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Project Delivery Strategies for Adaptable Buildings: A comparative case study of two Dutch modular projects

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Abstract

In the face of climate urgency and rapid urban change, buildings must become more adaptable to extend their lifespan and reduce environmental impact. Yet, adaptability is often undermined by project delivery methods (PDMs) that are not well equipped to manage, plan, and deliver long-term lifecycle requirements, even though in terms of design, it is technically possible, particularly in modular construction. This research examines how PDMs can be restructured to enhance building adaptability. Using a comparative case study of two Dutch modular projects (a campus office expansion and a relocatable housing development) this study applies a Design Structure Matrix (DSM) and RACI framework to analyze the alignment of technical design, process workflows, and stakeholder roles. The analysis reveals a critical socio-technical misalignment: while modular systems provided technical capability, adaptability was consistently compromised by process-related barriers, including delayed technical coordination, missing lifecycle documentation, and unclear post-use accountability. Findings are synthesized into a structured delivery framework that integrates disassembly planning, modular reuse logic, and iterative feedback loops from the project's outset. This research provides a practical approach for project managers to proactively structure delivery for adaptability. It contributes to the field by demonstrating that successful adaptability is not merely a technical feature but an output of a holistic alignment of the project delivery system.

Keywords: Project delivery method, adaptable buildings, modular construction, design structure matrix, lifecycle planning

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Introduction

According to the United Nations Environment Programme, (United Nations Environment Programme, 2025), building and construction sector accounted for 34% of total global CO_2 emissions, making it the highest-emitting sector globally. Therefore, it is important to find ways to reduce buildings' carbon footprint. Previous research has shown that sustainability can be achieved by the choice of processes and materials, especially renewable materials such as wood and its composites (Mlote & Budig, 2022). However, apart from the selection of materials, the longevity and maintainability of buildings are also crucial factors to consider (Mlote et al., 2024).

One way to overcome these problems is to ensure that buildings can accommodate the changing demands of society, community resistance, the need for new infrastructure, the pressure of climate change, and functional obsolescence (Ninan et al., 2024), thereby extending their lifespan and reducing the need for demolition and new construction. This will be of great help because cities are growing rapidly, driven by economic, social, and environmental challenges (Manewa et al., 2016), which leads to high demand for a variety of building types and may require frequent reconstruction. Without adaptability, buildings will be left empty, demolished or rebuilt with new structures to accommodate growing demands and changing needs. Furthermore, if this occurs frequently, it will lead to a scarcity of resources and contribute to environmental degradation.

One of the key principles of sustainability is that development today should not sacrifice the capability of future generations to fulfill their own need (World Commission on Environment and Development, 1987). However, most buildings are traditionally designed as static and permanent structures, which limits their capability to respond to changing demands (Askar et al., 2021). As a result, these outdated structures cause high building vacancy rates (building redundancy), which leads to substantial refurbishment or premature demolition. Both of these imply high costs and create large amounts of waste, which are only reused partially or downcycled into lower-quality products (Manewa et al., 2016).

Specifically in the Netherlands, due to the housing shortage on temporarily available land, which is often subject to future zoning changes, national planning authorities have documented that flexible and relocatable housing models (*flexwonen*) are increasingly being deployed to address this issue (Groot, 2022). This trend represents a policy-driven response to address the urban land issue in densely populated areas. They need fast-construction housing, with permanent quality, but have the capability to modify in the future when the permit ends.

These changes often happen in the whole life cycle of a building without being intended when they were initially designed and constructed (Pinder et al., 2013). One of the main problems is that buildings are made in such a way that many changes or alterations can cause the demolition of building parts or even whole structures (Durmisevic & Brouwer, 2022). Therefore, it is important to implement building adaptability to prolong their lifespan and reduce waste and resource consumption, which also aligns with environmental, social, and economic sustainability goals (Gosling et al., 2013).

Building adaptability is the capability of the building to accommodate change over, even in the use phase, without doing major deconstruction, which also supports resource efficiency, sustainability, and long-term value (Geraedts & van der Voordt, 2014). However, delivering an adaptable building is not just a matter of material selection or design; it is also influenced by how construction projects are managed, planned, and delivered.

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The existing Project Delivery Method (PDM) framework is often siloed from life-cycle and actor involvement programming. In the design, construction, and maintenance phases, they focus solely on the immediate function of a specific part of the project. The project delivery selection does not properly consider that the cycles are interconnected (Ahmed & El-Sayegh, 2020). They also do not consider how unmanaged activity interdependence may hinder future building modifications. Moreover, a lack of early stakeholder involvement will limit the potential of building adaptability to maintain or add its value (Pinder et al., 2013). This gap between adaptability and PDM consideration presents a critical opportunity that remains unaddressed.

However, commonly used project management tools, such as PERT, Gantt charts, or the Critical Path Method (CPM), are limited in addressing interdependence and feedback loops (Giancarlo, 2004). These tools primarily model sequential or parallel activities, but not enough to present the dynamic interaction that affects adaptability. To bridge this gap, this research explores a different approach to analyzing project activity interdependence and actor coordination.

The objective of this research is to develop a structured framework for enhancing PDM that supports building adaptability. By utilizing the DSM and RACI matrix. To address this socio-technical challenge, a multi-faceted analytical approach is required. The Design Structure Matrix (DSM) was selected for its proven ability to map and analyze process workflows and information dependencies, making it ideal for visualizing the process system of project delivery (Giancarlo, 2004). To analyze the social system, the RACI matrix was chosen to clarify stakeholder roles and responsibilities, which is critical for understanding coordination and accountability (Lee et al., 2021). By combining these two methods, this research can provide a holistic analysis of the alignment between project activities and the actors responsible for them.

1. Literature Review

1.1 Building Adaptability: Definitions and Classifications

Being adaptable is defined as the capability of being adapted and suitable to or fit with specific situations (Askar et al., 2021). In system engineering, adaptability can be defined as the ability of a system to change to follow changes in its environment (Haberfellner & De Weck, 2005). A primary objective of adaptability is the ability to prolong the proper lifetime of a building (Addis & Schouten, 2004). Most buildings become abandoned before their technical life comes to an end, because there are inevitable mismatches created between the supply of space and the demand for it (Leaman et al., 1998).

The general understanding of adaptability comes from a shift in the conventional perception of buildings as static, finished objects to dynamic systems consisting of objects and processes of construction, change, deconstruction, and reconstruction (Askar et al., 2021). Furthermore, due to the nature of varying terms describing adaptability, summaries of the similarities and differences among the three most recently and commonly used terms to define the adaptability of buildings, that is "Adaptability," "Flexibility," and "Design for Disassembly (DfD)," can be seen in Table 1.

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Table 1 Similarities and differences between adaptability, flexibility and DfD (Mlote et al., 2024)

Similarities	Differences			
	Factor	**Adaptable buildings**	**Flexible buildings**	**Design for disassembly (DfD)**
1. All address the evolving needs (allow reconfiguration and repurposing to an extent) 2. All seek to minimize waste - Reduce the need for new construction -Environmentally friendly 3. All aim to maximize the potential use of space	Scope	Long-term view	Short-term changes	End-of-life reuse/recycle
	Cost	Requires upfront investment and planning	Upfront cost-effective but may need frequent maintenance	Upfront investment and planning + Higher labor and time
	Scale	Large-scale projects: on the building scale	Small-scale projects: down to room/floor plan scale	Any/Both due to focus: mostly down to component or connections scale (per installation)
	Objective	Meeting major changing occupancy needs by extending the value of the structure in the long run	Easy and quick spatial reconfiguration when required	Reducing waste by reusing building materials and components

1.2 Project Delivery for Adaptable Buildings

The Project Delivery Method (PDM) is essential for all individuals involved in project management, regardless of the industry. Moreover, the PDMs discussed in this study apply to the construction industry. A PDM describes the relationship and working methods among project participants in the process of transforming the owner's goal into completed facilities (Chen et al., 2022). It affects construction performance, such as schedule, cost, quality, and efficiency (Al Khalil, 2002). The PDM can be viewed as both a contractual structure and a compensation arrangement that owners utilize to obtain completed infrastructures that meet their needs (Mafakheri et al., 2007)

To analyze and compare how different PDMs support adaptability, a standardized list of project activities is required. This list functions as a foundation for the DSM and RACI analyses in this research. Traditional construction project management neglects activities that are critical for long- term adaptation, such as Design for Demolition (DfD), post-occupancy planning, and life-cycle documentation. Therefore, a specific activity was developed to ensure these critical elements are explicitly included in the analysis.

