conditions, resource variability, and organizational interfaces [23]. Their relevance varies according to the type of project, project stage, geographical context, respondent perspective, and intended purpose of the measurement.

Based on this conceptual and empirical development, the present study distinguishes three context-specific dimensions: technical complexity, process-stage complexity, and planning-related complexity. Technical complexity concerns specialized systems, technical novelty, non-standard procedures, and interfaces among disciplines. Process-stage complexity concerns the number, overlap, sequencing, and interdependence of project phases and activities. Planning-related complexity concerns uncertainty in information, resources, site conditions, financial availability, and assumptions affecting planned execution.

These dimensions are not presented as an exhaustive or universally valid classification. Rather, they represent the latent structure identified in the analyzed construction-company data and provide an empirically grounded basis for examining how complexity relates to managerial processes, logistics, coordination, and operational performance.

2.4. Recent Empirical Approaches to Measuring Construction Project Complexity

Recent research has increasingly focused on converting the broad theoretical concept of project complexity into observable dimensions, indicators, and assessment procedures. These developments are important because conceptual agreement that construction projects are complex does not automatically provide a method for determining which sources of complexity are present, how strongly they are perceived, or how they relate to managerial and performance outcomes [24].

Nikolić and Cerić developed a contractor-oriented classification of construction-project complexity based on the frequency with which complexity characteristics had been identified in previous surveys and on empirical information obtained from construction-project managers [25]. Their study organized the relevant characteristics into eight groups and emphasized that contractors should evaluate these elements during project planning and implementation. This approach is relevant because it places measurement at the level of the actors responsible for coordinating construction execution.

Azmat and Siddiqui adopted a multidimensional survey approach and examined project complexity through seven dimensions: context, size, diversity, autonomy, connectivity, emergence, and belonging. Their model illustrates a broader tendency in contemporary research to represent complexity as a combination of structural characteristics, relational density, environmental conditions, and emergent behavior rather than as a single project attribute [26].

Ju et al. proposed a measurement method for international engineering projects based on organizational, technological, and environmental complexity. Their approach combined an indicator system with BP-DEMATEL and interval-valued intuitionistic fuzzy sets to estimate the overall degree of complexity and identify the factors contributing most strongly to it [27]. This type of model demonstrates that complexity assessment can be used not only to classify projects but also to support the allocation of managerial attention and resources.

Recent evidence also indicates that complexity measurements should be interpreted in relation to project outcomes. Hu et al. conducted a meta-analysis comprising 22 articles and 77 effect sizes and differentiated technical, organizational, environmental, and integrational complexity. Their results showed that different forms of complexity do not necessarily relate to project success and project-management success in the same manner. The study also identified national or regional income level as a relevant moderator, reinforcing the importance of contextual conditions when interpreting complexity effects [28].

Lafhaj et al. conducted a systematic review of 49 studies and identified multiple criteria used to define and assess complexity in construction projects. Their synthesis highlighted the number of stakeholders, project scope and objectives, and management structure among the most recurrent assessment criteria. The review also confirmed the absence of complete consensus concerning a single definition or measurement framework [21].

The contextual nature of complexity measurement was further demonstrated by Ramanathan and Rathore, who examined complexity sources across different types of building projects. Their approach incorporated 34 attributes grouped into six categories and showed that the relative relevance of design and performance characteristics varies according to building typology [22]. Therefore, a complexity indicator that is important in one type of building project may have limited relevance in another.

A different methodological direction is represented by network-based approaches. Álvarez-Espada et al. proposed separate metrics for structural and dynamic complexity based on project relationships and small-world network properties. Their model examines connectivity, centrality, interaction density, and changes in network behavior and combines them into a global complexity assessment [29]. This approach is particularly consistent with complexity theory because it measures the architecture and evolution of relationships rather than only the isolated characteristics of project elements.

More recently, Yang and Zhao examined project complexity through technological, goal-related, informational, organizational, and environmental dimensions in large-scale construction projects. Using PLS-SEM and expert evidence, they analyzed how BIM implementation may reduce specific forms of complexity and improve project-management performance. Their results reinforce the importance of information and goal complexity and demonstrate how digital technologies can modify the conditions under which complexity affects management outcomes [30].

Taken together, recent research shows three principal directions in complexity measurement. The first uses multidimensional questionnaires and latent-variable models. The second develops weighted indicator systems and decision-support indices. The third uses relational or network measures to capture structural and dynamic interaction patterns. These approaches are complementary rather than interchangeable because they address different units of analysis and management purposes. Table 1 summarizes the recent empirical and measurement approaches reviewed in this section.

Against this background, the present study is positioned within the survey-based exploratory direction. It uses respondents' evaluations and Exploratory Factor Analysis to examine the empirical organization of project complexity perceptions. The retained dimensions—technical complexity, process-stage complexity, and planning-related complexity—partially converge with the technical, organizational, environmental, informational, and relational dimensions reported in recent research. However, they are interpreted as a context-specific exploratory solution rather than as a universally applicable measurement model or as a replacement for alternative project complexity frameworks.

Table 1. Recent Empirical and Measurement Approaches to Project Complexity.

Study	Context and Methodological Approach	Principal Dimensions or Criteria	Relevance to the Present Study
Nikolić and Cerić (2022) [25]	Survey and classification from the contractor and construction-project-manager perspective	Eight groups of construction-project complexity characteristics	Supports contractor-oriented and multidimensional assessment
Ghaleb et al. (2022) [31]	Scientometric analysis and systematic review of construction-project complexity research	Measurement, system integration, uncertainty, risk, cost, and schedule research streams	Demonstrates recent expansion and methodological diversity of the field

Table 1. *Cont.*

Study	Context and Methodological Approach	Principal Dimensions or Criteria	Relevance to the Present Study
Azmat and Siddiqui (2023) [26]	Survey-based multidimensional model and structural-equation analysis	Context, size, diversity, autonomy, connectivity, emergence, and belonging	Supports the representation of complexity as a multidimensional latent construct
Ju et al. (2023) [27]	Indicator system, BP-DEMATEL, fuzzy-set assessment, and engineering-project case study	Organizational, technological, and environmental complexity	Provides a quantitative indicator-based alternative to psychometric scales
Hu et al. (2023) [28]	Meta-analysis of 22 articles and 77 effect sizes	Technical, organizational, environmental, and integrational complexity	Demonstrates differentiated effects and the relevance of contextual moderators
Lafhaj et al. (2024) [21]	Systematic review of 49 construction-complexity studies	Stakeholders, scope and objectives, management structure, and other complexity criteria	Confirms diversity of definitions and assessment criteria
Ramanathan and Rathore (2024) [22]	Practitioner survey across different building-project types	34 design and performance attributes grouped into six categories	Shows that complexity sources vary according to project typology
Álvarez-Espada et al. (2024) [29]	Small-world network and fuzzy-logic assessment	Structural complexity, dynamic complexity, and global complexity index	Introduces a relational and dynamic measurement approach
Yang and Zhao (2025) [30]	Survey, PLS-SEM, and expert evidence in large-scale construction projects	Technological, goal-related, informational, organizational, and environmental complexity	Links complexity measurement with BIM implementation and management performance

Note: The studies represent different approaches to project complexity operationalization, including classification frameworks, psychometric or latent-variable models, weighted indicator systems, systematic and meta-analytic syntheses, and network-based measures. Their dimensions are not directly interchangeable because they differ in research purpose, context, project type, and unit of analysis.

2.5. Productivity on Construction Sites

Within the construction management literature, labour productivity on site is regarded as a critical determinant of project performance, particularly in terms of cost and schedule adherence. Productivity has been conceptualized as the ratio between useful output (e.g., quantity of work completed with the required quality) and the inputs consumed (labour hours, materials, equipment, indirect resources) [15,32]. However, contemporary studies emphasize that productivity in construction is not merely a technical or operational variable; it is the emergent outcome of multiple interdependent factors spanning project planning, organizational practices, site management, and broader contextual conditions [4].

Classical contributions categorize productivity factors into groups such as: (i) project-related factors (design quality, completeness of information, constructability, degree of change during execution); (ii) planning and control factors (quality and reliability of schedules, coordination among trades, adequacy of work breakdown structures, lookahead planning); (iii) labour factors (skills, experience, motivation, absenteeism, learning curves, turnover); (iv) materials and equipment factors (availability, storage, handling, preventive maintenance, breakdowns); and (v) management and communication factors (supervision style, decision-making speed, clarity of instructions, conflict management). Empirical studies consistently show that deficiencies in planning and coordination, late or incorrect information, and material supply problems are recurrent causes of productivity losses in construction sites, often more influential than purely technical difficulties of tasks [33–35].

More recent research adopts a systems and complexity lens to interpret productivity. From this perspective, the construction site is seen as a local manifestation of the broader project system, where interdependencies, variability and uncertainty materialize in daily operations. Productivity losses are then understood as symptoms of systemic issues such as unstable workflows, misaligned interfaces among subcontractors, inadequate buffers, and fragile communication channels. Instead of treating productivity as an isolated variable, the literature suggests linking it to the structure of processes, the design of the supply chain and the organizational configuration of firms [15,36].

Studies based on survey methods and multivariate analysis in Latin-American contexts have reinforced this view by empirically identifying groups of factors that most strongly affect productivity on construction sites. These factors include preventive maintenance of tools and equipment, reliability of the construction programme, adequacy of material storage and handling, and effectiveness of on-site supervision. The findings indicate that productivity is highly sensitive to the quality of planning and the stability of resource flows, which in turn depend on how companies organize their logistics, managerial processes and decision-making structures. In this sense, site-level productivity becomes a key performance indicator that reflects the interaction between project complexity and the managerial capacity of construction firms.

2.6. Logistics, Organizational Configuration and Competitive Strategy in Construction Firms

Construction logistics has traditionally been treated as a subordinate operational function focused on supplying materials, equipment and services to the construction site. However, the literature increasingly recognizes that logistics in construction is a strategic activity that shapes and is shaped by the organizational configuration and competitive strategy of firms. Logistics encompasses not only transport and storage, but also procurement policies, supplier relationships, inventory management, site layout planning, just-in-time deliveries and coordination of on-site flows of materials, information and crews [37–39].

From a strategic management perspective, construction companies can pursue different competitive strategies—cost leadership, differentiation, specialization, or combinations thereof—which require distinct patterns of resource allocation, coordination and control. Organizational structure is one of the main mechanisms through which firms align their internal processes with their competitive strategy and with the external demands of markets and clients. In this context, logistics represents a crucial interface: it translates strategic intentions (e.g., fast-track delivery, high reliability, flexibility in customization) into concrete decisions about supply systems, contracts, and operational routines [40,41].

Empirical studies in construction firms have examined how logistic practices correlate with organizational and strategic variables. Results indicate that companies with more developed logistic systems tend to exhibit clearer strategic orientations, better integration between central offices and sites, and higher levels of formalization in planning and control processes. At the same time, evidence suggests that logistics is not always fully embedded in organizational design; in many firms it operates semi-autonomously, driven by immediate site needs rather than by explicit strategic and organizational choices. This partial decoupling can lead to inconsistencies between the formal structure and the actual flow of materials and information [1,10,19].

The literature further highlights that logistics complexity rises with the number of concurrent projects, geographical dispersion of sites, diversity of suppliers, and variability in demand. Under these conditions, linear, ad hoc logistic practices become insufficient.

Complexity-aware approaches underline the need for integrated planning of supply chains, collaborative arrangements with suppliers and subcontractors, and information systems capable of supporting real-time coordination. In addition, studies on Latin-American construction SMEs show that logistic maturity is uneven; while some firms develop relatively sophisticated practices, many others maintain informal, reactive systems that amplify the effects of project complexity on productivity and performance.

Thus, logistics constitutes a critical bridge between project-level complexity and firm-level strategy and organization. Understanding this bridge is essential for explaining why firms facing similar project complexity profiles may exhibit different levels of performance: it depends not only on the projects themselves, but also on how each organization structures and governs its logistic processes.

2.7. Organizational Structure and the Development of Managerial Processes in Construction Firms

Organizational theory offers a rich body of concepts for analyzing how firms structure their internal activities and decision-making [1,18]. Classical work on organizational design describes structural dimensions such as specialization, formalization, centralization, hierarchy, and departmentalization, as well as archetypal configurations (functional, divisional, matrix, project-based, network forms). In construction, these general concepts must be adapted to an industry where project-based work, temporary multi-organizational coalitions, and strong coupling between permanent organizations and temporary project teams are the norm [12,14,15].

The construction industry is characterized by hybrid organizational forms, in which permanent companies maintain functional departments (engineering, procurement, finance, human resources) while simultaneously managing multiple project-based structures dedicated to individual contracts. This duality generates structural tensions: functional units seek standardization and economies of scale, whereas project teams demand flexibility, responsiveness and local autonomy. The way in which firms resolve these tensions—through varying degrees of centralization, formalization, matrix arrangements or projectization—has significant implications for how complexity is handled in projects [42,43].

Alongside structural design, the literature emphasizes the role of managerial processes—planning, organizing, directing, controlling and learning—as the operational expression of management within organizations. Managerial processes include strategic and operational planning, budgeting, risk management, human resources management, communication and information management, quality management, and continuous improvement mechanisms. The level of development or maturity of these processes can be assessed through models that examine the presence, consistency and integration of practices, procedures and tools across the organization [44].

Studies focusing on construction companies have investigated the relationship between structural characteristics and the maturity of managerial processes. Evidence suggests that firms with more clearly defined structures, explicit roles and responsibilities, and formalized procedures tend to present higher levels of process development, particularly in planning, cost control, quality and safety management. However, overly mechanistic structures may reduce adaptability and obstruct feedback from projects to corporate levels. Conversely, highly informal structures may favour flexibility and rapid decision-making but at the cost of inconsistency, dependence on individual managers, and vulnerability to turnover [42].

In Latin-American construction SMEs, empirical research has identified frequent gaps in the development of managerial processes, especially in the early phases of project initiation and planning. These gaps manifest as weak definition of project objectives, incomplete scope definition, insufficient risk analysis, and limited integration between technical planning and financial management. When combined with ambiguous or unstable organizational structures, these deficiencies limit the capacity of firms to cope with contextual and project complexity, and contribute to recurrent problems of cost overruns, delays and quality deviations [1].

The literature also introduces the notion that managerial decision-making styles interact with structure and process maturity. In many small and medium construction firms, decision-making is concentrated in the owner–manager or a small group of senior managers, frequently adopting directive or intuitive styles. While this can accelerate responses in stable, low-complexity contexts, it may become a bottleneck in complex project portfolios, where distributed expertise and structured decision processes are required. Consequently, the alignment between organizational structure, managerial processes and decision-making styles emerges as a key determinant of how firms perceive and manage project complexity [1,12,14].

Taken together, these contributions suggest that the relationship between complexity and performance in construction cannot be understood without considering the organizational layer. Project complexity manifests at the level of tasks, phases and interfaces, but its effects are mediated by how companies are structured, how their managerial processes are designed and implemented, how logistics is integrated into organizational and strategic frameworks, and how decisions are made and enacted. This reinforces the need for integrative models that connect complexity factors in projects with organizational variables—structure, processes, logistics and decision-making—and with performance outcomes such as productivity, cost, schedule and quality. The present study is positioned precisely at this intersection.

2.8. Research Gap, Novelty, and Expected Contribution

The literature reviewed in the preceding sections demonstrates that project complexity, organizational structure, managerial processes, construction logistics, and productivity have each received substantial theoretical and empirical attention. Nevertheless, the available knowledge remains fragmented across distinct research traditions. Complexity research has primarily concentrated on identifying project characteristics and developing multidimensional measurement frameworks. Organizational studies have examined hierarchy, formalization, centralization, and managerial process maturity. Logistics research has focused on procurement, supplier coordination, material flows, and supply-chain integration, while productivity studies have emphasized labor, equipment, materials, planning, and site-control factors.

Although these research streams address related aspects of construction management, they do not fully resolve how their respective variables are connected within a multilevel management system. In particular, limited empirical attention has been given to the relative explanatory position of formal organizational structure compared with the processes through which organizational capacity is translated into project action. The unresolved question is not whether structure, planning, logistics, communication, or resource management matter independently. Rather, it is whether performance-relevant relationships are concentrated primarily in static organizational characteristics or in the dynamic interfaces linking managerial, logistical, and operational activities.

A second unresolved issue concerns the role assigned to project complexity. Complexity is commonly measured through technical, organizational, environmental, informational, stakeholder, or relational dimensions. However, it is less frequently integrated with firm-level organizational characteristics, intermediate managerial and logistical processes, and site-level operational outcomes. As a result, complexity is often treated as one additional explanatory variable rather than as a condition that changes the coordination burden placed on the management system.

The novelty of the present study is therefore empirical and explanatory rather than based on the introduction of previously unknown constructs. The study integrates module-specific evidence to identify how relationships are distributed across organizational, managerial, logistical, operational, and project complexity levels. This makes it possible to examine not only whether individual variables are important, but also which types of relationships are stronger, which are comparatively limited, and how they can be organized within a coherent complexity-based interpretation.

The first theoretical contribution is the distinction between structural capacity and enacted managerial capability. Structural capacity refers to the formal organizational possibility of coordinating activities through authority, hierarchy, role definition, procedures, and reporting relationships. Enacted managerial capability refers to the actual operation of planning, communication, information management, stakeholder coordination, supplier evaluation, conflict resolution, resource allocation, and adaptive decision-making. The study investigates whether enacted managerial capability has a closer empirical relationship with performance-oriented variables than structural capacity considered independently.

The second theoretical contribution is the positioning of logistics as a meso-level coordination interface. Logistics is not treated only as an operational support function responsible for procurement, transport, inventory, and storage. It is interpreted as the subsystem through which strategic and managerial decisions are translated into material availability, equipment continuity, supplier performance, schedule synchronization, and site-execution conditions.

The third contribution is the interpretation of productivity as an emergent operational outcome. Maintenance, schedule adherence, storage, material delivery, workforce conditions, and monitoring are not approached as isolated productivity determinants. They are interpreted as observable manifestations of the alignment or misalignment among planning, logistical flows, managerial decisions, and site-level execution.

The fourth contribution is the integration of technical, process-stage, and planning-related complexity as conditioning dimensions. The study does not statistically estimate moderation effects. Instead, it examines whether the observed relational pattern is consistent with the theoretical proposition that increasing complexity raises coordination requirements and reduces the sufficiency of static structural arrangements.

The empirical contribution is the construction of an integrated interpretation from several complementary analytical procedures, including descriptive comparisons, correlation analysis, exploratory factor analysis, principal component analysis, reliability assessment, discriminant analysis, and Relative Importance Index ranking. These procedures are not presented as a single causal test. Their integration is used to identify a cross-level configuration of relationships and to develop a conceptual framework suitable for future confirmatory examination.

The practical contribution lies in the prioritization logic derived from this framework. Rather than recommending organizational restructuring as a general solution, the study directs managerial attention toward the interfaces where information, resources, responsibilities, and decisions must remain synchronized. These interfaces include forecasting and procurement, supplier evaluation and material reliability, organizational information systems and site decisions, project schedules and equipment maintenance, and financial continuity and workforce performance.

Accordingly, the expected advancement is not a universal theory or measurement scale of construction complexity. It is a contextually grounded, multilevel explanation of how organizational arrangements become operationally relevant through managerial and logistical processes and how project complexity changes the coordination requirements under which those processes function.

2.9. Integrated Theoretical Framework and Research Propositions

The theoretical perspectives reviewed in the preceding sections are not treated as independent or competing explanations. They perform complementary functions within the integrated framework of the study. Systems theory establishes the multilevel organization of construction management and directs attention toward the relationships connecting organizational, managerial, logistical, and operational subsystems. Complexity theory explains why the behavior of this system cannot be inferred exclusively from its individual components, particularly under conditions of interdependence, uncertainty, variability, and changing project requirements.

Organizational theory provides the basis for examining structural capacity through hierarchy, formalization, centralization, specialization, role definition, and reporting relationships. These characteristics establish the formal architecture within which managerial activity occurs. However, organizational structure does not independently determine how information, resources, responsibilities, and decisions circulate during project execution.

Project-management theory explains the processes through which formal organizational capacity is converted into coordinated action. Planning, communication, stakeholder management, supplier evaluation, information integration, risk management, monitoring, and decision-making constitute enacted managerial mechanisms that connect organizational arrangements with project activities.

Lean construction contributes the operational principles of workflow reliability, variability reduction, resource synchronization, continuous improvement, and the management of interdependencies among activities. From this perspective, logistics and productivity are not isolated technical functions. Logistics connects strategic and managerial decisions with the availability and movement of materials, equipment, information, and other resources, whereas productivity reflects the stability and coordination of these flows at the construction-site level.

The integration of these perspectives produces a multilevel analytical sequence. At the organizational level, structural capacity defines the formal conditions for coordination. At the managerial level, planning, information management, communication, and stakeholder-oriented processes activate this capacity. Strategic–logistical coordination translates managerial decisions into procurement, supplier, equipment, material, and schedule conditions. At the operational level, the reliability of these conditions is reflected in productivity and other performance-related outcomes.

Project complexity operates across these levels. Technical complexity increases the need to integrate specialized knowledge, systems, and disciplines. Process-stage complexity increases the number and interdependence of interfaces among activities. Planning-related complexity introduces uncertainty and instability into the assumptions upon which schedules, resource allocations, and execution decisions are based. Complexity therefore increases the coordination requirements placed on the relationships linking organizational structure, managerial processes, logistics, and operational performance.

Based on this theoretical synthesis, the following propositions guide the integrated interpretation of the empirical analyses:

Proposition 1 (P1). *Formal organizational structure is expected to be positively associated with enacted managerial capability; however, its direct relationship with performance-related outcomes is expected to be weaker than the relationships involving managerial and coordination processes.*

This proposition derives from organizational theory and complexity theory. Formalization, hierarchy, and role definition establish an institutional basis for coordinated action, but their practical relevance depends on whether they are activated through planning, communication, information management, delegation, and stakeholder coordination. In temporary and interaction-intensive project organizations, formal structure alone is unlikely to explain operational outcomes.

Proposition 2 (P2). *Enacted managerial capability is expected to be positively associated with strategic–logistical coordination.*

Project-management and systems perspectives indicate that forecasting, planning, communication, supplier evaluation, information integration, and conflict resolution provide the mechanisms through which strategic decisions are translated into procurement, resource, and execution arrangements. Effective logistics therefore depends on managerial coordination rather than exclusively on the formal configuration of departments or authority.

Proposition 3 (P3). *Strategic–logistical coordination is expected to be positively associated with operational reliability and construction-site productivity.*

This proposition draws principally on systems theory and lean construction. Reliable procurement, supplier performance, material storage, equipment availability, information continuity, and schedule synchronization reduce variability and interruptions in construction flows. Logistics consequently operates as an interface between managerial planning and site-level execution.

Proposition 4 (P4). *Greater operational reliability is expected to be associated with more favorable performance-related outcomes.*

Maintenance, material availability, schedule adherence, workforce continuity, payment reliability, and monitoring represent complementary conditions supporting stable execution. Their relevance lies not only in their individual effects but also in their combined contribution to the continuity and synchronization of construction activities.

