

# STAKEHOLDERS INTEGRATION IN OFF-SITE CONSTRUCTION SUPPLY CHAIN: A CASE STUDY OF THE FLOWS AND RELATIONSHIPS UNDER DIFFERENT PROJECT DELIVERY METHODS

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**ABSTRACT:** Modular and Off-site Construction (MOC) is a construction methodology that can meet the demands of a rapidly growing population by overcoming productivity challenges associated with conventional construction. However, the adoption of MOC remains limited, partly due to a lack of understanding of the MOC Supply Chain's (MOC-SC) structure, particularly regarding material and information flows and stakeholder roles. Furthermore, previous research has not investigated the impact of different project delivery methods (PDMs) on stakeholder relationships. This paper addresses this challenge with a two-fold approach. First, a high-level MOC-SC process map for a panelized MOC was developed based on data collected from collaborative meetings with industry practitioners and a literature review. The high-level process map visualizes the MOC-SC's structure, as well as material and information flows throughout the MOC-SC. Second, this paper applies the salience model, a stakeholder analysis tool utilized widely in project management, to analyze how three PDMs (i) Design-Bid-Build (DBB); (ii) Design-Build (DB) with in-house prefabrication; and (iii) DB with outsourced prefabrication affect the stakeholders. The analysis of the MOC-SC under the selected PDMs has shown the influence of PDMs on communication channels. Consequently, the Design-Build PDM with in-house prefabrication fosters direct communication links between stakeholders, enhancing communication and facilitating successful project completion. These insights can help practitioners develop stakeholder management strategies tailored to their needs. Moreover, a deeper understanding of the MOC-SC can reduce industry hesitancy and facilitate broader adoption of MOC by the construction industry.

## 1. INTRODUCTION

Conventional construction methods face significant challenges, including labour shortages, cost overruns, poor productivity, delays, material waste, and environmental concerns (Ekanayake et al., 2021). These inefficiencies have limited the construction industry's ability to meet the housing demands of a rapidly growing population. For example, the Canadian Mortgage and Housing Corporation (CMHC) estimates that 3.5 million homes need to be built by 2030 to restore housing affordability to 2003-2004 levels (CMHC, 2022). In response to the shortcomings of conventional construction methods, MOC has been proposed as an alternative construction methodology to enhance the construction industry's productivity, improve construction quality, and minimize environmental impacts. MOC involves producing building components (e.g., panels or 3D volumetric modules) in a factory-controlled environment, which are then transported to the construction site for final assembly (Ayinla et al., 2019). Despite its benefits, the widespread adoption of MOC remains constrained due to limited research on the structure and operational processes of the

MOC-SC (Ortega et al., 2023). Furthermore, stakeholders' roles and collaboration patterns remain unclear, as key stakeholders, such as the prefabrication company, are involved in MOC processes. This contrasts with the supply chain structure of a conventional project, which typically includes fewer stakeholders and straightforward stakeholder management procedures. In addition to the common stakeholders involved in construction projects, such as clients and designers, MOC also requires the involvement of other stakeholders, including prefabricators and logistics providers (Xue et al., 2018). The complexity of MOC-SC stems from the need to coordinate material and information flows, financial transactions, and project scheduling among these stakeholders and across geographically dispersed facilities (Xue et al., 2018). The absence of standardized supply chain process maps and stakeholder coordination mechanisms further exacerbates the challenges of integrating MOC into mainstream construction practices. Previous efforts to improve MOC coordination have focused on various aspects of MOC Supply Chain Management (MOC-SCM), including production management (Yang et al., 2016), inventory management (Hsu et al., 2018), and logistics management (Ahn et al., 2020; Yi et al., 2020). However, MOC-SCM lacks a comprehensive understanding of the stakeholders and an analysis of how different PDMs influence their relationships. Understanding the differences in the structure and operation of the MOC-SC, as well as the interactions between stakeholders, is crucial for improving the performance of MOC and enabling its widespread adoption. To address these limitations, this paper examines the MOC-SC from a stakeholder management perspective, considering the interactions between stakeholders when different project PDMs, such as Design-Build, Design-Bid-Build, and Integrated Project Delivery, are employed.

