Modelling the spatial decisions of private developers: A case study of Jakarta Metropolitan Area, Indonesia

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Abstract

Urban models are important tools for planners in their capacity to offer insight into future urban growth. However, the majority of urban models overlook the role of developers' behaviour in capturing the growth of urban residential spaces. This paper redresses this gap by embedding the spatial consequences of privately-driven urban residential development on selection of potential land and their impact on land prices within an agent-based model. Jakarta (JMA), Indonesia forms the case study context. Results from the model highlight the emergence of new urban areas on the JMA's fringe that are strongly tied to land value. The model offers potential to offer new insights into the relationship between land cover and land prices and the role of developers' decisions in shaping the expansion of residential areas.

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1 Introduction

The expansion of urban residential areas has shaped the face of cities worldwide (Taubenböck et al., 2014). The transformation of non-urban areas into residential areas allied to the construction of urban services (school, hospital, and business district), and supporting infrastructure (street, power and water line) has expanded the size of cities from only few kilometres in the early 1900s to hundreds kilometres in recent decades (Taubenböck et al., 2014). To ensure sustainable urban expansion and to pre-empt the adverse impacts of urban residential expansion, there is a need to better understand the cause and impact of urban expansion. Urban models are conceived in a manner to capture the complexity of urban systems through the augmentation of the key characteristics that drive urban growth and change.

A variety of approaches to urban modelling have been developed with the capacity to simulate changes in urban growth and form. The variation of approaches from mathematical notion, to cellular automata (CA), and agent-based modelling (ABM) has been mainly influenced by the introduction of complex theory and artificial intelligence (Silva & Wu, 2012). The improving power of computer technology expands the ability of CA and ABM to simultaneously handle more than two factors influencing urban growth and changes. In the early period (1994- 2000) of these modelling approaches, factors considered to influence urban growth and change include physical, social, and economic. More recently, the view of urban modelling has shifted such that in addition to physical, social, and economic factors, scholars have suggested that urban growth and changes are triggered by bio-physical factors or in other words human behaviour (Lambin et al., 2001). More specifically, human behaviour include behaviours, decisions and actions as they relate to residential development by developers (Ligtenberg, Wachowicz, Bregt, Beulens, & Kettenis, 2004). Nevertheless, with the integration of human factors within urban models has been the subject of relatively little study and in particular when considering residential areas in the megacities of the developing world.

Study on residential area in megacities of developing world is importance for two reasons. First, past studies in urban modelling concentrated on the parcel base or city-scale and give less attention to region-scale cases. Current researches on the extent of urban area around the world suggest that the vicinity of the urban area has spilled over city's administrative boundary (Seto, Guneralp, & Hutyra, 2012; Taubenböck et al., 2014) and thus urban studies with cross-municipalities becomes crucial to improve coordination among municipalities. Secondly, the nature of data scarcity in developing country that called for alternative methods to address data scarcity problem. Given little attention by urban scholar in these regions and the fact that they will become home of 80 percent world urban population, more attention on urban modelling should be drawn in these regions (UN-DESA, 2014).

In light of above research gaps, the aim of this paper is to develop an urban model that adopts an Agent-based Modelling (ABM) approach to simulate the growth and change of urban residential areas. More specifically, this study examines the consequences of privately-driven urban development on the spatial designation of urban areas along with the fluctuation of land prices that follow changes in land cover. The case is drawn upon Jakarta Metropolitan Area (JMA), Indonesia; the 10th largest megacities in the world, and the biggest in Southeast Asia region (Jones, 2002; UN-DESA, 2014). Urban area of JMA grows at the pace of 80 km2 per year (1.11% of original size) between 1994 and 2012. The urban growth in JMA is among the highest in the world after Mumbai (2.17 %), Manila (2.03%), Lagos (1.52%), and Seoul (1.51%) (Barredo, Demicheli, Lavalle, Kasanko, & McCormick, 2004; Taubenböck et al., 2012).

The remainder of the paper is structured as follows: Section two discusses the theoretic framework underpinning the developers' behaviour that will be embedded within the urban model. Section three describes the key components and development of the model. Section 4 presents and discusses the results of the model simulations, whilst the final section offers some tentative conclusions limitations along with avenues for future work.

2 Background

This section presents the link of this study with past urban studies. This section has two parts. The first part explains the factors that influence the development of residential areas and the description of the developers' motive and behaviour on land acquisition both in the developed world context and in Indonesia (developing country). On the second part, a cost analysis model from developers' perspective is laid and explained.