Proposition 5 (P5). *Technical, process-stage, and planning-related complexity are expected to increase coordination requirements and the dependence of performance-related outcomes on integrated managerial and logistical processes.*

This proposition derives from complexity theory. As technical specialization, task interdependence, phase overlap, information uncertainty, and resource instability increase, static structural arrangements become less sufficient. Project execution depends increasingly on information exchange, distributed expertise, adaptive planning, cross-functional coordination, and rapid response to deviations.

These propositions define theoretically expected relationships rather than statistically confirmed causal paths. The study uses an exploratory, cross-sectional, and module-based analytical design; consequently, it does not estimate the complete framework through structural-equation modeling, mediation analysis, or moderation analysis. The propositions guide the organization and interpretation of the empirical results and provide a foundation for future confirmatory testing.

The integrated framework derived from these propositions is subsequently presented in Section 5.5. The framework combines the theoretically expected relationships with the cross-module empirical pattern identified in the study. It should therefore be interpreted as a theoretically and empirically informed conceptual framework rather than as a statistically estimated causal model.

The literature reviewed in Sections 2.3–2.7 also provided the conceptual basis for identifying the variables included in the research instrument. The variables were organized into four substantive domains: organizational structure and managerial processes; logistics, strategy, and organizational interaction; productivity and operational performance; and project complexity. These domains reflect the principal theoretical and empirical streams examined in the Literature Review and were subsequently operationalized through the module-based questionnaire and statistical procedures described in Sections 3.3–3.6. Firm and respondent characteristics were retained as a separate descriptive block rather than as a substantive theoretical construct.

3. Materials and Methods

3.1. Research Design and Conceptual Framework

This study adopted a quantitative, non-experimental, cross-sectional design based on structured survey data from participating construction firms. The research combined descriptive, correlational, exploratory dimensional-reduction, ranking, reliability, and regional comparison procedures to examine complementary aspects of construction management and project complexity.

The empirical analysis was organized into four substantive modules: (1) organizational structure and managerial processes; (2) logistics, strategy, and organizational interaction; (3) productivity and operational performance; and (4) project complexity. Firm and respondent characteristics constituted an additional descriptive layer used to characterize the participating sample and assess observed regional comparability.

The modules were derived from the broader survey instrument and were analyzed separately according to their conceptual purpose, response format, and statistical requirements. They were subsequently integrated through the theoretical framework developed in Section 2.9. This module-based organization avoided treating the complete questionnaire as one homogeneous measurement scale or as one confirmatory structural model.

The research process comprised literature review and variable identification, questionnaire development and pilot refinement, criterion-based participant recruitment, data collection, module-specific statistical analysis, and integrated interpretation. The conceptual framework drew on organizational theory, construction and project-management research, productivity and logistics studies, and complexity theory, while the empirical strategy used multivariate and association-based procedures appropriate to the exploratory design [38–43].

The conceptual framework of the research is grounded in the theory of organizational structures and managerial processes in construction companies, as discussed by Mintzberg (1979), Vivancos (2001), and Jones (2013) [45–47], as well as in studies addressing productivity and operational efficiency in construction projects [35,48]. In addition, statistical methodologies commonly used in social and management sciences were adopted, particularly multivariate analysis techniques such as factor analysis and correlation analysis [49,50].

The study was theory-guided but exploratory in its statistical design. The propositions developed in Section 2.9 established the expected organization of the relationships among structural capacity, enacted managerial capability, strategic–logistical coordination, operational reliability, performance-related outcomes, and project complexity.

The propositions were not treated as confirmatory hypotheses tested through one structural model. Instead, each analytical block examined a specific part of the integrated framework using the statistical procedure appropriate to its variables and research purpose.

The organizational–managerial analysis addressed the relationships associated with P1 and P2; the logistics strategy analysis informed P2 and P3; the productivity analysis informed P3 and P4; and the project complexity analysis provided evidence relevant to the theoretical interpretation proposed in P5.

The integrated interpretation was conducted after completing the module-specific analyses. Consequently, references to indirect, conditioning, or cross-level relationships represent theory-guided propositions supported to varying degrees by the observed association pattern, not statistically estimated mediation or moderation effects.

3.2. Study Area and Target Population

The empirical investigation was conducted in construction companies operating in Cochabamba, Bolivia, a region characterized by significant urban growth and increasing demand for civil construction projects. The target population consisted of legally registered and operational construction firms.

To incorporate a comparative perspective, an additional dataset was collected from construction companies located in the metropolitan region of Curitiba, Brazil. The inclusion of this second geographical context enables the examination of similarities and differences in construction project management practices across two Latin American construction markets with different institutional and economic characteristics.

The inclusion of the Metropolitan Region of Curitiba was intended to provide a contextual comparison rather than a statistically representative comparison between Bolivia and Brazil as national construction sectors. Both regional samples were drawn from construction firms operating in emerging-economy environments and responding to the same conceptual questionnaire, which made it possible to examine whether the measured perceptions of project complexity were restricted to one local setting or displayed a degree of cross-context consistency.

The comparison was conducted at the level of the participating firms and professionals from Cochabamba and the Metropolitan Region of Curitiba. It should not be interpreted as a country-level comparison capable of representing all construction organizations in Bolivia or Brazil. The inclusion of the Brazilian dataset therefore serves as an analytical contrast that increases contextual variation and permits evaluation of the regional stability of the measured project complexity perceptions.

The unit of analysis in this research was the construction company, while the respondents were professionals occupying managerial or technical positions related to project planning, project management, or construction site supervision.

3.3. Variable Identification and Analytical Organization

The conceptual identification of the study variables was developed through the literature reviewed in Sections 2.3–2.9. For methodological purposes, those variables were subsequently organized into four substantive analytical domains: organizational structure and managerial processes; logistics, strategy, and organizational interaction; productivity and operational performance; and project complexity.

The purpose of this methodological stage was not to redefine the theoretical domains, but to translate them into questionnaire items and analytical blocks. Each variable was assigned according to its conceptual meaning, intended response format, and role within the module-specific statistical analysis. Firm and respondent characteristics were organized separately for descriptive characterization and regional comparison.

The questionnaire development process began with the identification of variables reported in the literature on organizational design, managerial processes, construction logistics, productivity, project management, and project complexity. The variables were not selected solely on the basis of statistical convenience. Each item was linked to a conceptually defined domain and to a specific analytical purpose within the integrated study.

The instrument was not conceived as one homogeneous scale measuring a single latent construct. It combined complementary item blocks addressing firm and respondent characteristics, competitive environment, organizational structure, managerial processes, quality management, communication and information management, budget and financial management, occupational health and safety, operational performance, project-management methods, logistics, productivity, and project complexity.

During instrument construction, the correspondence among the theoretical definition of each domain, the wording of the items, the response format, and the intended statistical analysis was reviewed. Conceptually related items were organized within their corresponding analytical blocks, while items representing distinct operational outcomes were retained as separate indicators rather than being forced into one composite measure.

This procedure established content coverage through systematic alignment with the literature and the analytical framework. However, no formal expert-panel content-validity index was calculated. The measurement evidence reported in the present study therefore comprises pilot-based assessment of clarity and feasibility, internal consistency analysis for predefined multi-item scales, and exploratory assessment of dimensional structure.

3.4. Instrument Development

Based on the variables identified during the literature review, an integrated structured questionnaire was developed to collect data from construction companies. The instrument was designed according to psychometric and survey research principles commonly used in management and social science research [1]. It combined objective questions on company characteristics with perception-based items aimed at capturing organizational, strategic, operational, and complexity-related dimensions of construction management.

The integrated research instrument comprised a descriptive block and several perception-based item blocks. For statistical analysis, these blocks were organized into four substantive modules. The term "module" refers to the analytical grouping applied to conceptually related variables and does not imply that each module corresponded exactly to one visually separate questionnaire section or constituted one homogeneous measurement scale.

The descriptive block collected firm and respondent characteristics, including company size, years of operation, project experience, fields of activity, respondent position, and professional experience. These variables were used exclusively for sample characterization and regional comparability assessment.

Module 1—Organizational Structure and Managerial Processes—comprised variables related to the competitive environment and client orientation, organizational structure, planning and coordination, quality management, communication and information management, budget and financial management, and occupational health and safety management.

Module 2—Logistics, Strategy, and Organizational Interaction—comprised the 34 variables included in the corresponding Principal Component Analysis. These variables addressed procurement, supplier relationships, materials and storage, resource flows, logistical coordination, strategic orientation, and organizational interaction.

Module 3—Productivity and Operational Performance—comprised the 40 variables included in the productivity dimensional-reduction analysis, together with the operational performance indicators analyzed separately where their heterogeneous content did not support aggregation into one composite score.

Module 4—Project Complexity—comprised the ten variables used to examine technical complexity, process-stage complexity, and planning-related complexity. The complete ten-item block was used for reliability and Exploratory Factor Analysis, whereas the archived regional discriminant comparison contained nine of these variables, as explained in Sections 3.6.1 and 4.5.3.

The development of the integrated instrument followed four sequential steps. First, the theoretical domains and candidate variables were identified from the literature and the source research modules. Second, the items were classified according to their primary conceptual domain and analytical function. Third, the wording, instructions, response anchors, and sequence of the questionnaire were reviewed to facilitate interpretation by respondents occupying managerial and technical positions. Fourth, the resulting instrument was subjected to pilot testing before final data collection.

The use of different response formats reflected the content of the corresponding questions rather than an assumption that all items belonged to one measurement scale. Five-point Likert-type formats were retained for the organizational–managerial, logistics strategy, and productivity blocks where applicable, whereas the comparative project-management and project complexity blocks used seven-category formats coded from 0 to 6.

For this reason, responses from different formats were not pooled into a total questionnaire score. Reliability and dimensionality were evaluated within conceptually homogeneous blocks, and operational performance indicators were analyzed individually when their content did not support interpretation as interchangeable manifestations of one reflective construct.

The integrated research instrument combined objective questions concerning firm and respondent characteristics with multiple perception-based item blocks. The questionnaire covered competitive environment and client orientation, organizational structure, managerial processes, quality management, communication and information management, budget and financial management, occupational health and safety, operational performance, project-management methods, and project complexity.

The response format was not identical across all analytical blocks. The organizational–managerial, logistics strategy, and productivity modules used five-point Likert-type response formats where applicable, whereas the comparative project-management and project complexity questionnaire used seven-category Likert-type or semantic-differential scales coded from 0 to 6. The verbal anchors were adapted to the content of each item and included conditions such as never–always, very low–very high, nonexistent–highly developed, or below average–above average [51,52].

Because the integrated study combined conceptually related analytical modules, the statistical analyses were conducted within the corresponding item blocks. Scores obtained from different response formats were not directly pooled or treated as if they belonged to one homogeneous measurement scale.

The predefined multi-item scales available in the 108-response comparative questionnaire were evaluated through internal consistency analysis. By contrast, the logistics strategy and productivity components were exploratory structures identified through dimensional-reduction procedures and were not treated as predefined reflective scales. Their measurement adequacy was assessed through KMO, Bartlett's test, factor or component loadings, explained variance, and substantive interpretability.

3.5. Sampling Strategy and Data Collection

A non-probabilistic criterion-based and availability sampling strategy was adopted because a complete and updated sampling frame of eligible construction firms was not available for either study region. Participation was restricted to legally constituted and operational construction companies with recent experience in urban building or infrastructure projects [46]. The respondents were required to occupy managerial or technical positions related to project management, planning, engineering, architecture, or construction-site supervision.

The original survey invitations were sent electronically to representatives of construction companies and were also disseminated through professional and institutional contacts. The invitation described the objectives of the research, the voluntary nature of participation, the type of information requested, and the conditions of confidentiality. Before accessing the questionnaire, potential participants were presented with the informed-consent statement and were required to indicate their agreement to participate.

Before final data collection, the questionnaire was evaluated through an online pilot application involving 25 participants. The pilot was designed to assess the operational feasibility of the instrument rather than to provide evidence for the definitive factor structure.

At the end of the pilot questionnaire, participants were asked to evaluate the clarity and comprehensibility of the questions, the level of difficulty encountered, the overall length of the instrument, and whether any question generated discomfort, embarrassment, or stress. The responses and qualitative observations provided by the pilot participants were reviewed before the final application.

The refinement process focused on improving ambiguous wording, the sequence and presentation of the questions, the clarity of instructions, and the interpretation of response anchors. The revised instrument was then used for the final data-collection stage. The pilot application and the final analytical dataset were treated as separate stages; the final analyses reported in this article are based on the 108 complete and usable responses obtained after refinement of the instrument.

A total of 108 complete and usable responses were retained for analysis. Of these, 59 responses were obtained from Cochabamba, Bolivia, and 49 from the Metropolitan Region of Curitiba, Brazil. The regional distribution was therefore relatively balanced, with Cochabamba representing 54.6% of the sample and Curitiba representing 45.4%.

A conventional survey response rate could not be calculated because the recruitment process did not retain a verified denominator of unique eligible recipients who effectively received the invitation. Invitations were distributed through direct company contacts and professional or institutional channels, and the available records identify the number of usable responses but not the total number of distinct eligible firms reached. Consequently, the study reports the number of complete usable responses rather than an estimated response rate based on an uncertain denominator.

The absence of a calculable response rate and the use of voluntary non-probabilistic recruitment introduce a potential risk of non-response and self-selection bias. Companies and professionals with greater interest in project management, organizational development, or project complexity may have been more willing to participate. Similarly, firms with limited administrative capacity or less formalized management processes may be underrepresented. These possibilities cannot be eliminated because information on non-responding firms was not available.

Several procedures were adopted to reduce, although not eliminate, this risk. Eligibility criteria were applied consistently in both regions; respondents were required to have direct knowledge of construction management or project execution; the same conceptual questionnaire and response scales were applied; and only complete questionnaires meeting the study criteria were retained. Nevertheless, the resulting sample should be interpreted as an analytically relevant sample of participating construction firms rather than as a statistically representative sample of the entire construction-company population of Cochabamba or Curitiba.

Sample-Size Adequacy and Statistical Sensitivity

The final analytical sample comprised 108 complete and usable responses. Because recruitment was non-probabilistic and data collection had been completed before the integrated analytical framework was developed, the final sample size was not determined through an a priori statistical-power calculation. The revised study therefore reports a statistical sensitivity analysis rather than retrospectively claiming that the sample was selected to satisfy a predetermined power requirement.

For the correlation analyses conducted with the complete sample, a two-tailed test with $\alpha = 0.05$ and N = 108 provides approximately 80% power to detect an absolute correlation of $|r| \approx 0.27$ and approximately 90% power to detect $|r| \approx 0.31$. The study was therefore reasonably sensitive to moderate associations but had more limited capacity to detect small relationships.

For a reference comparison between the two regional groups, with n = 59 and n = 49, a two-tailed independent-group comparison at $\alpha = 0.05$ provides approximately 80% power to detect a standardized mean difference of $d \approx 0.55$. Consequently, the absence of statistical significance in a regional comparison should not be interpreted as evidence that small differences do not exist.

Sample-size adequacy for the exploratory factor and principal-component analyses was not inferred from statistical power alone. It was evaluated separately for each item matrix through the Kaiser–Meyer–Olkin measure, Bartlett's test of sphericity, the number and pattern of factor or component loadings, cumulative explained variance, scree-plot behavior, parsimony, and theoretical interpretability.

The number of cases per analyzed item varied across the five dimensional-reduction procedures. The ratios were approximately 6.35 cases per item for the 17-item competitive environment and organizational structure analysis, 2.25 for the 48-item managerial process analysis, 3.18 for the 34-item logistics strategy analysis, 2.70 for the 40-item productivity analysis, and 10.80 for the 10-item project complexity analysis.

These ratios and the corresponding KMO values indicate that sample adequacy was not equivalent across all analytical blocks. The project complexity and productivity matrices presented comparatively stronger adequacy, whereas the managerial process and logistics strategy analyses require more cautious interpretation. Accordingly, all dimensional-reduction results are presented as exploratory structures requiring replication rather than as definitive measurement models.

3.6. Data Processing and Statistical Analysis

All collected data were processed and analyzed using IBM SPSS Statistics version 24 and Microsoft Excel 2022, both widely used for quantitative analysis in social and management sciences [53]. The statistical treatment of the data followed an integrated design but was carried out according to the analytical requirements of each module.

3.6.1. Descriptive Statistical Analysis

The first stage consisted of descriptive statistical analysis aimed at characterizing the sample and understanding the overall distribution of responses. Frequency distributions, percentages, means, and standard deviations were calculated for the main variables. This stage provided a general overview of the construction firms and verified the variability of the responses prior to inferential analysis.

The descriptive analysis also examined the regional composition of the sample and the available organizational and respondent characteristics. Because the sampling procedure was non-probabilistic, these comparisons were not intended to establish population equivalence. Their purpose was to identify major observed differences between the participating firms from Cochabamba and Curitiba and to determine whether the regional interpretation of complexity could reasonably be conducted without ignoring evident sample-composition differences.

The organizational and respondent characteristics of the Cochabamba and Curitiba subsamples were compared before interpreting the regional results. Firm age was calculated as the difference between the data-collection year and the reported year of establishment.

The selection of the regional comparison procedures was based on the measurement level of each variable, the descriptive distributional patterns available in the original analytical records, and the characteristics of the corresponding group data. Firm age was compared using Welch's independent-samples *t*-test because this procedure does not require equality of group variances and is more robust than the conventional independent-samples *t*-test when variance conditions may differ.

Approximate employee counts and annual constructed area were summarized through medians and interquartile ranges and were compared using the Mann–Whitney U test because their observed distributions were asymmetric. Categorical characteristics were compared using Pearson's chi-square test, while Fisher's exact test was used when expected cell frequencies were below five.

Complete archived diagnostic outputs for univariate normality, variance homogeneity, and every contingency-table assumption were not available for retrospective reporting. Accordingly, these regional comparisons are presented as exploratory assessments of observed sample composition rather than as definitive assumption-verified population comparisons.

To avoid relying exclusively on statistical significance, effect sizes were also reported. Hedges' g was calculated for the comparison of firm age, rank-biserial correlation was reported for Mann–Whitney tests, and Cramér's V was calculated for categorical comparisons. Analyses were performed using available cases for variables containing missing responses, and two-tailed statistical significance was evaluated at $\alpha = 0.05$.

The regional analysis was conducted at two complementary levels. The first level examined the observed comparability of firm and respondent characteristics through descriptive statistics, Welch's *t*-test, Mann–Whitney U tests, Pearson's chi-square tests, and Fisher's exact tests, as appropriate. Effect sizes were reported to distinguish statistical significance from the magnitude of the observed regional differences.

The second level examined whether nine project complexity variables produced a statistically meaningful multivariate separation between the Cochabamba and Metropolitan Region of Curitiba respondents. The original comparative discriminant output available for the regional analysis included nine of the ten items contained in the complete project complexity block. The item concerning exposure of the construction-site location to adverse climatic conditions was included in the ten-item reliability and exploratory factor analyses but was not included in the archived regional discriminant model. Because the reason for this exclusion was not documented in the original comparative analysis, no substantive or statistical explanation is inferred retrospectively.

A canonical discriminant analysis was used for the nine-variable regional comparison, together with Wilks' Lambda, canonical correlation, and univariate tests of equality of group means. The resulting analysis should therefore be interpreted as a comparison of the nine variables included in that model rather than as a complete regional comparison of all ten project complexity items.

The canonical discriminant analysis was used as an exploratory assessment of whether the included project complexity variables produced a meaningful regional separation. Complete archived diagnostics for multivariate normality, equality of within-group covariance matrices, influential multivariate observations, and the stability of the discriminant function were not available. The discriminant results are therefore interpreted cautiously and are not treated as formal evidence of population equivalence or measurement invariance.

These two levels were interpreted separately. Similarity in the measured project complexity perceptions was not treated as evidence that the regional samples were demographically, organizationally, culturally, or institutionally equivalent.

3.6.2. Internal Consistency and Exploratory Measurement-Quality Assessment

Internal consistency reliability was assessed before conducting the correlation and exploratory dimensional-reduction analyses. Cronbach's alpha was calculated for the predefined multi-item scales available in the 108-response comparative questionnaire. Reliability was also evaluated for the three factor-derived project complexity subscales obtained from the retained exploratory factor solution.

The scales evaluated were competitive environment and client orientation, organizational structure, managerial processes related to planning and coordination, quality management, communication and information management, budget and financial management, occupational health and safety management, operational performance indicators, project-management methods adoption, and project complexity.

Before calculating the reliability coefficients, item direction was reviewed to ensure consistent interpretation within each item set. In the operational performance indicator set, material losses, nonconformities, and rework were reverse-coded so that higher scores consistently represented more favorable project performance. No missing-value imputation was performed for the reliability analyses.

Cronbach's alpha values of 0.70 or higher were interpreted as acceptable, values of 0.80 or higher as good, and values of 0.90 or higher as excellent. For the two-item process-stage complexity subscale, the inter-item correlation and the Spearman–Brown coefficient were also considered. For a two-item scale, Cronbach's alpha is equivalent to the Spearman–Brown coefficient.

Cronbach's alpha was interpreted exclusively as an indicator of internal consistency and not as evidence of unidimensionality or construct validity. The dimensional structure of the item blocks was evaluated separately through exploratory factor or principal component analysis.

The logistics strategy and productivity components were not included as predefined scales in the reliability table because they were generated through exploratory dimensional-reduction procedures. Their adequacy was evaluated using KMO, Bartlett's test, explained variance, scree-plot inspection, rotated loading patterns, and theoretical interpretability.

Measurement-quality assessment was adapted to the analytical status of each questionnaire block. The instrument did not constitute a single reflective measurement model, and the same psychometric indicators were therefore not applied indiscriminately to all item sets.

Cronbach's alpha was calculated for the predefined multi-item scales and for the factor-derived project complexity subscales. The operational performance variables were treated as heterogeneous outcome indicators and were not interpreted as interchangeable manifestations of one latent construct. Similarly, the project-management-methods block was interpreted as a descriptive adoption index rather than as a strictly reflective scale.

The logistics strategy and productivity dimensions were generated through exploratory dimensional-reduction procedures. Because these components were not specified a priori as reflective latent constructs, composite reliability and Average Variance Extracted were not calculated for their post hoc labels. Their measurement quality was evaluated through KMO, Bartlett's test, explained variance, scree-plot behavior, loading patterns, cross-loading inspection, and substantive interpretability.

Exploratory Composite Reliability and Average Variance Extracted were calculated only for the three factor-derived project complexity subscales because these dimensions presented an interpretable item-to-factor structure. Composite Reliability was calculated as $CR = (\Sigma\lambda)^2/[(\Sigma\lambda)^2 + \Sigma(1 - \lambda^2)]$, where λ represents the standardized rotated loading of each assigned item. Average Variance Extracted was calculated as $AVE = \Sigma\lambda^2/k$, where k represents the number of items assigned to the factor.

