ISSN 0853-2982

JURNAL TEKNIK SIPIL

eISSN 2549-2659

Jurnal Teoretis dan Terapan Bidang Rekayasa Sipil

The Study of Potential Application of Modular Construction in The Development of Indonesia's New Capital City

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Abstract.

The infrastructure industry is a crucial sector that significantly impacts economic growth. In the second quarter of 2020, infrastructure was the fourth most significant contributor to Indonesia's economy, contributing 10.56% of the total GDP. Recent research shows modular construction outweighs the conventional method in terms of cost, schedule, and quality. This paper investigates the opportunity to apply modular construction to develop Indonesia's New Capital City Project. The authors conducted a SWOT analysis and risk analysis to ensure the benefit of its application. The barrier to modularity application is in the transport cost-efficiency. The study shows that the modularity option provides more advantages in Indonesia's New Capital City development than the traditional cost and time reduction, longevity improvement, standardisation, product quality, minimising construction waste, and meeting high safety requirements. In large-scale demand, modularity is more profitable. The detailing design use BIM and RFID. The logistics efficiency supported by integrating transport and logistics processes as part of the project management system will outperform the conventional construction method.

Keywords: Modular construction, new capital city project, sustainable infrastructure, SDG

Abstrak.

Industri infrastruktur merupakan salah satu sektor penting yang berdampak signifikan terhadap pertumbuhan ekonomi. Pada triwulan kedua tahun 2020, infrastruktur menjadi penyumbang terbesar keempat bagi perekonomian Indonesia, dengan kontribusi 10,56% dari total PDB. Penelitian terbaru menunjukkan bahwa konstruksi modular memiliki keunggulan dari segi metode biaya, jadwal, maupun kualitas dibandingkan metode tradisional. Makalah ini membahas mengenai peluang untuk menerapkan konstruksi modular untuk pengembangan Proyek Ibu Kota Baru Indonesia. Penulis melakukan analisis SWOT dan analisis risiko untuk mengetahui manfaat dari penerapan tersebut. Kendala dari pengaplikasian system modular terutama dalam efisiensi biaya transportasi. Studi tersebut menunjukkan bahwa opsi konstruksi modular memberikan lebih banyak manfaat dalam pengembangan Ibu Kota Baru Indonesia daripada pengurangan biaya dan waktu tradisional, peningkatan umur panjang, standarisasi, kualitas produk, meminimalkan limbah konstruksi, dan memenuhi kriteria keselamatan tenaga kerja yang tinggi. Dalam permintaan skala besar, konstruksi modular akan lebih menguntungkan. Pengembangan DED untuk konstruksi modular menggunakan BIM dan RFID. Peningkatan efisiensi logistik dapat dilakukan dengan integrasi system transportasi dan logistik sebagai bagian dari manajemen proyek sehingga akan mengungguli metode konstruksi konvensional.

Kata Kunci: Konstruksi modular, ibu kota negara, infrastruktur berkesinambungan

1. Introduction

1.1 New capital city of Indonesia

1.1.1 Background

The historical record shows that in the Dutch Colonial era, the government mentioned the idea of Indonesia's capital city translocation (Purwanto, 2021). The idea emerged since then but never turned into concrete action until the second reign of President Joko Widodo. There are a few considerations for switching the location of Indonesia's capital city to Penajam Paser, Borneo Island, such as the lower potential of disaster risk compared to other regions, geographically positioned in the centre of Indonesia's territory and near the well-developed urban areas (Balikpapan and Samarinda). The land is primarily government-owned