## **1.1 Research Gaps and Objectives**

Despite its considerable influence on the success of the MOC project, stakeholder management has not received sufficient attention as part of MOC-SCM (Xue et al., 2018). Poor relationships amongst key stakeholders reduce the MOC project's time, cost, and quality performance (Xue et al., 2018). Information in the MOC-SC is dispersed throughout the MOC-SC, often in geographically separate locations, which reduces its efficiency and resilience. Moreover, transferring most production activities to off-site facilities limits the manager's ability to control the processes, mainly when the prefabricator is an independent entity with unique economic incentives. Improving stakeholder management practices and coordination in MOC necessitates an understanding of the stakeholders' relationships throughout the MOC-SC. Moreover, how stakeholders communicate under different PDMs is another area to explore to improve the overall operational efficiency of the MOC-SC. To fill these gaps, the objectives of this study are: (i) define the stakeholders in the MOC-SC; (ii) develop a MOC-SC Process Map (MOC-SCPM) to visualize and understand MOC-SC flows and communication channels among stakeholders; and (iii) investigate stakeholder relationships under different PDMs which can be adopted in the context of MOC-SC.

## **2. METHODOLOGY**

To develop a comprehensive understanding of stakeholders in MOC-SC and define their relationship, the proposed research methodology consists of three sequential stages as shown in Fig. 1. The first stage in the research was a literature review to understand the existing body of knowledge regarding MOC-SC, including key stakeholders and PDMs, as well as stakeholder analysis tools used in the construction industry. Next, the necessary data regarding the structure of the MOC-SC was collected using collaborative meetings, whose questions were developed based on the literature review. Collaborative meetings enable researchers to collect qualitative data in small settings, where experts can share their experiences and provide valuable insights (Neumayr et al., 2021). The MOC-SCPM was developed with input from industry practitioners and complemented with the results of a comprehensive literature review. The MOC-SCPM encompasses the complete life cycle of the MOC-SC, visualizing the flows of material and information across the MOC-SC phases, including material production, logistics, panel production, onsite assembly, and demolition. The MOC-SCPM incorporates the key MOC-SC stakeholders, including contractors, prefabricators, designers, and clients, that form the MOC-SC, as well as the material and information linkages between them. The preliminary MOC-SCPM was presented to the industry partner for discussion and validation. Finally, the collected data was used to develop a high-level MOC-SC process map and conduct the stakeholder analysis. The analysis provides insights into the relationships between stakeholders and their implications for the MOC-SC's performance under three PDMs (i.e., DBB, DBB with

in-house production). The stakeholder analysis presented in this paper benefits MOC-SC stakeholders, particularly prefabricators, as it provides a framework for understanding relationships within the MOC-SC and developing effective stakeholder engagement strategies.