These coefficients are reported as exploratory measurement-quality estimates rather than as evidence from a confirmatory measurement model. No Confirmatory Factor Analysis was conducted, and the study therefore does not claim definitive convergent or discriminant validity for the complete questionnaire.

3.6.3. Correlation Analysis Procedures

Pearson's correlation coefficient was used in the organizational–managerial module to examine the direction and strength of the linear associations among competitive environment, organizational structure, and managerial process variables. The reported coefficients were interpreted according to their magnitude and substantive context rather than solely according to statistical significance.

Because the study employed a cross-sectional and non-experimental design, the correlations were not interpreted as evidence of causal direction. A positive association between two variables may indicate that they develop jointly, that either variable influences the other, or that both are associated with an additional organizational or contextual characteristic. Accordingly, Section 4 presents plausible substantive interpretations of the observed patterns, while causal mechanisms are treated as propositions requiring subsequent confirmatory or longitudinal research.

The choice of correlation coefficient followed the analytical function and response format of each module. Pearson's correlation coefficient was retained for the organizational–managerial analysis, in which the corresponding variables were treated as approximately continuous in the original statistical procedure. Spearman's rank correlation coefficient was used for the reported ordinal and Likert-type associations in the logistics strategy and productivity modules. Statistical significance was evaluated using two-tailed tests with an alpha level of 0.05. The correlation tables identify the coefficients meeting this criterion through a consistent significance marker.

Complete archived diagnostic outputs for univariate and bivariate normality, linearity, homoscedasticity, and influential observations were not available for all reported Pearson correlations. Consequently, the Pearson coefficients are interpreted as exploratory measures of linear association within the participating sample rather than as estimates supported by a complete retrospective verification of all parametric assumptions.

All reported correlations were evaluated using two-tailed tests at $\alpha = 0.05$ [54]. The analyses were used to identify association patterns within the corresponding modules. As clarified in Section 4.5.2, a separate factor-score correlation analysis linking the project complexity subscales with the heterogeneous operational performance indicators is not reported in the present study.

Correlation analysis was used to examine the reported associations within the organizational–managerial, logistics strategy, and productivity modules. The project complexity analysis focused on dimensional structure, internal consistency, and regional comparison. A separate factor-score correlation analysis linking the factor-derived project complexity subscales with the heterogeneous operational performance indicators is not reported in the present study. Accordingly, complexity–performance relationships are treated as theory-guided propositions rather than as directly estimated correlation effects.

3.6.4. Exploratory Factor and Component Analyses

Exploratory factor and component analyses were used to identify latent or reduced-dimensional structures among the perception-based variables. Although the data-collection instrument was integrated, it was explicitly multidimensional and contained theoretically differentiated item blocks addressing organizational structure, managerial processes, logistics and strategy, construction-site productivity, and project complexity. Accordingly, the full set of items was not forced into a single extraction. Instead, separate analytical runs were conducted for conceptually homogeneous blocks.

The organizational–managerial block required two complementary factor analyses. The first included 17 variables related to the competitive environment and organizational structure. The second included 48 variables associated with the development of managerial processes. The resulting two- and three-factor structures were subsequently integrated into the five organizational–managerial dimensions presented in the Section 4. Separate analyses were also performed for the logistics strategy, productivity, and project complexity blocks.

The literature-derived variables and the empirically extracted dimensions represent different analytical levels and should not be interpreted as directly interchangeable. The Literature Review provided the conceptual basis for identifying the original variables, which were operationalized as individual questionnaire items and organized a priori into four substantive domains. Exploratory Factor Analysis and Principal Component Analysis did not replace those variables or generate a different set of questionnaire measures. Instead, they examined the covariance patterns among the original items to identify how those items were empirically grouped within the study sample.

Consequently, the factors and components reported in the Results represent exploratory, sample-specific summaries of the relationships among the measured items. Their labels were assigned after examining the loading patterns and the substantive meaning of the associated items. Differences between the initial literature-based domains and the extracted dimensions therefore reflect empirical reorganization within the broader theoretical domains rather than a departure from the variables identified in the literature. Items that did not meet the retained loading threshold remained part of the original instrument and, where applicable, were preserved for descriptive or item-level analysis, but they were not assigned to factor-derived subscales.

Prior to extraction, the suitability of each correlation matrix was assessed using the Kaiser–Meyer–Olkin measure of sampling adequacy and Bartlett's test of sphericity. KMO values equal to or greater than 0.50 were considered sufficient for an exploratory analysis. Bartlett's test was interpreted using the approximate chi-square statistic, degrees of freedom, and associated p-value; statistical significance indicated that the correlation matrix differed from an identity matrix and contained sufficient inter-item relationships for factor or component extraction.

The extraction method was selected according to the analytical purpose and the original structure of each module. Maximum-likelihood factor extraction was used for the organizational–managerial, productivity, and project complexity blocks because these analyses were oriented toward identifying underlying latent dimensions. Principal component analysis was used for the logistics strategy block because its primary objective was dimensional reduction and the preservation of the maximum amount of observed variance. Orthogonal varimax rotation was applied to facilitate interpretation and obtain a simpler distribution of loadings.

Factor retention was determined through a combined decision rule. Initial eigenvalues greater than 1.0 were treated as an initial diagnostic rather than as an automatic retention rule. The retained solutions also considered: (i) the shape and progressive flattening of the scree plot; (ii) the cumulative percentage of explained variance; (iii) the parsimony of the solution; (iv) the magnitude and distribution of the factor loadings; and (v) the theoretical interpretability of the resulting dimensions. Absolute loadings of 0.40 or higher were considered substantively relevant.

This combined approach was necessary because the Kaiser criterion tended to overextract components in the item-rich organizational–managerial and productivity blocks. In such cases, additional components with eigenvalues slightly above 1.0 contributed limited incremental explanatory value and generated fragmented or weakly interpretable structures. The final solutions therefore balanced statistical evidence with conceptual coherence.

For the productivity block, the exploratory analysis statistically extracted nine components, explaining 67.122% of the variance after rotation. These components were subsequently mapped into five higher-order operational domains—resource management, project management, safety, planning, and labor-related conditions—to facilitate comparison with the theoretical framework and the Relative Importance Index results. The five domains should therefore be understood as an interpretive synthesis of the extracted components, rather than as five components directly produced by the statistical extraction.

The exact KMO values, Bartlett statistics, retained factors or components, and cumulative variance explained are reported in Section 4.1.3. The complete eigenvalue tables, extraction and rotation sums of squared loadings, and scree plots are provided in the Supplementary Materials.

The scree plots were examined together with the initial eigenvalues, cumulative explained variance, loading patterns, parsimony, and theoretical interpretability. Because the study involved five analytical runs, the corresponding scree plots are provided in Supplementary Figures S1–S5 to avoid overloading the main manuscript. These figures support the retention decisions discussed for each analytical module in the Results section.

Absolute rotated loadings of 0.40 or greater were treated as salient for exploratory interpretation. Supplementary Tables S7–S15 provide loading-level information according to the analytical output available for each module. Supplementary Tables S7 and S8 report the salient rotated loading structures retained for the competitive environment and organizational structure variables and for the managerial process variables, respectively. Supplementary Table S9 presents the complete rotated component matrix for the logistics strategy analysis. Supplementary Tables S10–S14 reproduce the domain-specific component matrices preserved from the source productivity analyses; these matrices are distinct from the integrated nine-factor variance summary reported in Supplementary Table S5. Supplementary Table S15 presents the rotated factor matrix for the project complexity items, including the identified salient cross-loading.

Because the complete integrated 40-item by nine-factor rotated matrix for the productivity analysis was not preserved in the available analytical output, the supplementary material does not present it as if it were available. The productivity results are therefore documented through the complete variance summary in Supplementary Table S5 and the domain-specific loading matrices reproduced in Supplementary Tables S10–S14. This distinction is stated explicitly to avoid conflating the integrated nine-factor extraction with the separate source-study component solutions.

Items were assigned to a factor when they presented a salient primary loading and their substantive content was consistent with the interpretation of that factor. When an item did not reach the reporting threshold, it was not assigned to a factor-derived subscale. Items were not deleted solely to maximize Cronbach's alpha, Composite Reliability, explained variance, or conceptual simplicity.

Where an item set represented heterogeneous outcomes or a post hoc exploratory component rather than a predefined reflective construct, no purification procedure was used to transform it artificially into a unidimensional scale. Such variables were retained for item-level or exploratory analysis and were interpreted according to their original analytical function.

3.6.5. Relative Importance Index (RII)

For the analysis of productivity variables, the Relative Importance Index (RII) method was applied to rank the factors according to their perceived impact on construction productivity.

The RII is calculated using the following expression:

$$RII = \frac{\sum W}{A \times N}$$

where

- (W) represents the weight assigned to each factor by respondents;
- (A) represents the highest possible weight in the scale;
- (N) represents the total number of responses.

This method is widely used in construction management research to prioritize factors affecting productivity and project performance [35].

RII values were reported to three decimal places. Items with identical reported RII values were treated as tied and were assigned the same level of relative importance. No secondary criterion was applied to break ties. The order in which tied items are displayed is descriptive only and does not indicate a statistically meaningful difference between them. The RII summarizes the weighted central tendency of the responses and was not interpreted as a measure of inter-rater agreement or respondent consensus.

The RII was applied exclusively to the productivity module because the items in this block were formulated as directly comparable conditions evaluated according to a common criterion: their perceived importance or impact on construction productivity. This common evaluative purpose made it methodologically appropriate to rank the items within the same analytical set.

The organizational–managerial and logistics strategy modules served different measurement purposes. Their items represented heterogeneous structural characteristics, managerial practices, coordination mechanisms, organizational relationships, and levels of implementation rather than a uniform set of conditions rated according to one importance criterion. Applying the RII to those modules would therefore have required ranking conceptually different types of variables as though they were directly comparable. These modules were instead examined through descriptive statistics, reliability assessment, correlation analysis, Exploratory Factor Analysis, and Principal Component Analysis, according to the analytical function of each item block.

3.6.6. Analytical Scope and Rationale for the Selected Multivariate Strategy

The statistical strategy was selected to correspond with the exploratory, cross-sectional, and module-based design of the study. Descriptive statistics, regional comparability tests, reliability assessment, correlation analysis, Exploratory Factor Analysis, Principal Component Analysis, discriminant analysis, and Relative Importance Index ranking were used to examine complementary parts of the integrated theoretical framework.

The available analytical records did not provide a complete and uniform set of assumption diagnostics for every statistical procedure. The documented evidence included descriptive distributional characteristics for the regional variables, expected-frequency criteria for categorical comparisons, and KMO and Bartlett statistics for the dimensional-reduction analyses. However, complete retrospective diagnostics for normality, homoscedasticity, linearity, multivariate normality, covariance-matrix equality, and influential observations were not available across all correlation, group-comparison, and discriminant analyses.

The selected procedures are therefore presented as exploratory analytical decisions consistent with the available variables and preserved outputs. The manuscript does not claim that every assumption associated with each statistical technique was formally tested and satisfied.

The study did not estimate the complete framework through covariance-based Structural Equation Modeling. A structural-equation model requires a previously specified and adequately validated measurement structure linking latent constructs and their indicators. In the present study, the analytical blocks did not have an equivalent measurement status. Some variables formed predefined multi-item scales, some dimensions were identified through Exploratory Factor Analysis, the logistics and productivity structures were generated through exploratory dimensional reduction, the project-management-methods block was treated as a descriptive adoption index, and the operational performance variables represented heterogeneous outcomes rather than one reflective latent construct.

Consequently, combining all modules within one covariance-based structural model would require imposing a homogeneous measurement specification that was not supported by the design of the instrument. The complete measurement structure had also not been evaluated through Confirmatory Factor Analysis in an independent sample. Estimating the measurement and structural models after deriving the dimensional structure from the same 108 observations would increase the risk of sample-specific overfitting and would not constitute independent confirmation of the proposed framework.

The sample size also limited the defensible complexity of a structural model. Structural Equation Modeling does not have one universally applicable minimum sample size; adequacy depends on the number of latent variables, indicators, freely estimated parameters, expected effect sizes, distributional characteristics, and model reliability. Nevertheless, the proposed integrated framework contains several constructs, indirect relationships, complexity dimensions, and heterogeneous indicators. With $N = 108$, estimating this complete structure would produce a high parameter-to-sample burden and potentially unstable standard errors, fit indices, and path estimates.

Partial Least Squares Structural Equation Modeling was not adopted as a small-sample substitute. PLS-SEM also requires an explicitly specified measurement model, a defensible distinction between reflective and formative constructs, theoretically defined structural paths, assessment of reliability and validity, and sufficient statistical power for the relevant path coefficients. The use of PLS-SEM after inspecting the exploratory structures and empirical correlations would convert a theory-guided exploratory analysis into a post hoc structural model and could capitalize on sample-specific relationships.

Path analysis was not conducted because it would require defensible observed composite scores for all constructs included in the integrated framework. Such scores were not available for the heterogeneous performance indicators or for all post hoc factor and component interpretations. Constructing composite scores solely to estimate a path model would obscure the different measurement functions of the analytical blocks and could imply a level of construct validation that the study did not establish.

Mediation analysis was not performed because the cross-sectional design does not provide temporal ordering among structural capacity, managerial processes, logistics, operational reliability, and performance-related outcomes. Although cross-sectional indirect effects can be estimated statistically, they cannot establish the temporal process required for a strong mediation interpretation. The proposed indirect sequence is therefore presented as a theory-guided proposition requiring longitudinal or time-separated confirmation.

Moderation analysis was also not conducted. Project complexity was conceptualized as a conditioning framework that increases coordination requirements, but interaction effects between complexity dimensions and managerial or logistical variables were not specified as part of the original analytical design. Interaction effects generally require greater statistical power than corresponding main effects, and the available sample was not prospectively sized for multiple interaction tests. Complexity is therefore not described as a statistically demonstrated moderator.

Accordingly, the conceptual framework presented in Section 5.5 represents a theoretically and empirically informed conceptual framework rather than an estimated structural model. The exploratory analyses identify dimensional structures, associations, rankings, and cross-module patterns that provide a foundation for subsequent confirmatory research. Future studies should validate the measurement model in an independent sample before testing the proposed direct, indirect, mediation, and moderation relationships through covariance-based SEM, PLS-SEM, path analysis, or longitudinal modeling.

A latent-variable multigroup analysis was not conducted. Such an analysis would require a previously validated measurement model, evidence of configural, metric, and scalar measurement invariance, and adequate sample sizes within each regional group. The current study used exploratory factor and component structures, and the regional subsamples contained 59 and 49 observations, respectively.

Estimating separate structural models or testing invariant latent parameters with these group sizes would produce an unfavorable parameter-to-sample ratio and potentially unstable estimates. Moreover, the measurement structure was not independently confirmed before the regional comparison.

The principal correlation and dimensional-reduction analyses were conducted using the pooled sample of 108 responses to examine exploratory association and covariance patterns across the complete set of participating firms. This analytical decision should not be interpreted as evidence that the Cochabamba and Metropolitan Region of Curitiba subsamples were homogeneous or that measurement equivalence had been established across the four substantive modules.

Separate factor or component analyses by region were not considered methodologically defensible because the regional subsamples contained 59 and 49 observations, respectively, while the organizational–managerial, logistics strategy, and productivity matrices included up to 48, 34, and 40 items. Dividing the sample would therefore have produced highly unfavorable cases-per-item ratios and potentially unstable factor or component structures. Formal regional invariance testing was also not appropriate because the measurement structures were exploratory and had not first been confirmed in an independent sample.

Accordingly, the pooled solutions are interpreted as exploratory structures describing the complete participating sample and may contain unmodeled regional heterogeneity. They are not presented as invariant measurement models or as evidence that the same relationships necessarily operate with equal magnitude in both regional contexts.

The regional investigation was therefore limited to the observed firm and respondent characteristics and to the discriminant comparison of the nine project complexity variables included in the archived comparative model. Although the complete project complexity block contained ten items, the adverse-climatic-exposure item was not included in the original regional discriminant output. The regional analysis should consequently not be interpreted as a complete comparison of the full ten-item block. A formal multigroup analysis and a complete ten-item regional comparison should be undertaken in future research after the measurement model has been confirmed in a larger independent sample and measurement invariance has been established.

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4. Results

4.1. Structure of Results and Analytical Logic

The Results section follows the same analytical organization established in Sections 3.1 and 3.4. Firm and respondent characteristics are first presented as a separate descriptive layer. The subsequent findings are organized into four substantive modules:

1. Organizational structure and managerial processes;
2. Logistics, strategy, and organizational interaction;
3. Productivity and operational performance; and
4. Project complexity.

Project complexity is therefore treated as the fourth substantive empirical module. It also performs an integrative theoretical role in the subsequent Discussion, where its technical, process-stage, and planning-related dimensions are interpreted in relation to the coordination requirements connecting the other modules. This integrative interpretation does not represent a direct statistical test of complexity effects on performance.

Each subsection reports results derived explicitly from:

- Descriptive statistics;
- Correlation analysis (Pearson and Spearman);
- Exploratory factor analysis and principal component analysis, with varimax rotation where applicable;
- Relative Importance Index (RII) (for productivity module).

Throughout the Results section, the term "variable" refers to an original questionnaire item or predefined measure, whereas "factor" and "component" refer to empirical groupings obtained through Exploratory Factor Analysis or Principal Component Analysis. These empirical groupings are interpreted within the broader literature-derived domains and are not presented as replacements for the original theoretical variables.

The sequence of the Results Section follows the propositions developed in Section 2.9. The organizational–managerial findings examine the relative positions of formal structure and enacted managerial processes in P1 and P2. The logistics strategy results examine the managerial and coordination mechanisms represented in P2 and P3. The productivity results examine the operational-reliability relationships expressed in P3 and P4. The project complexity results inform the conditioning interpretation proposed in P5.

This organization does not constitute a formal statistical test of the complete proposition system. It provides a transparent correspondence between the theoretical framework, the analytical modules, and the subsequent integrated interpretation.

4.1.1. Sample Characteristics and Regional Comparability

The final sample comprised 108 construction companies, including 59 from Cochabamba and 49 from the Metropolitan Region of Curitiba. The regional groups therefore represented 54.6% and 45.4% of the total sample, respectively.

Table 2 presents the firm and respondent characteristics of the two regional subsamples and the preliminary statistical comparisons. The results indicate that the two samples were similar in several measured characteristics, including firm age, approximate workforce size, legal constitution, certification status, accumulated project experience, and participation in residential, commercial, and industrial projects.

However, statistically significant differences were identified in annual constructed area, management type, respondent position, and participation in infrastructure or urban projects. Consequently, the regional samples cannot be considered completely equivalent. The comparative findings should instead be interpreted as evidence of partial balance across some characteristics and meaningful differences across others.

Table 2. Regional Sample Characteristics and Preliminary Comparability Tests.

Characteristic	Cochabamba	Curitiba	Statistical Test	*p*-Value	Effect Size
Firm age, years	15.7 ± 4.1, n = 59	18.8 ± 12.9, n = 49	Welch's $t(56.20) = -1.635$	0.108	Hedges' g = −0.339
Approximate number of employees	19 [15–23], n = 58	20 [10–50], n = 48	$U = 1330.0$	0.696	*rr*b = −0.045
Annual constructed area, m^2	1200 [913–1825], n = 54	2250 [1000–4250], n = 44	$U = 792.5$	0.005	*rr*b = −0.333
Projects completed since establishment			$\chi^2(3) = 2.116$	0.549	Cramér's V = 0.140
Fewer than 10 projects	9 (15.3%)	9 (18.4%)			
11–20 projects	27 (45.8%)	16 (32.7%)			
21–40 projects	11 (18.6%)	13 (26.5%)			
41 or more projects	12 (20.3%)	11 (22.4%)			
Limited-liability company	46 (78.0%)	41 (83.7%)	$\chi^2(1) = 0.557$	0.456	Cramér's V = 0.072
Professional management	54 (91.5%)	26 (53.1%)	$\chi^2(1) = 20.622$	<0.001	Cramér's V = 0.437
Quality or environmental certification	15 (25.4%)	16 (32.7%)	$\chi^2(1) = 0.684$	0.408	Cramér's V = 0.080
Manager or director respondent	43 (72.9%)	13 (26.5%)	$\chi^2(1) = 23.035$	<0.001	Cramér's V = 0.462
Residential projects	56 (94.9%)	48 (98.0%)	Fisher's exact test	0.625	Cramér's V = 0.080
Commercial projects	32 (54.2%)	31 (63.3%)	$\chi^2(1) = 0.898$	0.343	Cramér's V = 0.091
Industrial projects	33 (55.9%)	24 (49.0%)	$\chi^2(1) = 0.519$	0.471	Cramér's V = 0.069
Infrastructure or urban projects	43 (72.9%)	16 (32.7%)	$\chi^2(1) = 17.478$	<0.001	Cramér's V = 0.402

Note: Values are reported as mean ± standard deviation, median [interquartile range], or n (%), as appropriate. Negative Hedges' g and rank-biserial correlation values indicate lower values in Cochabamba relative to Curitiba. Professional management was contrasted with family or mixed management. Manager or director was contrasted with architect, engineer, supervisor, intern, or other technical positions. Infrastructure or urban projects included roads, railways, urbanization works, water and sewer networks, pipelines, energy infrastructure, and telecommunications works. Fields of activity were multiple-response variables and were analyzed as separate binary indicators. Analyses used available cases; two employee-count responses and ten annual-area responses were unavailable or unusable.

Firm age did not differ significantly between the two regional samples, Welch's $t(56.20) = -1.635$, $p = 0.108$, with a small-to-moderate standardized difference. The approximate number of employees was also similar. Although the Curitiba firms displayed greater dispersion and several relatively large workforce values, the median workforce was 20 employees, compared with 19 in Cochabamba, $U = 1330.0$, $p = 0.696$.

A significant difference was observed in annual constructed area. The median reported area was 1200 m^2 among the Cochabamba firms and 2250 m^2 among the Curitiba firms, $U = 792.5$, $p = 0.005$. The rank-biserial effect size was −0.333, indicating a moderate tendency toward larger annual construction volumes in the Curitiba subsample.

The accumulated number of completed projects did not differ significantly between the regions, $\chi^2(3) = 2.116$, $p = 0.549$. Similarly, no statistically significant differences were found in legal constitution or quality and environmental certification. Most companies in both regions operated as limited-liability firms, and approximately one quarter to one third reported holding a quality or environmental certification.

By contrast, the type of administration differed significantly. Professional management was reported by 91.5% of the Cochabamba companies and 53.1% of the Curitiba companies, $\chi^2(1) = 20.622$, $p < 0.001$, Cramér's V = 0.437. The composition of respondent positions also differed. Managers or directors represented 72.9% of the Cochabamba respondents but 26.5% of the Curitiba respondents, $\chi^2(1) = 23.035$, $p < 0.001$, Cramér's V = 0.462. The Curitiba sample contained a greater proportion of architects and engineers.