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(Purwanto, 2021). Industrial plantation forests dominate most of the designated areas (Widjayatnika, 2018). The geological structure condition of the Sotek district is anti-clinal and synclinal, dominated by limestone (BAPPEDA Penajam Paser Utara, 2014). As limestone is well-known as a durable material for construction, the Head of Development Penajam Paser Utara City Council confirmed that the soil condition could suit the infrastructure development (AM. 2019). The new capital city of Indonesia in East Kalimantan is called Nusantara. This paper will express the New Capital City in Indonesia as Nusantara City. The relocation of Indonesia's capital city is a national large -scale strategic project requiring massive resources and many construction projects. The government planned to construct the development into three main zones: blue, yellow, and grey (AM. 2019), where blue is for the Central Governmental Region and yellow is for the Main Capital City Region. Grey will be an extension of the Capital City Region. The planned total area is about 256.142,74 hectares, with 56.180,87 hectares dedicated to the city centre (Purwanto, 2021). The city centre will include the government's essential facilities such as National Palace, government offices, main worship places, complex diplomatic area, Indonesian police and an army base, educational facility, medical facility, and residency area for public servant officers (Nainggolan, 2020). About 221.000 government officers were assigned and moved to the Nusantara, the National Development Planning Agency estimates that around 2.918 landed houses and 1.484 flats will accommodate them (Nainggolan, 2020). The construction of these massive residences starts in 2021-2024 .

1.1.2 The concept of future city.

In 2019, National Development Planning Agency stated that the development of Nusantara would bring in the concept of Smart and the Most Sustainable City (Ministry of National Development Planning, 2019) (updated based on the interview with the Ministry of Public Works). Creating a future city in the urban area in developing countries has challenges. There are challenges in the local government's system, the inadequacy of transport infrastructures, social and economic inequality and environmental consideration (Riffat, 2016). There are probably about 43 national regulations that need to be revised regarding Nusantara's positioning arrangement, regional boundaries, constitution and structure of local government, particular region for the centre of administration, and spatial and environmental planning for the Nusantara's development (Purwanto, 2021). There is a possibility of a functional shift of land use because the existing forest in the surrounding area of the designated location for Nusantara is unclassified as a protected forest (AM. 2019).

The infrastructure development of Nusantara requires to meet international standards and requirements. Developing a Smart Cities framework should align the strategic aspect (management process and implementations), processes (interoperability aspects), and technical aspects (developing the digital infrastructures) (Heaton, 2020). The currently adopted building, structural, mechanical, and plumbing codes follow the International Building Code, International Residential Code, and International Plumbing Code. The energy regulation follows the International Energy Conservation Code (Lee, 2018).

Table 1 shows the international standards for the creation of smart infrastructures.

2. Infrastructure development in Indonesia

According to the 2020 Quarterly Construction Establishment Survey (QCES) (BPS, 2020), the Central Bureau of Statistics (Indonesia) stated that Indonesia's Gross Domestic Product (GDP) was at a 10.56 per cent rate. The housing demand will continuously increase following the growth of the population, with a growth rate of 0.62 % within 2030-2035 (Jones, 2010). The initiative of Sustainable Development Goals (SDG) and the decarbonisation pathway toward 2030 has

Table 1. International standards for smart infrastructures *(Heaton, and Parlikad, 2020)*

Category	Reference	Descriptions
Strategic	ISO 8000 Quality Management System	To provide a framework for improving data quality in conjunction with Quality Management System
Strategic	ISO 9000 Quality Management System	To provide a framework for a quality management system within an organisation
Strategic/Process	ISO 55000 Asset Management	To provide a framework for adopting an asset management system for infrastructure asset
Strategic	ISO 26000 Guidance on social responsibility	Guides the social responsibility and stakeholder engagement
Process	ISO 37101 Sustainable development in communities - Management system for sustainable development	To provide the requirement for a management system for sustainable development in communities
Process/ Technical	ISO 37120 Sustainable development in communities' indicators for city services and quality of life	To provide definitions and methodology for a set of city indicators and improved quality of life
Process	ISO/TR 37150 Smart community infrastructure - Review of existing activities relevant to metrics	To provide current metrics and processes used to measure digital infrastructure in smart city
Technical	ISO/TR 37151 Smart community infrastructure - Principles and requirements for performance metric	To provide the requirement for community infrastructure performance metrics
Proses	ISO/TR 37152 Smart community infrastructure - Common framework for development and operation	To provide a framework for the development of smart community infrastructures

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become one of the criteria for public policy development. Intelligent, green, and sustainable infrastructure is developing the future city. In developed countries such as EU countries, Japan and Singapore, their construction sector has focused on the sustainability requirement. Their government also incentivised the industry towards the net-zero carbon era in 2050 (McKinsey & Company, 2019). Modular construction offers a higher value for energy efficiency index, interchangeability functionality, the standard quality, which are worth its values compared to the conventional method, as shown in **Figure 1**.