The 15 core activities used in this study, as can be seen in Table 2, were synthesized from a comprehensive review of academic literature on project delivery, modular construction, and building adaptability. Key sources include frameworks from PDM selection (Zhong et al., 2022), DfD principles (Ostapska et al., 2024), and constructability management (Khan, 2016). The activities were then clustered into key project phase (Planning, Design, Procurement, etc.) to provide a structured and comprehensive view of the project lifecycle. The validity of this activity list was established through multiple academic sources and was confirmed during the case study analysis.

Table 2 list of PDM Activities related to building adaptability

Activity Phase	Activity Clustered	No	Activity	Referenced In
Planning	Establish project intent and	1a	Client needs identification	MDPI Framework

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Activity Phase	Activity Clustered	No	Activity	Referenced In
	adaptability goals	1b	Feasibility studies	(2022)
		1c	Discussion on recycling goals	Khan (2016)
		1d	Review and implementation of past lessons learned	
	Select delivery method and define responsibilities	2a	Composing project delivery strategy	PDM Evolution (2021)
		2b	Define client-contractor-architect roles	
		2c	Selecting architect and contractor	Khan (2016)
	Appoint key design and execution stakeholders	3a	Conducting surveys	
		3b	Working out Construction Schedule	
		3c	Laying out site efficiently	
Design	Design for disassembly and lifecycle reuse (DfD)	4a	Design planning & lifecycle integration	Ostapska et al. (2024)
		4b	Disassembly-oriented detailing	
		4c	Modular detailing & system rationalization	
		4d	Material strategy & circularity	
	Develop spatial-modular design	5a	Foundational site & design requirement analysis	Khan (2016)
		5b	Design development & technical detailing	
		5c	Circularity, materials, and long-term use planning	Ostapska et al. (2024)
	Structural Design for Adaptability	6a	Design structural parts (column, beam, foundation, etc.)	
		6b	Design lightweight structure	
		6c	Over-dimension elements	
	Design building services (MEP)	7a	Design building services (MEP)	Khan (2016)
	Coordinate technical layout and system	8a	Review of design by other team members	
		8b	Clash detection (using BIM)	
		8c	System routing	
	Conduct constructability review and iteration planning	9a	Design coordination between stakeholders	BIM Workflow Mapping (2015)
		9b	Constructability review (via DSM or BIM)	DSM-Constructability (2016)
		9c	prepare deconstruction plan	Ostapska et al. (2024)
		9d	Prepare a documentation plan for adaptable purposes	
Procurement	Procure systems, materials, and subcontractors	10a	Select supplier/vendors	PDM Performance Comparison (2019)
		10b	Procure materials or services	Giancarlo (2004)
Fabrication	Fabricate modules and prepare off-site logistics	11a	Module fabrication	Giancarlo (2004)
		11b	Off-site material integration	
		11c	Logistics scheduling	
Execution	Prepare site and foundations	12a	Pre-execution setup & planning	Giancarlo (2004)
		12b	Site preparation & construction process enablement	
		12c	Monitoring, coordination & site efficiency	
	Deliver and install modules on site	13a	Core construction execution & sequencing	DB vs DBB Analysis (2017)
		13b	Monitoring, safety, and quality management	Khan (2016)
		13c	Innovation, adaptation, and knowledge retention	
	Test systems and perform commissioning	14	Systems testing and commissioning	DSM Planning Projects (2016)
		15a	Handover of documentation and occupancy	PDM Evolution (2021)

Activity Phase	Activity Clustered	No	Activity	Referenced In
Handover & Post-Occupancy	Handover documentation and plan post-occupancy support		certification	
		15b	Facility management setup and operation	PDM Evolution (2021)

1.3 Identified research gaps

Determine the appropriate project delivery method (PDM) is a crucial managerial decision that significantly influences the success of construction projects (Ahmed & El-Sayegh, 2020). The PDM defines roles on the procurement route, sequence of project phases, and sets a framework for organization, roles, and responsibilities, stating that the choice of PDM is often made ad hoc, with insight into how the decision will influence the final project risk allocation (Engebø et al., 2020). This argument is strengthened by, Lædre et al., (Lædre et al., 2006), maintaining that clients continue to select the same method based on previous projects or habit, without considering what suits each project. Although a wide range of PDMs exists, stakeholders often lack a structured PDM to match the delivery method to the project's adaptability needs.

2. Methodology

2.1 Research Design

This research aims to understand how project delivery models can be adapted to enhance the workflow of adaptable buildings. Exploratory research is the most suitable approach to gaining this understanding since this case has not previously been studied in depth, as it can develop initial ideas, identify problems, and provide direction for further research (Swaraj, 2019).

To gain meaningful insights from the cases, it is necessary to consider the holistic levels, rather than decomposing them into separate variables (Yin & Campbell, 2018). Instead, cross-case synthesis should resemble what has been called a 'case-base' rather than a 'variable-base' approach (Byrne, 2009). A synthesis of findings across multiple cases will generate recommendations on how project delivery models can be adapted to support adaptable buildings.

To integrate the DSM and RACI matrix into research design, the research design was made based on Yin & Campbell (2018). The model is shown in Figure 1.

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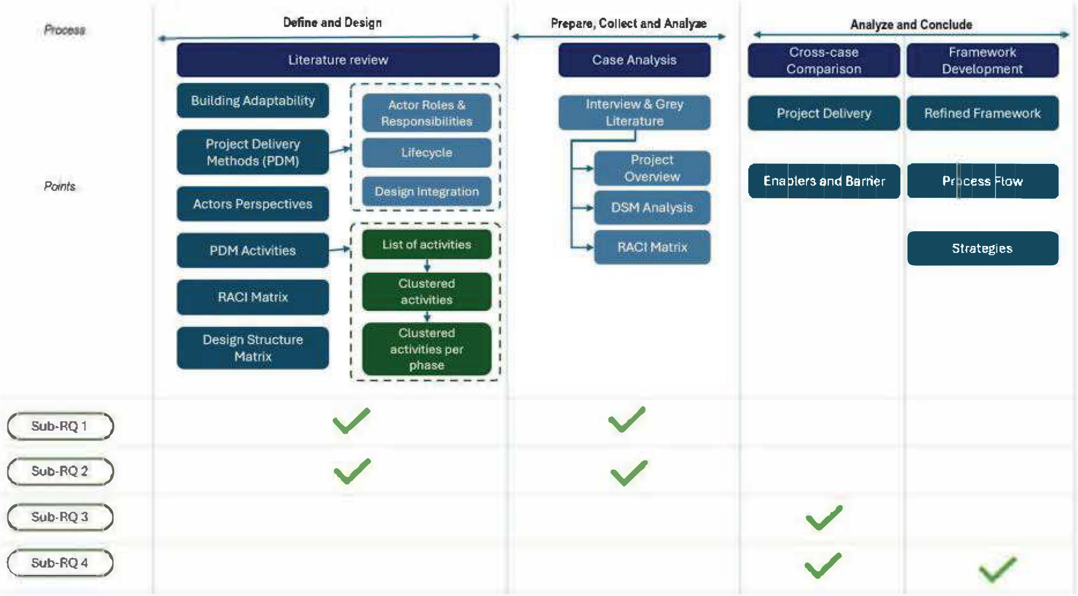

