Dynamic Model in Modular Construction on High-Rise Residential Buildings Based Risk Manageability to Increase Project Performance

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Dynamic Model In Modular Construction On High-Rise Residential Buildings Based Risk Manageability To Increase Project Performance

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Abstract. Modular Construction has been considered as an effective alternative to conventional high-rise buildings. It has gained an increasing attention amount of attention over the last few decades as a way to advance sustainable construction. Besides the many benefits of modular construction technology in high-rise building construction when compared to conventional methods, the application of a modular system requires the interaction of various activities. The modular system will change the relationship between activities that were originally independent of each other (conventional methods) to become interdependent, and the potential risk will certainly occur especially in high-rise buildings. Therefore, it is necessary to do research on risk management of modular construction in high-rise building. This research is focused on high rise residential building. This study aims to analyze the factors that influence risk manageability in high-rise residential building modular construction on cost and time performance and to build risk manageability modeling using Dynamic systems on high-rise residential building modular construction projects. Sixteen indicators were extracted from the literature review and specialist interviews to conduct a sustainability evaluation. A survey was submitted to case project developers, designers, supervisors, manufacturers and contractors in Indonesia. The tentative hypothesis is that risk manageability modeling using dynamic systems in modular construction projects high-risk residential building can improve cost and time performance. finally, policy recommendations for improvement are needed.

INTRODUCTION

The number of high-rise residential buildings either under construction or in the planning and development pipeline in UK cities is rising. The boom in high-rise residential development is especially intense in London and Manchester, where clusters of cranes assembling the luxury penthouses and high-density living spaces of the future are an everyday sight on the skyline. The ‘vertical urbanization’ [1] of major UK cities is a dynamic phenomenon driven, in part, by the powerful forces of global capital [2], but one that follows trends that are already well-established in other global urban property hotspots like Hong Kong, New York, Sydney and Vancouver [3], where ‘condominium’ or ‘strata’ ownership was introduction during the 1960s and 1970s. These trends have gathered pace since the early 2000s in response to calls for dense ‘sustainable development’ coupled with rapid migration to urban centers and the globalization of the residential real estate. High-rise buildings [4], “shape the identity of cities and the urban landscape, extend the scale of cities, and change the panoramic view of the urban skyline”. It is not surprising, therefore, that a significant body of international research on the regulatory context for high-rise residential development exists, with a particular focus on how high-rise buildings and neighborhoods are planned and designed. Since the construction and design techniques for high-rise buildings emerged in Chicago during the late 19thcentury, they have become the “most visible buildings in the urban landscape” [5] As powerful forms of ‘symbolic capital’ high-rise buildings have captured the imagination of local political leaders and citizens alike [5]. This relationship between “landscape and the politician,” [6] is “well established” and local politicians in cities around the world associate high-rise buildings with economic prowess and political power, viewing tall buildings on the skyline as a means of attracting successful businesses and individuals to their city. As a result, the visibility and image a high-rise building projects is often an important factor when the cost of construction is weighed against its potential economic and social benefits [7].

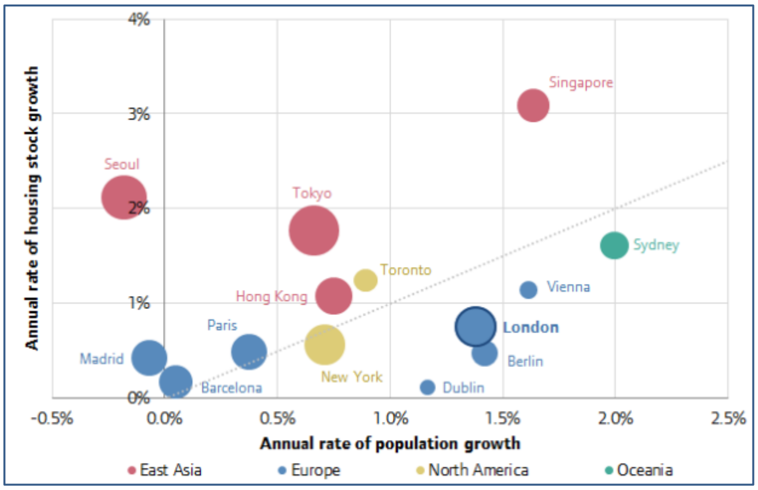

FIGURE 1. Annualized growth of population and housing stock in most recent five years for selected internationals cities