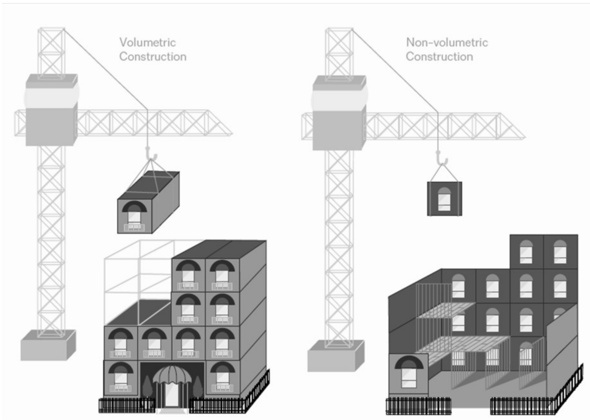

Figure 1. Onsite construction vs modular construction
(*The American Institute of Architects, 2019)*

By adopting the modular construction method, Indonesia will meet the eight criteria of sustainable development goals. The modular construction method achieves eight Sustainable Development Goals (SDG) parameters. **Figure 2** shows the SDG applicable to the implementation of modular construction.

Figure 2. Sustainable development goals for modular construction.

The sustainability criterion for building infrastructures should consider a few aspects such as (1) Environmental: related to material, water, and energy consumption, waste generation, and carbon emission; (2) Economical: related to construction lifecycle cost; (3) Social: people comfort (noise reduction, thermal condition, indoor air quality), human interaction, and user flexibility; (4) Disaster resiliency: earthquake resistance and flood resistance (Maleki, 2019).

The decision-making for the infrastructure development should consider the dignity of the built environment lifecycle that consists of (1) Process for land acquisition concerning the socio-economical condition of the local people; (2) Planning and financing of the public infrastructure, housing and transportation infrastructure with consideration of non-corruption and climate resiliency; (3) Design of the civil and architecture with inclusion of accessibility, physical and mental health; (4) Construction stage with consideration of high quality and managing construction worker's rights, health, and safety; (5) Operational, management and maintenance stage with technology adaption; and (6) Demolition & redevelopment with consideration of responsible disposal, re-use, recycling of building materials, project legacy, or land vacating (Institute for Human Rights and Business, 2019).

Performing standardisation and modularisation minimises the difficulty of ensuring the dignity of design and construction, where continuous monitoring of project integration is required. In this paper, the authors propose a strategy to overcome the challenges of creating a future city in North Penajam, East Kalimantan, by implementing the modular or off-site construction method to supply supporting infrastructures such as hospitals and school and office buildings. The modular construction concept can be the answer to the idea of Green, Smart and Sustainable (Ministry of National Development Planning, 2019). The supply chain modular construction cost is considered on the high-end side with about 10% to 15% of the entire building to accommodate the higher outlay cost for an initial fee of prefabricated construction, the off-site yard, and installation cost using heavy-duty cranes to lift and stack the modules (McKinsey & Company, 2019). Gibb (1999) stated that there are four degrees of modularisation comprising (1) components manufacture and subassembly, (2) non-volumetric preassembly, (3) volumetric preassembly and (4) an assembled modular building (Wuni, 2020). **Figure 3** shows the stakeholder mapping for the modular construction (Manley, at al., 2009).

3. Research Methodology

The possibility of modular construction starts by examining the site condition from the building's environmental state, supply, and demand. The authors evaluate the modular construction application and the

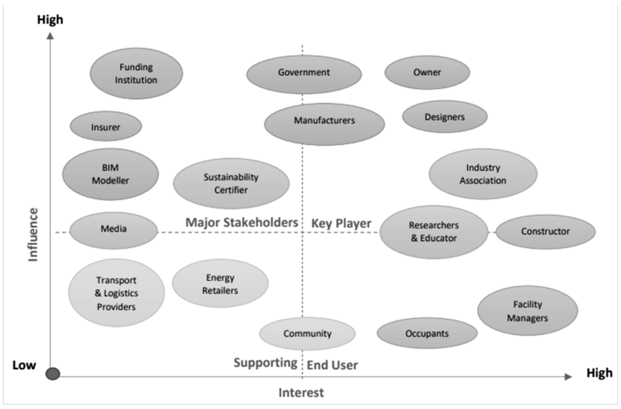

Figure 3. Stakeholder mapping for modular construction
(Manley, at al., 2009)

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comparison with the traditional construction from technical and cost aspects. **Figure 4** shows the research methodology for this study.