The regional samples were similar in their participation in residential, commercial, and industrial construction. However, infrastructure or urban projects were reported by 72.9% of the Cochabamba firms and 32.7% of the Curitiba firms, $\chi^2(1) = 17.478$, $p < 0.001$, Cramér's V = 0.402.

Taken together, these findings indicate partial rather than complete comparability. The samples were broadly similar in firm age, workforce size, legal constitution, certification, accumulated project experience, and several major project categories. Nevertheless, the differences in annual construction volume, management type, respondent position, and infrastructure participation must be considered when interpreting cross-regional results. The subsequent regional comparison is therefore restricted to the measured perceptions of project complexity and is not presented as evidence that the construction sectors of Cochabamba and Curitiba possess identical organizational profiles.

The observed partial comparability of the regional subsamples does not establish homogeneity across the organizational–managerial, logistics strategy, productivity, or project complexity modules. The subsequent pooled analyses therefore describe exploratory patterns across the complete participating sample. Regional equality of factor structures, loadings, correlations, or construct scores was not tested and should not be inferred from the pooled results.

4.1.2. Internal Consistency Reliability

Table 3 presents the internal consistency coefficients for the predefined questionnaire scales and the factor-derived project complexity subscales. The terminology used in the table corresponds to the constructs employed throughout the organizational–managerial and project complexity analyses.

Table 3. Internal Consistency Reliability of the Questionnaire Scales and Factor-Derived Project Complexity Subscales.

Scale or Construct Evaluated	Number of Items	Cronbach's α	Reliability Assessment	Use in the Analysis
Competitive environment and client orientation	9	0.787	Acceptable	Predefined scale; item-level, correlation, and factor analyses
Organizational structure	3	0.793	Acceptable	Predefined scale; item-level, correlation, and factor analyses
Managerial processes: planning and coordination	18	0.924	Excellent	Predefined scale; item-level, correlation, and factor analyses
Quality management practices	4	0.752	Acceptable	Predefined management subscale
Communication and information management	8	0.872	Good	Predefined management subscale

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Table 3. *Cont.*

Scale or Construct Evaluated	Number of Items	Cronbach's α	Reliability Assessment	Use in the Analysis
Budget and financial management	7	0.910	Excellent	Predefined management subscale
Occupational health and safety management	8	0.940	Excellent	Predefined management subscale
Operational performance indicators [1]	7	0.575	Limited	Indicators analyzed separately; no composite score
Project-management methods adoption [2]	13	0.892	Good	Descriptive adoption index
Overall project complexity block	10	0.847	Good	Complete ten-item block used for internal consistency analysis and EFA; nine-item subset used for the regional discriminant comparison
Technical complexity	3	0.867	Good	Factor-derived subscale
Process-stage complexity [3]	2	0.863	Good	Factor-derived two-item subscale
Planning-related complexity	3	0.779	Acceptable	Factor-derived subscale

Note: Cronbach's alpha coefficients were calculated using the complete 108-response comparative database. The predefined questionnaire scales were established from the conceptual organization of the instrument, whereas the technical, process-stage, and planning-related complexity subscales were derived from the retained exploratory factor solution. The factor-specific coefficients were calculated using the item sets assigned to each subscale; the alpha for the overall project complexity block was calculated using the complete ten-item set. The regional discriminant comparison was conducted using nine of the ten project complexity variables. The item concerning exposure of the construction-site location to adverse climatic conditions was included in the ten-item reliability and exploratory factor analyses but was not part of the archived comparative discriminant output used for the regional analysis. The reason for its exclusion was not documented in the original comparative analysis; therefore, the regional results are interpreted strictly as a nine-variable comparison. [1] For the operational performance indicators, material losses, nonconformities, and rework were reverse-coded so that higher values consistently represented more favorable performance. The resulting coefficient remained below the conventional 0.70 threshold. The indicators were therefore analyzed separately and were not aggregated into a composite performance score. [2] The project-management methods items represent the frequency or degree of adoption of different planning and management tools. Although the item set produced a high alpha coefficient, it was interpreted as a descriptive adoption index rather than as a strictly reflective latent construct. [3] The process-stage complexity subscale contains two items. For a two-item scale, Cronbach's alpha is equivalent to the Spearman–Brown coefficient. The corresponding inter-item correlation was $r = 0.762$. The logistics strategy and productivity components are not included in this table because they were exploratory structures identified through dimensional-reduction procedures rather than predefined reflective questionnaire scales. Composite Reliability and Average Variance Extracted were calculated only for the three factor-derived project complexity subscales and are reported in Supplementary Table S16. These coefficients were not calculated for heterogeneous operational indicators, descriptive adoption indices, or post hoc logistics and productivity components because those item sets were not specified as reflective measurement models.

Most predefined questionnaire scales demonstrated acceptable to excellent internal consistency. Competitive environment and client orientation obtained $\alpha = 0.787$, while organizational structure obtained $\alpha = 0.793$. The managerial processes scale, which included planning and coordination practices, demonstrated excellent reliability, with $\alpha = 0.924$.

The management-related subscales also produced adequate coefficients. Quality management practices obtained $\alpha = 0.752$, communication and information management obtained $\alpha = 0.872$, budget and financial management obtained $\alpha = 0.910$, and occupational health and safety management obtained $\alpha = 0.940$.

The project-management methods adoption index obtained $\alpha = 0.892$. Nevertheless, this result was interpreted cautiously because the items represent the adoption of different planning and management tools rather than interchangeable manifestations of a single reflective latent construct. The item set was therefore retained as a descriptive adoption index.

The overall ten-item project complexity block demonstrated good internal consistency, with $\alpha = 0.847$. The factor-derived complexity subscales also exceeded the conventional 0.70 threshold. Technical complexity obtained $\alpha = 0.867$, process-stage complexity obtained $\alpha = 0.863$, and planning-related complexity obtained $\alpha = 0.779$. Because process-stage complexity contained two items, the corresponding inter-item correlation was also examined and obtained r = 0.762.

The only item set that did not reach the conventional reliability threshold was operational performance. After aligning the direction of its negatively oriented items, the seven indicators produced $\alpha = 0.575$. This result indicates that material losses, productivity, schedule compliance, nonconformities, delivery performance, rework, and budget variance should not be interpreted as interchangeable manifestations of one homogeneous reflective construct.

Accordingly, the operational performance indicators were retained and analyzed separately. No overall operational performance composite score was calculated or used in the correlation, factor, or regional comparison analyses.

Cronbach's alpha was used as an indicator of internal consistency and was not interpreted as evidence of unidimensionality. The dimensional validity and latent structure of the corresponding analytical blocks were evaluated separately through exploratory factor or component analysis.

4.1.3. Assessment of Factorability and Factor-Retention Decisions

Table 4 summarizes the factorability indicators, extraction methods, retained solutions, and cumulative variance for the five dimensional-reduction analyses.

Because the questionnaire incorporated several theoretically differentiated dimensions, factorability was assessed separately for each analytical item block. The organizational–managerial section was further divided into two sub-analyses: one covering competitive environment and organizational structure variables, and another covering managerial process variables. This decision reduced the risk of forcing a large and conceptually heterogeneous item pool into a single unstable factor solution.

Table 4 presents the Kaiser–Meyer–Olkin measure, Bartlett's test of sphericity, extraction method, number of retained factors or components, and percentage of variance explained for each analytical run. All KMO values exceeded the minimum admissibility criterion of 0.50, ranging from 0.537 to 0.804. In all cases, Bartlett's test was statistically significant at $p < 0.001$, rejecting the null hypothesis that the corresponding correlation matrix was an identity matrix and supporting the application of dimensional-reduction procedures.

Factor retention was not based exclusively on the eigenvalue-greater-than-one criterion. The final solutions were evaluated through the combined consideration of initial eigenvalues, the shape and progressive flattening of the scree plots, cumulative variance, factor parsimony, loading patterns, and substantive interpretability. This combined procedure was particularly important in the high-dimensional organizational–managerial and productivity blocks, for which a mechanical application of the Kaiser criterion generated an excessive number of components.

Table 4. Summary of factorability, extraction, and variance explained across the analytical modules.

Item Block	Items	Valid N	Cases per Item	Extraction Method	KMO	Bartlett's χ^2	df	*p*-Value	Retained Factors /Components	Initial Cumulative Variance (%)	Extracted/ Rotated Cumulative Variance (%)
Competitive environment and organizational structure	17	108	6.35	Maximum likelihood	0.673	483.019	136	<0.001	2	39.684	32.205
Managerial processes	48	108	2.25	Maximum likelihood	0.537	2345.333	1128	<0.001	3	35.468	31.364
Logistics, strategy, and organizational interaction	34	108	3.18	Principal component analysis	0.573	1579.032	561	<0.001	5	54.954	54.954
Productivity and operational performance	40	108	2.70	Maximum likelihood	0.794	2431.914	780	<0.001	9	74.421	67.122
Project complexity	10	108	10.80	Maximum likelihood	0.804	571.564	45	<0.001	3	70.979	61.271

The initial cumulative variance corresponds to the variance represented by the retained initial eigenvalues. The final cumulative variance corresponds to the extracted and, where applicable, rotated solution. In the productivity module, the statistical extraction produced nine components; these components were subsequently interpreted within five higher-order operational domains and were not treated as five directly extracted factors. The percentage of variance explained by each retained factor or component is reported below and presented in full in Supplementary Tables S2–S6. For the competitive environment and organizational structure analysis, the two rotated factors explained 18.425% and 13.780% of the variance, respectively, resulting in a cumulative rotated variance of 32.205%. For the managerial process analysis, the three rotated factors explained 12.849%, 9.734%, and 8.781%, respectively, with a cumulative variance of 31.364%. For the logistics strategy analysis, the five rotated components explained 13.260%, 12.718%, 11.478%, 9.929%, and 7.569% of the variance, respectively. Together, they accounted for 54.954% of the total variance. The relatively balanced distribution after rotation indicates that the solution was not dominated by a single component and that logistical, strategic, operational, organizational, and cultural variables contributed distinct portions of the explained variance. The productivity analysis produced a more distributed nine-component solution. After rotation, the individual components explained 11.902%, 10.553%, 8.063%, 7.946%, 7.268%, 7.184%, 6.483%, 5.272%, and 2.451% of the variance, respectively, resulting in a cumulative rotated variance of 67.122%. This dispersed distribution is consistent with the multidimensional character of construction-site productivity and supports the interpretation that productivity constraints arise from several interacting operational and managerial mechanisms rather than from one dominant latent dimension. Finally, the three project complexity factors explained 24.460%, 20.524%, and 16.287% of the variance after rotation, respectively. The cumulative rotated variance was 61.271%. The distribution of variance across the three factors supports the differentiation between technical complexity, process-stage complexity, and planning-related complexity while also showing that none of these dimensions alone fully accounts for the complexity perceived in construction projects. Cases per item were calculated as the number of valid observations divided by the number of items included in each analytical run. These ratios are reported as descriptive indicators of matrix density and were not used as the sole criterion for determining factorability. Factorability and retention decisions were based on the combined evidence from KMO, Bartlett's test, eigenvalue distributions, scree plots, explained variance, loading patterns, parsimony, and theoretical interpretability.

The scree plots corresponding to the five analytical runs are presented in Supplementary Figures S1–S5. The competitive environment and organizational structure analysis showed a progressive flattening after the second factor, whereas the managerial process analysis displayed a comparable reduction in the contribution of additional factors after the third factor. The logistics strategy analysis showed that the first five components concentrated the most interpretable portion of the eigenvalue distribution. The productivity analysis presented a more dispersed multidimensional pattern, supporting the retention of nine statistical components. Finally, the project complexity analysis exhibited a clear stabilization after the third factor. These patterns were interpreted jointly with the eigenvalue criterion, cumulative explained variance, rotated loading structure, parsimony, and conceptual coherence.

The addition of sample-density information shows that the analytical blocks did not present identical sampling conditions. The project complexity block had the strongest cases-per-item ratio, while the managerial process, logistics strategy, and productivity analyses involved larger item sets relative to the available sample.

The significant Bartlett tests indicate that the corresponding correlation matrices were not identity matrices, but statistical significance alone does not guarantee stable factor recovery. The KMO values provide a more differentiated assessment. The project complexity and productivity blocks showed comparatively favorable adequacy, whereas the managerial process and logistics strategy matrices were closer to the minimum acceptable range.

The factor and component solutions are therefore interpreted as exploratory empirical structures. Particular caution is required for the managerial process analysis because of its 48-item matrix, cases-per-item ratio of 2.25, and KMO value of 0.537. These results remain informative for identifying association patterns, but they should be replicated in larger independent samples before being treated as stable measurement structures.

4.2. Organizational Structure and Managerial Processes

4.2.1. Descriptive Characterization

The descriptive interpretation of this module is restricted to the participating firms and respondents and should not be generalized to the complete construction sectors of Bolivia or Brazil. Table 2 indicates that the Cochabamba and Metropolitan Region of Curitiba subsamples were broadly similar in firm age, approximate workforce size, legal constitution, certification status, accumulated project experience, and participation in residential, commercial, and industrial projects.

However, the subsamples differed significantly in annual constructed area, management type, respondent position, and participation in infrastructure or urban projects. Within the participating firms in the Cochabamba subsample, professional management and manager- or director-level respondents were more frequent than in the Metropolitan Region of Curitiba subsample. These differences require the organizational and managerial results to be interpreted as evidence from the participating sample rather than as population-level organizational profiles.

The predefined organizational–managerial scales demonstrated adequate internal consistency. Competitive environment and client orientation obtained $\alpha = 0.787$, organizational structure obtained $\alpha = 0.793$, and managerial processes related to planning and coordination obtained $\alpha = 0.924$. Quality management, communication and information management, budget and financial management, and occupational health and safety management also exceeded the conventional 0.70 threshold, as reported in Table 3.

The available descriptive evidence does not support definitive statements concerning the prevalence of small and medium-sized firms, the general degree of hierarchy, the extent of organizational formalization, or the predominance of centralized decision-making across the broader Bolivian construction sector. These characteristics are therefore not presented as established descriptive findings of the study.

4.2.2. Correlation Analysis: Structural vs. Process Variables

Pearson correlation analysis revealed distinct relational patterns among competitive environment, organizational structure, and managerial process variables. The structural variables did not show uniformly strong associations with performance-related managerial practices. By contrast, several stronger and more coherent relationships were concentrated among variables representing planning, stakeholder orientation, information management, and process integration.

The selected coefficients are presented in Table 5. Their interpretation focuses on the organizational logic represented by each relationship. Because the analysis is cross-sectional, the direction of the relationships should not be interpreted as causal. All coefficients displayed in the table met the two-tailed statistical-significance criterion of $p < 0.05$.

Table 5. Selected Pearson Correlations among Competitive environment, Organizational structure, and Managerial process Variables.

Analytical Block	Variable 1	Variable 2	Pearson's r
Competitive environment	Impact of raw materials on projects	Cost of changing suppliers	0.68 *
Competitive environment	Cost of changing suppliers	Volume of raw-material purchases	−0.67 *
Competitive environment	Volume of raw-material purchases	Impact of raw materials on projects	−0.67 *
Competitive environment and organizational structure	Market predictability	Formalization of positions or functions	0.69 *
Organizational structure	Employee autonomy	Workforce growth during the previous three years	0.53 *
Organizational structure	Employee autonomy	Orientation toward cost reduction	0.56 *
Managerial processes	Customer-service practices	Supplier-relationship assessment	0.70 *
Managerial processes	Formal demand forecasting	Advertising, promotion, and pricing management	0.63 *
Managerial processes	IT-oriented business-process architecture	Organizational-climate assessment	0.60 *
Managerial processes	Information-management system	Technology compatible with business strategy	0.61 *
Managerial processes	Marketing strategy	Formal project-design development process	0.63 *

Note: The table presents selected Pearson correlation coefficients from the organizational–managerial module. * $p < 0.05$, two-tailed. The coefficients describe the direction and strength of association and should not be interpreted as evidence of causal direction.

The strongest association connecting the competitive environment with organizational structure was observed between market predictability and the level of formalization of positions or functions (r = 0.69). This coefficient should not be interpreted as evidence that market predictability directly causes organizational formalization. One plausible interpretation is that stable and recurrent market conditions make it easier for companies to identify repeated activities, establish specialized positions, define responsibilities, and standardize procedures. When clients, project types, procurement requirements, and commercial conditions are relatively predictable, the organizational benefits of maintaining formal job descriptions and stable functional arrangements become more evident.

Under highly unstable market conditions, by contrast, firms may depend more strongly on multifunctional roles, informal coordination, and rapid reassignment of responsibilities. Formal specialization may be more difficult to sustain when the type, volume, and requirements of projects change continuously.

An alternative interpretation is also possible. More formalized firms may possess better market-information systems, established commercial routines, and more systematic forecasting processes, which could lead them to perceive their operating environment as more predictable. Both variables may additionally reflect firm maturity, stable client portfolios, accumulated experience, or organizational size. The observed coefficient therefore indicates a close relationship between environmental stability and structural formalization but does not establish the direction of influence.

Within the competitive environment block, the perceived impact of raw materials on projects was positively associated with the cost of changing suppliers (r = 0.68). This relationship is substantively plausible because firms that depend on technically approved, specialized, or reliably supplied materials may perceive supplier substitution as costly. Switching suppliers can involve new quality evaluations, compatibility checks, renegotiation, transportation changes, delivery uncertainty, and potential disruption of construction activities.

The volume of raw-material purchases was negatively associated with both the cost of changing suppliers and the perceived impact of raw materials on projects (r = −0.67 in both cases). One possible explanation is that higher purchasing volumes provide stronger negotiating capacity, access to volume discounts, more stable supply agreements, and greater ability to distribute procurement costs across projects. The original analysis similarly suggested that large-volume purchasing could reduce the economic effect of materials through negotiated discounts. Nevertheless, the negative relationships may also reflect differences in company scale or procurement maturity and should not be treated as direct causal effects.

Employee autonomy was positively associated with workforce growth during the previous three years (r = 0.53). Growing companies commonly face a larger number of projects, decisions, and coordination requirements, making it increasingly difficult to concentrate all operational decisions at the senior-management level. The association may therefore reflect a progressive delegation of authority as firms expand. The reverse relationship is also possible: greater employee autonomy may support organizational responsiveness and facilitate growth.

Employee autonomy was also associated with the company's orientation toward cost reduction (r = 0.56). This relationship may indicate that employees with greater local decision capacity can identify and implement operational adjustments more rapidly, particularly in purchasing, resource use, sequencing, and site organization. However, autonomy is likely to contribute to cost control only when accompanied by clear responsibilities, adequate information, and defined decision limits.

The strongest managerial process association occurred between customer-service practices and the systematic evaluation of supplier relationships (r = 0.70). These variables represent the two external interfaces of the company's value network: the downstream relationship with clients and the upstream relationship with suppliers. The association suggests that firms with a more systematic external orientation tend to monitor both client satisfaction and supplier performance. Rather than representing isolated practices, customer service and supplier evaluation may be manifestations of a broader stakeholder-management capability.

Demand forecasting through a formal process was associated with advertising, promotion, and pricing management (r = 0.63). This result reflects the operational connection between market anticipation and commercial decision-making. Forecasting provides information about expected demand, project types, client segments, and market conditions, while advertising and pricing processes translate that information into commercial actions. The relationship therefore indicates integration between market intelligence and strategic preparation.

The definition of an information-technology-oriented business-process architecture was associated with organizational-climate assessment (r = 0.60). Although these practices address different organizational domains, both require formalized mechanisms for collecting, processing, and evaluating internal information. The association may consequently reflect a broader managerial orientation toward systematic monitoring and organizational diagnosis rather than a direct relationship between technology and workplace climate.

The availability of an information-management system was associated with the possession of software and hardware compatible with business strategy (r = 0.61). The substantive logic is complementary: information systems require adequate technological infrastructure, while software and hardware only produce organizational value when incorporated into information-management processes and aligned with strategic needs.

Marketing strategy was also associated with the existence of a formal project-design development process (r = 0.63). This relationship may indicate that firms seeking to position their services systematically in the market also tend to standardize how project proposals and designs are developed. A formal design-development process can translate client requirements and market positioning into technical specifications, scope definitions, and project solutions.

Taken together, the observed relationships indicate that the strongest associations are not isolated links between individual managerial practices. They represent clusters of complementary activities: market stability and formalization, procurement exposure and supplier dependence, organizational growth and delegation, client orientation and supplier assessment, forecasting and commercial planning, and technology and information management.

Pearson correlation analysis was used to evaluate the strength and direction of relationships between variables. The results show that most significant correlations are concentrated among managerial process variables, reflecting their strong interdependence. In contrast, company identification variables exhibit no significant relationship with managerial processes, as they represent general characteristics with limited operational impact.

The contrast between structural and process-related correlations constitutes a central result for the complexity-based interpretation of the study. Formal organizational attributes did not exhibit a uniformly strong relationship with performance-related managerial variables. Although some structural and environmental variables were significantly associated with each other—for example, market predictability and formalization of positions—the direct relationships between structural configuration and managerial-performance indicators were generally weaker and less consistent.

By contrast, stronger and more coherent associations were concentrated among managerial process variables. Customer-service practices were strongly associated with the systematic evaluation of supplier relationships (r = 0.70), demand forecasting was associated with advertising, promotion, and pricing management (r = 0.63), and the availability of information-management systems was associated with the possession of software and hardware compatible with business strategy (r = 0.61). These relationships connect functions that are formally located in different areas of the firm but operationally depend on continuous information exchange, coordination, and mutual adjustment.

The substantive relevance of this pattern is not simply that customer management, supplier evaluation, forecasting, or information technology are individually important. Rather, the results indicate that managerial capability is distributed across interdependent processes. Customer-service quality depends partly on how supplier relationships are monitored; commercial planning is linked to forecasting capacity; and information systems become operationally meaningful when they are aligned with business strategy. In each case, the observed relationship crosses conventional functional boundaries.

From a complexity perspective, these findings are consistent with the idea that performance-relevant behavior emerges through interaction among organizational subsystems. Formal structure establishes authority, role distribution, and reporting relationships, but process effectiveness depends on the quality of the connections activated within that structure. Therefore, the comparatively stronger process-to-process associations suggest that the dynamic coupling of activities is more directly related to managerial functioning than structural configuration considered in isolation.

4.2.3. Factor Analysis: Latent Dimensions

Because the organizational–managerial item block contained variables representing different levels of analysis, it was divided into two complementary maximum-likelihood factor analyses. The first analysis covered 17 competitive environment and organizational structure variables. Its KMO value was 0.673, and Bartlett's test was statistically significant, $\chi^2(136) = 483.019$, $p < 0.001$. Two factors were retained. The initial two eigenvalues represented 39.684% of the total variance, while the extracted and rotated solution accounted for 32.205%.

The second analysis covered 48 managerial process variables. The KMO value was 0.537, exceeding the minimum threshold for exploratory analysis, and Bartlett's test was statistically significant, $\chi^2(1128) = 2345.333$, $p < 0.001$. Three factors were retained. Their initial eigenvalues represented 35.468% of the variance, while the extracted and rotated solution explained 31.364%.