The annual rate of population growth for each city over the most recent five years available generally 2011-16 is on the X axis, while the annual rate of growth in its housing stock is on the Y axis shown at **Figure 1**. The size of the bubble represents the population of each city, while the color represents its region of the world. The dotted diagonal line represents equal rates of population and housing growth: cities above it have seen faster growth in the number of homes than in the number of people over the last five years, while in cities below its population has outgrown the housing stock. Unsurprisingly, none of these cities have seen a fall in their housing stock over this period (Dublin is closest with an annual growth rate of just 0.12%) [8]. In 2017, Indonesia committed to accomplishing Sustainable Development Goals (SDGs), incorporated into the National Development Plans as per Presidential Decree no. 59 (2017). To achieve these goals, the government of Daerah Khusus Ibukota (DKI) Jakarta encourages the implementation of the “compact city” concept and vertical development through its Regional Spatial Plan (2012). The compact city has been identified as a more sustainable approach, where intensification is supported by a good public transportation system and good city management [9].

FIGURE 2. Jakarta is highly dense, but the density mostly comes from low-rise kampung settlements, as opposed to its high-rise buildings

Jakarta is home to more than 10 million people, with an addition of more than one million daily commuters from its surrounding municipalities [10]. The city is predominantly built-up (see **Figure 3**). Despite the city's target of 30 percent urban green coverage, Jakarta's actual green coverage is only about 10 percent. On the other hand, the average population density is 14,464 people per square kilometer, mostly in the form of low-rise, high-density settlements across Jakarta, dominated by urban kampungs, the traditional neighborhood typology (see **Figure 2**). Jakarta's city centers lac relative density compared to other areas within the city.

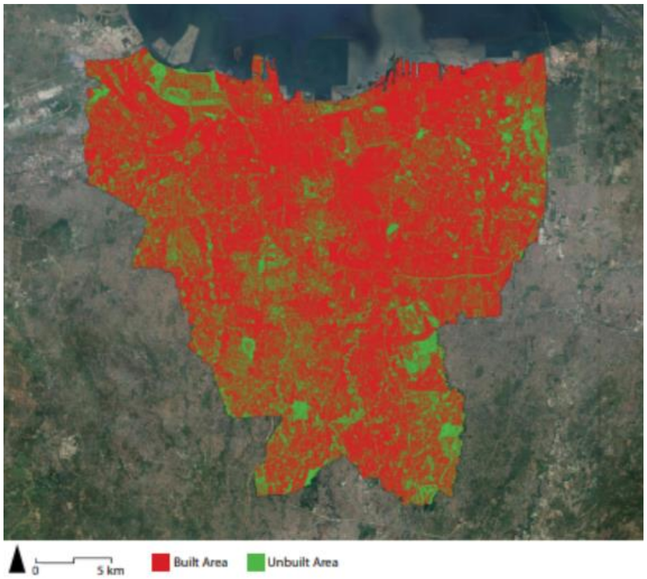

FIGURE 3. Annualised growth of population and housing stock in most recent five years for selected internationals cities

Several other factors may contribute to the complexity of land and housing provision. Skyrocketing land prices, especially in DKI Jakarta's CBD, have caused massive spikes in sales and rental prices for both residential and non-residential functions. This issue has materialized in a gap between the selling price and affordability in general, which has caused a decrease in property transactions [11]. The Indonesian real estate market is expected to register a CAGR of 17.63% during the forecast period. The demand for the housing market is expected to be driven by Indonesia's favorable demographic composition, increasing urbanization, rising per capita income of people, and a significant young population, in the country, emerging as first-time homebuyers in the next few years. Meanwhile, more developers are focusing on building affordable apartments in the mid-low segment targeting genuine homebuyers. This has also intensified the competition amongst such products and is expected to continue in the near future. Despite the rapid growth of the Indonesian property market in recent years, houses and apartments are still among the cheapest in the region. As per market estimates, the average price for a 120 sq. m property in Jakarta is USD 2,692 per sq. m, which is significantly cheaper than the prime locations in Malaysia, Cambodia, the Philippines, and Thailand. Increasing disposable incomes and migration of Indonesians to Jakarta, in search of better employment, makes Jakarta an attractive rental market for both buyers and investors. As per reports, Indonesia is amongst the list of countries where buy-to-let property earns the highest returns, with an excellent typical gross rental yield of 8.9% per annum in 2019.