Figure 1 Research Design Framework

This research uses a comparative case study of two Dutch modular projects, which will be referred to as Project A (a campus office expansion) and Project B (a relocatable social housing development) to ensure confidentiality. Case A (the campus office expansion) represents an owner-driven need for flexible and on-site growth. Case B (the relocatable housing development) represents a market- and policy-driven response to pressures on urban land use and the need for temporary housing solutions in densified areas (Groot, 2022). This temporary 15-year permit created a hard deadline for relocation, so it makes lifecycle planning a critical step to take before execution. Comparing these two cases allows for an analysis of how different motivations (internal flexibility versus external policy) shape project delivery strategies for adaptability. The timeline of the project can be seen in Figure 2.

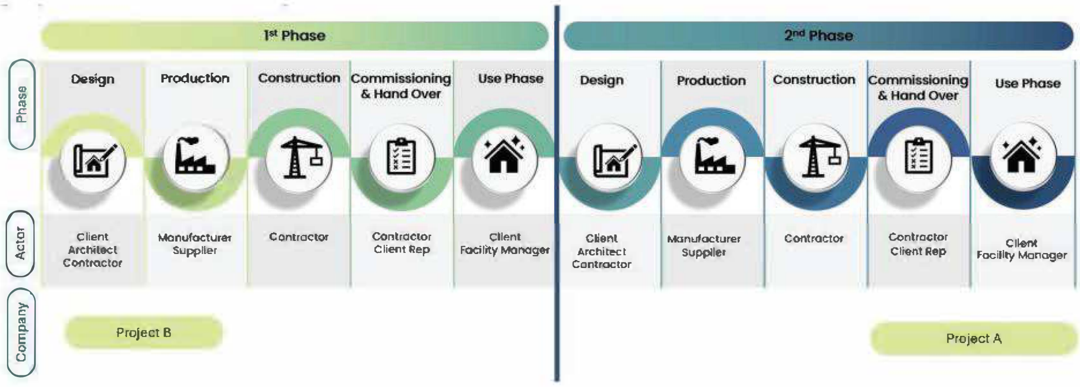

Figure 2 Timeline of project lifecycle: Project A (Campus Lab Expansion) and Project B (Relocatable Housing)

2.2 Definition of Key Actor Roles

To ensure the clarity and consistency throughout the case study analysis, this section defines the key actor roles referred to in this research. The following definition will be used to describe the primary stakeholders and their function within the project delivery process. Client refers to the project's commissioning party, owner, and/or primary end-user. Main Contractor is a single firm that holds the primary contractual responsibility for delivering the entire project, from design coordination through to final execution. The architect or designer is the entity responsible for the building's conceptual, spatial, and aesthetic design. The manufacturer (Modular Manufacturer) is a specialized organization responsible for the off-site, factory-based production of the building's modular components. A specialist contractor is a subcontractor hired for a specific, highly technical scope of work that requires specialized expertise, for example, an MEP contractor, HVAC, or façade.

2.3 Data collection

This research used two primary data collection methods: semi-structured interviews with the project stakeholders and analysis of project documentation. To explore the relationship between project delivery models and building adaptability in practice, semi-structured interviews will be conducted with key stakeholders involved in the case studies, as shown in Table 3.

Table 3 Correspondence Details

Project	Participant number	Stakeholder	Role
Project A	1	Client	Project Coordinator
	2	Client	Supervisor
	3	Client	Program Manager
	4	Main Contractor	Lead Engineer
	5	Main Contractor	Technical Designer
	6	Sub-contractor MEP	Installation Coordinator
	7	Contractor	Project Manager
	8	Contractor	Site Engineer
	9	Contractor	Site Engineer
	10	Client	Location Manager
Project B	11	Client	Junior Project Manager
	12	Contractor	Project Engineer
	13	Contractor	BIM Coordinator
	14	Contractor	Project Manager
	15	Architecture	Architecture

2.4 DSM and RACI as analytical tools in construction

A clear framework to map stakeholders' roles and responsibilities is essential for effectively managing the complex interactions between them. A key tool for this purpose is the responsible assignment matrix, most commonly known as the RACI matrix. The RACI matrix is a straightforward yet powerful tool used in project management to define and communicate the roles and responsibilities of various stakeholders for any given task or activity within a project (Project Management Institute, 2017).

RACI is an acronym that defines four key levels of involvement. Responsible (R): The person or people who do the work to complete the task. They are the "doers" who are responsible for taking

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action and implementing it. Accountable (A): The individual who is ultimately answerable for the correct and thorough completion of the task. It is a critical best practice that for any given task, there is only one Accountable person to avoid confusion over ownership. Consulted (C): Stakeholders who are sought out for their input and expertise. This typically involves two-way communication, where their opinions and advice are considered before a decision or action is taken. Informed (I): Individuals who are kept up-to-date on progress or decisions, but do not provide direct input. This is a one-way flow of communication to ensure these stakeholders are aware of project developments.

A Design Structure Matrix (DSM) is defined as a matrix representation of the connections among activities. A DSM provides an idea about various activities of any process that are connected, and what information is needed to start an activity, what activity will be followed by any previous activity, and does task sequencing and iterations (Yassine, 2004). Moreover, Khan (2016) explains that DSM is a representation and analysis tool for system modelling. A DSM displays the relationships between system components in a visual, compact, and analytically advantageous format.

In the context of delivering adaptable buildings, especially where early and continuous collaboration between stakeholders is critical, the RACI matrix serves as a powerful complementary tool to the DSM. While the DSM identifies the technical dependency and information flow between project activities, the RACI matrix clarifies who is responsible for executing those activities and managing the information exchanges.

2.5 Socio-technical Framework in Project Management

To understand the persistent misalignment between technical capability and delivery execution in complex projects, it is useful to adopt a socio-technical perspective. Leavitt's Diamond is a seminal socio-technical framework that provides a lens for this analysis (Leavitt, 1965). The model posits that any organization or project is a system of four interdependent variables: Technology, Tasks, Structure, and People (Actors).

3. Results and Discussion

3.1 Case A: Campus Lab Office Expansion Project

Project A, as can be seen in Figure 3, is located on the TU Delft campus, a living lab for sustainable innovation. In 2017, the Client constructed its original Office Lab 1.0, a modular timber building using CNC-milled Kerto wood modules developed by TU Delft spin-off. In 2024, Project A initiated the expansion of Office Lab 2.0, adding 14 horizontally arranged modules using the same system.

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Figure 3 Documentation of Project A

The ambition of Project A is to build an adaptable building was planned from the beginning of the project. However, there is no specific pathway that they follow to control the expansion. The activity list from the previous chapter is used to map the specific activities that the project should do. The organizational chart was pictured in Figure 4.

