ABM Project's Final Report

Residential Segregation in Jakarta

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Figures and Tables

I. Introduction

This section will explain the base model used in this project, background for extending the base model, the purpose of this project, hypothesis of the author, and limitation used in this project.

I.I. Base Model

The base model used during this project is "Urban Suite - Economic Disparity" from the Netlogo model library [1]. This model tries to show the city's residential pattern from an economic perspective. This model will use the socio-economic status of the agents as a factor in choosing the place to live. There are two classes of people in this model, the rich and the poor and both will be modeled as a turtle agent. Another kind of turtle agent in this model is a job site, which represents the location of the job or Central Business District. The patches used in this model is to represent the land used for living. Only one turtle is allowed in one patch, and each patch has the attribute of price, quality, and distance to the nearest job site.

This base model will show the growth of segregation between the rich and the poor based on the preferences for choosing the location to live. The rich will seek a location that has decent quality and is close to the job location too. Meanwhile, the poor will seek the location with cheap prices and close to the job site too. The job site will choose the location with the highest price because of the assumption that jobs will move towards where the money is. If the neighborhood is expensive, then it means more rich people live nearby and they will spend their money on the job or business.

At the beginning of the tick, the job-site agent will sample some number (controlled by parameter) of locations (patches) and choose the most expensive one. Several poor and rich agents will choose randomly locations near the job site as a place to live. The poor and agent will affect the neighborhood of the place they are living. The rich will increase the price and the quality of their neighborhood, but the poor will cause the neighborhood price and quality to decrease. At each tick, some number of the poor and the rich will enter the world and choose the place to live based on their preferences. In each tick, the poor and agent will die, and the agents removed will always be the ones that have been in this world for the longest period. For the job site, each tick will evaluate the proportion of the job and the population based on the resident-per-job slider. For every resident-per-job value, a new job site will be created, and choose the location based on its preferences (find the most expensive place).

I.II Purpose and Goal

I.II.1 Background and Motivation

Jakarta is the capital city and economic center of the country of Indonesia [2], and one of the social problems that Indonesia is faced is income inequality. One study from Suisse Research Institute Global Wealth Databook 2019 found that Indonesia's income inequality is still high, and they placed Indonesia in the rank three in terms of the Gini Index (Indonesia's score is 83.3) [3]. As the economic center in Indonesia, the income disparity of Indonesian people could be observed in Jakarta City. This income disparity will make a social class between the poor and the rich people who live or work in Jakarta.

One interesting study about Jakarta is this city is ranked as one of the most expensive cities in the world [4]. The survey from Bank Julies Baer's Global Wealth and Lifestyle Report 2021 placed Indonesia in the twentieth position in terms of the most expensive cities in the world. But another conflicting study also found that Jakarta is the most affordable city for the rich [5]. This study argues that for individuals that have a net worth of at least US$ 1 million, the price of technology gadgets, fine dining, LASIK eye surgery, and lawyer's service is comparatively cheap compared to other cities. From these two studies, a question is raised about whether or not Jakarta is an affordable city for all economic classes people (not only affordable for only rich people). Another interesting thing to observe is how the socio-economic status of people could affect the emergence of residential segregation in Jakarta.

The base model of "Urban Suite - Economic Disparity" already offers a good model of residential segregation based on the social class between the rich and the poor. The way the agents behave and how they choose the place to live is also like the preferences of rich and poor people in Jakarta. By extending this model to reflect the reality of living in Jakarta, we could argue that this model could also show how residential segregation emerged from the economic perspective. If the model shows that the location in the center of Jakarta is dominated by the rich, we could conclude that the city of Jakarta is only for the rich.

I.II.2 The Extension Goal for The Base Model

To use the base model to see the residential segregation in Jakarta and to see whether Jakarta could also be affordable for the poor people, several extensions need to be done. The extension that will be implemented during this project is:

1. Modified the patches to reflect the actual location of Jakarta.
   In the base model, each patch is a representation of each land for a living. There are 7921 patches in the base model and all of them will have the same value for the land quality and land price which is forty during the setup. The extension for this project will be to adapt to reflect more of the reality of the residential land in Jakarta. This project will separate the patches into two types, such as location inside Jakarta city and the location outside of Jakarta city. The reason for accommodating the land outside of the Jakarta city is because people who work in Jakarta could also in the nearby cities (satellite cities), and Jakarta has four satellite cities such as Bogor, Depok, and Tangerang, Bekasi. Indonesian usually called it the Jabodetabek (Jakarta-Bogor-Depok-Tangerang-Bekasi). In this project, the author also modified the land price and the quality of patches, so they reflect the reality of Jakarta, so they do not start with the same value during the setup phase.
2. Add phenomena of flood and traffic for living in Jakarta.
   Flood and traffic have been frequent problems in Jakarta. Every year, Jakarta faces a flood problem [6]. In terms of the traffic problem, Jakarta ranked tenth in the world according to TomTom Traffic in their 2020 study [7]. These two phenomena could affect the preference of place of living between the rich and the poor. That is why the author needs to extend the base model to reflect these two phenomena.
3. Adapt the preferences of the poor and the rich when choosing the place to live.
   Because of the added two phenomena in the previous point, the author will modify the preferences setting for both rich and the poor when choosing the place to live. The author will adapt the preferences two reflect how the rich and the poor will choose the place of living given these two phenomena.