2.1 Factors impacting urban changes

In the early 1940s and 1960s, the urban models proposed by Von Thunen (agricultural land theory), Burgess (concentric model), and Alonso (urban spatial structure theory) suggested that the factors influencing the location of residential areas were transport costs and distance to the city centre (Alonso, 1960; Getis & Getis, 1966; Ullman, 1941). Despite the hypothetical monocentric and unlimited land assumptions made in these models, they were widely accepted by urban researchers and largely been used for foundation on various urban modelling studies (Barros, 2004; Sietchiping, 2004). In the last three decades with the involvement of computer technology, urban modelling has evolved to extend the number and breadth of factors that drive urban growth and change. Factors such as slope, existing land cover, the elevation, and the angle of the area were used in numerous urban models between 1990–2000 (Wahyudi, 2013), but more recently, the addition of socio-economic factors has been increased in urban models (Dawn Cassandra Parker & Filatova, 2008). Population number, the size of household, and the income are the instances of socio-economic factors adopted in urban models. The combination of physical factor and socio-economic as the main urban driving factors has been challenged by other scholars who argue that urban expansion is not an endogenous process (O'Sullivan & Torrens, 2001). Urban system requires external stimulation to expand its urban area. The addition of bio-physical factor – that is the human – that responses to its surrounding is the key factor in urban system (Lambin et al., 2001).

In the context of urban residential development, the bio-physical factor (hereafter mentioned as development actors) that influences the development varies. They could be the government, the developers, or the house buyers. Of various development actors involved in urban residential development, the private developers have always the most important actor in the urban development process (Morgan & O'Sullivan, 2009). Especially in developing countries, the absence of government intervention in spatial planning has promotes the private developer to take the role as the primary actor in the expansion of urban residential area (Firman, 2004).

The motive behind every action and strategy taken by developers to acquire land are founded upon economic motives (Bookout, 1990). Developers wish to derive the greatest profit through the investment of funds into new residential development at the lowest possible cost (E. J. Coiacetto, 2000; Gillen & Fisher, 2002). Accordingly, the selection of land reflects the developers' view on occupying the best possible area for maximizing the profit.

Shifting the focus to JMA, though much of the developer behaviour in Indonesia is common to their counterparts elsewhere in the world, especially in regard to their economic motives, behaviours are differ given that spatial planning is weaker (Winarso, 2000). While in developed country the government impose a strict regulation upon developers through spatial planning, in Indonesia, the developers have greater flexibility to influence planning agency in municipalities (Firman, 2004; Winarso, 2000). For example in obtaining the location permit, the developers often negotiate with planning agency to modify the spatial planning to accommodate their goal to develop the area where it initially unmarked for development in spatial planning document. Secondly, the potential buyers have no insight on how land and house's prices are formed, thus they have no control and influence on the formation of land price. In JMA, formation of houses and land prices are heavily monopolized by groups of large developers (Winarso, 2000).

2.2 Cost analysis model by residential developers

The developer bases their decisions and action according to rational economic behaviour wherein maximization of profit is always the main priority. Before any decision to purchase and develop an area for new residential development was taken, the developers perform a cost analysis to guarantee the profit is achieved. In a generic cost analysis, the developer assesses the component of development cost such as land prices of the targeted sites, site clearance costs, and road construction costs (Bookout, 1990; Winarso, 2000). In parallel, the developers need to secure the capital to fund the development project and measure the expected selling prices on the targeted location. The relation among components in cost analysis in detail is displayed on Figure 1 and Equation 1 whilst each component in cost analysis will be briefly explained in the following paragraphs.