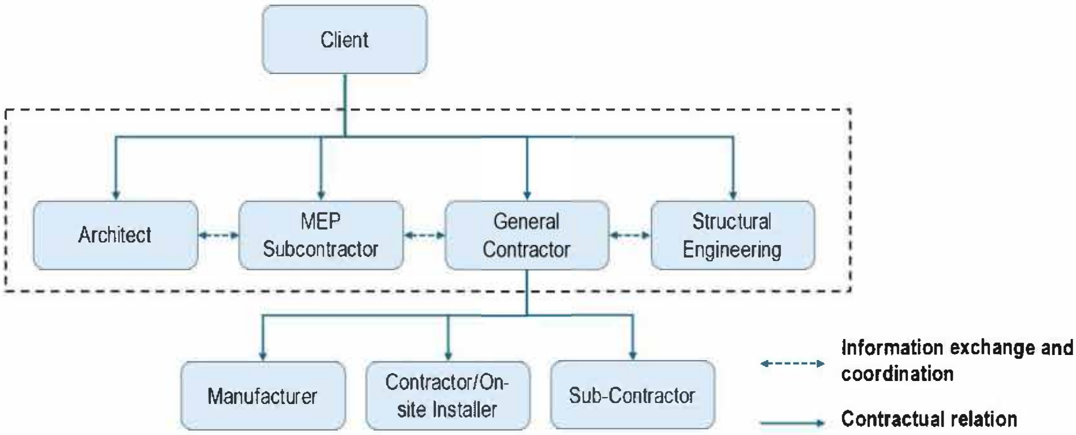

Figure 4 Organizational Chart of Project A

The project's delivery was managed through Design-Bid-Build contracts, where the Client coordinated the design, and the Contractor just executed the design. However, since the modular principle was used in this project, the modular contractor needs to share the limitations of modular with the architect before they start designing. Furthermore, the Modular Contractor or General Contractor runs the project by coordinating the manufacturer and the on-site contractor.

Table 4 show the RACI matrix for every activity that every stakeholder is doing based on the interview and document analysis. The actor-role mapping reveals that adaptability-related outcomes in Project A were not limited by technical capability, but rather by the lack of clearly defined assigned responsibilities across the project lifecycle. This absence of a formal line of collaboration, combined with the late engagement of the technical actor, resulted in project delivery that was able to finish short-term goals (Office Lab 1.0) but underperformed on the adaptability project (Office 2.0).

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Table 4 Activity Analysis of Project A

No.	Activity Name	Execution Status	RACI			
			Client	Contractor	Specialized Contractor	Architect
1	Establish project intent and adaptability goals	Modified	R	C	I	I
2	Select the delivery method and define responsibilities	Informal	R	C	I	C
3	Appoint key design and execution stakeholders	Informal	R	C	I	C
4	Develop spatial layout and modular configuration	Fully executed	C	R	I	R
5	Plan the structural system and floor/foundation strategy	Partially addressed	C	R	I	C
6	Design building services (MEP)	Modified	I	C	R	C
7	Coordinate layout and modular constraints	Iterated	I	C	R	C
8	Integrate disassembly and reuse requirements (DfD)	Lacking documentation	A	C	I	I
9	Conduct constructability and feasibility reviews	Minimal	A	I	I	C
10	Procure systems, materials, and subcontractors	Informal procurement	A	C	I	I
11	Fabricate modules and prepare off-site logistics	Fully executed	C	R	I	I
12	Prepare site and foundations	Fully executed	C	R	I	I
13	Deliver and install modules on site	On-site adaptations	C	R	I	C
14	Test systems and perform commissioning	Partial	I	C	R	C
15	Handover documentation and plan post-occupancy support	Missing	A	C	R	C

To understand how coordination and task sequencing influenced adaptability, a DSM was constructed in Table 5. This matrix captures the observed dependencies between activities based on interview data and document analysis.

Table 5 DSM Matrix of Project A

No.	Activity Name		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Establish project intent and adaptability goals	1	■	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Select delivery method and define responsibilities	2	0	■	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Appoint key design and execution stakeholders	3	0	0	■	0	0	0	0	0	0	0	0	0	0	0	0
4	Integrate disassembly and reuse requirements (DfD)	4	1	0	1	■	0	0	0	0	0	0	0	0	0	0	0
5	Develop spatial layout and modular configuration	5	0	0	0	0	■	0	0	0	0	0	0	0	0	0	0
6	Structural design for adaptability	6	0	0	0	0	0	■	0	0	0	0	0	0	0	0	0
7	Design building services (MEP)	7	0	0	0	1	1	0	■	0	0	0	0	0	0	0	0
8	Coordinate technical layout and system	8	0	0	0	0	0	1	1	■	0	0	0	0	0	0	0
9	Conduct constructability review and iteration planning	9	0	0	0	0	0	0	0	0	■	0	0	0	0	0	0
10	Procure systems, materials, and subcontractors	10	0	0	0	0	1	0	1	0	0	■	0	0	0	0	0
11	Fabricate modules and prepare off-site logistics	11	0	0	0	0	0	0	0	0	0	0	■	0	0	0	0

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No.	Activity Name		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12	Prepare site and foundations	12	0	0	0	0	0	0	0	0	0	0	0	■	0	0	0
13	Deliver and install modules on site	13	0	0	0	0	0	0	0	0	0	0	1	0	■	0	0
14	Test systems and perform commissioning	14	0	0	0	0	0	0	1	0	0	0	0	0	1	■	0
15	Handover documentation and plan post-occupancy support	15	0	0	0	0	0	0	0	1	0	0	0	0	0	1	■

3.2 Case B: Relocatable Housing

Project B, as shown in Figure 5, is a modular housing project situated in Hilversum, the Netherlands, which was launched to address the region's need for affordable rental housing. The project is built on Diependaalselaan, a site previously used as a temporary event space and will provide approximately 379 relocatable social rental homes. The project also includes public space improvements, communal green areas, and a sustainable energy strategy using all-electric systems. Due to the permit regulation from the municipality of Hilversum, these houses are expected to be relocated elsewhere after 15 years.

Figure 5 Project B Concept drawings

The homes are built using dry-stacked modular units, which are fabricated off-site in the Manufacturer B factory and transported to the site for on-site assembly. The design fulfills the requirements of permanent housing, including acoustic and fire safety regulations, while also allowing for full disassembly and reuse. Even though the superstructure is reusable, the foundation is site-specific and not intended to be relocated.

The Client entrusted the responsibility to build Contractor B, as a Manufacturer and Contractor company, with the prior design by the Architect. Contractor B has to manage off-site manufacturing by assembling modular elements in the factory, such as stairs and MEP systems, from specialized subcontractors. The organizational chart can be seen in Figure 6.

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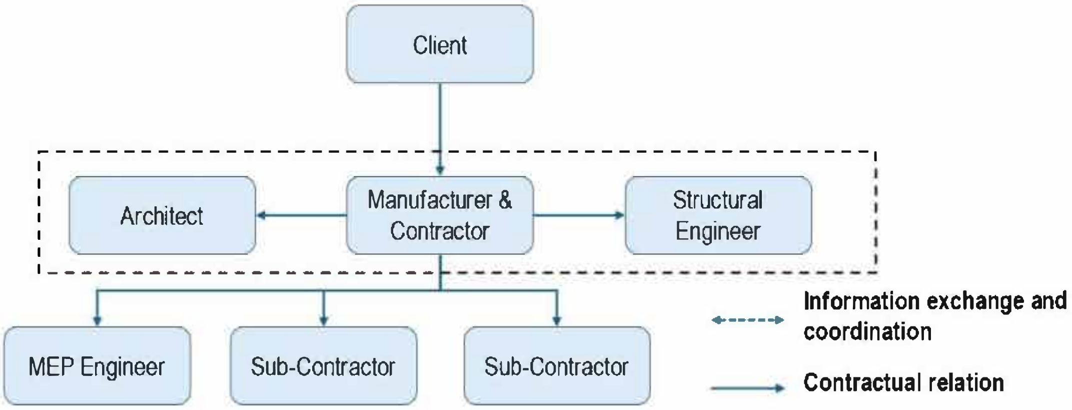

Figure 6 Project B's organizational chart

Project B was delivered using a formal Design & Build (D&B) or turnkey contract. The Client consortium held a contract with the Architect and the Main Contractor (who was also the Manufacturer) but assigned them the responsibility for coordination. Main Contractor has contractual relations with all downstream actors, for example, the MEP Engineer and subcontractors.