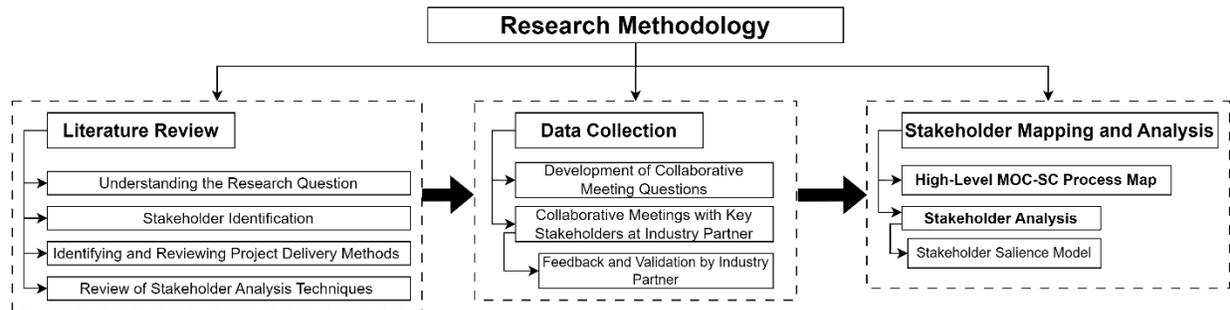


Figure 1: Summary of Research Methodology

## 2.1 Literature Review

### 2.1.1 MOC-SC and MOC-SCM

MOC encompasses various approaches that can be classified based on the level of prefabrication and onsite assembly requirements. Panelized MOC manufactures 2D panels (walls, floors, roofs) that are transported for assembly. In contrast, volumetric MOC features fully enclosed 3D units, like room modules or pods, requiring minimal onsite work (Ayinla et al., 2019; Zaalouk et al., 2023). Both MOC methodologies demonstrate the geographic separation between the sites of production and assembly. The geographic separation, coupled with the involvement of numerous stakeholders, increases the importance of Supply Chain Management (SCM) for MOC-SC (Bode and Wagner, 2015). SCM involves strategically coordinating processes, resources, and stakeholders engaged in procurement, production, and delivery to satisfy client needs (Vrijhoef and Koskela, 2000). Effective SCM enhances supply chain efficiency and productivity by minimizing waste, reducing lead times, and improving cost predictability through integrated planning, logistics, and procurement strategies. Moreover, effective SCM reduces the impacts of supply chain disruption through collaboration and transparency among stakeholders. Stakeholder management is a crucial aspect of MOC-SCM, vital for ensuring smooth coordination, collaboration, and decision-making among key stakeholders (PMI, 2017; Zaalouk et al., 2023).

### 2.1.2 Project Delivery Methods in MOC

Construction projects can be delivered using a range of PDMs, which are defined based on the relationships between the key stakeholders (i.e., client, designer, and contractor). A crucial difference between a conventional and MOC project is the inclusion of the prefabricator, a critical stakeholder in the MOC, which results in additional communication and supervision requirements. The prefabricator is responsible for producing building components according to the designs and specifications provided by the designer. However, due to the limited adoption of MOC, PDMs tailored to MOC projects have not been developed. In this regard, three PDMs that are utilized widely in the construction industry are discussed next. The Design-Bid-Build (DBB) approach follows a sequential process, where design and construction are contracted to separate entities, often resulting in fragmented communication and limited early input from manufacturers and suppliers. Alternatively, Design-Build (DB) integrates the role of designer and contractor into a single entity. This approach fosters greater collaboration by allowing a single entity to manage the design and construction. DB can facilitate the involvement of fabricators at an earlier stage, thereby optimizing design, streamlining procurement, and enabling early production of panels or modules. Integrated Project Delivery (IPD) adopts a more collaborative approach, engaging all stakeholders—including clients, designers, manufacturers, and logistics providers—early in the project process to enhance coordination and efficiency (Park and Kwak, 2017). Furthermore, some contractors enhance their control over the MOC-SC by owning the off-site prefabrication facilities, allowing them to streamline production, improve quality assurance, and reduce dependency on external prefabricators. The vertical integration,

which occurs when the same entity undertakes production, logistics, and assembly, enables better coordination between design, manufacturing, and onsite assembly, minimizing delays and ensuring just-in-time deliveries. By internalizing prefabrication, contractors can develop supply chain-wide standard operating procedures (SOPs), reduce waste, coordinate logistics, and implement lean manufacturing principles to enhance efficiency throughout the MOC-SC. Additionally, owning production facilities provides a competitive advantage by securing supply chain resilience, improving cost predictability, and allowing for greater flexibility in meeting project demands (Ekanayake et al., 2021).

### 2.1.3 Stakeholders Analysis Techniques

There are several tools available to researchers and practitioners, such as stakeholder influence matrices, power interest grids, stakeholder salience models, and Responsible, Accountable, Consulted, and Informed (RACI) matrices (PMI, 2017). A Stakeholder Influence Matrix evaluates stakeholders based on their power (ability to affect decisions) and interest (level of engagement), ensuring that high-power, high-interest stakeholders are actively managed, and lower-priority stakeholders receive proportional levels of attention. Power/Interest Grids refine this approach by mapping stakeholders into four quadrants—actively managing key influencers, keeping high-power but low-interest stakeholders satisfied, informing highly interested but less powerful groups, and passively monitoring those with minimal impact. The RACI Matrix (Responsible, Accountable, Consulted, Informed) clarifies roles and decision-making authority within teams, reducing confusion and ensuring clear accountability (PMI, 2017).