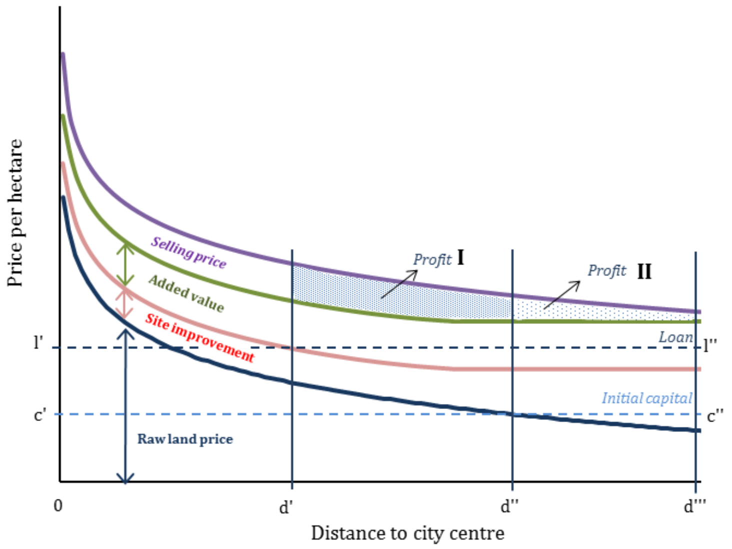


Figure 1. A cost analysis model from the developers' perspective; adapted from Winarso (2000).

The blue curve represents the raw land price *f(rlp)*. It is depicted with a decayed line pattern as indication of high land price in the CBD and ceases down as distance further from CBD. The pink curve represents the cost of site improvement which includes land clearing *f(land_cover)*, and road construction *f(dist_road)*. The cost of site improvement increases with the distance of city centre. The added value of a site after site improvement equals to 120-150 percent of raw land price (green curve) after site improvement (Dowall & Leaf, 1991). The purple line represents the expected of selling price as a distance function of the area from CBD *f(dist_cbd)*

- *The profit*

The developer gains the profit when there is a positive difference in selling price and total cost incurred for site improvement as formalized in Equation 1 below;

$$R_x = max\{(sp_x - (ac_x + id_x)|capital)\} \qquad \text{Equation 1}$$

where Rx, profit in location x, comes from a maximization of the expected selling price (sp) after land acquisition cost (ac), and infrastructure development (id). The maximization of profit is conditional to capital owned by the developer. The elements in Equation 1 are the function of physical factors as represented in Equation 2 below,

$$sp_x = f\,(dist\_cbd) \qquad \text{Equation 2}$$
$$ac_x = f\,(land\_cover)$$
$$id_x = f\,(dist\_road)$$

where the expected selling price (sp) is a distance function of an area from the CBD. The land acquisition cost (ac) is a function of land cover classes, and infrastructure development (id) is a distance function of an area from the toll road.

In Figure 1, the expected profit can be derived from either Profit I or Profit II. But as the maximization of profit is the target, the developer give priority to purchase area within d'- d" distance from the city centre where the expected profit is higher than of the area on d"– d'". Areas on d'– d" generate greater profit (Profit I) than d"– d'" because the former sits closer to city centre (Jakarta's CBD) where demand of new houses is higher than the latter.

- *The capital*

In Figure 1, the capital owned by developer is exemplified by the dotted blue line. Having only initial capital (*c'– c"* light blue dotted line), the developers' ability to purchase land is limited only on the area within *d"– d'"* from the city centre. The developers have no additional fund to improve the site through infrastructure installations; thus no profit can be generated in this situation. In the situation where developers decide to add loan into their initial capital (*l'– l"* dark blue dotted line), they have a flexibility to purchase the areas and perform site improvement. The site improvement increases the values of the purchased areas and if the developers decide to sell them, the purchased areas will generate option of profit for the developers. Taking additional funds from investors is a common practice for the developers not only to boost the capital but also to share the profit and in certain cases, losses (Bookout, 1990). The amount of loan reaches up to 75 percent of the initial capital (Winarso, 2000). The combination of initial capital and loan increase the ability of the developer to purchase land and develop the land into new urban area (Figure 1).

From a brief explanation in this section, it is clear whilst physical factors influence urban expansions; the bio-physical factor is the one who actuate the development. In the case of residential development in JMA where spatial planning is weakly implemented, the developer as the bio-physical factor plays the dominant role in actuating the residential development. The way developers approach the development through cost analysis to maximize the profit will be represented in each module on agent-based modelling in the following sections.

