Modeling Land Use in Megacities under Deep Uncertainty: The Case of Jakarta

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As the capital city of Indonesia, Jakarta's population number keeps increasing; thanks to the city contributes to a significant portion of economic activities of Indonesia. Accordingly, some trends can be observed in Jakarta. Firstly, despite the trend of decreasing average house prices in Indonesia, the average housing price in Jakarta kept increasing and remains the highest in Indonesia. Secondly, the combination of land scarcity and increasing house price affects the accumulating growth of slum areas which are built illegally in the non-private lands. Meanwhile, the need to develop more green spaces is growing due to increasing transportation-induced pollution. Finally, as a city with highest money circulation rate in Indonesia, it is necessary to consider the land use portion for improving the city economic growth. Therefore, land use division can lead to policy dilemma with respect to economic development, housing affordability, and environmental sustainability.

In this research, the focus is set on investigating land use allocation policy for improving urban settlement indicators in Jakarta. An exploratory system dynamics (SD) model for 40-year time span (year 2010-2050) is developed to analyze the development of urban land in Jakarta over time; addressing the availability and affordability of settlements in Jakarta over time while considering plausibility of land optimization for sustainable city growth with respect to the economy and environment.

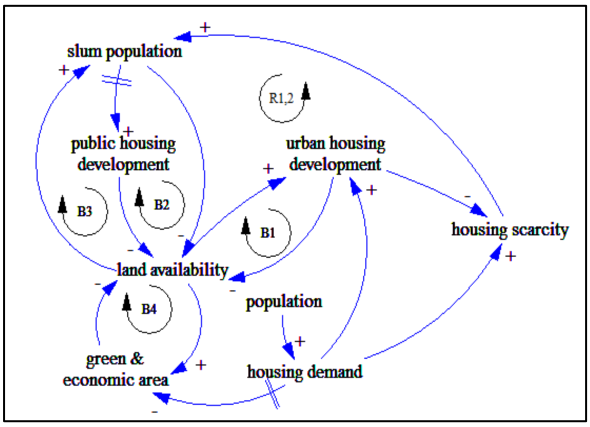

Figure 1. Causal Loop Diagram

The conceptual model for the study is shown in Figure 1. Two of the feedbacks are reinforcing loops (R1 and R2), which are related to the growth of slum areas and public housing development. Also, negative feedbacks exist, which are associated with multiple land requirements and limited land availability.

Based on Figure 1, stock-flow model is developed to inform the long-term condition of settlement, environment, and economic indicators over time; given the current development plan and population growth rate. The result implies that the urban settlement indicators may indeed face long-term risks. This confirms the need for land use policies to consider fulfillment of these objectives, altogether with the other relevant indicators.

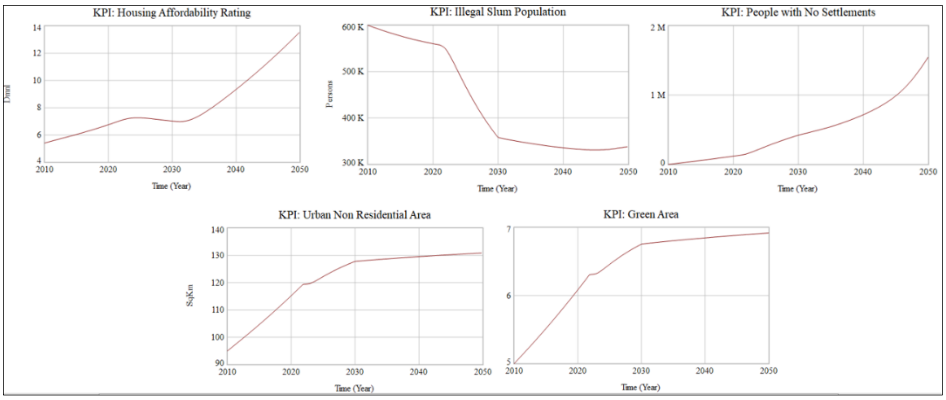

Figure 2. Base-case result for the KPIs (Key Performance Indicators)

Taking into account the uncertainties of parameters defined in the model, vulnerability analysis is performed using Scenario Discovery technique; which identifies the subspaces of uncertainties producing undesirable outcomes throughout the time span.

For this, the model run is divided into two time periods: 2010 – 2030 and 2010 – 2050, with following reason. This is to consider the possibilities to tailor the policies for short term period, i.e. until 2030, while having the strategic policies in place for the entire study period. Also, it is argued this mechanism can intrinsically reduce the required policy costs while maintaining the fulfillment to the objectives optimization. The result is shown in Figure 3. Given different uncertain variables affecting the KPIs, this justifies the proposition of treating the policy implementation separately for the two time zones.