The decision to retain two and three factors, respectively, was based on parsimony, the progressive flattening of the eigenvalue distributions, the rotated loading structures, and substantive interpretability. A mechanical application of the eigenvalue-greater-than-one criterion would have produced a larger and substantially more fragmented solution. The retained five-dimensional interpretation therefore emerged from the integration of the two complementary analyses rather than from a single five-factor extraction.

In the retained exploratory solution, the first sub-analysis yielded the provisional dimensions Competitive Environment and Organizational Structure, whereas the second yielded Planning, Resources and Strategy, and Organizational Management. Together, these sample-specific dimensions provide an exploratory representation of how market conditions, structural configuration, managerial routines, resource anticipation, and internal organizational evaluation were grouped within the participating firms. They should not be interpreted as established or independently validated measurement dimensions. The corresponding scree plots are presented in Supplementary Figures S1 and S2, and the integrated rotated factor structure is presented in Table 6.

The first factor, labeled Competitive Environment, groups variables related to employee autonomy, cost orientation, availability of market information, and workforce growth. This factor suggests that organizational responsiveness is closely linked to how firms interpret and react to market conditions.

The second factor, Organizational Structure, includes the formalization of positions, the level of centralization, market predictability, and the possibility of collaboration with competitors. This factor captures the structural and configurational characteristics of the firm.

Table 6. Integrated rotated factor structure obtained from the two organizational–managerial sub-analyses.

FACTOR 1—COMPETITIVE ENVIRONMENT	
Degree of employee autonomy	0.657
Company's orientation toward cost reduction in its activities and ventures	0.640
Amount of information available about the market	0.619
Percentage growth in the number of employees over the last 3 years	0.603
FACTOR 2—ORGANIZATIONAL STRUCTURE	
Level of formalization of positions or functions	0.628
Possibility of collaboration and strategic alliances with market competitors	0.602
Predictability of the market in which the company operates	0.601
Level of centralization of the organizational structure	−0.596
FACTOR 3-PLANNING	
Existence of a motivation and incentives program	0.656
Existence of customer service policies	0.622
Assessment of supplier relationships, including quality, cost, and contract evaluation	0.573
Identification and development of internal leaders for future key positions	0.569
Existence of an advertising, promotions, and pricing management process	0.558
Systematic analysis of external relationships	0.554
Monitoring of employee health and safety aspects in the work environment	0.542
Existence of defined operational flows of business processes	0.535
Systematic management and control of cash flow	0.527
Possession of software and hardware technologies compatible with business strategy	0.520
Investment in fixed assets, machinery, equipment, and properties	0.513
FACTOR 4- RESOURCES AND STRATEGY	
Existence of demand forecasting through a formal process	0.560
Existence of a sales strategy	−0.526
Existence of a procedure for handling customer complaints and suggestions	0.509
FACTOR 5-ORGANIZATIONAL MANAGEMENT	
Existence of an organizational climate assessment	0.549

The third factor, Planning, is the most densely populated and includes variables related to motivation and incentives, customer service policies, supplier evaluation, internal leadership development, business process flows, health and safety monitoring, cash-flow control, and technological compatibility with strategy. This factor reflects the central role of planning and process integration in organizational performance.

The fourth factor, Resources and Strategy, groups demand forecasting, sales strategy, and procedures for handling complaints and suggestions, thereby linking operational anticipation with external strategic orientation.

The fifth factor, Organizational Management, is represented by organizational climate assessment, suggesting the importance of internal evaluation and managerial awareness as a distinct organizational dimension.

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Taken together, the retained exploratory pattern suggests that planning, market-oriented managerial practices, and resource-related strategic coordination were more prominently represented in the observed managerial process structure than formal organizational characteristics considered alone. Organizational structure remained one relevant dimension within the exploratory solution, but the present analysis does not establish its relative causal or explanatory effect on performance. Accordingly, the factor solution is interpreted as a sample-specific dimensional pattern that complements the correlation results and requires replication in a larger independent sample before its stability or measurement validity can be established.

4.3. Logistics, Strategy, and Organizational Interaction

4.3.1. Correlation Analysis

The analysis of logistical variables reveals a differentiated pattern of relationships. Significant associations are concentrated between logistics and strategy-related variables, whereas logistics shows weak or non-significant relationships with structural variables. In general, the strongest logistics-related associations fall within a moderate range ($0.30 < |\rho| < 0.50$), indicating partial but meaningful dependence on strategic practices.

These results suggest that logistical performance is more closely associated with planning, communication, coordination, and anticipatory management than with the formal structural characteristics of the firm.

4.3.2. Interpretation of Strategic–Logistical Relationships

Table 7 presents the three selected Spearman correlations used to illustrate the relationships between strategic and logistical variables. The table is presented in pairwise format rather than as a partial correlation matrix because only the coefficients discussed in the main text are displayed. Supplier-management efficiency was positively associated with communication among project participants ($\rho = 0.434$) and with employee responsibility in task execution ($\rho = 0.440$). Short- and long-term organizational sustainability was positively associated with the speed of resolving internal and external conflicts ($\rho = 0.598$). All three displayed coefficients met the two-tailed statistical-significance criterion of $p < 0.05$.

Table 7. Selected Spearman Correlations between Strategic and Logistical Variables.

Variable 1	Variable 2	Spearman's ρ
Supplier-management efficiency	Communication among project participants	0.434 *
Supplier-management efficiency	Employee responsibility in task execution	0.440 *
Short- and long-term organizational sustainability	Speed of resolving internal and external conflicts	0.598 *

Note: The table reports only the three selected strategic–logistical correlations discussed in the main text and should not be interpreted as a complete correlation matrix. * $p < 0.05$, two-tailed. Coefficients not displayed were not selected for presentation and should not be inferred to be zero, statistically nonsignificant, or untested.

The positive association between supplier-management efficiency and communication among project participants indicates that supplier coordination depends partly on the timely exchange of requirements, schedules, technical specifications, delivery conditions, and quality information. A supplier-management system may be formally established, but its operational effectiveness requires information to circulate among procurement personnel, project managers, site teams, and suppliers.

Supplier-management efficiency was also associated with employee responsibility in task execution. This relationship may reflect the importance of clearly assigned commitments and follow-up responsibilities throughout the procurement and delivery process. Logistical problems can persist when responsibilities for defining specifications, approving purchases, issuing orders, inspecting materials, and confirming deliveries are fragmented or unclear. The result therefore suggests that logistical reliability depends not only on formal procedures but also on the extent to which participants assume and complete their assigned responsibilities.

The association between organizational sustainability and the speed of conflict resolution suggests that organizational continuity is partly related to the capacity to prevent local disagreements from spreading across the project system. Unresolved conflicts may delay technical decisions, supplier payments, material approvals, subcontractor coordination, and resource flows. Rapid conflict resolution may therefore be associated with greater operational continuity and organizational stability, although the cross-sectional design does not establish whether conflict-resolution capacity produces sustainability or whether more sustainable organizations possess stronger mechanisms for resolving disputes.

Taken together, these relationships indicate that logistics is not determined exclusively by transportation, procurement, inventory, or material-storage techniques. Its effectiveness depends on the relational processes through which participants exchange information, allocate responsibilities, coordinate commitments, and manage disruptions.

The results also clarify why logistics showed stronger associations with strategic and process-related variables than with formal organizational structure. Hierarchy and departmental configuration establish the institutional framework within which logistics operates, but they do not independently determine whether information reaches suppliers on time, responsibilities are fulfilled, or conflicts are resolved before affecting project execution. Logistical performance is therefore more closely associated with enacted coordination capability than with static organizational design.

Although the principal component analysis identified logistics management, strategic planning, operational quality, organizational structure, and cultural-identity factors as differentiated components, the correlation pattern shows that these dimensions remain operationally connected. Logistics and strategy are statistically distinguishable but functionally interdependent, particularly through communication, responsibility, planning, and disruption-management mechanisms.

4.3.3. Principal Component Analysis Results

The logistics-related components reported in this section were generated through principal component analysis and should not be interpreted as predefined reflective questionnaire scales. Consequently, Cronbach's alpha coefficients were not assigned to the post hoc component labels. Their statistical adequacy was evaluated through the KMO measure, Bartlett's test, explained variance, rotated component loadings, and substantive interpretability.

The logistics strategy block comprised 34 variables and was analyzed using principal component analysis with varimax rotation. The Kaiser–Meyer–Olkin measure was 0.573. Bartlett's test was statistically significant, $\chi^2(561) = 1579.032$, $p < 0.001$, indicating that the correlation matrix contained sufficient interrelationships for component extraction.

Five components were retained. Their initial and extracted eigenvalues jointly accounted for 54.954% of the total variance. After varimax rotation, the distribution of explained variance was 13.260% for the first component, 12.718% for the second, 11.478% for the third, 9.929% for the fourth, and 7.569% for the fifth.

Although additional components presented eigenvalues above 1.0, their incremental contribution was smaller and their substantive structure was less coherent. The five-component solution was therefore retained on the basis of the scree pattern, cumulative variance, parsimony, and interpretability. The eigenvalue distribution and the progressive flattening observed after the fifth component are shown in Supplementary Figure S3.

The principal component analysis identified five components:

1. Logistics management;
2. Strategic planning;
3. Operational quality;
4. Organizational structure;
5. Cultural and identity factors.

The structure of these components reveals that:

- Logistics and strategy are adjacent but distinct dimensions;
- Structure remains isolated within its own factor.

The results indicate that logistics performance is not embedded in structural design but in planning capacity and strategic coherence.

This implies:

- Logistics efficiency depends on temporal alignment (scheduling);
- Resource coordination is driven by strategic decisions;
- Structural hierarchy does not influence operational flows directly.

The broader analytical treatment of the logistics module suggested five relevant dimensions: logistics management, strategic planning, operational quality, organizational structure, and cultural-identity factors.

4.4. Productivity Factors in Construction Projects

The operational performance indicators were treated as separate project outcomes rather than as a single reflective performance scale. After reverse-coding the negatively oriented indicators, the seven-item set produced $\alpha = 0.575$. Therefore, material losses, productivity, schedule compliance, nonconformities, project-delivery performance, rework, and budget variance were not aggregated into an overall performance score.

4.4.1. RII-Based Ranking

Because the productivity items were the only variables formulated for comparative prioritization under a common evaluative criterion, the RII ranking was restricted to this module.

The Relative Importance Index analysis identified a closely grouped set of operational, managerial, and resource-flow factors associated with construction-site productivity. Figure 1 presents the seven variables with the highest RII values. Items with identical values are treated as tied; therefore, their order within the figure should not be interpreted as indicating different levels of importance.

Maintenance of tools and equipment, execution of activities according to schedule, and adequate storage of materials shared the highest observed RII value, with RII = 0.776 for each item. These variables were therefore treated as tied rather than as first-, second-, and third-ranked factors. Their identical aggregate scores indicate equal relative importance at the reported level of precision, but they do not by themselves demonstrate agreement or consensus among individual respondents. Substantively, the tied values highlight three complementary conditions associated with operational reliability: equipment availability, schedule discipline, and continuity in the condition and availability of materials.

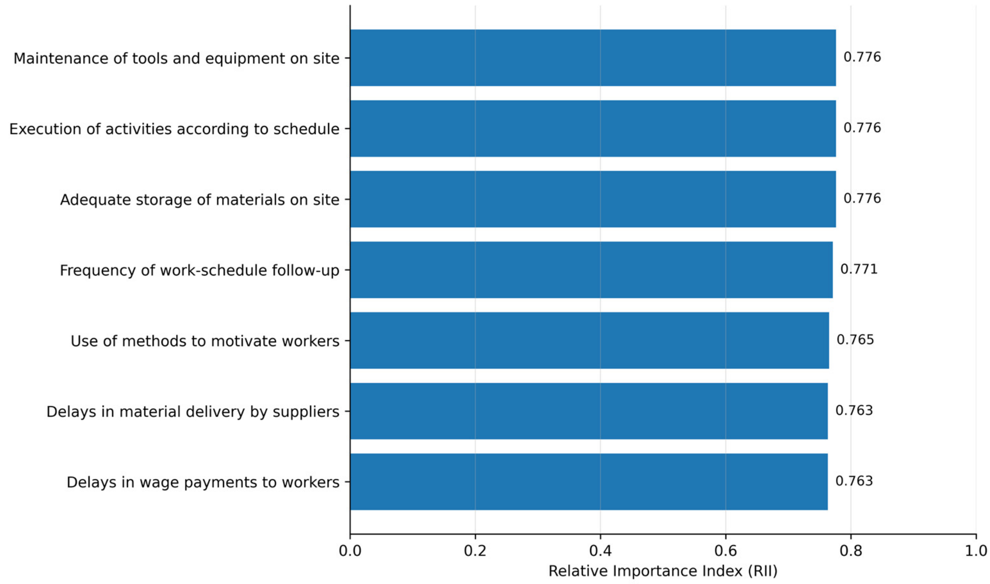

Figure 1. Highest-ranked factors affecting construction-site productivity according to the Relative Importance Index. Note: Items with identical RII values share the same level of relative importance. No secondary tie-breaking criterion was applied. The order of items within tied groups is descriptive only.

The next-highest RII value corresponded to the frequency of work-schedule follow-up, with RII = 0.771. This result reinforces the importance of active schedule control rather than relying only on the initial construction program. Schedule follow-up provides information about deviations and enables corrective decisions concerning resources, sequencing, suppliers, and work fronts.

The use of methods to motivate workers obtained RII = 0.765. Delays in material delivery by suppliers and delays in wage payments to workers shared an RII value of 0.763 and were therefore also treated as tied. Although these values were slightly lower than the highest observed scores, all seven variables remained within a narrow RII interval and represent relevant productivity-related conditions.

Taken together, the ranking indicates that construction-site productivity depends on the synchronization of equipment, materials, labor, information, and schedules. Equipment maintenance affects the availability of productive resources; schedule compliance depends on the coordination of multiple preceding conditions; adequate material storage protects material quality and availability; and schedule monitoring provides feedback for corrective action.

The rankings assigned to worker motivation, material-delivery delays, and wage-payment delays further demonstrate that productivity is influenced by both technical and managerial conditions. A disruption in any of these areas can affect subsequent activities because construction operations are sequentially and operationally interdependent. The RII results therefore support the interpretation of productivity as an outcome of operational reliability and coordinated resource flows rather than as the result of one isolated factor.

4.4.2. Statistical Components and Higher-Order Productivity Domains

The productivity components were identified through exploratory factor analysis and were not specified in advance as reflective questionnaire scales. Their adequacy was therefore assessed through factorability tests, explained variance, rotated loading patterns, and substantive interpretation rather than by assigning alpha coefficients to the post hoc factor labels.

The productivity block comprised 40 variables and was assessed using maximum-likelihood extraction with varimax rotation. Sampling adequacy was satisfactory, with a KMO value of 0.794. Bartlett's test was statistically significant, $\chi^2(780) = 2431.914$, $p < 0.001$, confirming the factorability of the correlation matrix.

The initial eigenvalue structure was highly multidimensional. The first nine components presented initial eigenvalues greater than 1.0 and together represented 74.421% of the total variance. Following extraction and varimax rotation, the nine-component solution explained 67.122% of the variance. The rotated components individually accounted for 11.902%, 10.553%, 8.063%, 7.946%, 7.268%, 7.184%, 6.483%, 5.272%, and 2.451%, respectively.

The scree plot and the eigenvalue-greater-than-one rule suggested a comparatively large number of dimensions, reflecting the heterogeneous and interdependent nature of construction-site productivity. A forced five-component statistical solution would therefore have oversimplified the empirical structure. For this reason, the nine extracted components were maintained as the statistical solution. The multidimensional eigenvalue pattern supporting the nine-component statistical solution is presented in Supplementary Figure S4.

For substantive interpretation and comparison with the Relative Importance Index, the items with the most relevant loadings were subsequently organized into five higher-order operational domains established in the theoretical framework: resource management, project management practices, safety conditions, planning, and labor-related factors. These five domains are interpretive categories that synthesize related components and should not be read as five directly extracted statistical factors.

The highest-impact domains were resource management, project management, and safety. This pattern indicates that productivity limitations were more strongly associated with the reliability and coordination of resources, equipment, schedules, and site-management practices than with labor availability considered in isolation.

4.5. Project Complexity Dimensions and Regional Comparison

4.5.1. Factorization of Complexity

The project complexity block included 10 variables and was analyzed through maximum-likelihood factor extraction with orthogonal rotation. The Kaiser–Meyer–Olkin measure was 0.804, indicating good sampling adequacy. Bartlett's test was statistically significant, $\chi^2(45) = 571.564$, $p < 0.001$, confirming that the correlation matrix was suitable for factor analysis.

Three factors were retained. The initial eigenvalues were 4.594, 1.447, and 1.057, representing 45.940%, 14.467%, and 10.572% of the total variance, respectively. Together, the three initial factors accounted for 70.979% of the variance. After rotation, the corresponding variance contributions were 24.460%, 20.524%, and 16.287%, producing a cumulative rotated variance of 61.271%.

The scree plot showed a marked decline between the first and second factors and a progressive flattening after the third factor. The three-factor solution was also supported by the eigenvalue criterion and by its substantive interpretability. The factors were labeled Technical Complexity, Process-Stage Complexity, and Planning-Related Complexity.

The retained three-factor structure shows partial conceptual convergence with recent project complexity measurement research. Technical complexity corresponds to dimensions associated with technological novelty, specialized systems, and multidisciplinary interfaces. Process-stage complexity reflects the number of execution phases and the degree of interdependence among phases or processes. Planning-related complexity reflects restricted construction-site conditions, exposure to adverse climatic conditions, and instability caused by continuous changes in financial resources.

Nevertheless, the retained solution should not be interpreted as a universal project complexity scale. Recent studies have proposed alternative classifications based on organizational, technological, environmental, informational, stakeholder, network, and project-type-specific characteristics. The present factor structure represents the organization of complexity perceptions within the analyzed sample and research instrument.

Technical complexity captures specialized functions, installations, technologies, and operations without fully standardized procedures. Process-stage complexity reflects the number of execution phases and the degree of interdependence among phases or processes. Planning-related complexity reflects restricted construction-site conditions, exposure to adverse climatic conditions, and instability caused by continuous changes in financial resources. The clear stabilization of the eigenvalue curve after the third factor is shown in Supplementary Figure S5.

The overall ten-item project complexity block demonstrated good internal consistency, with $\alpha = 0.847$. The factor-derived subscales also produced adequate coefficients: technical complexity obtained $\alpha = 0.867$, process-stage complexity obtained $\alpha = 0.863$, and planning-related complexity obtained $\alpha = 0.779$. The process-stage subscale contained two items and produced an inter-item correlation of $r = 0.762$.

Exploratory Composite Reliability and Average Variance Extracted were also calculated for the three factor-derived project complexity subscales. Technical complexity obtained CR = 0.801 and AVE = 0.583; process-stage complexity obtained CR = 0.736 and AVE = 0.592; and planning-related complexity obtained CR = 0.791 and AVE = 0.579.

All three Composite Reliability coefficients exceeded 0.70, and all three AVE values exceeded 0.50. These results provide preliminary evidence of internal reliability and convergent validity for the factor-derived complexity dimensions. Nevertheless, the coefficients were calculated from exploratory rotated loadings and should not be interpreted as confirmatory validation of a definitive measurement model.

Inspection of the rotated matrix identified one salient cross-loading at the absolute 0.40 reporting threshold. The item concerning a large number of execution phases loaded on Planning-related complexity (0.581) and Process-stage complexity (0.594). It was assigned to Process-stage complexity because the loading on this factor was slightly higher and because the item was substantively more closely aligned with the sequencing and interdependence of project phases. The remaining items assigned to the three factor-derived subscales did not present a second salient loading of 0.40 or greater.

The cross-loading indicates that the number of execution phases is not exclusively associated with one dimension of project complexity. Although the item was retained within Process-stage complexity for exploratory subscale construction, its loading on Planning-related complexity indicates partial empirical overlap between the coordination burden generated by project sequencing and the planning burden generated by an increasing number of phases. Accordingly, the retained dimensions should be interpreted as substantively distinguishable but not completely independent.

Eight of the ten project complexity items were assigned to the three factor-derived subscales. The items referring to a high degree of overlap between project phases and uncertainty regarding subsurface conditions did not reach the salient-loading threshold in the retained solution and were therefore not included in the factor-specific subscale scores. They were retained in the complete ten-item project complexity block for descriptive and regional analyses, preserving the content coverage of the original questionnaire.

This procedure represents item assignment for exploratory subscale construction rather than deletion from the complete instrument. No item was removed solely to increase reliability coefficients.

These coefficients support the internal coherence of the retained complexity dimensions. However, internal consistency was considered separately from factorial validity, which was evaluated through the KMO measure, Bartlett's test, explained variance, scree-plot pattern, and rotated factor structure.

The rotated loading pattern provides preliminary evidence that the three complexity dimensions are empirically distinguishable. However, definitive discriminant validity was not established through the Fornell–Larcker criterion or the Heterotrait–Monotrait ratio.

The factor solution used orthogonal Varimax rotation, which constrains the rotated factors to be uncorrelated. Using these imposed zero correlations as evidence of discriminant validity would therefore be circular. Confirmatory assessment of discriminant validity requires an independently estimated correlated-factor model, preferably using Confirmatory Factor Analysis in a separate or substantially larger sample.

4.5.2. Correlation with Performance

The empirical analyses conducted for project complexity focused on its exploratory dimensional structure, internal consistency, item-loading pattern, and regional distribution. The present manuscript does not report a separate correlation matrix linking the factor-derived project complexity subscales with the heterogeneous operational performance indicators.

Consequently, no statistical claim is made regarding the direction, magnitude, or significance of direct associations between technical, process-stage, or planning-related complexity and project-performance outcomes. The possible relevance of these dimensions for managerial effort, planning reliability, resource coordination, and operational performance is developed in Section 5.4 as a theory-guided interpretation rather than as a directly estimated correlation result.

This distinction is important because the operational performance indicators were retained as heterogeneous outcomes and were not aggregated into one validated performance construct. A formal evaluation of complexity–performance relationships will require independently validated complexity and performance measures and a larger dataset designed specifically for that analytical purpose.

4.5.3. Regional Sample Balance and Scope of Comparison

The organizational and respondent characteristics of the Cochabamba and Curitiba subsamples were examined in Section 4.1.1. The comparison demonstrated partial sample balance, together with significant differences in annual constructed area, management type, respondent position, and infrastructure-project participation.

Accordingly, the regional analysis presented in this section is restricted to perceptions of the project complexity variables measured in the questionnaire. It should not be interpreted as evidence that the complete construction sectors or participating firm samples are demographically, organizationally, or institutionally equivalent.

The regional subsamples comprised 59 responses from Cochabamba and 49 responses from the Metropolitan Region of Curitiba. The difference of ten observations resulted in a relatively balanced distribution of 54.6% and 45.4%, respectively. This numerical balance reduces the risk that the pooled results are dominated exclusively by one geographical group. However, similar group sizes do not demonstrate that the underlying firm populations are equivalent.