I.II.3 Limitations

When extending the model, the author will base its assumptions on the real data that the author could find. In the case of the location outside of Jakarta City (satellite cities), the author will not use the real data and all related data with this location will be generated randomly. Another limitation of the extended model is the author only sees the residential segregation from the economic perspective and will not accommodate another perspective like racial or cultural perspective.

I.II.4 Hypothesis

These are the hypotheses that the author makes in the beginning of the project:

1. The level of segregation is high in the Jakarta
2. Most of the rich people will live inside of Jakarta City.
3. Most of the poor people will live outside of Jakarta City (In the satellite cities).
4. The Flood Level in Jakarta will increase the number of poor people living inside the Jakarta City.

II. The Model

This section will explain in detail about the extended model that have been produced during the project and how the author verified the extended model.

II.I The Extended Model

II.I.1 Environment

As mentioned before, the extended model will reflect the reality of living in Jakarta city. The environment in this model is the land for living in the greater area of Jakarta (including the satellite cities of Jakarta). The environment will be represented by patches, where each patch is a place of living for the turtle. The author uses the GIS library from the NetLogo to draw the map of Jakarta city to the patches. The shape file used to import the geographic value in this project can be downloaded from the Open Street Map website [8]. Each patch will have six attributes in this model:

1. Quality: the value that indicate the quality of the land. Higher value means the land offers better quality. The value ranges from 0 to 100.
2. Price: the value that indicate the price of the land The value ranges from 0 to 100.
3. sd-dist: the value that indicate the distance of this land to the nearest job.
4. obj_id: this is the extended attribute from the base model. This attribute is used to save the object id from the shape file that is imported into the Netlogo. For the location outside of the Jakarta city, the value of object id is 0.
5. kab: this extended attribute will save the city administration code of Jakarta. Jakarta is divided into five administration city such as Central Jakarta, South Jakarta, North Jakarta, East Jakarta, and West Jakarta.
6. Flood-risk: This is the extended attribute that indicates the flood risk of that land. The value ranges from 0 to 1, where value 0 means safe from flood and value 1 mean a high probability of flood will happen on that land.

Figure 1 shows the patches after importing the shape file.

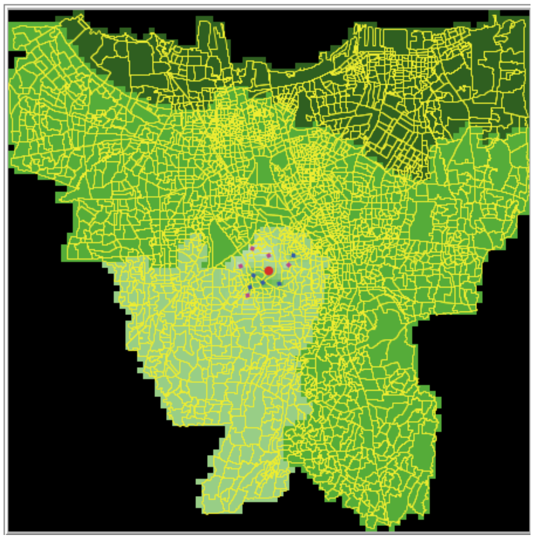


Figure 1 – Importing Shape File into NetLogo

The attribute value for the obj_id and the kab is gotten from the shape file, so it already reflects the reality of Jakarta. For the value of the price of land, the author uses the data from Triyasa Property Company to set the price of the land at the beginning of the tick [9]. The price distribution of the land in Jakarta could be seen in the Table 1 (all the price values in the million Rupiahs per square).

Table 1 - Land Price in Each Area of Jakarta

Area	Minimum	Maximum	Average
South Jakarta	2	25	2.5
East Jakarta	2	3	2.5
Central Jakarta	2	109	5
West Jakarta	2	2	2
North Jakarta	1	2	1.5

Based on the data in the Table 1, the starting price value for each patch in the beginning of tick will range according to Table 2. The author will randomize the price value based on the range found in the Table 2.

Table 2 – The Price Range in the Setup Phase

Area	Lower Range	Upper Range
South Jakarta	23	45
East Jakarta	12	23
Central Jakarta	12	100
West Jakarta	6.5	17.5
North Jakarta	1	12
Outside of Jakarta	1	10

For the land quality of Jakarta, the author used three indicators to determine the quality of the neighborhood. The three indicators are criminality rate, education systems, and healthcare. Based on the data gathered for criminality rate [10], the rank of high school [11], and the number of healthcare facilities [12], the author give the quality score for each area in Jakarta and this score could be seen in Table 3.