4. Result and Discussion

4.1 The production management

Managing off-site infrastructure production or modular construction should be supported with five components: workforce, materials, methods, machines, and money. The details are as follows

a. Workforce

In modular construction development, considering the labour supply is essential. According to the Ministry of Public Works (Works Mi of P, 2021), East Kalimantan Province has 9,481 skilled construction workers with 3 Class Qualifications, as shown in **Table 2**.

Table 2. The total number of skilled construction workers
(Works Mi of P, 2021)

Class	Qualification	Working Experience	Total Workers
1	Minimum D1 (Diploma 1)	Min. 3 years	5443
2	Minimum Vocational High School	Min. 3 years	1216
3	Minimum Elementary School	Min. 2 years	2882

Based on the above data, East Kalimantan Province has an ample supply of skilled labour and can be a potential indicator for the development of modular construction. On the other side, the migration of government officials from the current Capital City of Jakarta will support the level of engineers' and officers' needs.

b. Materials

There are two primary materials for making modular construction modules: cement/concrete and steel. Researchers found that Balikpapan City has quite a several suppliers for both materials. Cement/concrete is supplied from Tuban (East Java), Maros (South Sulawesi), and Pangkep (South Sulawesi). Furthermore, steel is supplied from Cilegon (Banten), Derawan (South Kalimantan), Sebuku (South Kalimantan), Lengkabana (South Sulawesi), Longkana (South Sulawesi), and Verbeek, (Central Sulawesi).

c. Methods

The modular block for the apartment building is usually divided into two types of alternatives the reinforced concrete module with an estimated weight of 20-35 tons each and the steel module with a lighter weight of 15 to 20 tons. The module blocks require completed protection packaging during transportation and handling, with either temporary or fixed roof decking, temporary stiffening, and lifting. A lifting frame is used during the handling - the installation methods are stacking with the hoisting by crane (Koraishy, at al., 2011).

d. Machine

Modular block fabrications use automatic or semi-automatic constructions. The components use precast technology, mass engineer timber (MET) or hybrid (Koraishy, at al., 2011). The welding for steel modules usually uses robotic welding - the concrete precast uses an automated machine to produce uniform quality.

e. Money

Modular construction models are considered standard in a developed country. The government in the developing countries emphasises the contractors to adopt this smart construction since it reduces waste and adopts a sustainability mindset - the infrastructure's funding from the national budget, public-private partnership scheme, or international bank loan. The recent funding criteria are clean environmental goals and financial sustainability indicators (Asian Development Bank, 2022).

4.2 SWOT analysis

The application of modular construction in Nusantara's infrastructure development promotes sustainability and a green environment, aligned with Nusantara's development theme. **Figure 5** shows the drivers, enablers, and barriers to applying modular construction in Nusantara.

The analysis has focused on assessing the strengths, weaknesses, opportunities, and threats of implementing modular construction. **Table 3** shows the SWOT analysis for implementing the modular construction method in Nusantara.

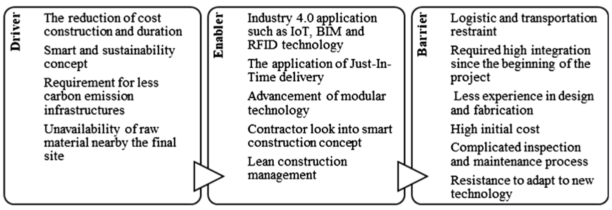

Figure 5. Driver, enabler, and barrier of application of modular construction
(Kamali, and Hewage 2016; Liu, at al., 2019; Nanyam, at al., 2017)