3 Materials and methods

3.1 Study area

The selected study area of Jakarta Metropolitan Area (JMA), Indonesia has area about 6400 hectare (ha) with 28 million inhabitants in 2010 (URDI, 2012). Like many megacities in developing countries, JMA has multi-faceted issues with its spatial planning. One in particular is in the implementation of its master plans where they rarely been referred as guidance to issue the permit for urban development by local municipals (Winarso, 2000). The lack of planning and commitment by city's majors has been seen by the private developer as a loophole to influence the decision of location permits; especially in the targeted areas where the developers ready to invest their capital. The influence of large-capital developers in spatial decision process can be indicated by the type of residential in JMA. Unlike in other developing countries where low-income settlement drive the majority of urban expansion in the megacity (Barros, 2004; Sietchiping, 2004), the urban residential expansion in JMA has been driven largely (> 60–80 percent) by medium-to-high income residential developments, which according to Susantono (1998) do not comply with municipals' spatial planning. The weak implementation of spatial planning prompts JMA with an irregular pattern and chaotic hierarchy of its urban areas. The unprecedented growths of urban area by large capital developer mainly focus on providing excellent infrastructure on their own cluster and ignoring the structure and pattern set on master plan. In the last two decades, the residential growths in JMA have been tremendous that it has spilled over Jakarta's administrative boundary and triggers high transportation cost and rising land prices around these new urban areas (URDI, 2012).

3.2 Overview of agent-based urban model

This study implements an Agent-based Model (ABM) in representing the development's actor and its actions. ABM suits best to simulate the diversity of agent's action and agent's interaction to its 'environment' (Malanson & Walsh, 2015). In a typical urban ABM, the model consists of three modules; the agent, the environment, and the interaction module. The three modules interact to each-others as defined by the modeller based on empirical data or conceptual framework. The environment module was based on the transformation of the study area into pixel. The study area was converted into pixel of 300 meters' resolution; equalling 9 ha area per pixel with total pixel of 337 x 370 pixels. The pixel size was based on the interest large developers (defined in the agent module) interested at least with 100 ha land. The models represent the specific period of urban development in JMA between1994 and 2012; the period where Indonesia's economic slump when the economic crisis crippling in the national economy in 1998 and the recovery period indicated by the boom of property industry in 2000.

The model was constructed in NetLogo. NetLogo is an agent-based programming tool with high-level codes that readable and can implement agent behaviours with relatively less codes than others ABM tools (Wilensky, 1999). The NetLogo has rich tutorial models, and strong users' community to support the learning process for first-time users. The model in NetLogo is scalable in that addition of agent behaviours can be implemented without changing the overall structure of the model. The simple interface and commands that NetLogo has allow this study to refine the parameters' values at the demand of the users. The following sections describe each module in the model.

3.2.1 The agent module: developers

The agent module represents the behaviour of residential developers in targeting a land for the new residential development. While type of developers may vary based on the capital owned and the spatial operating scale of the developers (E. Coiacetto, 2001; Morgan & O'Sullivan, 2009), we selected "large developer" to be represented in the model. The characteristics of large developers are the following (E. Coiacetto, 2001; Morgan & O'Sullivan, 2009); (i) large developers have an ability and resources to cover the entire of metropolitan area, (ii) they are less concerned on the influence of one local municipality and seek opportunities within cross municipality, (iii) they have long history in practice (more than ten years of operation in the area), (iv) large developers have options to compare the profit between potential sites, and (v) correct timing to launch the development into market is less of a concern.

The above characteristics were reflected in the initial values of agent's parameter in the model. In addition, in JMA the preferred size of development ranges between 100 to 500 hectare (Winarso, 2000). The ability to secure a capital from more than one source including foreign investment as well as from Indonesia stock exchange was represented with loan capability of maximum 75 percent of initial capital. Randomness in capital was introduced to vary land purchasing ability between developers' agent.

3.2.2 The environment module: land cover and land values

The environment module contains four major variables; (i) the land cover of JMA in 1994, (ii) estimated land prices, (iii) the distance of a pixel (in km) to Jakarta's CBD, and (iv) the distance of a pixel (in km) from toll roads. The following explains how this study defined and derived the variables.

- *Land cover*

Land cover of JMA was derived from Landsat images on previous study. The model starts with land cover of 1994. Land cover classes determine the cost for site clearing. An area with existing building cost more to clear for new residential construction than of the vegetation area. While it is not impossible to convert the existing urban area into residential area, the cost was assumed to be very high. The site clearing cost is assumed to be 1.5 times of land values for high-density urban area, and 1.2 for low-density urban area. Land covers map changes dynamically as a result of the developers acquiring the land and develop it.

- *Land prices*

According to Bookout (1990) more than 50 percent of cost component is to purchase the land. Thus, land price is the biggest concern for developers and immediately triggers response on the developers' spatial decision. In JMA, no systematic data on land prices has been successfully recorded by government agencies. The main agencies that provide the data, in the form of Land & building Tax Imposition Base or Nilai Jual Objek Pajak (NJOP, in Bahasa Indonesia) are municipal tax office and municipal land agency. Data from both tax offices and land agency, however, are incomplete, as they cover only the CBD of Jakarta or less than a third of Jakarta area.