The stakeholder salience model expands the stakeholder influence model, prioritizing stakeholders based on three key attributes: power, legitimacy, and urgency, which is well-suited to analyze complex relationships within a community (Parent and Deephouse, 2007; PMI, 2017). In the salience model, power refers to a stakeholder's ability to influence project outcomes, legitimacy pertains to the stakeholder's rightful involvement in the project, and urgency signifies the need for immediate attention due to time-sensitive claims or critical issues. The salience model ranks each stakeholder's power, legitimacy, and urgency on a scale of low, medium, and high for all stakeholders. Therefore, if a stakeholder is ranked highly across multiple categories, they are considered a critical stakeholder whose relationship must be managed carefully. The salience model can be expanded further using a stakeholder typology that classifies the stakeholders as follows: definitive (high power, legitimacy, and urgency), dangerous (high power and urgency), dominant (high power and legitimacy), dependent (high urgency and legitimacy), or dormant (high power), etc. (Aaltonen et al., 2008; Mitchell et al., 1997; Parent and Deephouse, 2007; PMI, 2017). Furthermore, to expand the analysis, the relationships between stakeholders are further classified into two categories: direct, where a contractual relationship exists, and indirect, where no contractual relationship exists.

## 2.2 Data Collection

After identifying stakeholders based on the literature review, data were collected from a large, panelized construction company in Alberta, Canada, through collaborative meetings and observations of MOC-SC operations. This approach allowed for the identification of workflows and decision-making processes at the factory, logistics, and construction sites. The company, with 200 employees, has over 22 years of experience in panelized MOC and has completed over 20,000 projects, making it an ideal partner to develop the MOC-SC process maps. The collaborative meetings were conducted for six months on a biweekly basis and were held with key individuals at the company that included: (i) the Enterprise Resource Planner (ERP) responsible for relationships with stakeholders; (ii) master planners and estimators that prepare project requirements, material quantity takeoffs, and schedules; and (iii) production, transportation, and construction managers. The meeting participants provided detailed information regarding planning and decision-making processes, workflows, resource requirements, and the flow of materials and information.

## 2.3 Stakeholders Mapping and Analysis

The information collected from the collaborative meetings was used to identify key stakeholder relationships within the MOC-SC and to develop the preliminary MOC-SCPM. The development of the MOC-SCPM was also complemented by data gathered from a literature review, which included global practices. At this stage, it is worth noting that the MOC-SC process maps presented in this paper are based on a panelized MOC-SC process. After the initial MOC-SCPM was developed, it was presented to key individuals for validation. As shown in Section 3.1, the process map represents a conceptual model for the MOC-SC, visualizing the relationships between stakeholders and their linkages, including contractual obligations, material flows, and information flows. Following the development of the MOC-SCPM, a stakeholder analysis was undertaken that leveraged the MOC-SCPM to understand the interactions between stakeholders in the MOC. Several PDMs are available to deliver conventional construction projects, including DB, DBB, and IPD. Each PDM influences the MOC-SC's operations, but more integrated models, such as DB, foster better stakeholder relationships, improve communication lines, mitigate risks, and improve cost predictability, which ultimately determines the success of projects (Zhang et al., 2023). This paper utilizes the stakeholder salience model to evaluate stakeholder relationships and MOC-SC structures under three PDMs: DBB, DB without outsourced production, and DB with in-house prefabrication facilities. The stakeholder analysis was complemented by the literature review's results, particularly in terms of applying the selected PDMs in conventional construction scenarios. Furthermore, the matrix that presented the results of the salience model was supplemented with information regarding the nature of the relationship between stakeholders.