3.3 Cross-Case Comparison

4.3.1 Project Delivery Comparison

Interview transcripts were thematically coded by the researcher using the Gioia methodology (Gioia, 2021), starting with open coding to label first-order concepts, as can be seen in Figure 7. These are informant-centric terms or phrases that closely reflect what interviewees said, such as “The ventilation system required more space than anticipated..." was coded as ”The existing space for ventilation is not enough to accommodate the new design”. Furthermore, these first-order concepts are grouped into broader second-order themes. These are researcher-centric categories that help reveal patterns or theoretical insights, such as “Late Technical Coordination Conflicts”. Finally, these themes are synthesized into aggregate dimensions, which represent higher-level constructs that answer the research questions.

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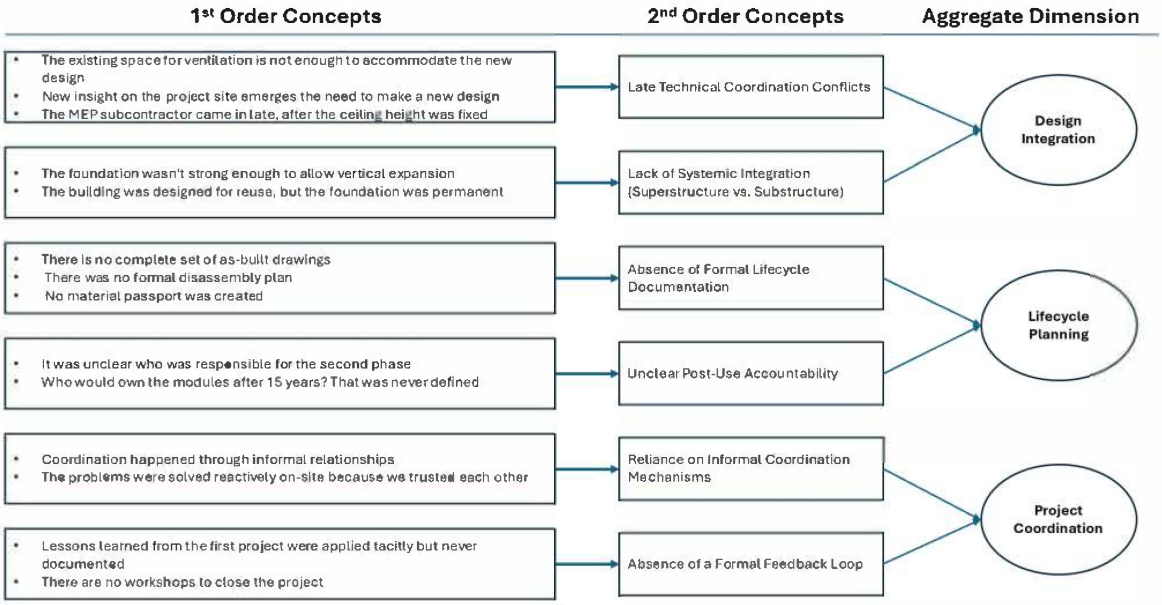

Figure 7 Bottom-up analysis with Gioia

The aggregate dimension is then used to analyse both cases in terms of integration, weaknesses, and lessons, as can be seen in Table 6.

Table 6 Cross-case comparison

Theme	Aspect	Case A - Expansion Office	Case B - Relocatable Housing	Synthesis: Key Lesson for Adaptability
Design Integration	Integration Model	Fragmented, siloed integration, late MEP involvement, linear DSM	Contractor-led D&B model, early alignment of modular constraints and design	Holistic integration is important. Avoid both horizontal silos (lack of cross-disciplinary coordination) Integration between adaptable and non-adaptable components needs to be considered. The scope of integration must encompass all critical systems that impact long-term adaptability.
	Key Weakness	No feedback loops, constructability issues led to rework, MEP routes fixed late	Foundation not designed for relocation	
	Lesson	Horizontal silos blocked systemic adaptability	Future usage of the foundation should be considered	
Lifecycle Planning	Lifecycle Approach	Informal ambition, no formal requirements or deliverables	Clear goal for relocation after 15 years influenced design decisions	Formalized lifecycle governance is imperative. Adaptability must be a contractual deliverable, with clear deliverables (e.g., as-built drawings, DfD manuals), explicit ownership for post-use planning, and a governance structure that persists beyond initial handover.
	Key Weakness	No accountability for lifecycle planning, no reuse documentation	Responsibility for relocation process left undefined; no material passport or guide	
	Lesson	Lifecycle was a hope, not a structured plan	Adaptability goal defined, but execution plan missing	

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Theme	Aspect	Case A - Expansion Office	Case B - Relocatable Housing	Synthesis: Key Lesson for Adaptability
Project Coordination	Coordination Style	Informal, trust-based coordination relying on relationships	Formal, hierarchical coordination through single contractor	Combine formal processes and clear hierarchies for contractual definition, documentation, and accountability of lifecycle goals with collaborative communication and trust for early, iterative, and cross-disciplinary dialogue. Embed collaborative routines within a formal contractual framework.
	Key Weakness	Lack of documentation and formal accountability, lost project memory	Efficient but rigid; limited early-stage input from consultants	
	Lesson	Short-term agility, but high risk for long-term adaptability	Clear roles and schedule, but constrained innovation due to centralization	

Design Integration, as a theme, examines the quality and timing of collaboration between key technical disciplines. For adaptable buildings, where the interaction between architectural form, structural systems, and MEP services is crucial for future flexibility, effective integration is paramount. A comparison of Case A and Case B reveals two distinct approaches to design integration, each with its consequences for achieving adaptability goals. Case A demonstrates a fragmented, reactive process, while Case B showcases a more integrated but still incomplete model.

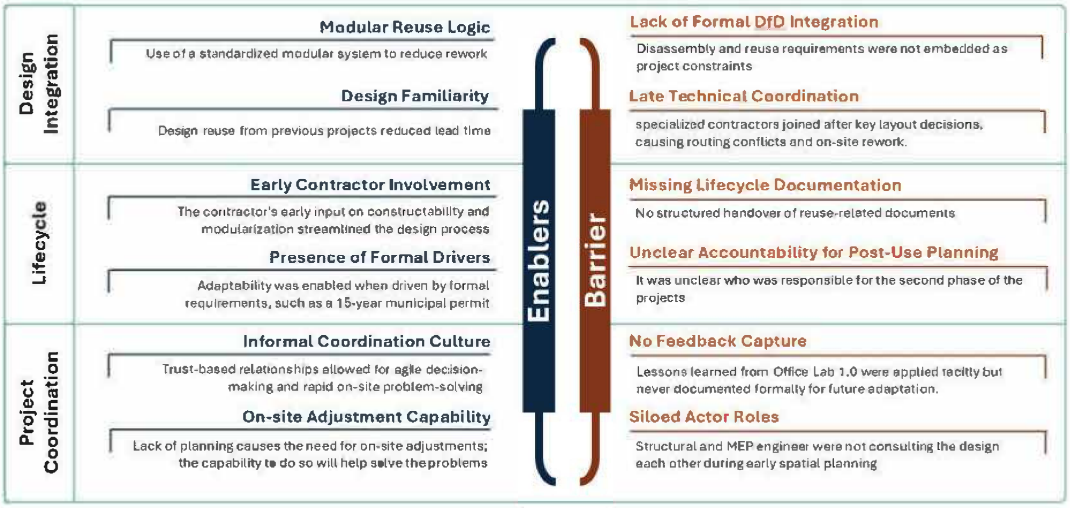
Lifecycle planning encompasses the strategies and processes to manage a building's future, from its ongoing use to its eventual disassembly, relocation, or reconfiguration. While both Case A and Case B were conceived with adaptability in mind, a comparative analysis reveals a significant gap between their lifecycle ambitions and the reality of their planning. This gap demonstrates that without formal documentation and clear accountability, even the most explicit adaptability goals can remain unrealized.