With the lacks of reliable data on land prices, a reconstruction of hypothetical land prices were done using a combination of median land value by Dowall and Leaf (1991) with the actual land prices on 130 points in JMA based on marketed prices from the online sources. The initial median land values from Dowall and Leaf (1991) were digitized, standardized onto 2014 land prices, and combined with land values of other areas from online sources. Land values in form of data points were converted into surface map using interpolation technique (spline) in ArcGIS.

- *Distance from toll road*

Accessibility in the form of the distance of an area to the toll road is another important factor for developer in searching the potential land. The influence of road on cost by the developer forms a decayed curve as a function of distance from the road (Dawn C. Parker & Meretsky, 2004). In Indonesia, developer sees the distance from the toll road as both a way to promote the image of their new development and a function of development cost as he needs to construct the road and improve the accessibility (Dowall & Leaf, 1991). In the model, an area with no direct access to toll road costs more than the area near to toll road We assumed that the cost for road construction per kilometre ranges between 15 billion Indonesian rupiah (IDR) for area < 6 km or 4 minutes driving distance from toll road and increase to 20 and 30 billion IDR on area with 12 and 18 km distance from toll road, respectively. This assumed construction cost was based on the material and labour costs for infrastructure construction project in Indonesia.

- *Distance from Jakarta's Central Business District (CBD)*

While this study does not explicitly represented the demand of new residential area from the potential buyer, it is assumed that the developers could sense – based on their previous experiences – the new location within less than 1 hour driving to working place (Jakarta) is much sought after area by the potential buyers. This assumption comes from the fact that despite effort by the central government to relocate numbers of its central government office to peripheries of Jakarta, the large portion of offices, head-quarters of national and multi-national companies still sits in the CBD of Jakarta. The agglomeration of workplaces in CBD of Jakarta attracts a high degree of JMA's population to commute from them Jakarta's peripheries to CBD (Hakim & Parolin, 2009). It is thus, having a house close to CBD will help Jakarta's worker to travel shorter to workplaces.

Furthermore, distance to the city centre influence the marketability of a land prepared by the developers. The closer area of development to city, the more customers are looking to buy the houses (Bookout, 1990).

3.2.3 The interaction module: profit oriented behaviour of developer and its spatial impact

The third module of the model is the interaction between the agent (developer) and the environment. In similar vein with what Ligtenberg et al. (2004) proposed where the agent observe the situation before taking a decision, the interaction module consists of developers' assessment on raw land price and then taking the decision to purchase and build new residential area based on their capital. Based on the maximisation of profit, the developers follow three steps of finding, assessing, and developing the land.

The model acts according to the following procedures (pseudo code).

i. Assign to each developer the initial capital and additional capital from external loan to start the land searching process.
ii. Given the developers' capital, assess the expected profit on land development process. This brings to possible ranges of land prices that can be secured.
iii. Start land searching with the lowest land price.
iv. If land is found, assess the site improvement and road construction cost of current land and neighbouring land. Check if the total cost exceeds the capital.
v. Decide whether to abandon or develop the site based on (i) the capital owned, (ii) total development cost, and (iii) potential profit.
vi. If taking the development decision, update the land cover into new urban area and increased land prices in the area and neighbouring areas.
vii. Update the developers' capital by reducing it with the total development cost.
viii. When all area has been assessed, then stop.

The entire procedure of find-assess-develop process is depicted in Figure 2.