## 3. RESULTS AND DISCUSSION

### 3.1 High-Level MOC-SC Process Map

The high-level MOC-SCPM presented in Fig. 2 was developed based on the literature review and collaborative meetings with staff at a large-scale prefabricator in Alberta, Canada. The process map depicts a DBB PDM with separate designers, prefabricators, and prime contractors linked through contractual relationships. In this regard, it highlights the MOC-SC relationships based on contractual obligations (e.g., between the prime contractor and the client), as well as the associated flows of material and information between stakeholders. Therefore, the MOC-SCPM is the basis for further analysis under different PDMs, as illustrated in Section 3.2. It should also be noted that the process map has been developed from the perspective of the prefabricator. Direct relationships between stakeholders (shown in red) are established through contractual agreements. Supply chains involve the flow of materials and information between stakeholders, and in the MOC-SC, there are three primary material flows (shown in blue): (i) raw materials, which flow from suppliers to the prefabricator; (ii) completed panels that are transported from the factory to the construction sites; and (iii) waste materials transported to either disposal sites or recycling centers after the demolition of the building. Material flows in the MOC-SC are primarily unidirectional and associated with a contractual obligation (e.g., the prefabricator delivers panels to the prime contractor as part of its obligations). Moreover, material flows originate from upstream sources (i.e., material producers and suppliers) and flow towards the factory, where the panel production occurs, and onto the construction sites. Alternatively, the information flows in the MOC-SC (highlighted in dashed black lines) are bidirectional, such as the exchange of reports, expected delivery dates, designs, and inventory information between the designer, contractor, and client. Information flows ensure effective coordination amongst the stakeholders in the MOC-SC. Furthermore, financial flows (shown in green) are considered part of the information flows and originate from the client, flowing to the designer and prime contractor. Additionally, the prime contractor makes payments to the prefabricator, who in turn pays its raw material suppliers. As such, it can be observed that financial flows accompany all contractual relationships in the MOC-SC.

The MOC-SC can be divided into four phases: (i) design and planning; (ii) manufacturing; (iii) construction; and (iv) use and end-of-life phase. The design and planning phase of the MOC-SC is the initial phase, as all operations within the MOC-SC are initiated in response to the client's demand. Accordingly, after identifying its needs (e.g., a new housing project, office space, etc.), the client engages the services of a designer to prepare building designs that meet its requirements and supervise the eventual construction works. This represents the first contractual relationship between the designer and the client in the MOC-

SC. After the designs are completed, the client will engage the services of a prime contractor, who will be responsible for the construction work, representing a second contractual arrangement. During the manufacturing phase, the prime contractor contracts with a prefabricator to prepare the panels in accordance with the designer's specifications. This is the third contractual arrangement in the MOC-SC under which the prefabrication is subcontracted to the prefabricator. Accordingly, there is no contractual relationship between the client and the prefabricator, and the prime contractor oversees the prefabricator's operations.

The prime contractor and the construction sites transfer the panel designs and delivery requirements to the prefabricator, particularly the expected early delivery dates. The prefabricators serve multiple clients and must coordinate the material and information flows to ensure the panels are produced and delivered as per the delivery schedules. The prefabricator must also coordinate both upstream operations (i.e., raw material delivery and receipt of designs) and downstream operations (i.e., panel delivery and onsite operations) throughout the MOC-SC in addition to producing the panels. Therefore, the early start dates and designs submitted by the prime contractors serve as a critical planning input to (i) prepare material quantity takeoffs and transfer them to its raw material suppliers; and (ii) develop the production and transportation schedules. The timely delivery of raw materials is crucial to the success of the manufacturing process; therefore, the prefabricator must effectively manage its relationships with material producers and suppliers with whom it has contractual relationships.

The third phase of the MOC-SC is the construction phase, which occurs in parallel with the manufacturing phase. The prime contractor must conduct site preparation and build the building foundations, which ensures the site is ready to receive and assemble the panels. Thus, after the panels are produced, they are transferred to the construction sites using either the prefabricator's logistics resources (i.e., truck and trailer) or external logistics service providers. The prefabricator must effectively coordinate with the logistics service providers and the prime contractor to ensure the timely delivery of the panels. Once the panels are delivered to the construction sites, the prime contractor is responsible for the assembly according to the designs. Following the completion of the construction activities, the prime contractor returns the completed project to the client, and the use phase of the building commences. Upon completion of the use phase, the client will engage the services of a demolition contractor to demolish the building and handle the waste material. Waste materials can be classified into (i) reusable materials, which are refurbished and reused in new construction; (ii) recyclable materials, which are processed at recycling facilities and reintroduced into the supply chain as raw material by the material producers; and (iii) waste material that is disposed at dump sites.

