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The Effect of Fragmentation as A Moderation on The Relationship Between Supply Chain Management And Project Performance

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Abstract

Project fragmentation can be understood as breaking down the construction work into several parts due to the complexity and massive scale of a project. Initially, this division was intended to focus work on specific sectors, ensuring precision, speed, and guaranteeing Project Performance. However, high levels of fragmentation can result in a lack of integration between parts of the project, which can adversely affect both the implementation process and the final outcome of the project. One such adverse effect is project delay, which can diminish project performance, as seen in the X PEB steel construction project. Previous studies have identified an approach to improve project quality through the implementation of supply chain management (SCM). Therefore, this study examines the impact of fragmentation on SCM concerning project performance, comparing the effect of SCM on performance under conditions of high fragmentation versus when fragmentation is disregarded in the PEB steel construction project. The results show that SCM influences performance by 51%. This analysis indicates that SCM plays a crucial role in achieving the performance of PEB steel construction projects. When project fragmentation is assumed to be non-existent, SCM's influence on project performance is even greater, reaching 82%, indicating that SCM has a significant impact on project performance and serves as a solution to maintaining project performance. This study concludes that fragmentation serves as a moderating variable affecting project performance in PEB steel construction.

Keywords: *Fragmentation, Supply Chain Management, Project Performance.*

1. Introduction

Construction projects, during their execution from start to finish, often face challenges related to project fragmentation. Complex construction projects are frequently divided into parts managed separately by contractors, subcontractors, or third parties. Project fragmentation can be defined as breaking down the construction work into several parts due to the complexity and scale of a project [1]. This division is done to focus the work on their respective sectors. This can lead to a lack of integration between project parts, negatively impacting both the execution process and the project's final outcome, one of which is project delay, which can alter the performance of a project. Empirical analysis of management function failures in terms of project delays reveals several factors: poor construction planning, poor construction schedule control, poor project schedule direction, and poor organization of project finances[2].

Previous research has found that an approach to addressing project fragmentation is through the implementation of supply chain management (SCM) concepts [3]. Supply chain management (SCM) is an integrated flow from upstream to downstream involving parties in the construction project, namely the owner, consultant, contractor, subcontractor, and supplier, for the project's success [4]. SCM indicators integrate various efforts to manage and regulate the total flow in a supply chain network from suppliers to end consumers. Managing supply chain management is a crucial step adopted to enhance quality and efficiency in productivity as well as optimize value achievement and provide satisfaction to service users [5]. However, project fragmentation in supply chain management becomes more complex and challenging. A deep understanding of how project fragmentation can affect the management of the project's supply chain in the construction industry is needed to support the performance of the project [6].

Optimal project performance is essential in achieving project goals, whether in terms of cost, time, quality, or customer satisfaction. Ineffective project fragmentation can impact overall project performance [7]. Therefore, research is needed to understand the influence of project fragmentation on project performance in the context of the pre-engineering building steel structure industry. In Project X, supply chain management has been applied in the pre-engineering building (PEB) system; however, project delays still occur. This is the urgency that drives the researcher to study the above phenomenon.

2. Research Method

The type of research used in this study is quantitative research. Quantitative research is a research method based on positivist philosophy, which is used to study a specific population or sample, typically with random sampling, and data is collected using research instruments. Then, the data is analyzed quantitatively/statistically with the aim of testing predetermined hypotheses [8].

Quantitative research has an important goal in conducting measurements, which is the center of measurement [9]. This is because the results of measurements can help in understanding the fundamental relationship between empirical observations and the data collected quantitatively. The steps to be taken during the preparation of the thesis on "The Influence of Project Fragmentation on Supply Chain Management and Project Performance (a study on pre-engineering building steel structures)".

2.1 Population and Sampling

The term population in research refers to the complete group of participants being investigated. Population refers to the total number of research subjects [10]. The population is a generalization area made up of items or individuals with specific features and characteristics that the researcher has chosen to study and from which conclusions will be generated. Respondents in this study include implementing contractors, planning consultants, project owners, suppliers, and vendors who have previously or currently worked on pre-engineered building (PEB) steel construction projects in Indonesia [11]. Data collection for these studies was done through observational approaches.