Table 3 – Quality Score for Each Area of Jakarta

Indicator	South	East	Center	West	North
Criminality	3	1	5	4	2
Education	5	4	1	3	2
Healthcare	5	4	3	2	1
Overall	**13**	**9**	**9**	**9**	**5**

From the quality score above, we could conclude that the south area of Jakarta is the area with the best area in terms of quality of the neighborhood, meanwhile, the north area of Jakarta is having the worst quality. From this data, the author will set the quality of the land in each area during the setup phase in with the value that could be seen in Table 4.

Table 4 – The Quality Attribute's Value in Setup Phase

Area	Quality Value in Setup
South Jakarta	70
East Jakarta	49
Central Jakarta	49
West Jakarta	49
North Jakarta	27
Outside of Jakarta	25

The last thing that needs to be set in the patch's attribute is the flood-risk. Here, the author uses data from the infographic published by the National Agency for Disaster Management to see the risk level of flood occurrences in Jakarta. The lowest risk of flood disaster is in the north and central of Jakarta. The highest risk for flood is in the West and East area of Jakarta. Table 5 will show the flood risk value ranges in each area. During the setup phase, the value of flood risk will be randomized according to the ranges in Table 5.

Table 5 – The Flood Risk Range in Each Area of Jakarta

Area	Lower Range	Upper Range
South Jakarta	0.3	0.5
East Jakarta	0.3	0.9
Central Jakarta	0	0.3
West Jakarta	0.6	1
North Jakarta	0	0.3
Outside of Jakarta	0	0.6

The value of the flood risk could be changed by using the slider that the author provided in the extended model. The slider is range from 0 to 1 to indicate the percentage of risk that will apply to the experiment. If the slider is set to 0.5, it means that the flood risk in all areas will decrease by 50%. The author chooses to limit the upper value of the slider to 1 because the flood risk in Jakarta is already relatively high, and during the analysis, the author wants to know the effect of solving the flood problem on the residential segregation of Jakarta.

II.I.2 Turtle Agents

The types of turtles in the extended model are still the same with the base model. Table 6 shows the types of turtles and their goal.

Table 6 - Types of Turtles and Their Goal

Types of Turtles	Goal
Poor	Find the closest place to live with the cheapest price.
Rich	Find the closest place to live with the highest quality
Job-Site	Find the most expensive place.

Same with the base model, agents influence the environment based on the land they inhabit. For the rich agents, every time they are moving to the area, it causes an increase in price and quality. And for the poor agents, every time they are moving to the area, it causes a decrease in the land and the price is still the same. This is different from the base model because based on the survey data from the Central Bank of Indonesia, the price of the land is never decreasing in the last decade [13]. Same with the base model, the nearby land is affected too with the effect of diminishing over distance.

II.I.4 Setup Phase

During when setup phase, the patches will be created using the shape file of map Jakarta. The total number of patches created is 7921. After the patches are created, it will assign the value of price, quality, and flood risk according to the value previously explain in the environment section. After that one job is created in the middle of the environment. And it creates 5 poor and rich turtles and places them randomly around the job site location. The price and the quality of the land will change after the rich and poor are assigned to the patches, based on the effect of the rich and the poor on the environment that was previously discussed in the section on the Turtle Agents.

II.I.3 Behavior in Each Ticks

In each tick, some number of rich and poor people (controlled by the RICH-PER-STEP slider and POOR-PER-STEP slider respectively) enter the world. They will sample some number of land (controlled by the number-of-tests slider) and choose the best land to live in according to their objectives. The way they choose the best land is by calculating the utility function, and the base model uses the hedonistic utility function. In this extended model, the author adds the effect of traffic level for calculating the utility function. When the traffic level is high, the agent will give more weight to the closeness to the job site compared to price and quality. When the traffic level is high, the rich people tend to value more for the closeness to the job site compared than the poor people. This is because in Jakarta, rich people usually use a car for their mobility and with the high level of traffic the cost and the time for commuting increase significantly [14]. That is why they will choose to live near the job site if the traffic level is high.