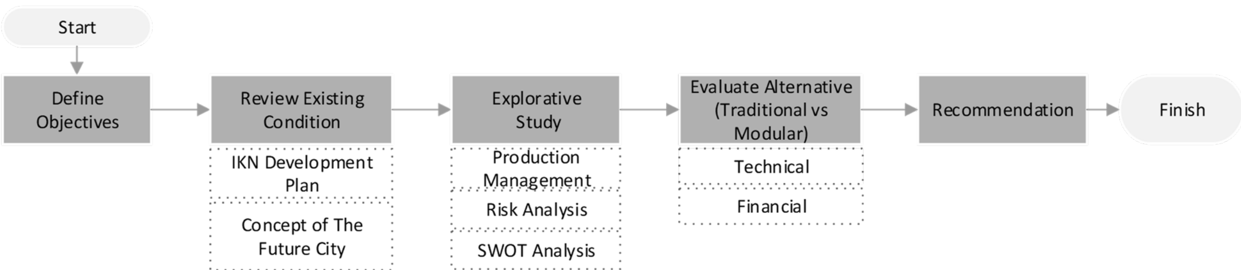

Figure 4. Research methodology.

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Table 3. SWOT analysis for implementing modular building in Nusantara (Lee, and Kim, 2018; Green, at al., 2014; Li, at al., 2019)

	STRENGTHS		WEAKNESS
1	Project cost reduction	1	The limitation of capacity Building
2	Project time reduction	2	The negative perception toward Industry 4.0 technology
3	Improving productivity	3	Difficulties in the integration of modular block
4	Improving quality and standardisation	4	Relatively high cost in inspection and maintenance
5	Construction waste reduction	5	Complexity in the integration
6	Working in control working environment	6	Transportation constraints
7	Promoting energy efficiency		
	OPPORTUNITIES		**THREATS**
1	The need for Affordable Housing/Building	1	High initial investment
2	Job creation	2	Difficulty in financing
3	Contribution to Sustainability	3	Negative attitude toward a new method
4	Financial approval	4	Competition in market trends

Table 4. Risk assessment categories (AS/NZS 4360, 2004)

		Consequences				
Likelihood		1	2	3	4	5
		Insignificant	Minor	Moderate	Major	Catastrophic
1	Rare	L	L	M	H	H
2	Unlikely	L	L	M	H	E
3	Moderate	L	M	H	E	E
4	Likely	M	H	H	E	E
5	Almost Certain	H	H	E	E	E

Legend:
E = Extreme risk; immediate action required
H = High risk; senior management attention needed
M = Moderate risk; management responsibility must be specified
L = Low risk; manage by routine procedures