Sample as a subset of a population that represents its characteristics. This study's sample includes data from 31 respondents as well as observations from the Rich Valley Indonesia project. The selection criteria were carefully chosen by the researcher to guarantee that the sample correctly reflects the population's characteristics. A representative sample is

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essential for producing data that reflects the greater population[12]. The findings from the research sample can then be extended to the entire population without prejudice. Bias arises when sample selection is based on subjective factors, resulting in biased findings.

Table 1. Sample Criteria for Implementing Contractors, Planning Consultants, and Project Owners

Criteria	Details
Minimum Education Level	Bachelor's degree (S1) in civil engineering, architecture, or related fields in construction
Experience	Involvement in pre-engineering building (PEB) steel structure construction work
Job Positions	General Manager, Manager/Site Manager, Project Manager, QC Engineer, Design Engineer, Production Engineer, Site Engineer, and related positions
Age Range	25 – 60 years old

The sample selection criteria for implementing contractors, planning consultants, and project owners were designed to ensure that participants possess relevant qualifications and experience in the context of PEB steel structure construction projects [13]. As shown in Table 1, participants are required to have a minimum educational qualification of a Bachelor's degree (S1) in civil engineering, architecture, or a related field. Furthermore, they must have been involved in PEB steel structure construction work, ensuring that they have practical knowledge and experience. The specified job positions, such as General Manager, Project Manager, and various engineering roles, guarantee that only individuals with substantial authority and expertise are included in the sample. The age range of 25 to 60 years captures professionals at various stages of their careers, ensuring diversity in experience levels.

Table 2. Sample Criteria for Suppliers and Vendors

Criteria	Details
Experience	Handling pre-engineered building (PEB) steel structure construction work
Knowledge	Understanding the procurement process until delivery onsite
Job Positions	Procurement, Finance, Cost Estimation, and Production departments
Minimum Education Level	Bachelor's degree (S1)
Age Range	25 – 60 years old

Table 2 outlines the sample criteria for suppliers and vendors involved in the supply chain management of PEB steel structure construction projects. The criteria emphasize the importance of practical experience in handling PEB construction work, with a particular focus on understanding the procurement process, from raw material selection to onsite delivery. The specified job positions in procurement, finance, cost estimation, and production departments ensure that only those directly influencing supply chain management are included. Similar to the criteria for contractors and consultants, the minimum education level is set at a Bachelor's degree (S1), and the age range of 25 to 60 years ensures that participants have varying levels of experience.

These sample criteria are designed to represent the key stakeholders involved in the construction process and supply chain management of PEB steel structures. By adhering to these criteria, the study ensures that the sample is representative of the population, enabling the research to produce valid and reliable conclusions that can be generalized to the entire population [14].

2.2 Operational Definition and Measurement of Variables

An operational definition is an abstract concept formulated to facilitate the measurement of variables [15]. It serves as a guide for conducting research activities and details the variables emerging from a study into more specific, measurable indicators [16]. The following are the operational variables for this study, categorized into three main groups: Fragmentation of Project (Z), Supply Chain Management (SCM) (X), and Project Performance (Y). Each variable is broken down into dimensions and corresponding indicators, which provide the basis for data collection and analysis.

Fragmentation of Project (Variable Z) encompasses five main dimensions: Design and Construction Separation (z1), Scope of Knowledge (z2), Integration (z3), Barriers (z4), and Diversity Separation (z5). These dimensions represent the challenges in project execution, including communication barriers, coordination problems, and knowledge gaps between project participants [17]. These factors are crucial in determining how well the project operates and influence the overall performance [18].

Supply Chain Management (Variable X) focuses on essential processes such as Production (X1), Supply (X2), Inventory (X3), Location (X4), Transportation (X5), and Information (X6). These dimensions are critical for ensuring the timely and efficient delivery of materials, maintaining adequate inventory levels, and managing supplier relationships, all of which impact the project's progress and performance.