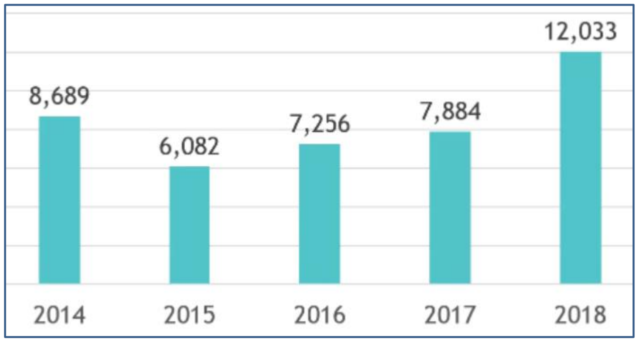

FIGURE 4. Sales of house built in Indonesia (In Units) 2014-2018

As per estimates, the residential property sales in Indonesia increased by nearly 20.15% Y-o-Y in the first half of 2018, up sharply from a decline of 34.53% in 2017. Small properties led the demand surge, followed by medium houses and big houses. In order to meet the property demand, the Indonesian government adopted several measures, such as lowering the key interest rates, giving tax incentives to Indonesian REITs, eased restrictions on individual foreign ownership, and increased loan-to-value ratios (see **Figure 4**). Among the most pressing issues that have spurred tall building development and will likely continue, is the exponential increase in urban population worldwide in conjunction with wealth accumulation. Currently, almost half of the world is urban when 20 years ago it was only one-third. By 2030, it is expected that about 60% of the world's population will be urban. In 2050, over 80% of the world population will live in urban areas when the world's population is expected to reach 9 billion. At that time, all major cities of the world, particularly those in Asia, Africa, and Latin America, will have enormous populations, probably ranging from 30 million to 50 million, or more [14]. Accommodating such a large population in cities will be a colossal challenge. Horizontal scale of cities is continually being strained with no alternative but to build upward to accommodate people. Rural-to-urban migration is one of the causes of urban population increase. Between 1945 and 1985, the urban population of South Korea grew from 14.5% to 65.4%, and to 78.3% of the total population by 2000. In China, it is projected that by 2025, 350 million people will migrate from a rural to an urban environment. Marcos Fava Neves predicted: "This will require five million buildings…equivalent of ten cities the size of New York" [15]. In other words, Chinese cities need to build to accommodate a population increase equivalent to the U.S. population in just 13 years. In such cases, high-rise development is almost certain to be part of the solution.

Land prices always have been a prime driver for constructing tall buildings. A phrase for skyscrapers came from Cass Gilbert in 1900, "A skyscraper is a machine that makes the land Buildings 2012, 2 393 pay" [16]. In large cities, properties are very expensive, and buildings logically grow upward. Low land costs clearly keep buildings closer to the ground; tall buildings are not an attractive option for small towns where land is cheap. Carol Willis has coined the expression "form follows finance" in which she argues that the economics of tall buildings play a key role in shaping a tall building [17]. Land prices recently have been significant drivers for tall building development in many cities seeking to re-populate their urban centers with residential-recreational complexes inserted in the predominantly commercial-retail Central Business Districts (CBD). These relatively new markets help drive up city center land prices, which makes building tall for investment return increasingly necessary. In the City of London, land prices are among the highest in the world, and great economic advantages exist for developers to maximize the rentable floor space of an area of land by building high. Consequently, London has witnessed a recent boom in tall building construction. In cities like New York, Hong Kong, and Singapore, there is hardly any choice other than to build tall because geographic boundaries limit horizontal growth. In Singapore and urban Hong Kong, land prices are so high that almost the entire population lives in high-rise apartments. Of Hong Kong's total expanse of land, only around 25% is buildable; and yet it needs to house some 7.5 million inhabitants. Land value is unbelievably high, in the range of $30,000 per square meter, and therefore, developers maximize the site by building very tall buildings, between 50 to 80 floors [18]. In the case of New York, Rem Koolhaas, in his book Delirious New York, explained that Manhattan has no choice but extruding the city grid vertically [19]. Similarly, in Mecca, Saudi Arabia, land nearby the Sacred Mosque (Al-Masjid Al-Haram) is limited and extremely expensive and, therefore, has recently witnessed significant high-rise development, including the ultra-tall 95-story Abraj Al-Bait Towers.