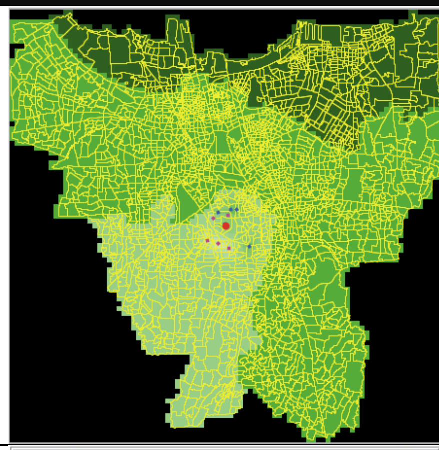
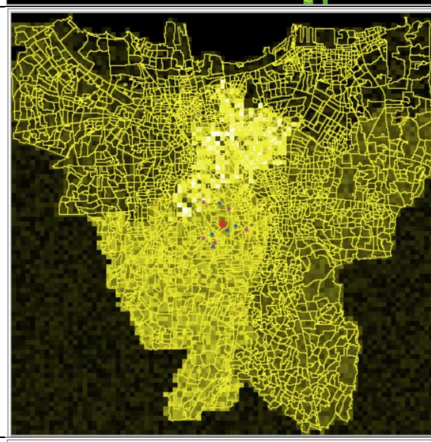
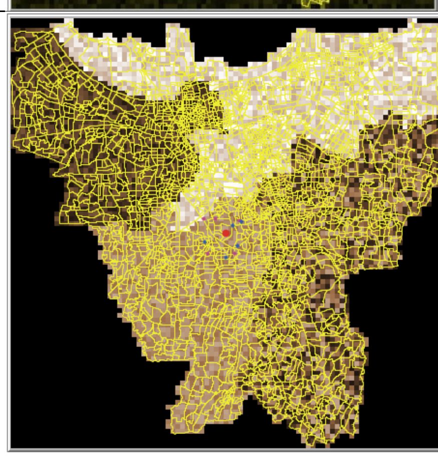
Another thing that the author modified in terms of choosing the place to live is to use flood-risk value as a decision factor. In this extended model, the author argues that the rich people have the tolerance of how high the flood risk level of their place to live. The tolerance level for the rich is vary from ranges 0.3 to 0.7. In here, the author uses the randomized value between this range to assign the tolerance level for the rich. If the flood risk level value is higher than the tolerance level value, then the land is not considered as a candidate for choosing the place to live. For the poor, they do not have any tolerance level and they don't pay attention to the flood risk when choosing the place to live. The author makes this assumption based on the real story that some poor people willingly to live in the high-risk flood area because they don't know other alternative place to live inside Jakarta [15].

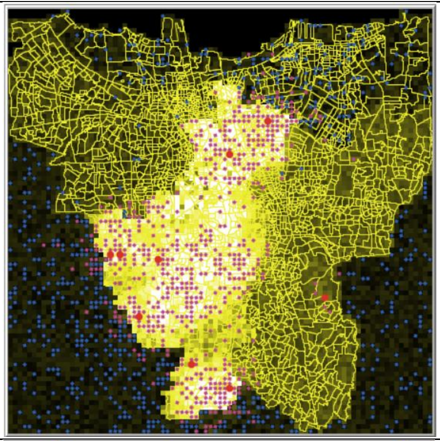
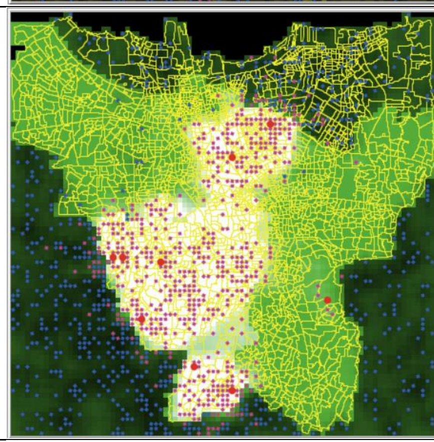
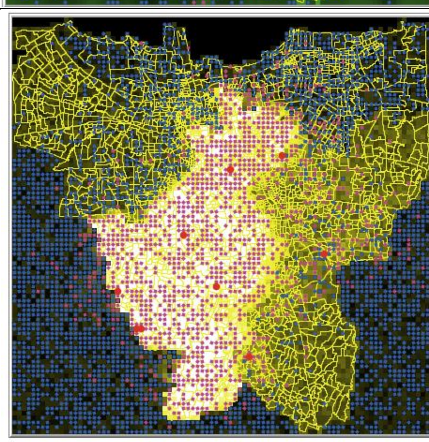
When the rich and poor move to the patch, it will change the price and quality of the patch and its nearby patches. After that, a new job is created if the number of populations achieves a certain threshold. This value is controlled by RESIDENTS-PER-JOBS slider. In each tick, some number of rich and poor people also died. DEATH-RATE-POOR and DEATH-RATE-RICH control this number respectively.

II.II Verification of Model

When verifying the model, the author uses visual testing and extreme use case testing. Visual testing is used to check the correctness of the environment variable value. Table 7 shows the result of visual testing for the extending model.

Table 7 - Visual Testing and Verification

Expected	Visual Result	Conclusion
In the setup, the location with the highest quality is in the South of Jakarta and the lowest quality is in the area of North Jakarta.		The area with the highest quality is represented with the brightest shade. And the brightest side is in the area of South Jakarta. The area with the darker shade is in the North Area of Jakarta. So, the model passed this visual testing.
In the setup, the location with the highest price is in the center of Jakarta and the least expensive land is in the area of North Jakarta and outside of Jakarta.		The area with the highest price is represented with the brightest shade. And the brightest side is in the area of Central Jakarta. The area with the darker shade is in the North Area of Jakarta and the area outside of Jakarta. So, the model passed this visual testing.
The location with the safest place from floods should be in Central and North Jakarta. The area with the riskiest flood is in the West and East Jakarta.		The area with the lowest risk of flood is represented with the brightest shade. And the brightest side is in the Central and North Jakarta. The area with the darker shade is in the West and East Jakarta. The area outside of Jakarta do not have flood risk level (because of limitation of our data) and all of them is represented with black. So, the model passed this visual testing.