Project Performance (Variable Y) assesses the success of the project through several management areas: Project Integration Management (Y1), Project Scope Management (Y2), Project Schedule Management (Y3), Project Cost Management (Y4), Project Quality Management (Y5), and Project Resource Management (Y6). These dimensions cover the effectiveness of project monitoring, cost control, scheduling, quality assurance, and resource allocation, which are key indicators of a project's success [19].

Table 3. Operational Definitions for Fragmentation of Project (Z)

Dimension	Indicators
Design and Construction Separation (z1)	Lack of communication feedback between sectors, lack of interaction between contractors & design, lack of ownership, confrontational culture, sequential nature of construction activities, limited communication in the supply chain, language and cultural differences, limited essential information among related parties, communication between contractors and subcontractors, interaction between specialists and procurement for goods delivery, premature material procurement, large-scale material procurement without considering actual site production, design changes, limiting client involvement, lack of continuity and responsiveness, client's lack of focus, reducing expert contributions while contractors make design decisions
Scope of Knowledge (z2)	Sufficient information from previous phases, adequate information from other consultants, interpersonal relationships, not blaming individuals, improved prediction of time and cost, ease of access to information, role of IT, good relationships with other members
Integration (z3)	Participation, common goals, lateral relationships (regular meetings), focus on end-users, office availability on-site, mutually beneficial outcomes, lateral relationships (direct contact), self-regulating teams
Barriers (z4)	Organizational boundaries, cultural boundaries, language barriers, expertise boundaries, coordination issues, customer absence, learning problems
Diversity Separation (z5)	Diversity, resolving differences or conflicts, understanding information from other experts

Table 1 presents the operational definitions for the Fragmentation of Project (Z) variable. This table breaks down key aspects such as Design and Construction Separation, Scope of Knowledge, Integration, Barriers, and Diversity Separation, highlighting critical indicators that influence project fragmentation [20]. These indicators, such as communication gaps, limited information, and organizational boundaries, play a significant role in how different teams interact and execute tasks, ultimately affecting project success [21].

Table 4. Operational Definitions for Supply Chain Management (X) and Project Performance (Y)

Variable	Dimension	Indicators
Supply Chain Management (X)	**Production (X1)**	Volume suitability, product type suitability, product quality control.
	Supply (X2)	Selecting raw material suppliers, cost reduction, speed, supplier flexibility.
	Inventory (X3)	Availability of suitable stock, meeting market demand, stability of material procurement.
	Location (X4)	Strategic location, tax and tariff suitability, supplier distance from customers.
	Transportation (X5)	Transportation mode selection, timeliness of delivery, and shipping costs.
	Information (X6)	Clarity of information, inter-party communication, maintaining accurate information.
Project Performance (Y)	**Integration Management (Y1)**	Monitoring and controlling project work, material transportation, integrated change control, flexibility, prioritization.
	Scope Management (Y2)	Scope validation, planning and stability, scope control.
	Schedule Management (Y3)	Schedule control, project duration.
	Cost Management (Y4)	Cost control, productivity, planning.
	Quality Management (Y5)	Quality control, production control, project supervision, defect rate, material quality.
	Resource Management (Y6)	Resource control.

Table 2 outlines the operational definitions for Supply Chain Management (X) and Project Performance (Y). For Supply Chain Management, it covers essential dimensions like Production, Supply, Inventory, Location, Transportation, and Information, all of which are crucial for the efficient operation of the supply chain. Ensuring the availability of materials, timely delivery, and accurate information are key to preventing delays and cost overruns in construction projects [22].

Project Performance (Y) is measured through dimensions such as Project Integration Management, Scope Management, Schedule Management, Cost Management, Quality Management, and Resource Management. These dimensions assess the project's ability to meet its goals regarding time, cost, quality, and resource utilization. Effective project

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performance ensures that the project is completed on schedule, within budget, and to the required quality standards [23].

Together, these tables provide a structured framework for measuring and analyzing the key variables in this research, ensuring clarity and precision in data collection and interpretation. By operationalizing these variables, the study can systematically examine the factors that influence project fragmentation, supply chain efficiency, and project performance [24].