Modular Construction In High-Rise residential building

Modular construction has been widely used for low-rise buildings worldwide [20], particularly in UK [21], North America [22], China [23–24], Singapore [25] and Australia [23,26. Despite the technical challenges in implementing modular construction technology in high-rise buildings, several modular high-rise buildings have been built in recent years due to advancements in manufacturing and material technology. However, the number of modular high-rise buildings worldwide is still limited (less than 1%) [27]. Only ten of the world's tallest modular buildings were reviewed herein as summarized in Table 1. Most of the modular high-rise buildings built with 3D volumetric modules are based on steel, whilst concrete is commonly used in modular high-rise buildings built by a combination of penalized and volumetric methods. Although adopting modular building techniques slower in Australia than international counterparts in North America, Europe and Asia, the Australian construction industry is now experiencing rapid growth in modular construction [28]. This is evidenced by the fact that four out of ten of the world's tallest modular buildings were constructed in Australia in the last five years as shown in Table 1. Notable among them is Collins House in Melbourne which currently sets a new record as the world's tallest modular building with 60 storeys.

(a) Core [32] (b) Podium [33] (c) Infilled frame [34].

FIGURE 4. Construction methods for modular high-rise buildings (a) Core [32] (b) Podium [33] (c) Infilled frame [34].

Modular prefabrication helps improve sustainability in construction and provides environmental benefits [12,13]. However, most studies have focused on the life cycle building performance as a whole, and no one has explained that risk management can improve cost and time performance. The interviews were completed at a face-to-face conference. Finally, 16 indicators were selected for the indicator system: five indicators belong to the economic dimension, including cost savings, construction time, labor reduction, executing costs, and weather disruption; six indicators belong to the environmental dimension, including site disruption, construction waste, pollution generation, energy consumption, water consumption, and formwork consumption; and five indicators belong to the social dimension, including constructability, health and safety risk, construction quality, aesthetic options, and labor availability.

Table 1. Survey distribution and responses.

Respondents	Number of Responses		Percentage (%)
	Sent-Out	Valid Response	
Developers	8	8	15.69%
Designers	9	9	17.65%
Superintendents	7	7	13.73%
Manufacturers	11	11	21.57%
Contractors	16	16	31.37%

Table 2. Risk Manageability Factors

Dimension	Indicator	Brief Descriptions	Reference
Economic	Cost savings	The reduction of costs including labor, materials and machinery equipment fees	[1,2,3]
	Construction time	Total duration of construction from planning to project delivery.	[1,2,15]
	Labor reduction	The amount of labors used on site	[1,2,3]
	Labor reduction	The amount of labors used on site	[1,2,3]
	Executing costs	The costs of construction activities' execution and operation on site.	[16,43]
	Weather disruption	Total duration of schedule delays due to adverse weather.	[1,15,39]
Environmental	Environmental Site disruption	Construction activities influenced by labor, materials, machineries equipment, and environment on site	[1,2,15,]
	Construction waste	The amount of construction waste produced on site Pollution generation Pollution level on site (e.g., noise, dust, etc.)	[1,2,15]
	Energy consumption	The amount of diesel and electricity used during the construction phase.	[1,3,15]
	Water consumption	the amount of water used on site.	[1,3,15]
	Formwork consumption	the amount of formwork used on site.	[1,2,3]
Social	Social Constructability	The difficulty degree of construction	[1,2,15]
	Health and safety risk	Risks of health and safety issues in the workplace (e.g., injury, fatality, etc.).	[1,2,15]
	Construction quality	The quality and durability of building (e.g., fewer de-bonding tiles and water leakage).	[15,23]

Aesthetic options	Visual appearance of internal and external of the building.	[1,2,15]
Labor availability	The amount of available labor to need.	[1,15,39]

Risk management and control are important to do so that the project targets are still within the established corridor. Currently there are several journals that discuss control indicators on likelihood and impact, but these indicators are not yet clearly related to risk parameters. Definition of Risk Manageability can be defined as follows:

a. Risk Manageability is the capacity to reduce the possibility and or impact of negative risks.

b. Manageability is defined as the ease with which risk owners can manage the events or impacts of a risk. When management is easy to deal with, then high manageability.