The Job site should choose the highest price.		The job site is represented with the big red circle. From the visual result, the big red dots is always appear in the area with the relatively bright shade. So, the model passed this visual testing.
Rich people tend to live in the best quality area.		The majority of the small red dot appear in the area with brightest shade. So, the model passed this visual testing.
Poor people tend to live in the cheapest area.		The majority of the small blue dot appear in the area with brightest shade. So, the model passed this visual testing.

Another verification step that is conducted in this project is to see how the result of the model under the extreme setting conditions. In this extended model, the major change of the agent behavior is to accommodate the traffic level and flood risk level when the agent chooses the place to live. So here, the author will check the result of the model under extreme conditions in terms of the traffic level and flood risk level. The author will check how different the result of the model is under the different extreme settings. In this testing, the author will compare the absence of traffic and flood, represented with the setting Flood Level (FL) is 0 and Traffic Level (TL) is 0, with the condition of extreme traffic and flood problem, represented with the setting Flood Level (FL) is 0 and Traffic Level (TL) is 0, under 100 ticks. The result of this testing could be seen in the Table 8

Table 8 – Result of Testing under Extreme Use Case

Observed Items	TL=1; FL=1	k=0; FL=0	Conclusion
Total of the poor inside the city	220	185	When in condition traffic level and flood risk is 0, the less of poor people live inside the city. This behaviour is expected because the poor people will do not have to live near the job site. Also, the availability of land inside of Jakarta for poor people is reduced because rich people could live in all of land inside of Jakarta. So, the model passed this extreme condition testing.
Average price of the poor's home	3.7	3.11	When there is no constraint in terms of traffic and flood, the poor people will always choose the cheapest place to live. The result of the model shows that the average home price for poor is lower in this condition (3.11). So, the model passed this extreme condition testing.
Average quality of the rich's home	73.37	82.37	When there is no constraint in terms of traffic and flood, the rich people will always choose the highest quality place to live. The result of the model shows that the average home quality for the rich is higher in this condition (82.37). So, the model passed this extreme condition testing.

Based on the explanation above, the extended model passed the visual testing and extreme use case testing.

III. Simulation Analysis

This section will explain in the simulation experiment that was conducted using the extended model and explain the interpretation of the experiment results.

III.1 Experiment Settings

This section will explain the parameters used for setting the experiments and the measurements that the author tries to observe during the experiment. The parameters used in this project could be seen in the Table 9.

Table 9 - Parameter Used in The Simulation

Parameter	Explanation
Death rate poor	This parameter controls how many agents of the poor will die in each tick. The default value is 9.
Death rate poor	This parameter controls how many agents of the rich will die in each tick. The default value is 2.
Number of Test	This parameter controls how many patches that the agent should sample before deciding the one patch to move. The default value is 15.
Residents per Jobs	This parameter controls the how many new people should exist before the new job is created. The default value is 100.
Poor per Step	This parameter controls how many of poor agent will be created for each tick. The default value is 15.
Rich per Step	This parameter controls how many of rich agent will be created for each tick. The default value is 5.
Max Jobs	This parameter will controls the maximum number of jobs is allowed in the experiments. The default value is 10.
Traffic Level	This parameter will control the severity of the traffic level in the environment. The value is ranges from 0 to 1.0.
Flood Level	This parameter will control the overall flood risk of the environment. The value is ranges from 0 to 1.0.

The list of measurements for this simulation experiment could be seen in the table 10.

Table 10 - Measurement of the Simulation

Measurement	Explanation
Same Neighbors Percentage	Count the total number of neighbors with different economic class and then divided by the total number of all neighbors. The best value is the 50%, which mean the proportion of agent neighbors is the same for the same and the different economic class. If the value is 100%, it means all the neighbors is from the same economic class. The higher this value, the more severe the segregation is.
Population inside the City	The total number of the people who work in Jakarta and live inside the city of Jakarta. We could also measure the population for each of poor and rich people.
Population outside the City	The total number of the people who work in Jakarta and live outside the city of Jakarta. We could also measure the population for each of poor and rich people.

Home Price	The average home price of both the poor and the rich people.
Distance to Work	The average distance to work for both the poor and the rich people.

All the experiments conducted in this project will be run using the BehaviorSpace in Netlogo and use ten repetitions.

III.2 Experiment Results

Experiment 1

In this experiment, the author wants to know the effect of the flood and traffic problems on the preferred place of living for the rich and the poor. In this experiment, the parameter of traffic level and flood level will be varied from the range 0 to 1.0. The result for the same neighbor percentage measure could be seen in the figure 2, 3, and 4. From the picture, the higher traffic level will produce the less segregation. Also, when the flood level is high then the more segregation is only increase slightly.

