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Enhancing Resilience in Modular Construction Supply Chains: Drivers, Strategies and Innovations for Improvement

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Abstract

This paper addressed the question of the Modular construction that has been emerged as a transformative approach in the construction industry, offering benefits such as reduced project timelines, cost efficiency, and improved quality control. However, its supply chain remains vulnerable to disruptions caused by material shortages, logistical delays, labor constraints, and external shocks such as pandemics and geopolitical instability. The research investigates the drivers of resilience in modular construction supply chains (MCSCs) as well as identifies key strategies for improvement, and explores innovative solutions to enhance robustness. Using a mixed-methods approach—including case studies, surveys, and simulation modeling—this study also evaluates resilience-enhancing mechanisms such as digital technologies (e.g., Building Information Modeling (BIM), blockchain, and IoT), supplier diversification, inventory optimization, and agile project management. The findings contribute to a framework for resilient MCSCs, offering actionable insights for industry practitioners and policymakers.

Keywords: Modular construction; supply chain resilience; risk management; digital innovation; construction logistics

Introduction

In general terms, modular construction involves producing standardized components of a structure in an off-site factory and then assembling them on-site. The terms "off-site construction," "prefabrication," and "modular construction" are used interchangeably.

In other words, modular construction is defined as construction approaches that do not follow traditional procedures. The system often consists of assembling prefabricated buildings with individual modules. These modular elements are usually manufactured in factories.

The modular construction involves the off-site fabrication of building components in controlled environments, which are then transported and assembled on-site. While this method enhances efficiency, its supply chain is complex, involving multiple stakeholders, just-in-time deliveries, and high dependency on logistics. Disruptions in any segment can lead to cascading delays and cost overruns.

Despite the advantages of modular construction, its supply chain lacks sufficient resilience to withstand

disruptions. Existing literature focuses primarily on traditional construction supply chains, leaving a gap in understanding resilience mechanisms specific to modular methods.

The questions we may ask are: What is the modular construction? what is the advantage of modular construction?

Materials and Methods

Generally speaking, the research objectives refer to what researchers expect to achieve by a project. These objectives are "affirmative statements that explain what the researcher aims for, seeks to achieve" (ibid: 50).

The objectives of this research are more circumscribed and mainly to examine the resilience's factors of modular construction supply chains; to Identify the principal's strategy of improvement; and to propose some innovative solutions.

The crucial aspect of research is the selection of suitable research methodology because it acts as a foundation for data processing and determines the kinds of data that shall be collected. By research methodology, I mean the process of research which includes the assumptions and values, which serve as the foundation of the research, the principles, and standards the research uses for collecting, analyzing and achieving conclusion; Its simply mean the tools or techniques used for collecting data. Martino (2015:7) argues that methodology refers to "how the study is undertaken and involves justification and explanation of the methods used in conducting a particular research project. "For this research we use some mixed methods such as qualitative.

Generally modular construction' advantages offer several advantages over traditional construction, such as faster construction, increased flexibility, better budget control, and reduced environmental impact. The modular construction also has some inconvenient which can be developed il the following lines.

Results and Discussions

Advantages of modular construction Speed of execution

Modules are factory-built, significantly speeding up the construction process and reducing lead times; Th flexibility and scalability, modular construction makes it easy to adapt structures to specific client needs and to easily expand, modify, or relocate them as needed; the Budget management, modular construction allows for better budget control, thanks to reduced labor and material costs; Reduced environmental impact, modular construction generates less waste and reduces CO2 emissions compared to traditional methods. It also generates less waste on the construction site compared to traditional construction, reducing the project's environmental impact; The Better site management. The construction site is quieter and less polluted than traditional construction, and disruptions are reduced thanks to the rapid installation of the modules; Concerning environmental performance, buildings can be designed to be more environmentally friendly, using sustainable materials and optimizing insulation.

The vulnerability of chains supply

The supply chains in modular construction are usually essential for optimizing the production process, reducing costs, and ensuring fast and reliable building delivery. These supply chains involve several stakeholders, including module manufacturers, material suppliers, transporters, and installers.

Key stakeholders in the modular construction supply chain:

Module Manufacturers: Companies that manufacture prefabricated modules, often in factories using industrial processes.

Material Suppliers: Companies that supply building materials, such as steel, wood, cladding, etc.

Transporters: Companies that transport modules and materials to the construction site.

Installers: Companies that install the modules on site, connecting them to existing infrastructure.

Contractors/Developers are the companies that coordinate the entire construction process and interact with end customers. There are some benefits of modular construction which are pineries des matrix

Logistics delays, most delays arise because modular construction components are prefabricated far from the construction site, so transportation costs and the risk of damage during transport must be taken into account. Even a small incident during transport can cause a major setback.

Transportation and assembly companies often have to spend a lot of their time and effort for planning the logistics of moving modular building components. To limit the risk of damaging these components, transportation costs can consume a large portion of a project's budget.

Conclusions

This research is important for scientific study as well as for those who will be willing to do such research in the future, economic as well as in architecture (infrastructures). Research is among of the most distinctive, clear, and simple practices architectures who brings to the study of modular construction in a specific way through my research. This paper seeks a detailed and intimate understanding of the context of modular construction and chains supply.

Improving resilience of chains supply of modular construction?

Improving the resilience of modular construction requires incorporating sustainable design principles, to optimize manufacture and assembly processes, and have to choose robust materials suited to the local conditions.

Some suggestions and recommendations for improvement.

To improve the resilience chains supply, it should take into account Somes very important points. First, the sustainable design which incorporate green design principles such as using recycled or sustainable materials (recycled steel, recycled concrete), optimizing insulation to reduce energy consumption, and integrating renewable energy systems. Secondly, the material suppliers. The companies that supply construction materials, such as steel, wood, coatings, etc.

Carriers: Companies that transport modules and materials to the construction site.

Installers: Companies that install the modules on site, connecting them to existing infrastructure.

Manufacturing and Assembly: There should be what called the quality control which maintain strict quality throughout the factory manufacturing process to minimize errors and ensure compliance with standards; also the process optimization to automate certain manufacturing and material management processes to improve efficiency and reduce waste; the coordination and collaboration ensure seamless communication and close collaboration between all project stakeholders (designers, manufacturers, assembly teams) to avoid errors and delays.

By applying all these principles, we can make sure that modular construction can become an even more resilient, sustainable and efficient choice, capable of meeting the challenges of climate change and contributing to the construction of safer and more resilient cities.

Conclusion

It has lately developed a way to significantly improve the country's infrastructure. As part of this purpose, the government has invested a positive.

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