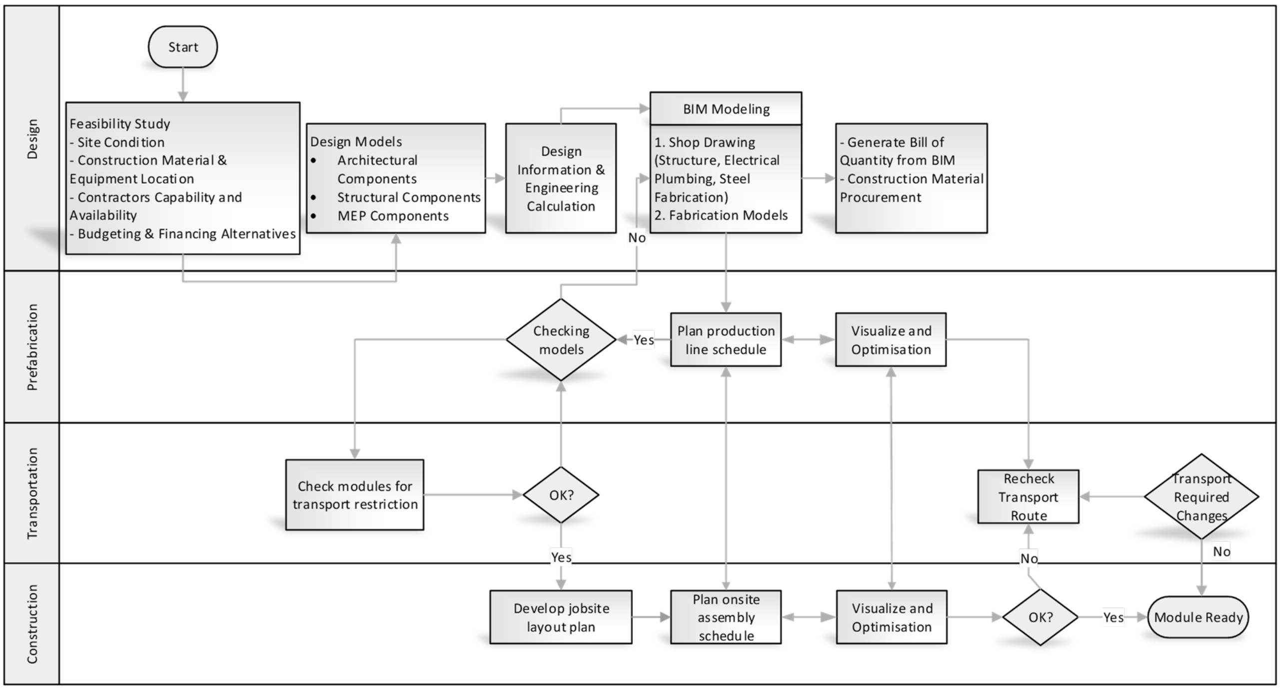

Figure 6. Modular construction process planning (Ezzeddine, and García, 2021)

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Table 5. Risk analysis for implementing modular construction in Nusantara
(McKinsey & Company, 2019; Wuni, at al., 2020; Liu, at al., 2019)

	Type of Risk	Likelihood	Consequences	Risk Matrix	Mitigation Risk
			Implementation Risk		
1.	Contractor's lack of experience in executing modular construction methods	2	4	High	Joint Venture/Partnership with experience contracted
2.	Lack of best management practices and experiences	2	2	Low	Involving project stakeholders to collaborate closely
3.	Inadequate Modular design codes and standards	1	2	Low	Formulate a policy for modular construction
4.	Lack of quality monitoring mechanism	2	3	Moderate	Using IoT and sensor technology
5.	Massive dominance of traditional construction	3	2	Moderate	Training Human Resources to adapt to Industry 4.0
			Supply Chain Risk		
1	The design information gap between designer and fabricator	2	3	Moderate	Stakeholder integration starting the beginning of the projects
2	Inconsistency of logistic composition	3	2	Moderate	Scheduling and procurement configuration
3	Supply Chain Distribution and Instabilities	2	3	Moderate	Resources planning control and workflow
4	Insufficient capacity of modular manufacturers	1	3	Moderate	Ensure the proper scheduling for production as per the required capacity
			Schedule Risk		
1	Delays in modular delivery	2	3	Moderate	Scheduling optimisation
2	Crane failure	1	2	Low	Ensure maintenance and provision of contingency plan
3	Permit/Design Approval	2	3	Moderate	Integrating permits in the early stage of construction
			Investment Risk		
1	The economic, political, and social condition	2	2	Low	Stakeholder integration starting the beginning of the projects
2	Lending rate, currency fluctuation, and inflation	1	2	Low	Involving strong funding institution
3	Inaccurate investment valuation	1	3	Moderate	
4	High initial capital cost and construction prices	2	4	High	
5	Lack of stable modules manufacturers and suppliers	2	3	Moderate	Joint Venture/Partnership with experience contracted
6	Traditional mindset	3	2	Moderate	HR training for the application of Industry 4.0
			Structural Risks		
1	Poor cooperation among multi-interface	2	3	Moderate	Stakeholder integration starting the beginning of the projects
2	Flexing, warping, and damage from transportation and handling	1	3	Moderate	Multi-hazard reliability design consideration
3	Geometric conflicts between module and site interfaces	2	3	Moderate	Usage of application of BIM and 3D volumetric software design
4	Dimensional and geometric tolerances	3	2	Moderate	Hire an experienced designer and engineer
			Safety/Ergonomic Risk		
1	Struck by tilt-up roof objects during hoisting and rigging of large items	1	3	Moderate	Eliminate or reduce ergonomic risk
2	Lifting, carrying, erecting of heavy panelled walls	2	3	Moderate	Ensure application of PPE (Personal Protective Equipment)
3	Exposure to combustion fumes, excessive noise, and carcinogenic compounds	3	2	Moderate	Systematic workflow, 5S
4	Repeated motion and overexertion	1	1	Low	Application of the Lean Integrated Kaizen
5	Falls from ladders, roofs, and attic areas	1	3	Moderate	Housekeeping