Project coordination governs the flow of information, decision-making authority, and stakeholder relationships that define a project's delivery. The comparison between Case A and Case B reveals a fundamental tension between informal, relationship-based coordination and formal, process-driven coordination. While both models have distinct advantages, they also present significant risks to achieving long-term adaptability.

An ideal model does not force a choice between agility and structure. Instead, it embeds collaborative routines (like early-stage workshops and integrated design reviews) within a formal contractual framework that holds all parties accountable for the project's long-term adaptability. This balanced approach ensures that adaptability is not only designed efficiently but is also managed robustly throughout the building's entire lifecycle.

4.3.2 Enablers and Barriers

Although modular construction offers the ability to be modified, in terms of project delivery, it still requires specific enablers to ensure the entire process runs smoothly. Conversely, mismanagement of project delivery will become a barrier to efficiently modifying the building. Insight into how the enablers and barriers affect the adaptability process can be seen in Figure 8.



Use of a standardized modular system to reduce rework

Design reuse from previous projects reduced lead time

The contractor's early input on constructability and modularization streamlined the design process

Adaptability was enabled when driven by formal requirements, such as a 15-year municipal permit

Trust-based relationships allowed for agile decision-making and rapid on-site problem-solving

Lack of planning causes the need for on-site adjustments; the capability to do so will help solve the problems

Disassembly and reuse requirements were not embedded as project constraints

specialized contractors joined after key layout decisions, causing routing conflicts and on-site rework.

No structured handover of reuse-related documents

It was unclear who was responsible for the second phase of the projects

Lessons learned from Office Lab 1.0 were applied tacitly but never documented formally for future adaptation.

Structural and MEP engineer were not consulting the design each other during early spatial planning

Figure 8 Enablers and Barriers of Implementing Adaptable Buildings

Figure 8 synthesizes the key enablers and barriers to delivering adaptable buildings, as identified from the cross-case analysis. The framework is structured around the three core themes of the research: Design Integration, Lifecycle, and Project Coordination. The left column details the Enablers, which is favorable conditions and practices that were found to support adaptability. These include technical factors, such as using a standardized modular system, and procedural factors, such as early contractor involvement. The right column details the Barriers, which is the critical process gaps and structural shortcomings that undermine adaptability goals. These include issues like a lack of formal Design for Disassembly (DfD) integration and unclear accountability for post-use planning.

This visual comparison highlights a central tension in delivering adaptable buildings: while technical and informal enablers can provide a degree of flexibility, they are often negated by systemic barriers rooted in poor planning and fragmented coordination. For instance, the benefit of an "Informal Coordination Culture" is counteracted by the risk of "No Feedback Capture," and the potential of "Modular Reuse Logic" is lost without formal lifecycle documentation. The diagram illustrates that achieving true, lasting adaptability requires a delivery model that not only leverages its enablers but, more importantly, systematically addresses and mitigates its barriers through structured processes and clear governance.

3.4 Framework Development

4.4.1 The Refined Framework

Table 7 and Table 8 show a synthesized DSM matrix and RACI matrix that combines insights from DSM analysis, RACI mapping, and observation from both case studies. It visualizes how the modular construction workflow for adaptable buildings can be structured across the delivery phase, with specific dependencies between activities, to make the entire process seamless.

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Table 7 Refined DSM Matrix

No.	Activity Name		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Establish project intent and adaptability goals	1	■	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Select delivery method and define responsibilities	2	1	■	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Appoint key design and execution stakeholders	3	1	0	■	0	0	0	0	0	0	0	0	0	0	0	0
4	Develop spatial layout and modular configuration	4	1	1	1	■	0	0	0	0	0	0	0	0	0	0	0
5	Plan structural system and floor/foundation strategy	5	0	0	0	1	■	0	0	0	0	0	0	0	0	0	0
6	Design building services (MEP)	6	0	0	0	1	1	■	0	0	0	0	0	0	0	0	0
7	Coordinate layout and modular constraints	7	0	0	0	1	1	1	■	1	0	0	0	0	0	0	0
8	Integrate disassembly and reuse requirements (DfD)	8	0	0	0	1	1	1	1	■	1	0	0	0	0	0	0
9	Conduct constructability and feasibility reviews	9	0	0	0	1	0	0	0	1	■	0	0	0	0	0	0
10	Procure systems, materials, and subcontractors	10	0	0	0	0	0	0	0	0	1	■	0	0	0	0	0
11	Fabricate modules and prepare off-site logistics	11	0	0	0	0	0	0	0	0	0	1	■	0	0	0	0
12	Prepare site and foundations	12	0	0	0	0	0	0	0	0	0	0	1	■	0	0	0
13	Deliver and install modules on site	13	0	0	0	0	0	0	0	0	0	0	1	1	■	0	0
14	Test systems and perform commissioning	14	0	0	0	0	0	0	0	0	0	0	0	0	1	■	0
15	Handover documentation and plan post-occupancy support	15	0	0	0	1	0	0	0	1	1	0	1	1	1	1	■

Table 8 Refined RACI matrix

No.	Activity Name	Client	Architect	Contractor	Specialized Subcontractor
1	Establish project intent and adaptability goals	R	C	I	I
2	Select delivery method and define responsibilities	R	C	C	I
3	Appoint key design and execution stakeholders	R	C	C	I
4	Develop spatial layout and modular configuration	A	C	R	C
5	Plan structural system and floor/foundation strategy	A	R	C	C
6	Design building services (MEP)	I	C	C	R
7	Coordinate layout and modular constraints	I	C	C	I
8	Integrate disassembly and reuse requirements (DfD)	I	C	R	C
9	Conduct constructability and feasibility reviews	I	C	R	C
10	Procure systems, materials, and subcontractors	I	I	R	C
11	Fabricate modules and prepare off-site logistics	I	I	R	I
12	Prepare site and foundations	I	I	R	C
13	Deliver and install modules on site	I	I	R	I
14	Test systems and perform commissioning	I	I	R	I
15	Handover documentation and plan post- occupancy support	A	C	R	I

Design Integration

The delivery flow consolidates fifteen activities into six interconnected domains (planning, design, procurement, fabrication, execution, and handover). The DSM matrix highlights the high-dependency pathways, such as how early planning choices (Activities 1–3) directly shape design integration (Activities 4–9), and how disassembly and documentation efforts (Activities 4, 9, and 15) are either dependent or missed depending on the project's governance.

In this framework, delivery logic is no longer linear but reflexive. Design coordination (Activities 8a–8c) and constructability reviews (Activities 9a–9d) are explicitly staged to act as mid-stream evaluative loops rather than post-design correction. This resolves one of the key barriers identified in both cases, which is late technical involvement.

Lifecycle Adaptability

Activities such as "Integrate disassembly and reuse requirements" (Activity 4) and "Prepare a documentation plan for adaptable purposes" (Activity 9d) are emphasized as central to adaptability. These are supported by modular detailing and feedback-enabled loops that span fabrication and post-occupancy planning (Activity 15). Unlike in Project A (where these steps were isolated), the framework positions them as an embedded coordination hub.