Time-Period	KPI	Vulnerability Threshold	Key Uncertainties	Vulnerability Range
2010 - 2030	Housing Affordability Rating	>7	Average payment to Income ratio for housing	0.32 – 0.5
			inflation effect to housing price	0.01 – 0.067
	Illegal Slum Population	>20000	Base Slum reconversion rate	0.01 – 0.038
	People with No Settlements	>800000	average Immigration rate	0.025 – 0.06
			Base Slum reconversion rate	0.02 – 0.06
	Urban Non-Residential Area	<115	Average Immigration rate	0.025 – 0.06
			Base Non-Economic Reconversion Rate	0.016 – 0.05
	Green Area	<7	Base Economic Area Conversion rate	0.036 – 0.06
2010-2050	Housing Affordability Rating	>13	Average payment to income ratio for housing	0.45 – 0.5
	Illegal Slum Population	>20000	Base Slum reconversion rate	0.01 – 0.038
	People with No Settlements	>2000000	Average Immigration rate	0.015 – 0.06
	Urban Non-Residential Area	<115	Average immigration rate	0.025 – 0.06
	Green Area	<6	Base economic Area Conversion rate	0.029 – 0.06
			Base Green Area Conversion Rate	0.02 – 0.054

Figure 3. Scenario Discovery result for two different model time spans

Table 1. Identified policy parameters based on the result in Figure 3

Policy Parameters	Levers
High Rise	Floor area ratio
Slum Revitalization	Slum area reconversion rate
Accelerated City Growth	Green area reconversion rate
Inflation Targeting	Economic area reconversion rate
Relocation Area Development	Relocation rate, relocation housing factor
Housing Subsidy	Household expenses for housing purchase

Aligned with the vulnerability investigation, policy levers specific to land use mechanism are identified from literature review and interview; altogether with their associated parameter contexts. Table 1 specifies the result. Thereafter, using ε-NSGA-II algorithm, the time-based many-objective optimization is analyzed. The analysis results in Pareto-optimal set of policy outcomes, which is shown in Figure 4. It is assumed that all policies start post-2020, considering the nature of policy planning phase.

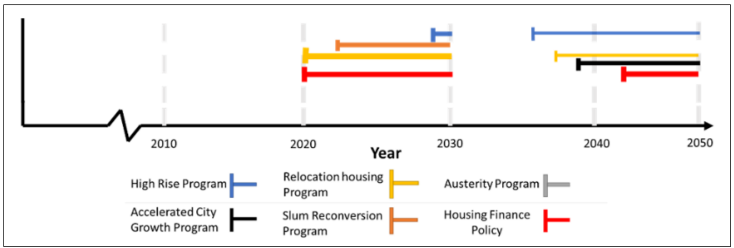

Figure 4. Summary of the candidate policy set

This optimized policy set is then exposed to the uncertainty analysis, which shows that the Housing Affordability Rating and Urban Non-Residential Area still have higher variation in the outcomes relative to the other KPIs (Figure 5). This implies that trade-off nonetheless still exists among the land use indicators. Therefore, vulnerability analysis is once again performed to identify other plausible measures tackling these unintended outcomes. The result in Figure 6 shows in the long term, even after the different policy programs are combined, the influx of the population into the city plays a key role to aid the trade-offs.

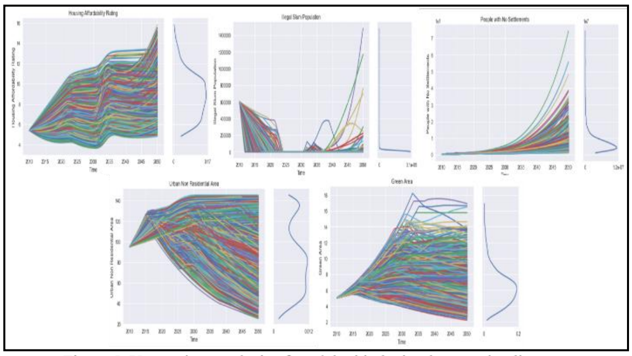

Figure 5. Uncertainty analysis of model with the implemented policy set

All in all, two recommendations can be provided. Firstly, no single policy can be seen effective in handling the current situation in Jakarta. Accordingly, the adaptive approach, in which combination of policy measures is implemented in phases, is recommended. Secondly, given the implementation of the integrated policies, trade-off nonetheless still exists among the land use indicators. Addressing the growing population influx to Jakarta without hindering its socio-economic growth may provide sustainable remedy to the issue.

KPI	Vulnerability Threshold	Key Uncertainties	Vulnerability Range
Housing Affordability Rating	>7	average payment to income ratio for housing	0.32 – 0.5
Illegal Slum Population	>20000	Base Slum Reconversion Rate	0.01 – 0.045
People with No Settlements	>800000	Average Immigration rate	0.015 – 0.06
Urban Non-Residential Area	<115	Average Immigration rate	0.029 – 0.06
Green Area	<6	Base Economic Area Conversion rate	0.027 – 0.06

Figure 6. Vulnerability analysis result of the policy set

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