The available descriptive characteristics indicate that the overall sample was predominantly composed of limited-liability companies and professionally managed firms. Most respondents occupied positions directly connected with project management or technical decision-making, particularly managers and architects or engineers. These characteristics support the relevance of the respondents for evaluating construction-project complexity, but they do not eliminate the possibility of regional differences in company size, age, workforce, project portfolio, organizational maturity, or professional experience.

Accordingly, the regional comparison in this study is restricted to the measured project complexity perceptions and should not be interpreted as evidence that the construction sectors of Cochabamba and Curitiba possess identical organizational or demographic structures.

4.5.4. Regional Comparison of Project Complexity Perceptions

The regional discriminant comparison was based on nine of the ten items contained in the complete project complexity block. The item concerning exposure of the construction-site location to adverse climatic conditions was included in the reliability and exploratory factor analyses but was not included in the archived comparative discriminant output. Because the original analytical record did not document the reason for its exclusion, the following findings are restricted to the nine variables included in the regional model.

Because complete diagnostic evidence concerning multivariate normality, equality of covariance matrices, and influential multivariate observations was not preserved in the archived analytical output, the discriminant analysis is interpreted as an exploratory regional-separation procedure. Its results should not be understood as a formal test of regional equivalence or latent measurement invariance.

The canonical discriminant analysis did not identify a statistically significant multivariate separation between the participating respondents from Cochabamba and the Metropolitan Region of Curitiba, Wilks' $\lambda = 0.876$, $\chi^2(9) = 13.492$, $p = 0.142$. The canonical correlation was 0.353, indicating limited discriminatory capacity of the nine project complexity variables.

The univariate tests of equality of group means are presented in Supplementary Table S17. None of the nine project complexity variables produced a statistically significant regional difference at the 0.05 level. The p-values ranged from 0.102 for uncertainty regarding subsurface conditions to 0.838 for instability associated with continuous changes in financial resources.

These results indicate that the available data did not identify statistically detectable differences between the two participating groups in their ratings of the measured project complexity characteristics. The finding is restricted to the variables included in the questionnaire and should not be interpreted as evidence that the two regional samples are identical.

The regional similarity in project complexity perceptions coexists with the compositional differences identified in Table 2. The Cochabamba and Curitiba samples differed significantly in annual constructed area, management type, respondent position, and participation in infrastructure or urban projects. Accordingly, perceptual similarity does not establish demographic, organizational, cultural, market, or institutional equivalence.

The results indicate that the nine measured project complexity characteristics included in the discriminant model did not produce statistically detectable regional differences in the available sample. However, because the adverse-climatic-exposure item was not included in the regional model, these findings should not be interpreted as evidence of regional consistency across the complete ten-item project complexity block. The study also does not demonstrate that project complexity has identical causes, consequences, measurement properties, or managerial responses in the two contexts.

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4.6. Integrated Cross-Module Analysis

4.6.1. Cross-Module Synthesis

Across the four substantive modules, the findings show a consistent asymmetry in the distribution of the observed relationships. Formal organizational structure displayed comparatively limited and inconsistent associations with performance-related variables, whereas stronger and more coherent associations were concentrated among managerial processes. The logistics strategy findings connected logistical performance more closely with strategic planning, communication, responsibility allocation, and conflict resolution than with formal hierarchy. At the operational level, equipment and tool maintenance, schedule adherence, material storage, schedule monitoring, supplier delivery, worker motivation, and payment continuity emerged as the principal productivity-related priorities. The three project complexity dimensions provide the contextual framework within which these cross-module relationships are interpreted. This synthesis describes the relative position of the observed associations and rankings; it does not establish that strategy causes logistics, that operational practices cause productivity, or that complexity statistically affects every analytical level.

4.6.2. Multi-Level Interpretation

The findings can be organized across three analytically connected levels. At the organizational level, formal structure and strategic orientation establish the broad conditions within which firms allocate authority and define priorities. At the managerial level, planning, communication, information management, supplier evaluation, conflict resolution, and strategic–logistical coordination translate those conditions into coordinated decisions and resource arrangements. At the operational level, site management, equipment reliability, material continuity, schedule control, and workforce conditions are reflected in productivity-related outcomes. These levels are analytically distinct but interdependent because organizational arrangements provide coordination capacity, managerial processes enact that capacity, and operational practices express it during project execution.

4.6.3. System Behavior

Taken together, the cross-module evidence indicates that performance-related outcomes were more consistently associated with the interaction of managerial, logistical, and operational processes than with static organizational configurations considered independently. This pattern is compatible with systems and complexity perspectives because it highlights interdependence among analytical levels and the absence of one dominant isolated explanatory variable. Nevertheless, the cross-sectional design does not directly demonstrate emergence, nonlinearity, feedback, adaptation, or causal system behavior.

4.6.4. Complexity-Based Interpretation of the Empirical Pattern

The integrated results reveal a relational pattern that extends beyond the individual significance of the managerial variables. The principal empirical distinction is between static organizational characteristics and dynamic process interactions. Organizational structure remains relevant as an enabling or constraining condition, but the stronger and more consistent associations are concentrated in processes that connect actors, decisions, information, resources, and operational activities.

This distinction is compatible with a complexity-based interpretation of construction management. In a decomposable and predominantly linear system, improvements in an individual structural element would be expected to produce relatively direct and stable effects on performance. The results of this study do not show such a dominant structural pathway. Instead, they show that performance-related variables are distributed across managerial, logistical, and operational interfaces. This suggests that no single formal arrangement, resource, or isolated practice is sufficient to explain the observed outcomes.

The organizational–managerial findings indicate that formal structure provides the institutional framework for action, whereas planning, communication, supplier evaluation, information management, and stakeholder-oriented practices activate that framework. The logistics findings extend this pattern by showing that operational supply performance is more closely associated with strategic coordination and communication than with formal hierarchy. At the construction-site level, the productivity findings show that maintenance, schedule compliance, material storage, and resource continuity operate jointly rather than as independent causes.

Project complexity provides the theoretical context within which these cross-module relationships are interpreted. Technical requirements may be associated with greater coordination demands; process-stage interdependence may be linked to greater sensitivity to sequencing and interface disruptions; and planning-related complexity may be associated with greater vulnerability to incomplete information, resource instability, and schedule variation. Complexity is therefore not presented as an alternative causal explanation for performance. Rather, the identified dimensions support the theory-guided proposition that the relevance of managerial, logistical, and operational arrangements may vary according to the conditions under which they are enacted. This proposition was not tested through direct complexity–performance correlations, interaction terms, or longitudinal analysis.

Accordingly, the empirical contribution of the study is not the isolated confirmation that managerial practices matter. It is the identification of a distributed system of relationships in which formal structure has limited direct explanatory relevance, while managerial processes, logistics, and operational coordination form the principal interaction mechanisms through which project performance is generated.

Table 8 synthesizes the principal empirical patterns and distinguishes their immediate managerial interpretation from the broader complexity-based explanation developed in the Discussion.

Table 8. Critical Synthesis of Empirical Patterns, Conventional Interpretations, and Complexity-Based Explanations.

Analytical Level	Main Empirical Pattern	Conventional Managerial Interpretation	Complexity-Based Interpretation
Organizational structure	Structural variables showed limited and inconsistent direct associations with performance-related managerial variables	Formalization and hierarchy are necessary for organizational order	Structure acts as an enabling or constraining condition, but it does not independently determine system behavior
Managerial processes	Stronger associations occurred among customer service, supplier evaluation, forecasting, information systems, and strategic practices	Integrated managerial practices improve efficiency	Performance-relevant capability is distributed across interdependent processes and functional boundaries
Logistics and strategy	Logistics was more closely related to communication, responsibility, conflict resolution, and strategic planning than to hierarchy	Logistics requires planning and coordination	Logistics operates as a cross-level interface linking strategic decisions with operational resource flows

Table 8. *Cont.*

Analytical Level	Main Empirical Pattern	Conventional Managerial Interpretation	Complexity-Based Interpretation
Productivity	Maintenance, schedule adherence, storage, material delivery, and follow-up were the most influential variables	Operational control improves construction productivity	Site productivity emerges from the stability and synchronization of multiple upstream and on-site processes
Project complexity	Technical, process-stage, and Planning-Related Complexity were associated with management effort, coordination, and schedule reliability	Complex projects require more management resources	Complexity may be associated with differences in the conditions and intensity of interaction among managerial, logistical, and operational subsystems.
Regional comparison	Similar perceptions of complexity were observed in Cochabamba and Curitiba	Construction firms face comparable project-management challenges	Comparable patterns may reflect structural characteristics of construction as an interaction-intensive project system

Note: The table distinguishes between the immediate managerial interpretation of each empirical pattern and its broader complexity-based explanation. Convergence with previous research does not imply identical empirical conditions, and divergence is interpreted in relation to differences in context, measurement, unit of analysis, and analytical design. The complexity-based interpretations should not be understood as direct statistical demonstrations of causality, mediation, moderation, non-linearity, emergence, or feedback.

5. Discussion

The results of this study support the argument that construction performance cannot be adequately explained through isolated variables or purely linear management models. Productivity, logistics, organizational practices, managerial processes, and project complexity operate as interdependent dimensions of a broader management system. This interpretation is consistent with the theoretical premise established in the Introduction and Literature Review: construction projects behave as open, dynamic, and interaction-intensive systems whose outcomes depend on the quality of coordination among subsystems rather than on the independent optimization of individual components [10,55–58].

The principal theoretical contribution of the study is not the general conclusion that planning, communication, supplier management, logistics, maintenance, or schedule control are beneficial to construction performance. These relationships are already broadly recognized in construction management research. The contribution lies instead in the configuration of the empirical relationships. The strongest and most consistent associations were concentrated among processes connecting different organizational functions, whereas formal structural characteristics showed more limited and inconsistent direct relationships with performance-related variables.

This configuration shifts the explanatory focus from organizational elements to the relationships among those elements. Hierarchy, formalization, departments, and assigned roles constitute identifiable parts of the organizational system. However, their existence does not, by itself, explain how information, resources, responsibilities, and decisions circulate during project execution. The more relevant empirical associations involved customer and supplier interfaces, alignment between technology and strategy, integration between forecasting and commercial processes, communication among participants, conflict resolution, and synchronization between planning and site operations [59–61].

The findings therefore suggest a distinction between structural capacity and enacted managerial capability. Structural capacity refers to the formal possibility of coordinating work through hierarchy, role definition, authority, procedures, and reporting relationships. Enacted managerial capability refers to the actual operation of planning, communication, evaluation, learning, decision-making, stakeholder coordination, and resource-synchronization processes. Construction performance appears to be more directly associated with enacted managerial capability than with structural capacity considered independently [62].

The following discussion evaluates the findings through three complementary questions. First, it examines the extent to which the observed patterns converge with previous international research on organizational design, managerial processes, construction logistics, productivity, and project complexity. Second, it considers the findings that diverge from conventional expectations or cannot be explained through one dominant managerial mechanism. Third, it identifies the theoretical and practical implications derived from these convergent, divergent, and unexpected patterns.

The comparison with previous research is interpretive rather than confirmatory. Differences between the present findings and earlier studies may reflect variation in the unit of analysis, project type, organizational scale, measurement instrument, regional context, respondent composition, or analytical method. Accordingly, divergence from the previous literature is not treated automatically as contradiction; it is examined as evidence that the relevance of construction management variables may depend on the configuration in which they operate.

The regional samples were only partially comparable in the measured organizational characteristics. Preliminary tests identified no significant differences in firm age, workforce size, legal constitution, certification, accumulated project experience, or participation in residential, commercial, and industrial projects. However, significant differences were found in annual constructed area, management type, respondent position, and participation in infrastructure or urban projects.

These differences may influence how organizational practices and project complexity are perceived. In particular, the greater representation of managers in Cochabamba and architects or engineers in Curitiba may introduce role-related differences in the interpretation of managerial and operational variables. Likewise, differences in annual construction volume and project portfolio may reflect distinct levels of resource availability, organizational scale, and technical exposure.

The preliminary tests do not constitute formal equivalence testing. Non-significant results indicate an absence of sufficient evidence of a difference in the available sample; they do not prove that the underlying regional populations are identical. Unmeasured institutional, regulatory, contractual, technological, and market differences may also affect the findings. Future comparative studies should use stratified sampling and matched regional samples or apply multivariable adjustment to control for firm size, respondent role, management type, and project portfolio.

5.1. Why Formal Organizational Structure Has Limited Direct Explanatory Power

The limited direct association between organizational structure and performance-related variables should not be interpreted as evidence that structure is irrelevant. Formal structure establishes authority, responsibilities, reporting relationships, and the allocation of work. Its practical relevance, however, depends on whether managerial processes trans-

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late those formal arrangements into effective communication, decision-making, resource coordination, and project-level action.

This distinction separates formal organizational design from enacted organizational practice. Hierarchy, centralization, formalization, and role definition describe how an organization is intended to operate, whereas project execution depends on how managers, site personnel, suppliers, subcontractors, consultants, and clients actually exchange information, resolve conflicts, allocate responsibilities, and respond to changing conditions.

The distinction is especially relevant in construction because permanent organizational departments coexist with temporary project teams and external participants assembled around individual contracts. Consequently, a formally defined structure may coexist with fragmented information or delayed decisions, while a comparatively simple structure may function effectively when communication and adjustment processes are reliable. The present data do not support broader claims regarding the general prevalence of small firms, moderate formalization, or centralized decision-making across the Bolivian construction sector.

A second explanation concerns the uncertainty surrounding construction activity in emerging markets. The firms examined operate in environments affected by changes in demand, material prices, payment conditions, supplier availability, regulatory requirements, and access to resources. Under these conditions, formal structure can provide order and accountability, but rigid application of structural rules may be insufficient for responding to emerging problems. The practical value of structure depends on whether the organization possesses processes capable of interpreting changing conditions and translating that information into coordinated action.

A third explanation is that organizational structure is a relatively distal condition, whereas managerial processes are more proximal to project execution. Hierarchy, centralization, and formalization influence the context in which decisions are made. Planning, supplier evaluation, communication, scheduling, financial coordination, resource allocation, and conflict resolution affect project activities more immediately. The limited direct correlations involving structure may therefore reflect an indirect pathway: structure influences the processes through which performance is ultimately generated.

The stronger associations among managerial process variables reinforce this interpretation. The relationship between customer-service policies and supplier evaluation connects the downstream interface with the client and the upstream interface with the supply system. This association may indicate that firms with more developed external-orientation practices evaluate both sides of their value network more systematically.

Similarly, the association between demand forecasting and advertising, promotion, and pricing management reflects the coupling between anticipated market conditions and commercial preparation. The relationship between information-management systems and technology compatible with business strategy indicates that digital resources generate organizational value when they are embedded in broader strategic and procedural arrangements.

The substantive relevance of these findings is not merely that customer policies, supplier evaluations, forecasting routines, or information systems are individually beneficial. Their relevance lies in their interdependence. Managerial capability is distributed across processes that cross conventional functional boundaries. Complexity theory provides a framework for interpreting these interdependencies as mechanisms through which system-level organizational behavior emerges.

This result partially converges with international research emphasizing that organizational structure provides role clarity, authority, formal communication channels, and accountability, but that its performance effects depend on the routines and relationships enacted within project organizations [9–13,50–57]. The present findings extend this literature by showing that the stronger empirical relationships were concentrated among managerial processes crossing functional and organizational boundaries rather than among formal structural characteristics considered independently.

At the same time, the limited direct explanatory relevance of structure differs from interpretations in which formalization, specialization, or decentralization are expected to produce relatively direct performance improvements. Several explanations are plausible. First, construction projects create temporary and multi-organizational arrangements that only partially coincide with the permanent organizational chart. Second, procedures and reporting relationships may exist formally but may not be applied consistently across projects. Third, centralized structures may provide strategic and financial control while simultaneously delaying project-level responses when information must move through several hierarchical levels.

The result should therefore not be interpreted as evidence that organizational structure is unimportant. A more defensible interpretation is that structure represents a distal organizational condition whose effects are activated, transmitted, or constrained through planning, communication, information management, delegation, stakeholder coordination, and resource-allocation processes. This distinction explains why firms with similar formal structures may display different levels of managerial and project performance.

5.2. Logistics as a Strategic Coordination Interface

A second major finding concerns the relationship between logistics and strategy. Logistics variables were moderately associated with strategic-planning, communication, responsibility, and conflict-resolution variables, while showing limited relationships with formal organizational structure. This pattern suggests that logistics in construction should not be understood merely as a technical support function embedded within a hierarchy. Rather, logistics operates as a strategic coordination interface connecting procurement, resource availability, material flow, information exchange, scheduling, and site-execution requirements [17,46].

This interpretation is consistent with the literature that positions construction logistics as a bridge between firm-level strategy and project-level operations [20,39]. Procurement decisions, supplier relationships, inventory policies, delivery schedules, equipment allocation, and material storage convert strategic intentions into operational conditions. The effectiveness of logistics therefore depends less on the location of the function within the organizational chart and more on the quality of planning, communication, anticipation, and synchronization among participants.

The association between supplier-management efficiency and communication among project participants illustrates this relational character. Supplier performance cannot be managed exclusively through contractual specifications. It requires timely transmission of needs, updated schedules, technical clarification, feedback on quality, and coordination of delivery conditions. Similarly, the relationship between employee responsibility and supplier management suggests that logistics depends on the clarity with which operational commitments are assumed and followed.

The relationship between organizational sustainability and the speed of conflict resolution also indicates that strategic continuity depends on the capacity to manage disruptions before they spread across the system. Delayed conflict resolution can affect procurement, approvals, subcontractor coordination, material availability, and schedule reliability. In a highly interdependent project system, a local disagreement can create wider operational consequences.

If logistics is driven primarily by strategic and process-related variables rather than by formal structure, attempts to improve logistical performance through organizational redesign alone are likely to be insufficient. Improvements should focus on integrating logistics with planning cycles, procurement policies, information systems, supplier evaluation, site schedules, and decision-making routines.

This interpretation helps explain why firms with apparently acceptable organizational structures may still experience recurrent logistical inefficiencies. The problem may not be the absence of hierarchy or departments but the weak coupling between strategic intent and operational execution. This issue is especially relevant in environments where firms operate under resource constraints and external uncertainty, because limited buffers make resource synchronization and anticipatory coordination more critical.

The interpretation of logistics as a coordination interface is consistent with international studies that associate construction-supply performance with planning, information exchange, supplier collaboration, material availability, procurement integration, and disruption management [8,19,63]. These studies similarly indicate that logistical reliability depends on relationships among participants rather than only on the technical efficiency of purchasing, transportation, or storage.

The present findings add a different emphasis. Logistics was not strongly embedded in the formal organizational structure dimension; it was more closely connected with communication, responsibility, conflict resolution, strategic planning, and project execution. This suggests that creating a logistics department or assigning procurement responsibilities may be insufficient when the associated information and decision processes remain fragmented.

The absence of a dominant structural relationship may also reflect the temporary configuration of construction supply chains. Suppliers, subcontractors, project personnel, clients, and consultants are assembled around individual projects and may not be governed fully through the permanent hierarchy of one firm. Under these conditions, logistical performance depends on cross-organizational coordination mechanisms that extend beyond the formal boundaries of the participating companies.

5.3. Productivity as an Emergent Operational Outcome

The findings related to construction-site productivity further reinforce the systemic interpretation of the study. The Relative Importance Index identified equipment and tool maintenance, adherence to the construction schedule, adequate material storage, frequent schedule monitoring, worker motivation, supplier delivery delays, and delays in wage payments as the most influential variables.

These factors are not exclusively technical, labor-related, or logistical. They represent the operational consequences of interactions among planning, resource management, maintenance, communication, procurement, workforce management, and site control. Productivity losses are therefore not explained solely by the absolute scarcity of labor, materials, or equipment. They also depend on how available resources are coordinated and synchronized in time and space.

Equipment maintenance, for example, is an operational activity, but its reliability depends on planning, budgeting, information about equipment condition, availability of spare parts, assignment of responsibilities, and coordination with the work schedule. Material storage is a site-management issue, but its adequacy depends on procurement timing, site-layout decisions, delivery planning, inventory control, and protection measures. Schedule adherence depends not only on the quality of the schedule itself but also on material availability, labor coordination, equipment reliability, design information, approvals, and subcontractor interfaces.

Productivity should consequently be interpreted as the local expression of broader organizational and logistical conditions. Delays in material delivery, inadequate storage, insufficient maintenance, weak schedule follow-up, or delayed payments are visible site-level manifestations of upstream weaknesses in planning, coordination, information, and resource flow.

From a complexity perspective, productivity problems are not merely isolated operational disturbances. They can represent symptoms of instability in the relationships among project components. A disruption in one area may propagate through several activities because construction processes are interdependent. A delayed material delivery can interrupt a crew, alter equipment utilization, affect subsequent trades, increase indirect costs, and require schedule reorganization.

This interpretation is consistent with previous studies showing that planning reliability, material handling, equipment conditions, and maintenance practices are decisive productivity drivers in construction [6,64,65]. The present study extends this interpretation by positioning productivity within a multilevel system. Site performance depends on the alignment of managerial processes, strategic–logistical coordination, and operational practices rather than on one dominant factor considered separately.

The productivity ranking is broadly consistent with international evidence identifying planning reliability, material management, equipment conditions, maintenance, supplier delivery, and workforce continuity as important determinants of construction productivity [66–68]. However, an important feature of the present results is that no single labor, equipment, material, or managerial category dominated the complete ranking.

The highest-ranked variables crossed several conventional categories: equipment maintenance represented operational reliability; schedule adherence and follow-up represented planning control; material storage and supplier delivery represented logistics; worker motivation and wage-payment continuity represented workforce management. This distribution differs from explanations that locate productivity loss primarily in labor efficiency or technical execution.

The apparently heterogeneous ranking is therefore theoretically informative rather than inconsistent. It indicates that productivity problems may originate in different subsystems but become visible through a common operational consequence: the interruption or destabilization of site production. The result supports an interpretation of productivity as the local expression of coordination quality across planning, logistics, equipment, finance, and workforce systems.

A further unexpected result was the low internal consistency of the seven operational performance indicators. Rather than concealing this result or constructing a single performance score, the indicators were retained separately. The low coefficient suggests that cost, schedule, productivity, quality, delivery, rework, and material-loss outcomes do not respond uniformly to the same managerial conditions. This finding supports a multidimensional interpretation of project performance and cautions against representing performance through one undifferentiated composite measure.

5.4. Complexity as a Conditioning Mechanism

The identification of technical, process-stage, and planning-related complexity provides the integrative layer connecting the organizational, logistical, and productivity findings. Complexity in construction cannot be reduced to project size, number of stakeholders, technological sophistication, or number of activities alone. It arises from differentiation, interdependence, uncertainty, contextual exposure, and the structure of interactions among project elements [35,38].

Technical complexity relates to specialized systems, innovative technologies, non-standardized procedures, and interfaces among different technical disciplines. Process-stage complexity reflects the number of execution phases and the degree of interdependence among phases or processes. Planning-related complexity reflects restricted construction-site conditions, exposure to adverse climatic conditions, and instability caused by continuous changes in financial resources.