By connecting the modular reuse logic (11a–11c) to both procurement sequencing and early MEP routing strategies (7a, 8c), the framework ensures that construction and adaptation are not contradictory. On the contrary, they become co-optimized through spatial prefiguration.

Actor Coordination

The embedded RACI logic further strengthens this framework. Each clustered activity group is aligned with responsibility distribution lessons, for example, early contractor involvement (2a), design coordination (8a), and lifecycle continuity (15). These align with roles and gaps observed in the Project A and Project B projects, particularly the need for clear accountability in post-use planning, technical documentation, and disassembly procedures.

The modular diagram highlights the shift from informal, reactive coordination (Project A) to a more layered, cross-disciplinary integration (Project B). Colored arrows and spatial zones illustrate the activity dependencies and the timing of inter-stakeholder handovers, which will enable project teams to visually map risk, role, and resource needs at each phase.

4.4.2 The Process Flow for Adaptability

The process flow in Figure 9 presents a structured sequence of interdependent activities tailored to support adaptable modular construction projects. The flow is derived from both DSM analysis and cross-case insights, which emphasize how early design decisions, stakeholder coordination, and lifecycle planning interact to enable long-term adaptability. The process aligns activities across time and stakeholders, ensuring that adaptability is not an afterthought but a systemic output of design, delivery, and handover. Feedback loops, multi-actor coordination, and early DfD integration are explicitly structured to enhance the project's capacity for change. For example, activities 8 and 9 become the center of design and execution, ensuring that all designs will be constructible on site when executed. After activities 15, there will be another loop of project life-cycle, which in this case is second project life-cycle.

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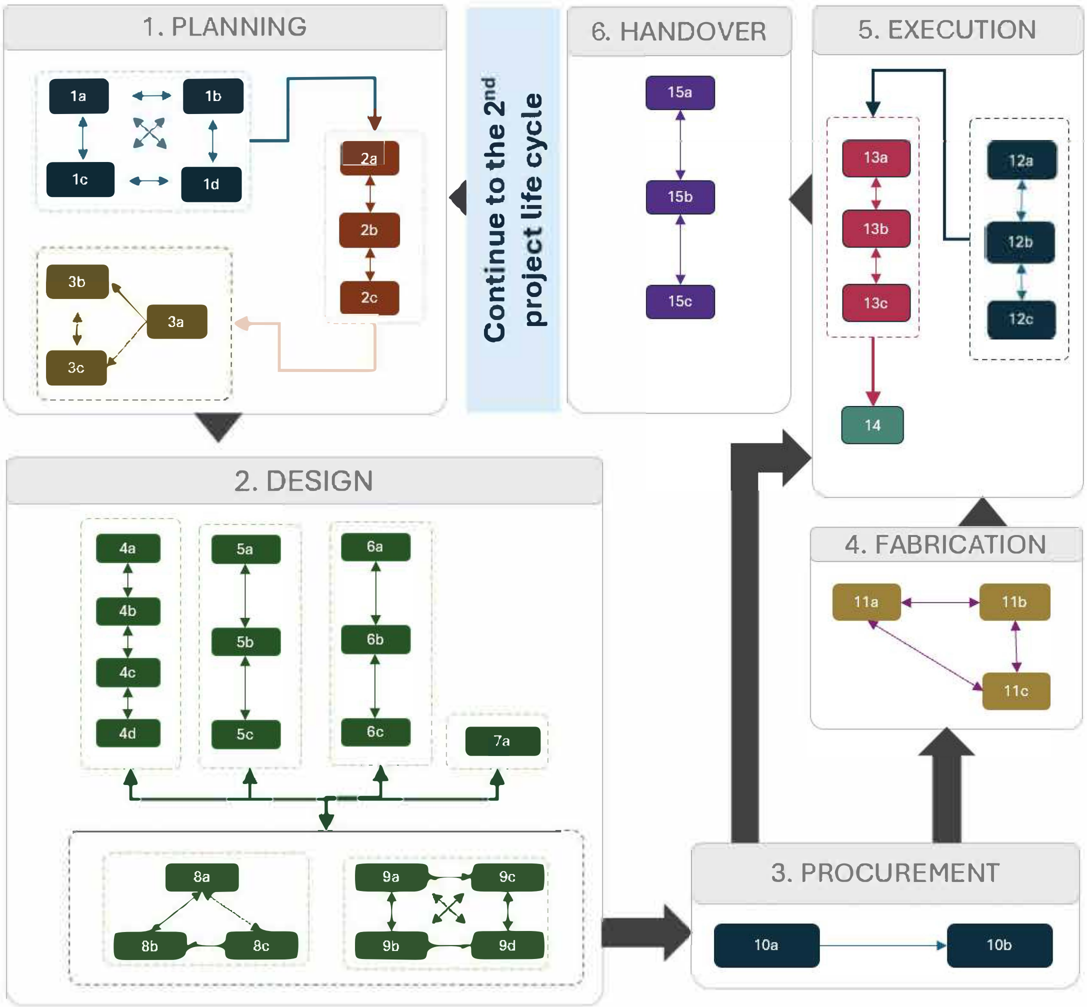

Figure 9 Process Flow of Adaptability Building Project

4.4.3 Core Strategies for Implementation

Figure 10 presents a set of actionable strategies designed to overcome the barriers identified in the case study analysis and systematically embed adaptability into project delivery. The strategies are organized according to the three core themes of this research: Design Integration, Lifecycle, and Coordination, to provide a holistic framework for improvement. Each strategy is a direct response to the shortcomings observed, aiming to shift project delivery from a reactive to a proactive model. The final column, "Related Flow Activity," links each strategic recommendation to specific, numbered activities within the refined project workflow.

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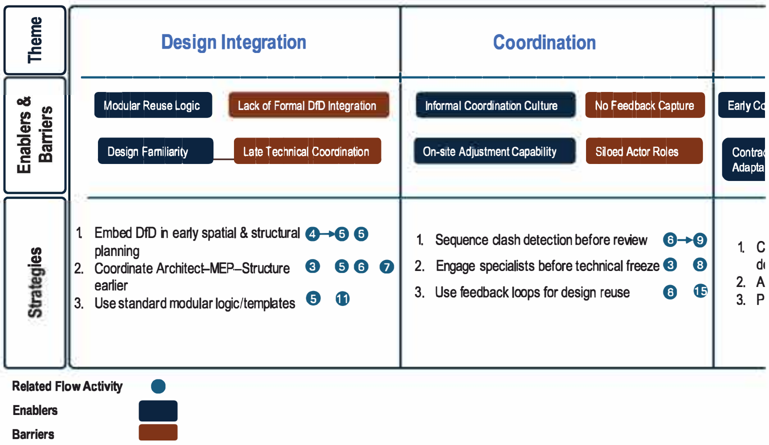

Figure 10 Strategies for Building an Adaptability Project

The content of the strategies reflects a clear focus on formalizing processes and enhancing collaboration at the early stages. Under Design Integration, the strategies concentrate on embedding Design for Disassembly (DfD) principles from the outset and ensuring that architectural, MEP, and structural disciplines are coordinated far earlier than in traditional workflows. Lifecycle strategies address the critical gap in long-term planning by mandating the creation of formal documentation, assigning clear accountability for post-use phases, and requiring DfD plans to be reviewed as a key project deliverable. Finally, the Coordination strategies focus on improving the timing and quality of information flow by sequencing clash detection before constructability reviews and establishing feedback loops for organizational learning and design reuse.