2.3 Types and Sources of Research Data

This research incorporates both primary and secondary data sources to obtain comprehensive insights into project fragmentation, supply chain management, and project performance in pre-engineering building steel structure projects [25]. Primary data is collected through questionnaires distributed to construction practitioners, including engineers and managers, via a Google Form, utilizing a Likert scale to assess variables like cooperative behavior, opinions, and experiences. Secondary data is gathered from previous studies, journals, and literature, alongside specific project data from the Rich Valley pre-engineering building project [26]. Additionally, the study employs observation as a complementary technique, systematically observing and recording relevant phenomena through sensory input to provide qualitative insights that enhance the questionnaire-based quantitative data.

2.4 Testing the Outer Model or Measurement

Model Measurement testing functions to assess the validity and reliability of indicators or measurement tools manifested by the collected data. To measure a latent variable, it is necessary to determine first whether it is a reflective or formative type [27]. In the measurement model in the journal on Empirical Study to Determine Fragmentation of Construction Projects, a formative measurement model was used .

Figure 1. Reflective and Formative Constructs in the Measurement Model

Figure 1 illustrates the difference between reflective and formative measurement models. On the left, the formative construct is shown, where the indicators (Indicator 1 and Indicator 2) combine to form the latent variable, meaning changes in the indicators directly influence the construct [28]. On the right, the reflective construct is displayed, where the latent variable influences the indicators, implying that changes in the latent variable are reflected by the indicators. This distinction between the two types of models highlights the importance of choosing the appropriate approach for assessing the validity and reliability of the indicators used in the research [29].

2.5 Data Analysis Technique

The data analysis method employed in this research is Structural Equation Modeling (SEM) using Partial Least Squares (PLS). This method has been widely used in previous studies on project fragmentation for its suitability in further research [30]. To facilitate data analysis using SEM-PLS, the statistical software SmartPLS is utilized. SEM, which is also referred to as covariance structure analysis, latent variable analysis, confirmatory factor analysis, or Linear Structural Relations (LISREL) analysis [31], integrates various statistical techniques such as

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factor analysis, structural model, and path analysis. SEM is a multivariate statistical analysis method that allows researchers to test complex relationships between observed and latent variables [32].

The decision to use the SEM-PLS method is based on its ability to handle both formative and reflective indicators, as demonstrated in previous studies [33]. SEM-PLS is particularly appropriate for research involving small sample sizes or limited case numbers, typically ranging from 30 to 100 samples. Given that this study includes the analysis of latent variables formed through both formative and reflective indicators, SEM-PLS is the most suitable approach. This method enables the examination of complex relationships between variables and provides robust results even when sample sizes are limited.

3. Findings

3.1 Relationship Between Supply Chain Management and Project Performance

The following diagram presents the outer loading modeling scheme analyzing the relationship between supply chain management and project performance as shown below:

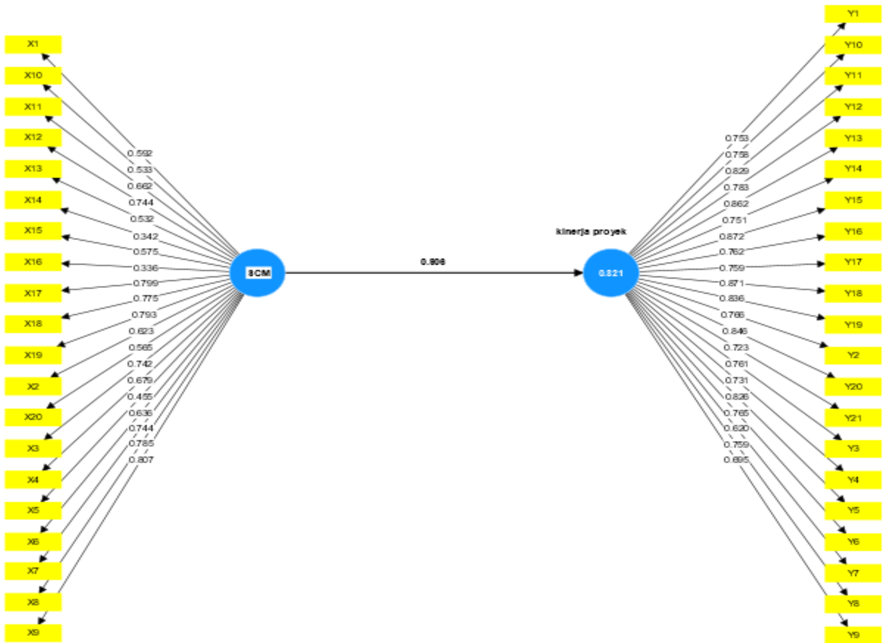

Figure 2. Diagram of the Outer Loading Scheme of SCM on Project Performance

Based on figure 2 above modeling, the overall indicators of the two variables in the model show that all outer loading values meet the criteria/are valid, with all values being > 0.70, making it suitable for further testing. The results indicate that the influence of SCM on performance is significant, as seen from the "path coefficient" value of 0.908, indicating that the influence on project performance reaches 82.1% (R Square value of 0.821). From this study, to achieve 100% project performance, only 17.9% is influenced by factors other than SCM, which were not tested in this research.

3.2 The Influence of Fragmentation on Project Performance

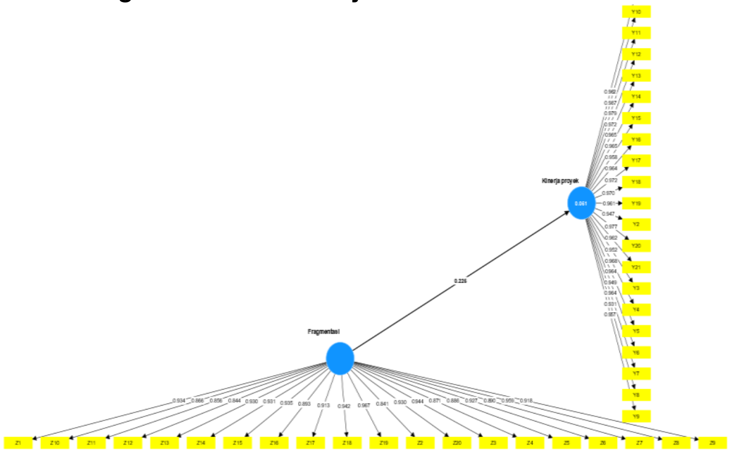

Figure 3. Diagram of the Outer Loading Scheme of Fragmentation on Project Performance

Based on figure 3, the indicators for both variables in the model demonstrate that all outer loading values exceed the threshold of 0.70, confirming their validity and making them suitable for further testing. Despite this, the analysis reveals that project fragmentation does not have a significant impact on project performance. This conclusion is supported by the model's R Square value of 0.051, indicating that project fragmentation accounts for only 5.1% of the variance in project performance. Therefore, the influence of project fragmentation on project performance is minimal, suggesting that other factors may play a more critical role in determining project outcomes.

3.3. The Influence of Fragmentation on the Relationship Between SCM and Project Performance

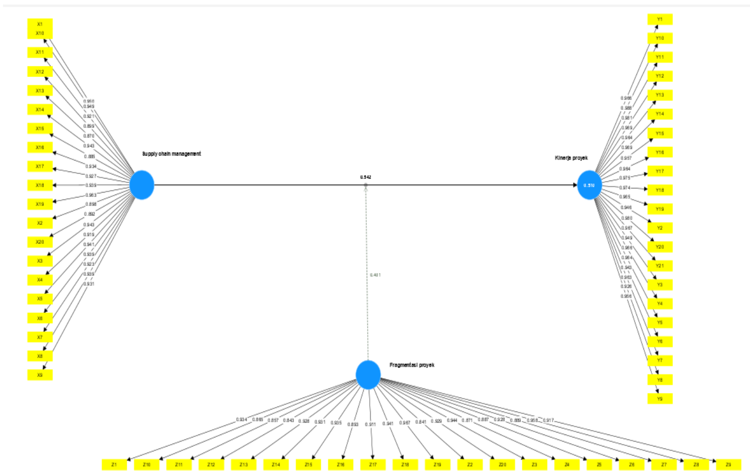

Figure 4. Diagram of the Outer Loading Scheme of Fragmentation on SCM & Performance