The present study did not estimate direct correlations between the factor-derived project complexity subscale scores and the heterogeneous operational performance indicators. Accordingly, the conditioning role discussed in this section is a theoretical interpretation informed by the identified complexity dimensions and the broader cross-module empirical pattern. It should not be understood as a statistically demonstrated direct effect, moderation effect, or complexity–performance pathway.

Complexity offers a theoretical basis for expecting that the relevance of the same organizational structure may vary across companies and projects. Projects differ in technical requirements, stakeholder configurations, information uncertainty, environmental exposure, and planning instability. These conditions may be associated with different coordination requirements and with different levels of reliance on organizational and managerial mechanisms. The present study did not estimate whether these conditions statistically changed the strength of the relationships among structure, processes, logistics, and performance.

Under conditions of relatively low complexity, formal roles, standardized procedures, centralized authority, and routine planning may be sufficient to coordinate execution. Tasks are more predictable, interfaces are fewer, and deviations can be resolved through established procedures. In such circumstances, the relationship between structure and managerial processes may be comparatively direct.

Projects characterized by greater technical specialization, phase interdependence, information instability, supply variability, and stakeholder-interface density may require more frequent communication, broader distribution of expertise, negotiation, and iterative adjustment. Under such conditions, static structural arrangements may be less sufficient when considered independently. Highly formalized or centralized structures may support control but may also be associated with slower responses when decisions pass through several hierarchical levels. Conversely, highly informal arrangements may permit faster local adjustment but may also be associated with information loss, unclear accountability, inconsistency, and dependence on individual managers. These relationships constitute theoretically plausible mechanisms and were not estimated as causal effects in the present study.

Complexity is therefore treated as a theory-guided conditioning framework whose role requires future empirical testing. The present evidence does not demonstrate that complexity changes the effectiveness of organizational arrangements. Instead, the framework proposes that different complexity conditions may be associated with different combinations of formalization, flexibility, information exchange, distributed expertise, and coordination. It does not necessarily weaken formal structure in every circumstance. Instead, the framework proposes that effective management may require different combinations of structure, flexibility, information, and decision authority under different complexity conditions.

Formalization may improve planning reliability when procedures are continuously updated and connected to operational information. Decentralization may accelerate responses when decision rights are assigned to participants possessing relevant local knowledge. Centralization can remain useful for strategic coherence, contractual control, and financial oversight, provided that it does not obstruct project-level adaptation.

The empirical pattern is consistent with this interpretation. Managerial process variables showed stronger and more coherent relationships than static structural variables. Logistics was more closely associated with strategy, communication, responsibility, and conflict resolution than with hierarchy. Productivity depended on the synchronization of maintenance, scheduling, storage, material delivery, workforce conditions, and site monitoring.

The empirical pattern is consistent with the theory-guided proposition that project complexity may be associated with greater coordination burdens across subsystems. Technical complexity may require more specialized coordination; process-stage complexity may be linked to greater dependence on sequencing and interface management; and planning-related complexity may heighten vulnerability to incomplete information, weak forecasting, resource instability, and fragmented control. These relationships were not estimated as direct causal effects in the present study.

The retained complexity structure both converges with and differs from recent multidimensional approaches. Its distinction among technical, process-stage, and planning-related complexity is consistent with the broader international recognition that complexity includes technological differentiation, connectivity among activities, and uncertainty affecting project organization. However, the empirical composition of the factors was context-specific and did not reproduce every theoretically anticipated indicator.

In particular, phase overlap and subsurface uncertainty did not reach the retained loading threshold for the factor-specific subscales. In addition, the number-of-phases item loaded on both planning-related and process-stage complexity, although its slightly stronger and more substantively coherent loading supported assignment to the latter dimension. This cross-loading indicates that project phases are not exclusively a process characteristic: an increasing number of phases may also expand the planning and information burden.

These results should not be treated as measurement failures to be eliminated automatically. They show that the boundaries among complexity dimensions are permeable and that one project characteristic may generate several forms of managerial burden simultaneously. This is theoretically compatible with complexity thinking, although the stability of the retained structure requires confirmation in a larger independent sample.

The present cross-sectional analysis does not statistically test a moderation effect. Complexity is therefore interpreted as a theoretically proposed conditioning mechanism rather than as an empirically confirmed moderator. Confirming whether technical, process-stage, and Planning-Related Complexity change the strength of the relationships among structure, managerial processes, logistics, and performance would require interaction models, multi-group analysis, structural equation modeling, or longitudinal research.

5.5. Integrated Conceptual Model of Construction Management Under Complexity

Figure 2 consolidates the theoretical propositions developed in Section 2.9 and the cross-module empirical pattern reported in Section 4. The framework links structural capacity, enacted managerial capability, strategic–logistical coordination, operational reliability, and performance-related outcomes. Project complexity is represented as a theory-guided conditioning framework under which greater complexity is expected to be associated with greater coordination requirements; it is not represented as a statistically estimated moderator.

Organizational structure occupies the macro-organizational level and includes formalization, centralization, hierarchy, role definition, and organizational flexibility. The model proposes that structure has a limited direct relationship with project performance. The framework proposes that its performance relevance is expressed principally through its relationship with enacted managerial processes.

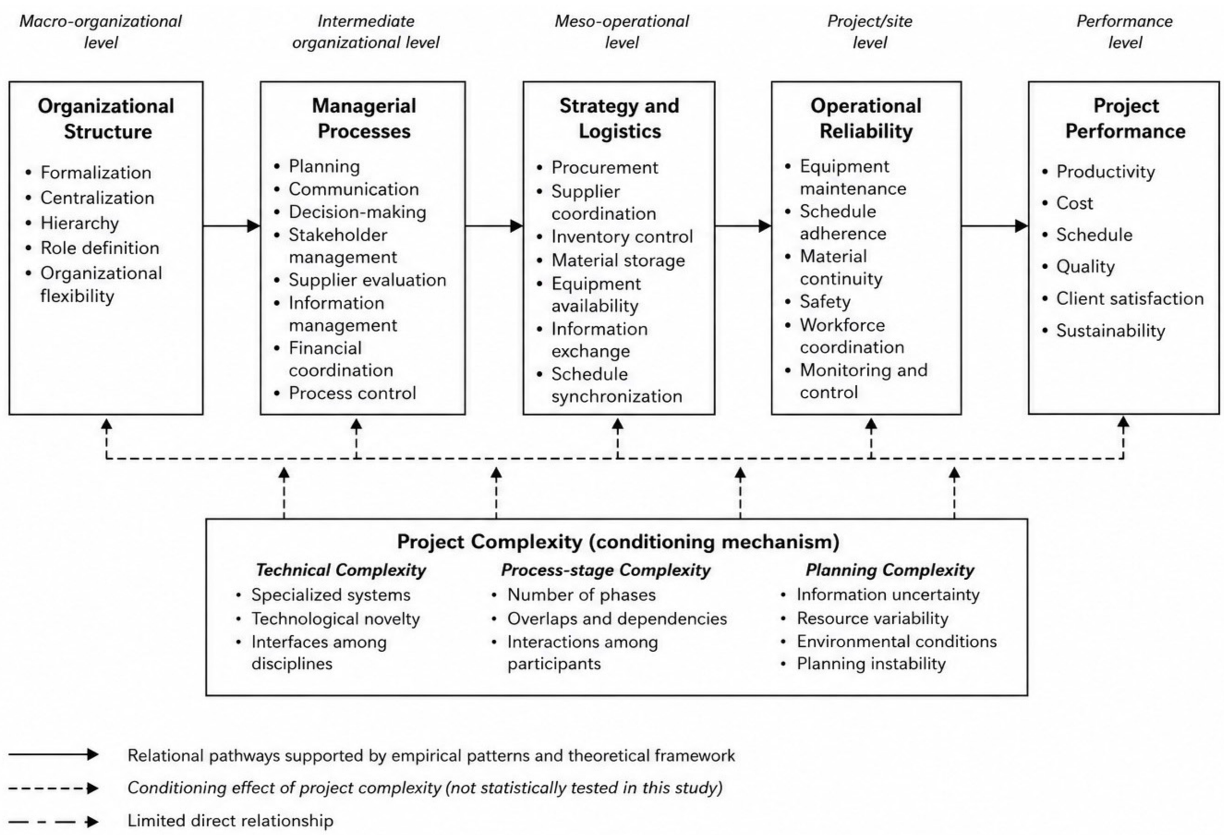

Figure 2. Integrated theoretical and empirical framework linking structural capacity, enacted managerial capability, strategic–logistical coordination, operational reliability, and performance-related outcomes under conditions of technical, process-stage, and planning-related complexity. The relationships represent theory-guided propositions informed by the observed cross-module association pattern; they do not represent statistically estimated causal, mediation, or moderation effects.

Managerial processes occupy the intermediate organizational level and include planning, communication, decision-making, stakeholder management, supplier evaluation, information management, financial coordination, and process control. These processes are interpreted as the mechanisms linking organizational arrangements with coordinated project action and constitute the principal connection between firm-level organization and project execution.

The framework positions strategy and managerial processes upstream of logistics and operational coordination. Logistics includes procurement, supplier coordination, inventory control, material storage, equipment availability, information exchange, and schedule synchronization. It operates as the interface between organizational decisions and the conditions required for construction-site execution.

Operational reliability occupies the project and site level. Maintenance, schedule adherence, material continuity, safety, workforce coordination, and monitoring routines represent conditions associated with consistent project execution. Productivity and project performance are therefore interpreted as outcomes emerging from the alignment among managerial processes, logistics, and site practices rather than as results attributable to one isolated variable.

Technical, process-stage, and planning-related complexity are represented as theoretically proposed conditioning dimensions across the relationships included in the framework. The framework hypothesizes that projects characterized by greater complexity may place higher coordination demands on structural and process arrangements. It further proposes, for future empirical testing, that static structural mechanisms may become less sufficient when considered independently and that reliance on adaptive managerial processes, integrated logistics, reliable information, and operational feedback may become greater. These relationships are conceptual propositions informed by the theoretical framework and the cross-module empirical pattern; they are not estimated effects of complexity.

The conceptual framework proposes the following theoretically informed sequence for future empirical testing:

Organizational Structure → Managerial Processes → Strategy and Logistics → Operational Reliability → Project Performance.

The framework also retains a theoretically proposed limited direct relationship between Organizational Structure and Project Performance. Project complexity is hypothesized to condition the relationships between structure and processes, processes and logistics, logistics and operational reliability, and operational reliability and performance. These directional relationships represent propositions requiring future confirmatory validation rather than empirically established causal paths.

The conceptual model is not a statistically estimated causal model. Its pathways are theoretically derived from the integrated interpretation of the correlations, factor structures, and productivity rankings. Its purpose is to organize the findings into a coherent framework and to establish testable relationships for future confirmatory research.

The empirical analyses provide different levels of evidence consistent with the theoretical propositions. The comparatively limited and inconsistent relationships involving formal organizational characteristics, together with the stronger associations among managerial processes, are consistent with P1. The relationships connecting communication, supplier management, information integration, strategic planning, and conflict resolution provide evidence relevant to P2 and P3.

The RII ranking and operational analyses provide evidence consistent with P3 and P4 by emphasizing equipment maintenance, schedule adherence, material storage, supplier delivery, workforce conditions, and monitoring as interdependent conditions of operational reliability. The project complexity results provide a basis for the interpretation proposed in P5, although the study does not statistically test complexity as a moderator.

The propositions should therefore be understood as being informed to different degrees by complementary empirical patterns rather than as having been accepted or rejected through a single inferential test. Their principal function is to translate the integrated findings into a coherent and testable framework for subsequent confirmatory research.

5.6. Comparative Interpretation of Cochabamba and Curitiba

The comparative analysis identified no statistically significant difference between the participating respondents from Cochabamba and Curitiba in the combined perception of the nine project complexity variables. The discriminant function produced Wilks' Lambda = 0.876, $\chi^2 = 13.492$, df = 9, and $p = 0.142$, while the individual tests of group means were also non-significant. These results support perceptual similarity for the specific complexity indicators measured in the study.

The regional comparison reveals two findings that must be interpreted jointly. First, the participating firm and respondent samples showed partial, rather than complete, compositional comparability. Second, the nine measured project complexity variables did not produce a statistically significant separation between the Cochabamba and Curitiba respondent groups.

The samples were broadly similar in firm age, approximate workforce size, accumulated project experience, legal constitution, certification status, and participation in residential, commercial, and industrial projects. These similarities provide a reasonable basis for a limited comparison of the measured perceptions.

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Nevertheless, meaningful differences were also identified. The Curitiba firms reported a larger median annual constructed area, while professional management and manager- or director-level respondents were more prevalent in the Cochabamba sample. Participation in infrastructure and urban projects was also considerably higher among the Cochabamba firms. The corresponding effect sizes indicate that these differences were substantively relevant and should not be treated as minor sampling fluctuations.

These compositional differences may influence how organizational practices, logistical conditions, and project complexity are experienced and reported. For example, differences in construction volume may be associated with the scale and coordination requirements of the participating firms, while differences in management type and respondent position may affect access to strategic information and the level from which project conditions are evaluated. Differences in project portfolios may also expose firms to distinct technical, stakeholder, regulatory, and interorganizational interfaces.

However, the present data do not include direct measures of national culture, regulatory quality, contracting systems, labor-market institutions, professional norms, or public-procurement environments. The findings therefore do not support attributing the observed compositional differences to cultural or institutional causes. Such explanations remain plausible contextual hypotheses that require direct measurement and comparative institutional analysis.

Against this heterogeneous background, the absence of statistically detectable differences in the nine project complexity perceptions is analytically relevant. It suggests that respondents from both participating regions recognized similar characteristics when evaluating complexity, including phase interdependence, technical specialization, non-standard operations, site restrictions, subsurface uncertainty, and financial instability.

This perceptual similarity should not be interpreted as evidence that the construction sectors of Bolivia and Brazil are equivalent or that complexity operates identically in both countries. Rather, it indicates that the measured complexity characteristics were not sufficient to discriminate statistically between the two regional participant groups.

The inclusion of Curitiba therefore contributes contextual contrast rather than national representativeness. It allows the study to examine whether the complexity-perception pattern identified in Cochabamba was entirely location-specific. The findings provide preliminary evidence of cross-context consistency in the recognition of the measured complexity characteristics, while the observed organizational and project-portfolio differences demonstrate the need for caution in interpreting pooled results.

Future comparative studies should include larger probability-based regional samples, direct measures of regulatory and institutional conditions, harmonized organizational characteristics, and multigroup measurement-invariance testing. These steps would make it possible to determine whether the relationships among structure, managerial capability, logistics, complexity, and performance differ systematically between regional or national construction contexts.

5.7. Theoretical Implications

The principal theoretical advancement of this study is the identification of an empirical asymmetry between organizational architecture and enacted coordination capability. Previous construction management research has established the relevance of organizational design, planning, logistics, communication, and productivity factors. The present findings add to this knowledge by showing that these dimensions do not occupy equivalent explanatory positions within the management system. Formal structural characteristics provide an enabling or constraining architecture, whereas the stronger performance-relevant relationships are concentrated in the processes connecting organizational functions, external stakeholders, resource flows, and project execution.

This distinction advances a complexity-based interpretation because it relocates the unit of explanation from isolated organizational elements to the quality and distribution of relationships among them. The theoretical contribution is therefore not that managerial practices matter, but that construction management capability appears to be enacted through cross-functional and cross-level interfaces. Structure becomes operationally relevant through managerial processes; managerial processes are translated into execution through strategic–logistical coordination; and productivity reflects the reliability of these interactions at the construction-site level. Project complexity is theoretically expected to be associated with different coordination requirements across these connections.

The comparison with previous international research indicates that the findings are predominantly convergent at the level of individual managerial practices but more distinctive at the level of their systemic configuration. Previous studies have demonstrated the relevance of planning, communication, supplier coordination, material management, maintenance, schedule control, and complexity assessment. The theoretical advancement of the present study lies in explaining how these variables occupy different positions within a multilevel management system.

Three findings are particularly significant. First, formal structure appears to provide organizational capacity without guaranteeing that this capacity is enacted during project execution. Second, logistics operates between the organizational and operational levels by translating information and strategic decisions into resource-flow conditions. Third, productivity represents an operational manifestation of the reliability of these interconnected processes rather than an isolated labor or technical outcome.

The unexpected or weak findings are equally relevant theoretically. The limited direct structural relationships suggest that formal organizational attributes may have primarily indirect or contingent effects. The low internal consistency of the operational performance indicators indicates that project performance is multidimensional. The overlap observed in the complexity-factor structure suggests that technical, process, and planning burdens are analytically distinguishable but not completely independent in practice.

These findings move the theoretical argument beyond a confirmatory statement that "management practices matter." They support a relational explanation in which organizational elements acquire performance relevance through the connections among them. The central theoretical unit is therefore not the isolated variable but the interface through which decisions, information, responsibilities, resources, and operational consequences are linked.

The findings contribute to construction management theory by distinguishing organizational architecture from enacted coordination capability. Traditional management approaches frequently assume that formalization, role clarity, hierarchy, and control improve performance through relatively direct pathways. The present results suggest that this assumption is incomplete in project-based construction environments.

The effect of organizational structure appears to depend on whether it supports reliable planning, communication, information exchange, supplier coordination, and adaptation. Structural characteristics should therefore not be evaluated only according to their formal presence. They should also be assessed according to the interactions and processes they enable.

This interpretation is compatible with contingency and organizational-process perspectives, according to which organizational arrangements become effective only when translated into coherent routines and decision mechanisms [57]. It is also consistent with complexity theory because it recognizes that system-level outcomes depend on the organization of relationships among elements rather than on their isolated characteristics.

The study also contributes by clarifying the role of complexity. Complexity is not treated as an additional independent factor located alongside structure, logistics, or productivity. Instead, it is conceptualized as a theory-guided condition under which coordination requirements may vary across the management system. Technical novelty, interdependent phases, information instability, and environmental uncertainty may be associated with differences in how organizational arrangements are translated into project behavior.

The three complexity dimensions identified in this study also contribute to the recent discussion on project complexity measurement. Contemporary research has proposed multidimensional survey models, technical–organizational–environmental indicator systems, project-type-specific classifications, and structural and dynamic network metrics. The diversity of these approaches indicates that complexity is not adequately represented by one universally applicable measure.

The technical, process-stage, and planning-related dimensions identified here provide a parsimonious structure for the participating construction firms. Technical complexity captures the difficulty and novelty of specialized project systems. Process-stage complexity captures the density and interdependence of activities and interfaces. Planning-related complexity captures uncertainty and instability affecting the assumptions upon which project execution is organized.

This structure overlaps conceptually with recent technical, organizational, environmental, informational, and connectivity-based models, but it does not reproduce them completely. The differences are theoretically relevant because complexity dimensions depend on the object being measured. A model designed to compare international engineering projects, assess contractor exposure, evaluate building typologies, analyze project networks, or examine digital-technology effects does not necessarily require the same indicators as a survey examining managerial perceptions in construction companies.

Accordingly, the principal theoretical value of the retained structure lies in its contextual explanatory usefulness rather than in a claim of universal measurement validity. Future studies should compare this three-dimensional solution with recent alternative scales and indicator systems through confirmatory factor analysis, measurement-invariance testing, and cross-context validation.

A further theoretical implication is the positioning of logistics as a meso-level interface rather than as a subordinate operational activity. Logistics connects strategic decisions and managerial planning with resource flows and site reliability. Its effectiveness depends simultaneously on upstream strategic decisions, horizontal coordination among participants, and downstream execution conditions.

Finally, productivity is conceptualized as an emergent project-level outcome. Maintenance failures, material delays, inadequate storage, and schedule deviations are not merely isolated site problems. They may represent manifestations of incomplete coordination among organizational, managerial, logistical, and operational subsystems [69,70].

From the perspective of complex adaptive systems, construction performance emerges from process interactions rather than from static organizational design; from adaptive coordination rather than rigid control; and from the alignment of strategy, logistics, and operations rather than from the isolated optimization of individual functions. This interpretation is consistent with systems-based critiques of deterministic project-management models and with process- and flow-oriented approaches emphasizing variability reduction, coordination reliability, and continuous adjustment [24].

5.8. Managerial and Policy Implications

The practical implications follow directly from the distinction between findings that confirmed previous evidence and findings that challenged conventional assumptions. The confirmation of the importance of planning, logistics, maintenance, material management, and communication supports continued investment in these practices. However, the limited direct relevance of formal structure indicates that these investments should be evaluated according to their capacity to improve cross-functional coordination and operational reliability, rather than according to the existence of procedures or organizational units alone.

The conceptual model suggests that construction firms should not assume that changes to organizational charts, reporting lines, or formal procedures will automatically improve project outcomes. Structural reform should be accompanied by mechanisms ensuring that roles, information, decisions, and resources remain connected across organizational and project boundaries.

In relatively stable and low-complexity projects, standardized procedures and centralized control may provide sufficient coordination. In projects characterized by technical novelty, greater interdependence, stakeholder diversity, or planning uncertainty, firms should complement formal control with flexible decision rights, cross-functional coordination routines, rapid escalation mechanisms, and frequent information updates.

Managerial attention should concentrate on the interfaces between subsystems. Relevant interfaces include forecasting and procurement, supplier evaluation and material reliability, project schedules and equipment maintenance, customer requirements and production planning, financial decisions and resource continuity, and organizational information systems and site-level decision-making.

Logistics should be managed as a strategic subsystem connected to planning and resource decisions rather than as a reactive support activity. Procurement, supplier coordination, storage, equipment availability, and material delivery should be integrated with project schedules and operational priorities.

Productivity improvement strategies should focus on operational reliability. Investments in workforce capacity are important, but they may have limited effects if equipment is unavailable, materials are poorly stored, schedules are not monitored, payments are delayed, or information is fragmented. Productivity interventions should therefore address the stability of the entire operational system.

The practical objective is not to replace structure with informality. It is to design organizational arrangements that enable adaptation while maintaining accountability, strategic coherence, contractual control, and financial discipline. This requires distinguishing which decisions should remain centralized and which should be delegated to project participants with immediate knowledge of site conditions.

Finally, complexity should be explicitly recognized during project planning and governance. Firms should assess technical interfaces, process dependencies, information uncertainty, supply risks, stakeholder diversity, and planning instability before determining the appropriate degree of formalization, decentralization, contingency planning, and operational buffering.

5.8.1. Actionable Recommendations for Project Managers

At the project level, the findings indicate that managers should prioritize the reliability of the interfaces connecting planning, procurement, information, equipment, materials, finance, and workforce management. The recommended actions are therefore organized around the operational points at which disruptions can propagate from one subsystem to another.

First, project managers should establish a recurring cross-functional coordination meeting involving site management, planning, procurement, logistics, cost control, equipment management, and occupational health and safety. The purpose of this meeting should not be limited to reporting progress. It should identify constraints affecting the next planning period, assign responsibility for their resolution, establish deadlines, and verify closure during the following meeting.