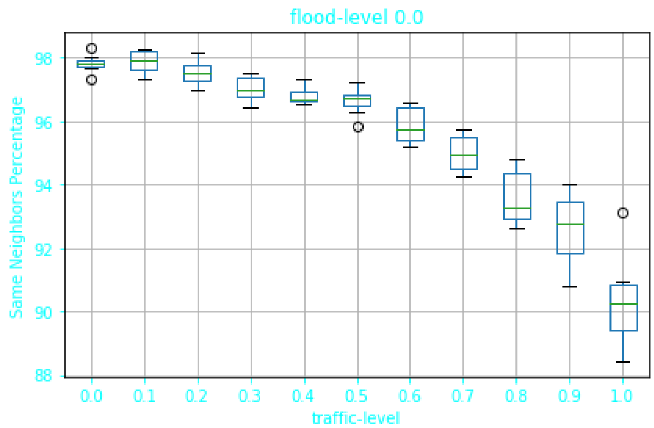


Figure 2

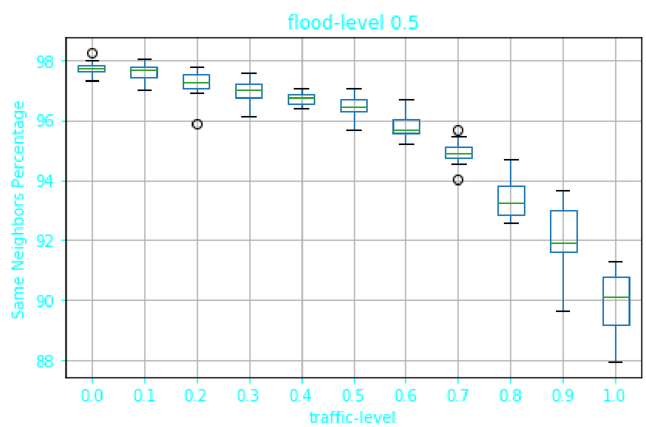


Figure 3

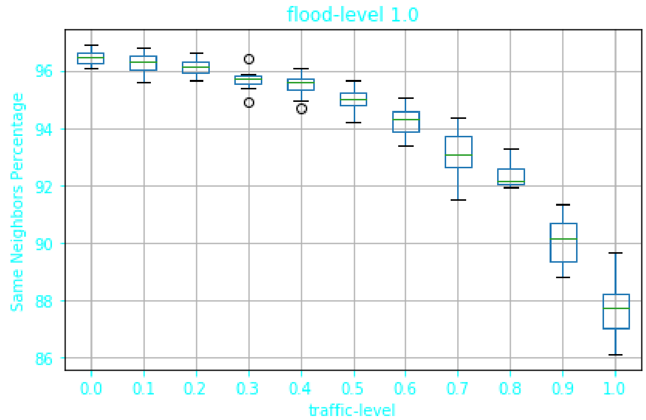


Figure 4

From figure 5, we could see that the number of poor people increases when the flood level and traffic level is high. We can conclude that traffic level makes more poor people live inside the city to avoid traffic congestion when commuting to their workplace. Figure 6 shows us that the average home price of the poor is increasing too due to the poor live inside the city more. From figure 7, we can see that the average distance to work for the poor is not reduced significantly. This result is counter-intuitive because when it is safely to assume that when the number of poor people live inside the city is increased, their distance to work should be decreased. We could conclude that the home price increase for the poor when moving inside the city of Jakarta is not worth it because the distance to work is not reduced significantly.