Based on Figure 4, the data analysis results the researcher categorized the indicators of the fragmentation variable and interpreted them by dividing them into several groups to reflect their influence on moderating the relationship between Supply Chain Management (SCM) and project performance. Group I consists of indicators with the highest and most significant impact, where fragmentation strongly moderates SCM and has a substantial influence on project performance. Group II includes indicators slightly below Group I, showing a moderate effect of fragmentation on SCM and project performance. Group III consists of indicators that demonstrate a lesser degree of influence than Group II, but still play a role in moderating the relationship between SCM and project performance. Group IV encompasses indicators with a minimal moderating effect, positioning them below Group III in terms of significance. Finally, Group V includes indicators that exhibit a relatively weak influence on fragmentation and SCM's impact on project performance, contributing the least among all groups. This classification aids in understanding the varying degrees of fragmentation's influence on SCM and its overall impact on project outcomes.

3.4 Partial Least Squares (PLS)

This analysis is a multivariate statistical analysis that estimates the influence between variables simultaneously with the aim of prediction, exploration, or development of a structural model [34]. This study utilizes PLS-SEM, which means: The analysis does not assume that the data are normally distributed, can work with limited sample sizes, and the research model develops a structural model where Fragmentation acts as a moderating variable. This research model involves a moderating variable, Fragmentation, which is suspected to influence the supply chain on project performance. Model evaluation in PLS consists of measurement model evaluation, structural model evaluation, and model fit and goodness-of-fit evaluation.

3.5 Secondary Data Observation

In X project, which the researcher participated in, the work areas are as explained in the previous chapter and also include attachments such as schedules, site plans, and erection methods. This project fully utilizes PEB steel imported from Vietnam, and upon arrival in Indonesia, only the erection process is carried out without fabrication and assembling from scratch, with the aim of expediting the work through division of tasks among different fields. Work can be conducted in parallel both at the site and in workshops in Vietnam, thus avoiding interference from each other's activities. Everything has been planned and designed in such a way to expedite the process involving many parties, working in different locations to enable parallel progress, and designing effective work methods to meet the predetermined schedule. However, the project still experienced a delay of approximately 3 weeks.

The findings of this research emphasize the significant role that Supply Chain Management (SCM) plays in determining project performance, with SCM accounting for a large proportion of the variance in performance outcomes. On the other hand, project fragmentation was found to have a minimal direct impact on project performance, although it moderates the relationship between SCM and performance to varying degrees, depending on the specific indicators involved. The combination of efficient SCM and the mitigation of fragmentation's negative effects is crucial for enhancing project outcomes. Additionally, the secondary data observation reinforces the importance of strategic planning, coordination, and task division in managing large construction projects, where even small inefficiencies can lead to delays. These findings suggest that future studies should explore additional factors beyond SCM and fragmentation to fully understand what drives project success.

4. Conclusion

This research emphasizes the significant influence of Supply Chain Management (SCM) on project performance, particularly in pre-engineered building (PEB) steel structure projects, where SCM accounts for 82.1% of the performance variance when project fragmentation is minimized. Effective SCM practices are vital for ensuring efficient procurement, logistics, and overall resource management, which are crucial for project success. While project fragmentation only directly influences 5.1% of project performance, it plays a moderating role in the SCM-performance relationship, highlighting the need to address fragmentation to enhance SCM's effectiveness further. Secondary data analysis from the X project underscores the importance of strategic planning and coordination to prevent delays, even when SCM is applied effectively. Future research could explore additional factors influencing project performance, such as technological innovations and human resource management, which were not covered in this study. Further studies could also assess SCM and fragmentation in other sectors of the construction industry to generalize the findings. Moreover, investigating the impact of emerging technologies, such as artificial intelligence and blockchain, in mitigating fragmentation and improving SCM efficiency, could provide valuable insights for enhancing project performance in large-scale construction projects.

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