A short-term constraint register should accompany the construction schedule. For each forthcoming activity, the register should indicate whether drawings, decisions, labor, materials, equipment, access conditions, subcontractors, permits, financial resources, and safety requirements are available. Activities with unresolved constraints should not be treated as fully executable commitments.

Second, managerial responsibility should be defined at the interfaces between functions. A responsibility-assignment matrix or equivalent interface register should specify who produces information, who authorizes decisions, who provides resources, who executes the activity, and who must be informed. This is particularly important for activities involving several departments, subcontractors, suppliers, or technical disciplines.

Third, the empirical importance of equipment maintenance, schedule adherence, schedule follow-up, material storage, supplier delivery, worker motivation, and wage-payment continuity indicates that operational reliability should be monitored through a focused set of indicators. Recommended indicators include equipment downtime, preventive-maintenance compliance, percentage of planned activities completed, number of activities delayed by missing materials, supplier on-time delivery, material-damage incidents, unresolved constraints, and payroll delays.

Fourth, managers should establish escalation thresholds. A deviation should be escalated when it affects more than one work package, threatens the critical or near-critical path, requires a decision outside the authority of the site team, or remains unresolved beyond the agreed response period. This practice reduces the risk that local problems propagate through interdependent activities.

Fifth, project closeout should include a structured review of coordination failures and successful responses. Lessons learned should be recorded according to the interface affected—planning, procurement, supplier management, equipment, workforce, information, finance, or stakeholder coordination—and incorporated into subsequent project-planning procedures.

5.8.2. Organizational Strategies for Logistics Integration

The findings indicate that logistics should be integrated with planning and project decision-making rather than treated exclusively as a downstream purchasing or transportation function. Organizational integration requires common information, synchronized planning horizons, defined responsibilities, and shared performance indicators.

Construction firms should develop an integrated procurement and logistics plan linked directly to the project schedule. For each major material, equipment item, subcontracted service, and critical resource, the plan should identify the required-on-site date, procurement lead time, approval period, supplier commitment, transportation arrangement, storage requirement, inspection procedure, and responsible person.

The procurement schedule should be reviewed together with the short-term construction plan. This alignment allows supply risks to be detected before they generate site interruptions. Materials and equipment with long lead times, limited local availability, high price volatility, or dependence on imported inputs should be classified as critical and monitored through specific contingency actions.

Supplier management should move beyond price comparison. Firms should maintain supplier-performance records covering delivery reliability, conformity with technical requirements, response time, documentation quality, flexibility during changes, and resolution of nonconformities. Supplier selection and contract renewal should incorporate these performance records.

Information integration is also required. Site teams, procurement personnel, warehouse staff, cost controllers, and managers should use one consistent record of approved quantities, requested dates, purchase status, delivery status, inspection results, and available inventory. Where advanced digital platforms are not economically feasible, standardized shared spreadsheets, controlled document repositories, and clearly defined update responsibilities can provide a practical intermediate solution.

Logistics coordination should also include physical site conditions. Storage zones, internal transport routes, unloading areas, equipment circulation, access restrictions, and protection requirements should be incorporated into site planning. This is particularly important where restricted locations or adverse climatic conditions form part of planning-related complexity.

The effectiveness of logistics integration should be evaluated through operational indicators such as supplier on-time and in-full delivery, procurement-cycle duration, frequency of material shortages, percentage of urgent purchases, material losses during storage, delivery-related schedule disruptions, and variation between planned and actual resource availability.

5.8.3. Managing Project Complexity in Emerging-Economy Contexts

In emerging-economy construction markets, project complexity may be intensified by financial instability, uneven supplier capacity, limited availability of specialized resources, informal coordination practices, infrastructure restrictions, regulatory uncertainty, and variation in firms' managerial maturity. These conditions do not affect every project equally, but they increase the importance of early complexity assessment and adaptive coordination.

At project initiation, managers should conduct a structured complexity screening covering at least technical specialization, number and interdependence of execution phases, site restrictions, climatic exposure, financial-resource stability, supplier availability, stakeholder interfaces, information uncertainty, and the novelty of procedures or technologies.

The assessment should not produce only one overall complexity score. It should identify the source of the coordination burden. Technical complexity may require specialist integration, design reviews, interface control, and technical decision protocols. Process-stage complexity may require detailed sequencing, dependency mapping, coordination of parallel work fronts, and stricter constraint management. Planning-related complexity may require shorter planning cycles, contingency scenarios, financial monitoring, alternative suppliers, and more frequent schedule revision.

The complexity assessment should be repeated at defined project gates, including completion of design development, mobilization, commencement of major construction phases, introduction of significant design changes, and occurrence of major financial or supply disruptions. Complexity is not necessarily stable throughout the project life cycle.

Projects with higher complexity should receive a corresponding increase in coordination capacity. This may include more frequent coordination meetings, dedicated interface managers, shorter information-response periods, greater contingency reserves, enhanced supplier monitoring, additional design reviews, and stronger authority for project-level decisions.

Where organizations have limited digital, financial, or human resources, the priority should be procedural reliability rather than technological sophistication. Standardized constraint registers, interface matrices, procurement schedules, document-control procedures, maintenance plans, and decision logs can improve coordination without requiring expensive enterprise systems.

The findings also indicate that resilience in resource-constrained environments depends on maintaining alternatives. Critical materials, equipment, suppliers, financial sources, and specialist capabilities should be identified before execution, together with feasible substitute options and the conditions under which they would be activated.

5.8.4. Firm-Level and Public-Policy Implications

At the firm level, the findings support the development of internal policies that prioritize coordination performance rather than formal compliance alone. Construction companies should define minimum requirements for short-term planning, constraint management, supplier evaluation, preventive maintenance, information control, material storage, schedule follow-up, and timely workforce payment.

Corporate procedures should specify not only what documents must exist but also how frequently they must be updated, who is responsible for their use, how deviations are escalated, and which indicators demonstrate that the process is functioning effectively.

Professional and industry associations can contribute by developing standardized templates and training programs for small and medium-sized construction firms. Priority areas include integrated planning, construction logistics, supplier-performance evaluation, complexity screening, project-information management, equipment maintenance, and performance measurement.

For public and private clients, procurement and contracting practices should recognize the importance of coordination capability. Prequalification and proposal evaluation may consider evidence of planning systems, logistics arrangements, qualified project personnel, supplier-management procedures, equipment-maintenance systems, and mechanisms for managing technical and stakeholder interfaces. These criteria should be proportional to project complexity and should not create unnecessary administrative barriers for smaller firms.

Governmental agencies and public clients should also recognize the operational consequences of delayed approvals, design changes, incomplete information, and payment interruptions. More predictable payment processes, timely technical decisions, clear change-management procedures, and consistent contract administration can reduce instability that is subsequently transferred to suppliers, workers, equipment availability, and construction schedules.

Public institutions may further support sector development through standardized digital reporting requirements, interoperable project-information protocols, supplier-development programs, professional training, and anonymized databases on productivity, delays, material shortages, change orders, and project complexity characteristics.

These recommendations should not be interpreted as evidence that one regulatory model will be equally effective in all settings. Their implementation should be adapted to firm size, project type, procurement system, institutional capacity, and the specific sources of technical, process-stage, and planning-related complexity.

5.9. Limitations and Future Research

The internal consistency analysis also identified a limitation in the operational performance indicator set. Although the organizational, managerial, and project complexity scales demonstrated acceptable to excellent reliability, the seven operational performance indicators produced $\alpha = 0.575$ after directional alignment.

This coefficient indicates that the indicators should not be interpreted as a homogeneous reflective scale. Material losses, productivity, schedule compliance, nonconformities, delivery performance, rework, and budget variance represent different aspects of project outcomes and may respond differently to organizational, logistical, and complexity conditions. For this reason, no composite operational performance score was calculated.

Future research should develop and validate a multidimensional performance-measurement model that distinguishes cost, schedule, productivity, quality, and operational-reliability outcomes. Confirmatory factor analysis could subsequently determine whether these outcomes form correlated first-order dimensions or a defensible higher-order project-performance construct.

The measurement evidence also remains exploratory. Although the predefined scales demonstrated predominantly adequate internal consistency and the factor-derived project complexity subscales exceeded the exploratory CR and AVE reference values, the complete instrument was not evaluated through Confirmatory Factor Analysis.

Convergent validity was examined preliminarily only for the factor-derived project complexity subscales. The rotated loading pattern supported a substantively interpretable three-factor solution, but it did not demonstrate complete separation among the dimensions. The item concerning a large number of execution phases loaded on both Planning-related complexity (0.581) and Process-stage complexity (0.594) and was assigned to the latter factor based on its slightly higher loading and substantive alignment. This cross-loading indicates partial overlap between the two dimensions. Consequently, definitive discriminant validity was not established through the exploratory solution and was not evaluated through a correlated latent-variable model, the Fornell–Larcker criterion, or the Heterotrait–Monotrait ratio.

Future research should administer the refined instrument to a larger independent sample and evaluate the proposed measurement structure through Confirmatory Factor Analysis. This would permit estimation of standardized loadings, correlated measurement errors where theoretically justified, Composite Reliability, Average Variance Extracted, HTMT, discriminant validity, measurement invariance, and cross-validation of the factor structure.

A methodological boundary of the complexity-based interpretation must be acknowledged. The study is cross-sectional and relies primarily on correlation analysis, exploratory dimensional reduction, and Relative Importance Index rankings. These procedures identify associations, dimensional patterns, and perceived importance, but they do not directly estimate causal relationships, mediation effects, moderation effects, reciprocal influence, temporal feedback, threshold behavior, or adaptation trajectories.

An additional analytical limitation concerns the incomplete availability of assumption diagnostics in the archived statistical outputs. The study documented the criteria used to select Welch's *t*-test, Mann–Whitney U, chi-square, Fisher's exact test, Pearson and Spearman correlations, factor or component analysis, and canonical discriminant analysis. KMO and Bartlett statistics were available for the dimensional-reduction procedures, and expected-frequency criteria were used to determine when Fisher's exact test was appropriate.

However, complete retrospective evidence concerning normality, homoscedasticity, linearity, multivariate normality, equality of covariance matrices, and influential observations was not available for every procedure. The corresponding inferential results should therefore be interpreted as exploratory and sample-specific. Future studies should define and report assumption diagnostics prospectively and should use robust or nonparametric alternatives when the relevant conditions are not supported.

A further limitation arises from the self-reported nature of the survey data. The organizational, managerial, logistical, productivity, and project complexity variables were assessed through respondents' perceptions during a single questionnaire administration. The responses may therefore be influenced by recall limitations, social-desirability tendencies, consistency motives, differences in respondents' access to organizational information, and subjective interpretation of the questionnaire items.

The collection of predictor- and outcome-related information through the same survey also introduces the possibility of common method variance. A dedicated marker variable, a latent common-method factor, temporal separation, or an independently validated common-method assessment was not included in the original research design. Consequently, the study cannot exclude the possibility that some observed associations were inflated or attenuated by the measurement method shared across variables.

No post hoc single-factor test was used to claim that common method bias was absent. Such a conclusion would be particularly inappropriate because the questionnaire contained conceptually distinct modules, heterogeneous outcome indicators, different response formats, and several exploratory dimensional structures. The correlations should therefore be interpreted as respondent-reported associations rather than as method-independent estimates of organizational or project relationships.

A further analytical limitation is that the integrated conceptual framework was not estimated as a simultaneous structural model. The relationships among structural capacity, enacted managerial capability, strategic–logistical coordination, operational reliability, performance-related outcomes, and project complexity were examined through complementary analytical modules rather than through covariance-based SEM, PLS-SEM, or path analysis.

This decision reflects the exploratory status of the measurement structure, the heterogeneous analytical functions of the item blocks, the absence of an independent confirmatory sample, and the sample-size constraints associated with estimating a model containing several constructs, indicators, indirect paths, and potential interaction effects. The directional sequence presented in Figure 2 should therefore be interpreted as a system of theoretically justified and empirically informed propositions rather than as a set of estimated causal paths.

A confirmatory second-stage study should proceed sequentially. First, the proposed measurement structure should be evaluated through Confirmatory Factor Analysis using a larger independent sample. Second, measurement invariance should be examined before conducting regional or multigroup comparisons. Third, the direct relationships among structural capacity, managerial capability, strategic–logistical coordination, operational reliability, and performance-related outcomes should be estimated through a parsimonious structural model.

Only after establishing an acceptable measurement and direct-effects model should indirect effects, mediation pathways, and complexity-related interaction effects be evaluated. Longitudinal or time-separated data would be preferable for mediation analysis because they would establish a more defensible temporal sequence among organizational arrangements, managerial processes, logistical conditions, and project outcomes. Moderation analysis should be supported by prospectively determined statistical power and theoretically specified interaction terms.

A further limitation concerns the non-probabilistic and voluntary sampling procedure. Because a verified denominator of unique eligible recipients was not retained during survey distribution, a conventional response rate could not be calculated. The possibility of non-response and self-selection bias must therefore be considered. Professionals and companies with greater interest in project management, organizational practices, or complexity may have been more likely to participate, whereas less formalized firms or companies with limited administrative capacity may be underrepresented.

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Information about non-responding firms was unavailable, preventing a direct comparison between respondents and non-respondents. Consequently, the results should not be generalized statistically to the complete populations of construction firms in Cochabamba or Curitiba. They represent the patterns observed within the participating firms that met the eligibility criteria.

The statistical sensitivity of the study also constrains the interpretation of nonsignificant findings. With N = 108, the complete-sample correlation analyses were reasonably sensitive to moderate relationships but had limited power to detect small associations. Similarly, the regional subsamples were not sufficiently large to exclude small between-group differences. The dimensional-reduction analyses also presented unequal sample density across item blocks, with comparatively low cases-per-item ratios and marginal KMO values in some matrices. These findings should therefore be interpreted as exploratory and require replication in larger independent samples.

Although the Cochabamba and Curitiba subsamples were relatively balanced in size, numerical balance does not establish demographic equivalence. The absence of significant differences in the complexity-perception variables supports comparison of those specific perceptions but does not demonstrate that the two regional samples are equivalent in all organizational or professional characteristics. Future research should employ probability-based or stratified sampling, retain complete recruitment records, and collect information permitting direct assessment of non-response bias.

The regional discriminant analysis also included nine rather than all ten project complexity items. The adverse-climatic-exposure item was part of the complete reliability and exploratory factor analyses but was not included in the archived comparative discriminant output. Because the reason for this exclusion was not documented, the regional findings cannot be generalized to the complete ten-item project complexity block. Future regional comparisons should include all items prospectively and report the criteria for any item exclusion.

Taken together, the sampling, measurement, and regional conditions limit the external validity of the findings. The results describe the association patterns observed among the participating construction firms and qualified respondents from Cochabamba and the Metropolitan Region of Curitiba. They should not be interpreted as population estimates for all construction firms in either city or as representative findings for the Bolivian and Brazilian construction sectors.

Generalization is also limited by the heterogeneity of the participating firms, respondents, project portfolios, management arrangements, and regional conditions. The integrated framework may provide analytically transferable propositions for other construction contexts, but the magnitude, direction, and stability of its relationships require independent examination before broader empirical generalization.

The use of the pooled 108-response dataset may also conceal region-specific association patterns. Although the Cochabamba and Metropolitan Region of Curitiba subsamples were compared on available firm and respondent characteristics, complete measurement equivalence was not established across the organizational–managerial, logistics strategy, productivity, and project complexity modules. The regional group sizes were insufficient for stable replication of the item-rich exploratory factor and component analyses. Future research should obtain larger independent samples in each context, confirm the measurement structures separately, test configural, metric, and scalar invariance, and only then compare latent means, structural relationships, or regional path coefficients.

The regional analysis was also limited to observed sample characteristics and the measured project complexity perceptions. The study did not include direct indicators of cultural values, regulatory systems, contracting institutions, labor conditions, public-procurement environments, or professional norms. Consequently, the observed regional differences cannot be attributed empirically to cultural or institutional causes.

A latent-variable multigroup analysis was not feasible because the measurement structure had not been independently confirmed, measurement invariance had not been established, and the regional group sizes were insufficient for the complexity of the proposed model. Future comparative research should address these requirements before estimating regional differences in structural paths.

Future studies should determine sample size prospectively according to the primary confirmatory model, anticipated effect sizes, number of latent variables, indicator structure, and planned regional comparisons. Larger samples would permit independent exploratory and confirmatory stages, cross-validation of the factor structures, measurement-invariance testing, and adequately powered structural, mediation, and moderation analyses.

Consequently, the findings should be interpreted as empirically consistent with a complexity-based view of construction management rather than as a direct statistical demonstration of non-linearity, emergence, or causal feedback. The proposed conditioning role of technical, process-stage, and Planning-Related Complexity remains theoretical and requires confirmatory testing.

Future research should calculate composite measures for organizational structure, managerial processes, strategic–logistical coordination, operational reliability, complexity, and project performance. These constructs could subsequently be tested through covariance-based structural equation modeling or partial least squares structural equation modeling.

The indirect relationship between organizational structure and performance could be evaluated by testing managerial processes and logistics as mediating variables. Moderation could be assessed by incorporating interaction terms between organizational structure and the three complexity dimensions. Multi-group analysis could compare projects or firms characterized by lower and higher levels of technical, process-stage, and Planning-Related Complexity.

Longitudinal studies would be particularly valuable for determining whether changes in complexity modify the effectiveness of structures and processes across different phases of a project. Repeated observations could reveal how planning instability, coordination mechanisms, and productivity evolve over time.

Organizational-network analysis could compare formal organizational charts with actual communication, decision, and resource-flow networks. Such an approach would provide stronger evidence regarding the difference between designed structure and enacted organizational practice.

System-dynamics modeling, agent-based modeling, and other complexity-oriented approaches could represent feedback mechanisms among planning instability, resource availability, logistical disruptions, productivity, and managerial responses. These methods would provide a more direct basis for examining non-linear interaction and emergent project behavior.

Future studies should also incorporate objective project-performance measures, including cost variance, schedule variance, quality deviations, safety indicators, and productivity records. Combining perceptual and objective data would strengthen the validation of the proposed conceptual model.

Taken together, the findings confirm the central argument of this study: construction performance does not depend primarily on isolated variables such as formal structure or resource availability. It emerges from the interaction among managerial processes, logistics systems, operational practices, and project complexity conditions. The explanatory value of these dimensions becomes stronger when they are interpreted as components of an integrated and adaptive management system rather than as independent areas of organizational activity.

Future research should reduce dependence on single-source and single-occasion survey data. Studies could collect information from multiple respondents within each firm or project, including senior managers, project managers, site personnel, procurement staff, suppliers, and clients. Agreement among respondents should be evaluated before aggregating information at the organizational or project level.

Respondent-reported measures should also be complemented with objective or independently recorded indicators, such as schedule deviation, cost variance, equipment downtime, procurement lead time, supplier-delivery reliability, rework frequency, material losses, safety incidents, and productivity records. This would permit assessment of whether perceived managerial and logistical conditions correspond with observable project outcomes.

Time-separated and longitudinal designs should measure organizational structure, managerial processes, logistical conditions, complexity, and project outcomes at different stages of the project life cycle. Such designs would provide a more defensible temporal basis for testing direct effects, mediation pathways, reciprocal relationships, adaptation, and changes in coordination requirements. Accordingly, the proposed conditioning role of project complexity and the directional relationships illustrated in Figure 2 should be interpreted as hypotheses for future testing rather than as effects demonstrated by the present cross-sectional data.

Future questionnaire-based studies should incorporate procedural and statistical controls for common method variance prospectively. Possible strategies include temporal or source separation, protection of respondent confidentiality, separation of predictor and outcome blocks, use of marker variables, and comparison of substantive measurement models with latent common-method-factor models.

Finally, future validation should use larger probability-based or stratified samples, independent exploratory and confirmatory datasets, measurement-invariance testing, and broader regional coverage. These steps would strengthen measurement validity, external validity, and the evaluation of whether the proposed relationships remain stable across firms, project types, procurement systems, and institutional contexts.

6. Conclusions

This study examined how organizational structure, managerial processes, logistics, productivity-related conditions, and project complexity are positioned within an integrated multilevel construction management framework. The principal finding is an asymmetry in the observed relationships: formal organizational characteristics displayed a comparatively dispersed and limited pattern of direct associations, whereas stronger and more coherent relationships were concentrated among enacted managerial, strategic–logistical, and operational processes. The project complexity analysis also retained three context-specific dimensions—technical, process-stage, and planning-related complexity—which jointly accounted for 61.271% of the rotated variance. These dimensions provide a framework for interpreting different coordination conditions but are not presented as direct causal predictors of performance.

The theoretical contribution lies in positioning the analyzed domains according to the functions they perform within the management system. Organizational structure represents formal coordination capacity; managerial processes represent the mechanisms through which that capacity is enacted; logistics constitutes the interface connecting decisions with resource and workflow conditions; and operational reliability reflects the continuity of those arrangements during project execution. Project complexity is incorporated as a theory-guided context under which the relevance and coordination requirements of these relationships may vary. This framework is empirically informed and testable, but it is not a statistically confirmed causal, mediation, or moderation model.

The practical implication is that construction firms should complement formal organizational design with stronger management of the interfaces connecting planning, information, suppliers, resources, and site execution. Priority actions include linking procurement and logistics plans with construction schedules, clarifying responsibilities at organizational and project interfaces, monitoring equipment and material continuity, strengthening supplier evaluation, maintaining reliable payment and approval processes, and escalating constraints before they affect multiple activities. These recommendations are implications derived from the observed association and ranking patterns; their effectiveness was not evaluated as an intervention in the present study.

The findings remain exploratory and specific to the participating firms and respondents. The pooled, cross-sectional, self-reported, and non-probability sample does not establish temporal ordering, causal effects, population representativeness, or measurement invariance between Cochabamba and the Metropolitan Region of Curitiba. Similarly, the absence of statistically detectable regional separation in the nine project complexity variables included in the archived comparison should not be interpreted as complete regional equivalence. Future research should use larger independent samples, confirmatory factor analysis, measurement-invariance testing, objective and longitudinal performance data, and adequately powered structural, mediation, moderation, network, or multigroup models. The next analytical step is therefore to determine when, through which interfaces, and under which complexity conditions coordinated managerial and logistical capabilities become most consequential for project performance.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/buildings16173406/s1. Figures S1–S5, scree plots for the five analytical runs; Table S1, analytical overview of factorability, extraction, and explained variance across the five analytical runs; Tables S2–S6, complete Total Variance Explained outputs for the competitive environment and organizational structure, managerial process, logistics strategy, productivity and operational performance, and project complexity analyses; Table S7, salient rotated loading structure for the competitive environment and organizational structure variables; Table S8, salient rotated loading structure for the managerial process variables; Table S9, complete rotated component matrix for logistics, strategy, and organizational interaction; Tables S10–S14, source-study domain-specific rotated component matrices for the productivity variables; Table S15, rotated factor matrix for the project complexity items; Table S16, exploratory reliability and convergent validity indicators for the factor-derived project complexity subscales; and Table S17, univariate tests of equality of group means for the project complexity variables.

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