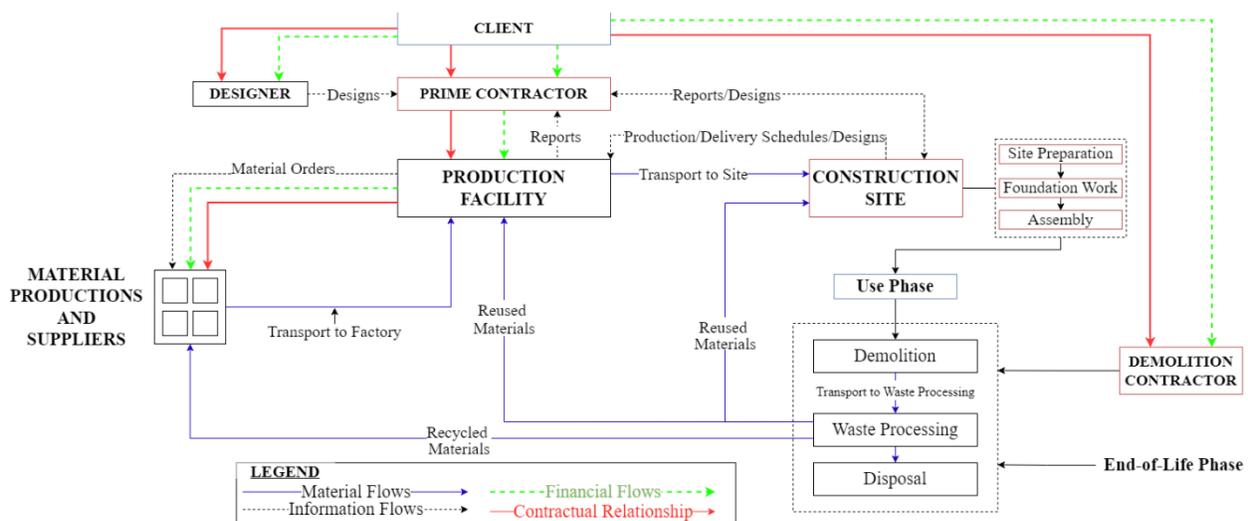


Figure 2: High-Level MOC-SC Process Map

### 3.2 Stakeholder Analysis

Following the development of the MOC-SCPM, a stakeholder analysis is undertaken using the stakeholder salience model. As highlighted in the MOC-SCPM, the prefabricator is a critical node in the MOC-SC, coordinating operations throughout the SC. Therefore, it is crucial to stress that the stakeholder analysis is undertaken from the perspective of the prefabricator. At this stage, the stakeholder relationships under the DBB PDM are discussed first because the PDM represents separate relationships between all stakeholders. Accordingly, the stakeholder analysis under DB PDMs builds upon the insights from the DBB PDM scenario and considers the effects of merging stakeholders on their relationships, communication, and influence.

#### 3.2.1 DBB PDM

The first scenario in Table 1 considers stakeholder relationships in a DBB-based PDM with separate entities for design, prefabrication, and construction in the MOC-SC. For the prefabricator, the prime contractors represent a definitive stakeholder with a direct relationship based on the contractual obligations that the prefabricator has made with them. Moreover, the factory's operations are directly influenced by the demands of the prime contractor; thus, the contractor is granted power, legitimacy, and urgency based on its contractual relationships. Accordingly, the prefabricator must actively manage its relationships with prime contractors. Despite the legitimacy of their relationship, raw material suppliers have minimal power over the prefabricator, creating a dependent relationship that allows the prefabricator to leverage its relative strength to ensure a smooth flow of materials to the factory. Finally, in a DBB scenario, there is no contractual relationship between the designer/client and the prefabricator. Despite their urgency, the client and designer have limited influence over the prefabricator and cannot supervise the prefabricator's activities, creating a risky relationship. They must rely on the prime contractor to oversee the prefabricator's operations. However, despite the lack of a direct relationship, the prefabricator's operations can be directly influenced by changes to the designs or specifications or any errors, which highlights the importance of this relationship. Thus, it can be shown that in a DBB PDM, the prefabricator's relationships with other stakeholders exhibit varying levels of power and legitimacy. However, even stakeholders with limited power and legitimacy can directly affect the prefabricator's operations, which increases the potential for disruptions. Alternative PDMs that create direct communication links between all stakeholders can reduce the potential for disruptions.