This table serves as a strategic roadmap for project teams. It translates the high-level findings of the research into a coherent set of operational interventions that can be directly implemented in a project plan. By connecting each strategy to specific activities, the table provides a tangible guide for mitigating risks associated with fragmented delivery, ensuring that adaptability is not treated as an optional feature but as a systemic outcome of a well-structured and integrated project delivery process.

4. 5 Discussion

Referring to Leavitt (1965), this research, as can be seen in Figure 11, the Technology component is represented by the advanced modular systems and DfD principles. The Tasks are the 15 core delivery activities required for the project. The Structure is defined by the Project Delivery Method and the process workflows mapped by the DSM. Finally, the People are the project stakeholders, whose roles and responsibilities were analyzed using the RACI matrix.

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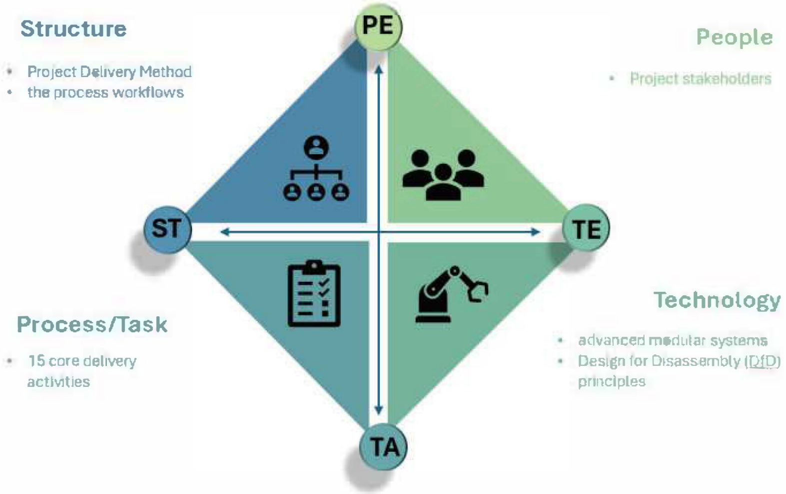

Figure 11 Leavitt's Diamond Diagram

The analysis presented in the preceding chapters reveals a clear and compelling conclusion: the successful delivery of an adaptable building is not merely a technical achievement but a socio-technical one. While the physical design, modular logic, and material selection form the essential technical system that enables change, this research demonstrates that these elements are insufficient on their own. Their potential is often wasted if not supported by a coherent process system (as mapped by the DSM) and a social system that defines stakeholder roles and responsibilities (as analyzed through the RACI matrix). The failures observed in both case studies were not rooted in a lack of technical capability, but rather in the misalignment between these critical systems.

These cases reveal a crucial lesson, visually summarized in Figure 12. This concept illustrates that modularity, on its own, does not guarantee adaptability; it only provides the initial Technical Potential. Realizing this potential is entirely dependent on the strength of the subsequent links in the chain. As the diagram on the left shows, even when the link between a modular system and the project is strong, the overall goal fails if the Delivery Process itself is a "Broken Link." In the case studies, this broken link was represented by siloed workflows, incomplete planning, and a lack of holistic integration, which ultimately severed the connection to a successful Adaptability Outcome.

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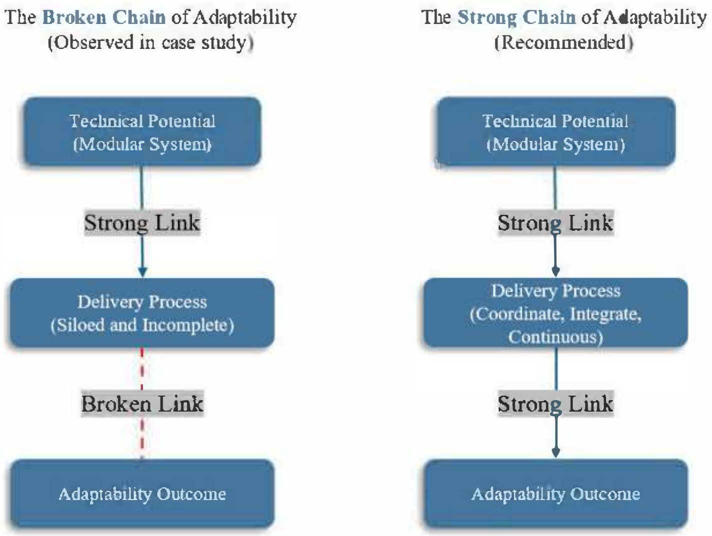

Figure 12 The Chain of Adaptability

The framework proposed in this paper is designed to repair this broken chain. The diagram on the right, "The Strong Chain of Adaptability," illustrates the recommended approach. It posits that an enhanced Delivery Process, one that is coordinated, integrated, and continuous throughout the lifecycle, is the critical connecting link. This includes ensuring that all interconnected systems, from the foundation to the MEP, are part of the adaptability plan, and that the "soft" infrastructure of documentation and lifecycle governance is as strong as the physical modules themselves. Without this comprehensive and holistic delivery framework, even the most advanced modular system risks becoming a fixed asset with unfulfilled promises, its potential lost to a single weak link in the delivery chain.

4 Conclusion

In the face of increasing climate pressure and dynamic urban demands, the construction industry must transition from delivering static objects to creating adaptable and long-life assets. Delivering an adaptable building is not just a matter of material selection or design, but it is also influenced by how construction projects are managed, planned, and delivered. A critical disconnect drove this research: while the need for building adaptability is clear, existing PDMs often fail to properly support it, as they focus on short-term metrics at the expense of long-term value. This study examined how project delivery can be restructured to systematically incorporate adaptability, with a focus on modular and industrialized construction as a key enabler. By applying a socio-technical lens to two Dutch case studies, utilizing the DSM and RACI matrix as analytical tools, this research aimed to develop a more comprehensive delivery framework.

The comparative analysis provides a crucial insight: technical capability alone does not guarantee adaptability. Both case studies possessed the modular systems necessary for physical modification, yet both fell short of their long-term adaptability goals due to significant process and organizational gaps. It fails not because of technical limitations, but because of fragmented workflows, siloed communication between key disciplines, and a lack of formalized lifecycle procedures within the project delivery structure.

In response to these findings, this research has synthesized a structured framework designed to bridge the gap between adaptability ambition and delivery reality. The proposed framework is built upon a foundation of 15 interdependent delivery activities mapped across six project phases. It explicitly integrates critical but often-neglected tasks such as DfD planning, modular reuse logic, and lifecycle feedback loops to ensure adaptability is embedded from the project's inception. By using the DSM to optimize activity sequencing and the RACI matrix to clarify stakeholder roles, the framework provides a clear roadmap for aligning the technical, process, and social systems of a project.

This study offers both practical and theoretical contributions. For project management practitioners, it provides a concrete method to move beyond reactive problem-solving toward a proactive and integrated delivery strategy. It equips them with a structured approach to foster early coordination, establish role clarity, and leverage the full potential of modular systems. This contributes to the field of project management by demonstrating a system approach to aligning project delivery with long-term asset value, which shifts from short-term project completion to long-term lifecycle performance. While the findings are based on two case studies and further research is needed to test the framework in other contexts, this study provides a vital step toward creating a built environment that is not only constructed efficiently today but is also prepared for the challenges of tomorrow.

While this research focuses on the context of adaptable construction, the core findings speak to a more universal challenge: the management of complex systems under long-term uncertainty. The observed 'socio-technical misalignment' is not unique to the building industry but is a common failure mode in fields ranging from software development to public policy, where static project delivery models are often misapplied to dynamic, evolving problems.

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