4.3 Risk analysis

In the modular construction methods, to avoid issues during construction stages, the designer should consider the module assembly modification and installation, water penetration during construction (stacked and unstacked modules), the access for inspection, the fire protection cost, the work environmental safety issues, the construction worker skills, module access hole and architectural flexibility (Pang, at al., 2016). The authors perform a risk analysis to understand the high risk of implementing modular construction for infrastructure development in Nusantara, as shown in **Table 4**.

The monitoring of the modular construction using the application of a combination of BIM software and RFID (Radio-Frequency Identification) tag. The authentication check for the module part performs when composing the moulding part onto a module. The RFID tag also improves the efficiency in creating the cargo manifest for transporting to the construction site (Abbott, at al., 2020). The combination of BIM software and RFID is considered a good tool for monitoring modular construction's entire supply chain process. **Figure 6** shows the flowchart for the adaption of BIM software into the whole of modular construction planning.

4.4 The modular construction potential application in nusantara, Indonesia

In this study, modular construction more focusing on the potential application of modular construction for

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Table 6. **Adapted modular construction cost model** (Mills, 2017)

Activities	Unit	Unit Cost		Percentage
A. SHELL AND CORE WORKS			**2022**	
Substructure	m2	$	30.95	0.26%
Frame and upperfloors	m2	$	23.95	2.00%
Stairs (G to 16 floor)	m2	$	7.48	0.62%
Roof	m2	$	11.23	0.94%
External walls, windows, doors, balconies	m2	$	73.42	6.12%
Internal walls, partition and doors	m2	$	3.72	0.31%
Wall finishes	m2	$	9.83	0.82%
Floor finishes	m2	$	4.02	0.34%
Ceiling finishes	m2	$	0.86	0.07%
Fittings, furnishing and equipment	m2	$	265.49	22.13%
Sanitary ware	m2	$	0.41	0.03%
Mechanical, Electrical, Pumbling	m2	$	129.11	10.76%
Preliminaries and Contingencies	m2	$	152.36	12.70%
SUB TOTAL A (SHELL & COREWORKS)	**m2**	**$**	**712.84**	**59.43%**
B. RESIDENTIAL FITOUT WORKS				
Internal walls, partition and doors	m2	$	17.10	1.43%
Wall finishes	m2	$	17.78	1.48%
Floor finishes	m2	$	22.91	1.91%
Ceiling finishes	m2	$	9.24	0.77%
Fittings, furnishing and equipment	m2	$	90.97	7.58%
Sanitary ware	m2	$	17.10	1.43%
Mechanical Electrical Pumbling	m2	$	252.27	21.03%
Preliminaries and Contingencies	m2	$	19.00	1.58%
SUB TOTAL B (FIT OUT WORKS)	**m2**	**$**	**446.37**	**37.21%**
External works (allowance)	m2	$	25.87	2.16%
Utilities	m2	$	14.38	1.20%
SUBTOTAL C (EXTERNAL WORKS)	**m2**	**$**	**40.24**	**3.36%**
TOTAL A + B + C	**m2**	**$**	**1,199.45**	**100.00%**

the apartment block. Modular construction methods should consider multi-criteria factors such as resources, lifecycle cost, environmental requirements, architectural quality, and functionality (Balcomb and Curtner, 2002). The analysis of infrastructure development costs starts from the preliminary to the disposal stage. The lifecycle cost for modular construction (Mao, at al., 2016) uses the following equation:

$$MLC = FC + MC + PC + CC + FMC + DC + OC \quad (1)$$

Where:

MLC = Modular construction lifecycle cost
PC = Preliminary Cost (Land acquisition cost and development fees)
MC = Management cost
FC = Financial cost
OC = Overhead cost
CC = Capital Cost (Tendering Cost, Design Cost, Prefabricated Cost, Construction Cost)
FMC = Facility Management Cost (Operating Cost, Maintenance and Replacement Cost)
DC = Disposal cost (Demolition and site clearance)

The onsite construction cost includes site preparation, substructure, super substructure, finishes, assembly, fit-out, and external works. In contrast, the prefabricated price consists of prefabrication component cost and transportation fee (Mao, at al., 2016). **Table 6** shows the modular construction unit cost model (Mills, 2017).