Table 1: Stakeholder Salience Model for DBB PDM

Stakeholder	Relationship Type	Power	Legitimacy	Urgency	Stakeholder Typology
Clients	Indirect	Medium	Low	High	Dangerous
Raw Material Suppliers	Direct	Low	Medium	Medium	Dependent
Prime Contractors	Direct	High	High	High	Definitive
Designers	Indirect	Medium	Medium	High	Dangerous

#### 3.2.2 DB With Outsourced Prefabrication

DB is an alternative PDM that integrates the designer and prime contractor into a single entity. Moreover, depending on the scale of their operation, prime contractors can own in-house prefabrication facilities, vertically integrating the MOC-SC. However, the prime contractors can also outsource the fabrication of panels to a third party. The stakeholder analysis presented next considers the scenario in which the prefabrication is outsourced. As shown in Table 2, adopting DB without an in-house prefabricator results in a direct relationship between the prefabricator and the prime contractor/designer. Integrating the roles of the designer and prime contractor enables the designer to monitor and influence the prefabricator's operations directly. Accordingly, the designer's position is strengthened with high power, legitimacy, and urgency compared to the DBB PDM. Furthermore, combining the designer and prime contractor into a single entity reduces the overall number of communication channels, positively impacting change management and quality control in the MOC-SC. However, in this PDM, the client remains a dangerous but

indirect stakeholder as it must still rely on the prime contractor/design team to communicate and supervise factor operations, thus creating an extra communication layer.

Table 2: Stakeholder Saliency Model for DB PDM Without In-House Prefabrication

	Relationship Type	Power	Legitimacy	Urgency	Stakeholder Typology
Clients	Indirect	Medium	Low	High	Dangerous
Raw Material Suppliers	Direct	Low	Medium	Medium	Dependent
Prime Contractors & Designers	Direct	High	High	High	Definitive

### 3.2.3 DB with In-house Prefabrication

Finally, a DB PDM with an in-house prefabricator is considered, leading to the vertical integration of the MOC-SC. In this scenario, the prime contractor assumes responsibility for the MOC-SC directly due to its ownership of the prefabrication facility. As such, the stakeholder analysis is undertaken from the perspective of the combined entity that designs, produces, transports, and assembles the panels. As shown in Table 3, integrating the prime contractor, designer, and prefabricator into a single entity creates direct communication links between all stakeholders in the MOC-SC. Thus, the direct contractual relationship between the client and the prefabricator establishes a definitive relationship, enabling the client to monitor and directly influence factory operations. However, in line with the previous scenarios, the raw material suppliers remain a dependent stakeholder due to their minimal power.

Table 3: Stakeholder Saliency Model for DB PDM With In-house Prefabrication

Stakeholder	Relationship Type	Power	Legitimacy	Urgency	Stakeholder Typology
Clients	Direct	High	High	High	Definitive
Raw Material Suppliers	Direct	Low	Medium	Medium	Dependent
Prefabricator/Prime Contractor & Designers	Direct	High	High	High	Definitive

### 3.3 Discussion of Results

Adopting different PDMs has significant implications for overall relationships and communication strategies in the MOC-SC, as summarized in Fig. 3, which presents the relationships from the perspective of the prefabricator. Accordingly, adopting DB reduces the number of contractual links (shown in black) and the number of communications links (shown in red). Thus, adopting DB, especially with in-house prefabrication, improves information flow by reducing communication links and creating definitive relationships between all stakeholders except for raw material suppliers. For example, in a DBB PDM, if the client requests changes to the design, the designer must make the necessary changes and communicate them to the prime contractor. The prime contractor must then transfer the updated designs to the prefabricator. In contrast, with a DB PDM with in-house prefabrication, the client's changes are directly transmitted from the in-house design team to the prefabricator, which communicates the changes to the builders. This illustrates how reducing communication channels reduces the time and effort necessary to transmit information between stakeholders, resulting in increased efficiency.