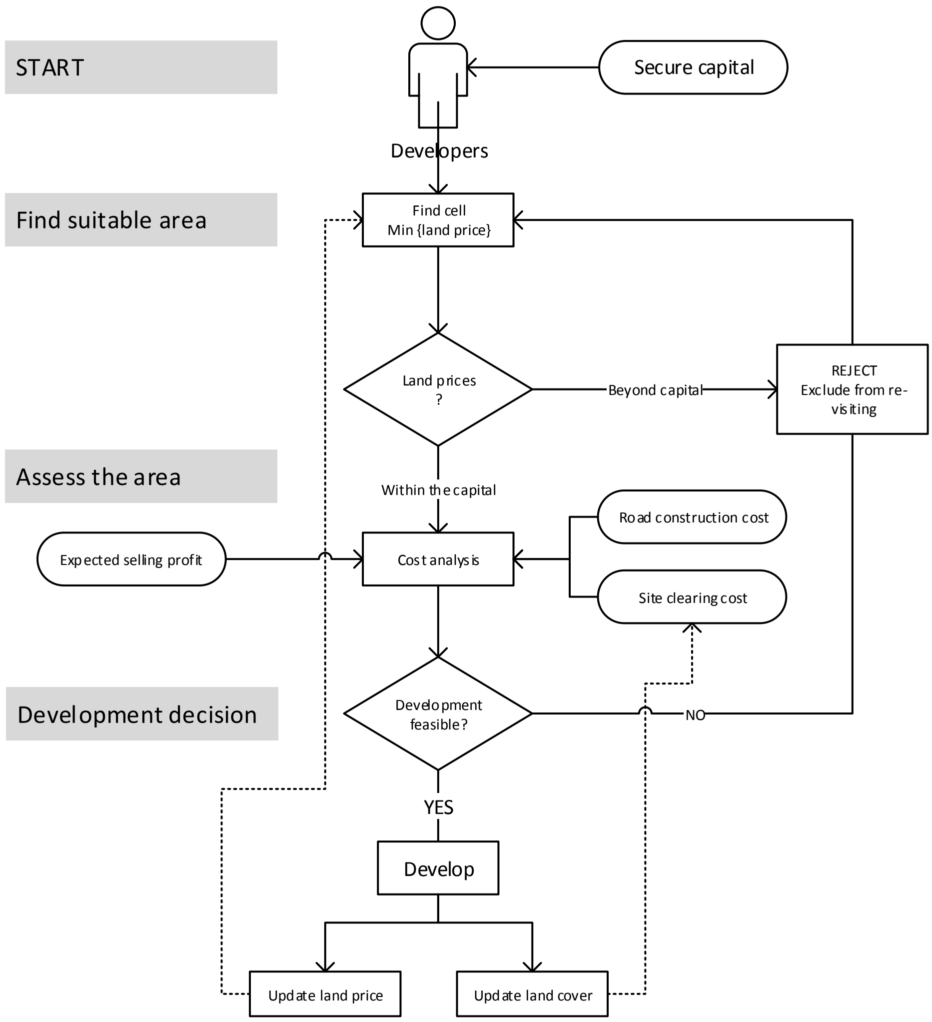
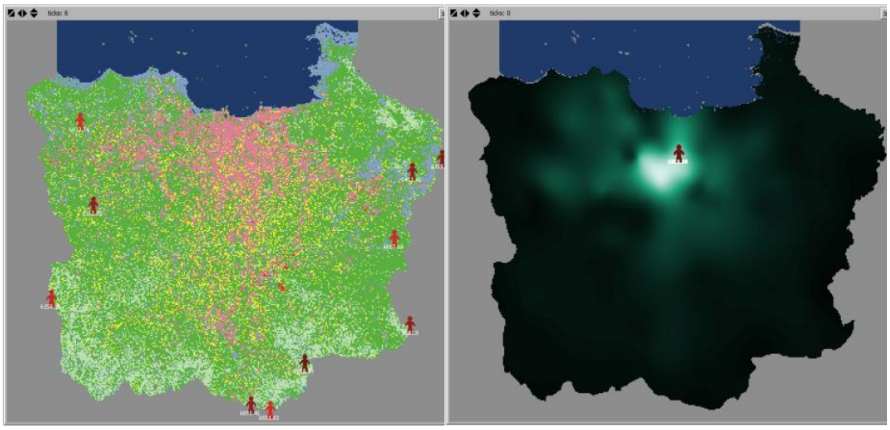


Figure 2. The illustration of find-assess-develop process by the private residential developers in JMA in securing land for new residential development.