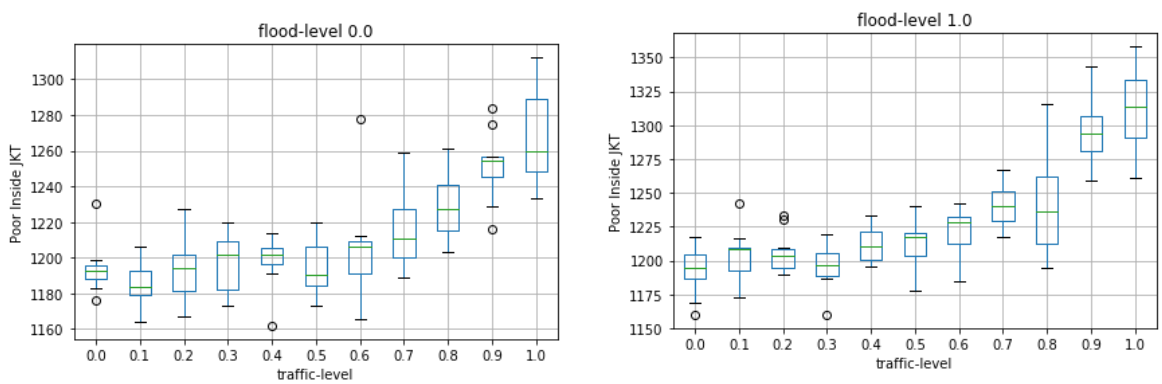


Figure 5 – Population of The Poor Inside the City

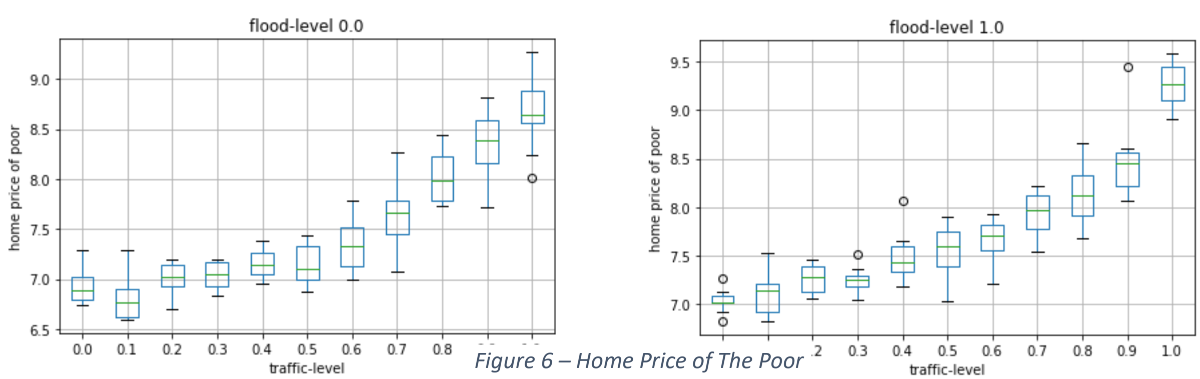


Figure 6 – Home Price of The Poor

In the case of the rich people (Figure 8), the average home price that they need to pay is less when the traffic level is high. When the flood level is high, the rich people tend to pay more money for homes because they avoid certain locations with a higher risk of flood. In terms of distance to work, there is no significant change in terms of flood level and traffic level (Figure 9). It seems like the rich always find a home with the shortest distance to the job site, or maybe the job site always follows where the rich people reside.