The cost analysis for the modular construction includes the pricing of MEP (Mechanical, Electrical and Plumbing) installation as part of the modular blocks in the manufacturing facility. MEP installation in conventional construction methods requires completing all the structural buildings. For Nusantara's infrastructure development, the government may utilise the off-site modular construction method to accelerate the provision of essential infrastructure in Nusantara. Converting the existing fabrication yard in the East Kalimantan area into a modular fabrication space will open new job markets.

5. Conclusion and Further Research

5.1 Conclusion

1. There is a high possibility of implementing the modular or off-site prefabrication construction concept for infrastructure development in Nusantara. The modular construction method provides high-quality standard infrastructure and promotes an innovative and

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Table 7. Propose decision-making criteria for infrastructure

Criteria /Sub Criteria	Option 1 - Conventional	Option 2 - Modular
CRITERIA: TECHNOLOGY		
Design Layout	One time application	Repetitive design and process
Productivity	Adaptation to onsite design	Increase productivity with automation
Quality Performance	Potentially nonstandard quality	High and uniform quality (automation)
Time Savings	Normal	20-50% time savings
Tracking and Monitoring	Manual tracking	Easy tracking by RFID [28]
Adaption to Industry 4.0	The broad range of onsite skills	80% of workers in manufacturer facility
Project delayed	Low certainty in delivery	Higher certainty in delivery
Reworks or repair	Require proper planning	Minimise reworks
Supply Chain Integration	Manual monitoring and checking	Possibility for higher efficiency (Inventory & Transportation) by using BIM
Technology	Manual handling	Automation Construction
CRITERIA: ENVIRONMENTAL		
Construction material waste	High	Almost zero material waste (JIT)
Re-use and recycling	Not applicable	High potential for re-use and recycling
Level of carbon emission	High	Low
Transportation impact	High	Higher efficiency in the transport of raw materials
Weather dependency	Depending on the site condition	Modules fabricated in a manufacturing facility
Energy Efficiency	Normal	Environmental Adaptation/Modification
	CRITERIA: SOCIAL	
Energy Efficiency	Normal	Environmental Adaptation/Modification
Durability	Unpredictable	Extended durability
New Job Market	Normal	New construction market [12]
Labour safety and well being	Normal	Promote a safer work environment
CRITERIA: STRUCTURAL AND ARCHITECTURAL		
Structural Flexibility	Fixed Location	Interchangeable/Movable
Economic of Scale	Small to Large Scale Demand	Medium to Large Scale Demand
Stability requirements	Normal	Normal
Indoor Air Quality	Normal	Normal
Installation Method	Time-consuming (depending on weather and site condition)	Modules assembly on site
CRITERIA: ECONOMY		
Capital Cost	Relatively less capital investment	High capital investment
Construction Cost	Higher construction cost	Potential reduction in construction cost
Operational & Maintenance	Relatively easy	Required special contractor maintenance
MEP Cost	Built-in separately	Included in the modular blocks
Cost per m2	US$ 1250	US$1200

Table 7 shows the decision-making criteria for selecting the infrastructure construction method.

sustainable vision. The sustainability criteria should involve all economic, social, and environmental aspects.

2. In order to ensure the successful application of the modular construction method, it is advisable to have integrated planning for the modular supply chain at all stages, including design, prefabrication, transportation, and construction with BIM software and RFID technology.
3. The authors identify several potential risks in modular construction applications, such as implementation, supply chain, structural, schedule, and investment risks. The supply chain risk also introduces difficulties in optimising the transport and logistics costs for transferring the modular blocks from the manufacturing facilities to the installations.
4. The government should engage competent contractors experienced in modular construction to mitigate all hazards. On the social side, educating the local people to adapt to smart technology will support the development of infrastructure sustainability development.

5.2 Further research

The deepening research of this study is to optimise transport and logistics cost for transporting prefabricated modules from the fabrication yard to the

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construction site in North Penajam Paser, East Kalimantan.

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