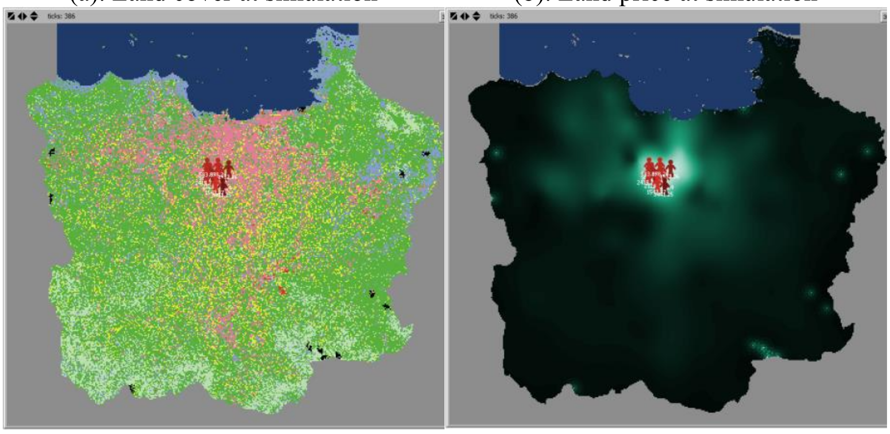
4 Results and discussions

- *The location of new residential areas.*

Running the model with default 10 developers, 1 km window searching area, 3000 billion IDR capital with 75 percent loan, the results show that initially the developers visit area in the boundary of JMA, looking for the cheapest land available (Figure 3a). Developers then assess the raw land price at his current position and possible profit he obtained from developing the land of current position. After assessing area on current position, the developer decides whether to go for another run on finding the land or develop the land based on capital and the expected profit. The find-assess-develop process continues until the developers spend the entire capital for developing new area.



(a). Land cover at simulation (b). Land price at simulation



(c). Land cover after simulation. Black color indicates the new residential development (d). Land price after simulation

Figure 3. The maps of land cover of JMA in 1994 and maps of land prices. The maps on the first row display the situation before simulation whereas the maps below show the results after simulation.

From the simulation, the general pattern of new development lies in the peripheries of JMA (Figure 3c). But the simulated new urban areas occur on distance more than 18 km from existing toll road, suggesting the toll road weakly affects the decision of urban development, contrary to initially believed that toll road affecting developers' decision for new urban developments. The location discrepancy is perhaps because the model considers only the construction cost and not the marketing value of an area as a function of distance from toll road. In the simulation, the developer could afford the construction cost of an area far from the toll road, while in the real situation; the developer might struggle to market the new area far from the toll road.

- *The influence of land prices after new residential development*

The new development accounts for the increasing land price on its surrounding as much as 30 percent from the raw land price before development. As shown in Figure 3d, the land price increased in the area where new residential development occur for instance on the southeast of JMA. The increasing land price is a consequence of adding land value by installing new infrastructure and accessibility through new road construction connecting the area with the toll road. The developers enjoy two benefits from new development; first the increasing land price and secondly the benefit from selling the new houses. For other developers, the new land price will affect his decision to purchase the area in the vicinity of the new urban development because the land price has increased. In the current version of the model, the shape of area affected by the new residential development is circle, whereas in reality the area affected follows the shape of new area. This will be accounted for the next version of the model

5 Conclusions

In the situation where land market is heavily driven by the private sector – a current practice of spatial planning in Indonesia – this model gave insight on how new residential area and land prices in JMA is formed by the developers. The model implemented the find-assess-develop process to represent the developers' perception on his current environment. The elements in the model represent the element in developers' cost analysis; in that the developers secure a capital (and possibly a loan), assess the expected profit and site improvement cost to maximize their profit.

Using agent-based urban model with JMA as case study, the urban model offers flexibility in demonstrating the developers' ability in selecting and acquiring land. From the results, we can conclude that the spatial decision to develop sites in the outskirt is due to affordable land price with suitable land cover (mostly vegetation) to be converted to new residential area. The construction cost seems to be less of a concern for the developer.

Due to the complex interaction elements in the urban system, the model could only represent very few part of the system and thus it is still in conceptual stage and exhibits limitations. First, the construction and number of element in the model is simple, in that selecting only large developer and considering only development cost and expected profit. But the real gained profit by the developer after urban development was not accounted. Secondly, the model is naïve in that variables were simplified to exclude variation that occurs because of influence macro socio-economic e.g. government policy and other development agent e.g. household buyer. Lastly, the model has no temporal scale in that the variables were kept constant independent to the natural increase of 6 percent land prices every year.

The future of this model will focus on refining the modules to better represent the interaction between developers and introducing diverse characteristic in particular the collaborators and competitors' behaviour among of the developers. The next version of this model will add the temporal scale onto the simulation; thus every run in the simulation will refer to certain period of time. But the challenge for future study remains similar with the present study that is the limited availability of data to support the model and analysis. Applying ABM for megacities whilst offering flexibility and insight into the element in the system, it demands a rich supply of data across different municipalities and in time-series; a rare situation for developing country like Indonesia.

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