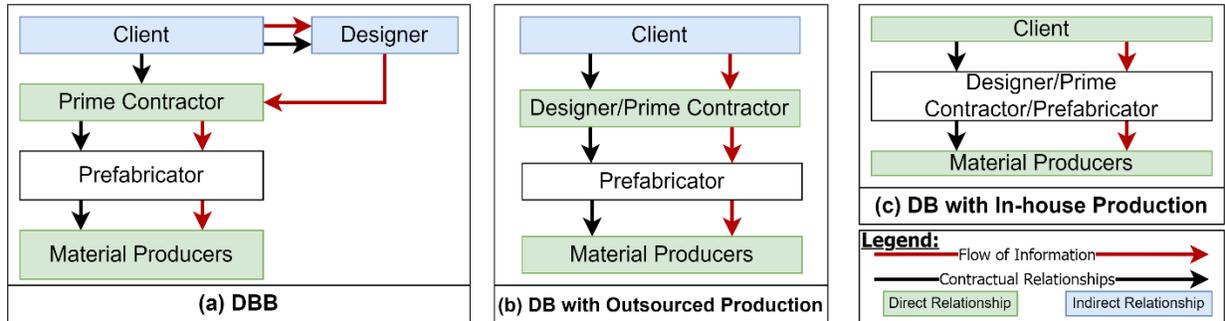


Figure 3: Summary of Contractual Relationships and Information Flows

### 3.3.1 Research Limitations

The process map and stakeholder analysis presented in this paper are key starting points for MOC-SCM improvement. However, further investigation is needed to address research shortcomings. First, the MOC-SCPM and subsequent analysis of different PDMs are based on data collected from a single industry partner. Therefore, the proposed approach should be validated using data from additional sources, such as firms outside the Canadian market, to ensure it accurately represents panelized MOC-SC. Additionally, the MOC-SCPM is based on a panelized MOC-SC, and its applicability in alternative MOC methodologies, such as modular and precast MOC, should be investigated. Second, researchers can extend the methodology demonstrated in this paper by: (i) constructing an analysis of the impact of other PDMs such as IPD, Construction Management, and Construction Management at Risk; (ii) undertaking the stakeholder analysis using alternative stakeholder analysis techniques; (iii) developing stakeholder engagement strategies based on the results of the stakeholder analysis; and (iv) undertaking a similar analysis from the client's perspective.

## 4. CONCLUSIONS

Despite the potential benefits of MOC, its adoption remains limited due to hesitancy by industry practitioners. The hesitancy is partly driven by a lack of understanding of the MOC-SC's structure, stakeholders, and their relationships. Moreover, a key element of MOC-SCM is effective stakeholder management, but it has not received sufficient attention from researchers. This paper addressed these shortcomings by (i) developing an MOC-SCPM for a panelized MOC-SC that visualizes the key stakeholders and their relationships, and (ii) undertaking a stakeholder analysis using a salience model under three PDMs. The results of the stakeholder analysis revealed that the choice of PDM affects the communication channels and relationships in the MOC-SC, which in turn influences the efficiency of the MOC and its ability to meet the client's needs. The analysis found that DB with in-house prefabrication vertically integrates the MOC-SC, which results in direct communication channels and supervision of MOC-SC operations. Therefore, it is recommended that a vertically integrated MOC-SC, utilizing a DB PDM with in-house prefabrication, be adopted to increase the operational efficiency of the MOC-SC. However, while the vertical integration of the MOC-SC improves its efficiency, additional managerial effort is needed to coordinate the activities throughout the MOC-SC. Therefore, the degree to which the MOC-SC is vertically integrated should be balanced with the costs associated with increased managerial effort.

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