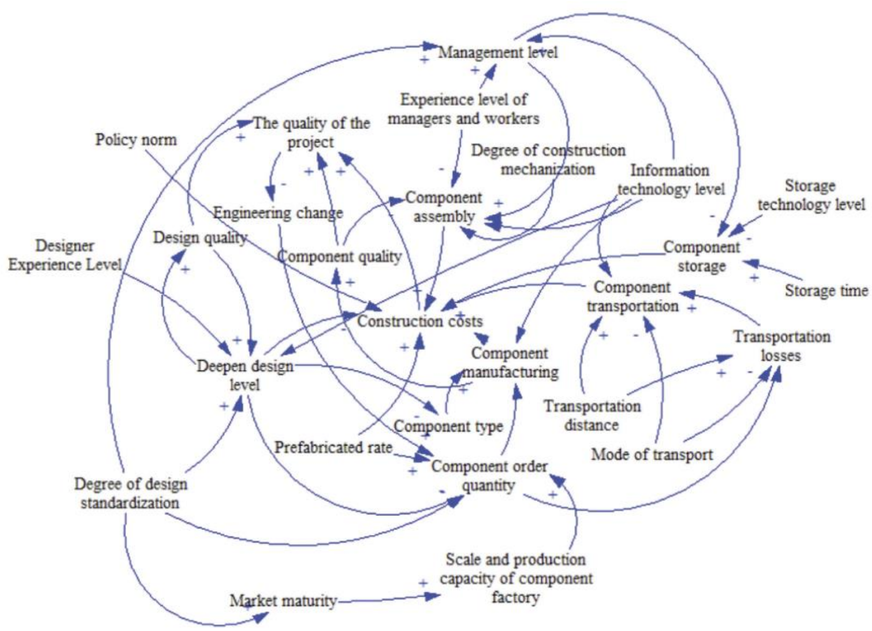

FIGURE 5. System Dynamics Modeling of Prefabricated Buildings

Methodology

This research consists of 5 stages, in stage 1 is to conduct a literature study from previous research related to modular costruction to obtain the main aspects of the application of residential high-rise. Phase 2 is to conduct interviews with modular construction Developers, Designers, Superintendents, Manufacturers, Contractors. This is to justify and validate the main aspects that have been obtained from the previous literature review. Phase 3 develops a questionnaire based on the main aspects that have been determined and these aspects are described with indicators of the application of risk manageability in modular construction on residential high risk poject based on the literature and . These indicators become research variables which are measured using a Likert scale as the measurement scale. Stage 4 conducted a survey by distributing questionnaires to obtain data on perceptions of modular constrcution regarding the application of modular construction concept to risk manageability. After that, stage 5 is the processing of the survey results. The results of the survey questionnaire are then interpreted using descriptive analysis and Cartesian diagrams to see the position of the variables in the priority quadrant. Based on the main factors and sub-factors risk manageability, then modeled in the Dynamic System to see the influence of the interrelationship of these factors. With this System Dynamic modeling, it can be seen modular construction projects high-risk residential building can improve cost and time performance. which is shown in Figure 6 below.

FIGURE 6. Modular construction based Risk Manageability on System Dynamics Modeling

Results and Discussion

What are the factors that affect Risk Manageability in modular construction projects in high-risk residential projects on cost and time performance? Changes in Design, Geological Conditions, SD modeling is necessary, Use of dynamic systems in the project organization is necessary, There is also resistance to the use of models, There are problems in project management, Readiness of owner funds, Increase in foreign exchange rates, Owner's needs, Organization & owner culture, Fulfillment of other needs, Fulfillment of other needs, Changes in owner's needs, Material quality, Low supervision. How is Risk Manageability modeling using dynamic systems in modular construction projects in high-risk residential? Risk Manageability modeling can be modeled. What are the results of the Risk Manageability modeling simulation using dynamic systems in modular construction projects in high-risk residential? The simulation results of risk manageability modeling with dynamic systems show risk simulation without any treatment from factors with time overrun and with the highest simulation results.

Conclusion

From the results of the research that has been carried out, several suggestions can be given, namely that it is hoped that further research can be carried out on the implementation of the use of dynamic system methods and risk manageability for case studies on modular construction projects in residential high-risk buildings with different characteristics. The results of this study are expected to be used as the basis for the operations of construction companies to take corrective actions in terms of cost and time performance.

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