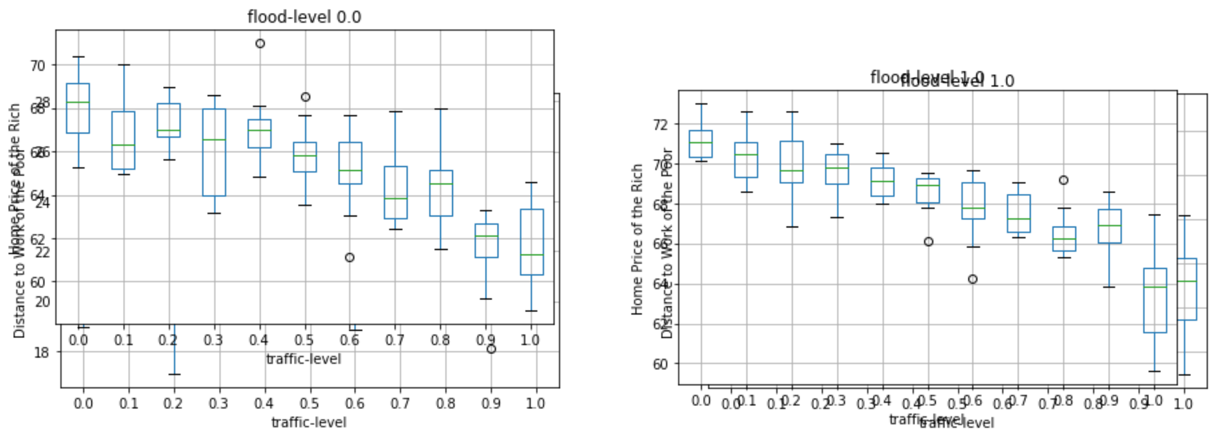


Figure 9 - Average Home Price for the Rich

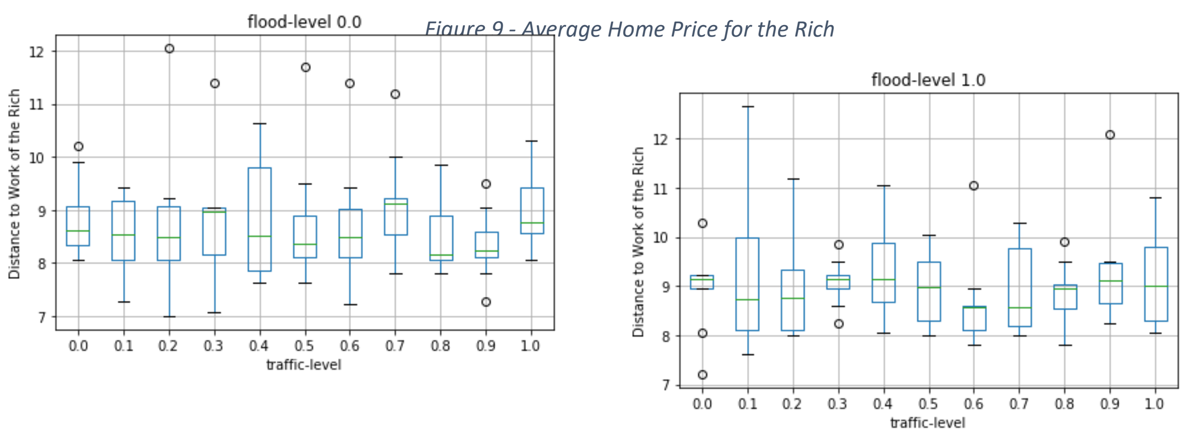


Figure 8 – Average Distance to Work for the Rich

Experiment 2

In this experiment, the author wants to know the effect of having more choice (control by number-of-tests slider) on the preferred place of living for the rich and the poor. In this experiment, the number of choices will be varied from 1 to 30. From Figure 10, we could conclude that more choice means more segregation. And from Figure 11 we could see that the average distance to work for the rich is decreasing as the number of choices is increased. But for the poor, the distance to work is increased when the number of choices is increased. This could mean that the higher number of choices could give opportunities for the rich and job site to live nearby but the poor will force to live farther from the job site.

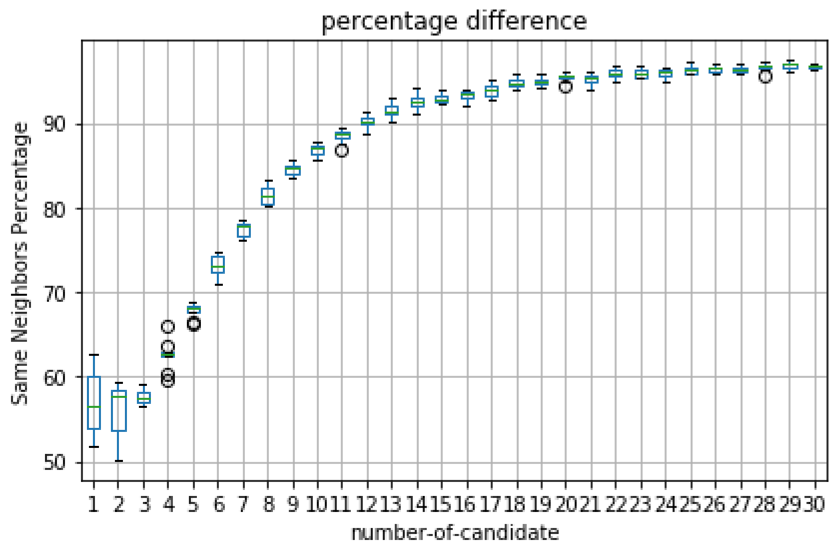


Figure 11 – Percentage of the Same Neighbor

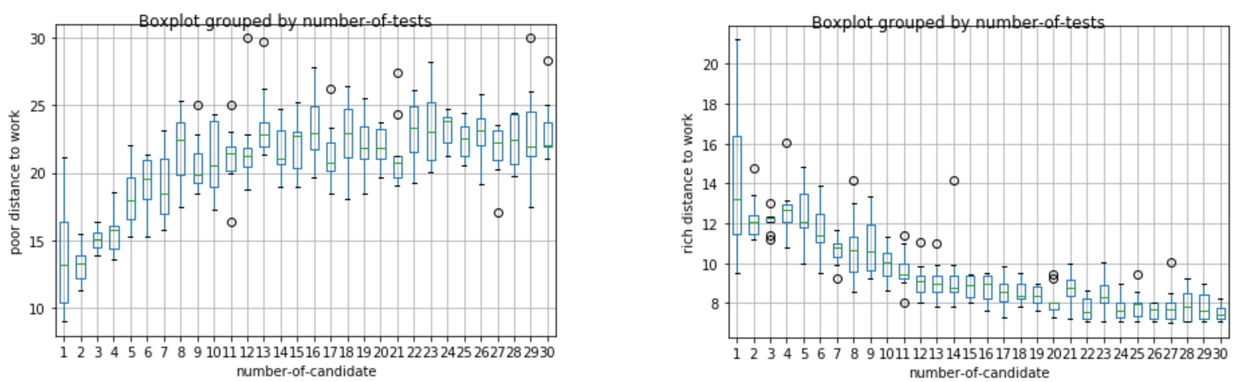


Figure 10 – Distance to Work for the Poor and the Rich

Experiment 3

In this experiment, the author wants to know the effect of a maximum number of job sites on the preferred place of living for the rich and the poor. The maximum number of job sites could refer to the growth of business in the city. When the number of maximum jobs is large, it means the business is growing, but when the number of maximum jobs is small, it means the business is stagnant. From Figure 12 we could see that the highest segregation level will be when the maximum number of jobs is 18 and 19. But this segregation level is reduced when the number of maximum jobs is 20. Here we could conclude that when the number of jobs is high enough, it could reduce the segregation level. In Figure 13 we could see that as the maximum number of jobs increases, the distance to work for the rich and the poor is decreased too. From this experiment, we could conclude that a higher number of jobs is beneficial for both the rich and the poor.

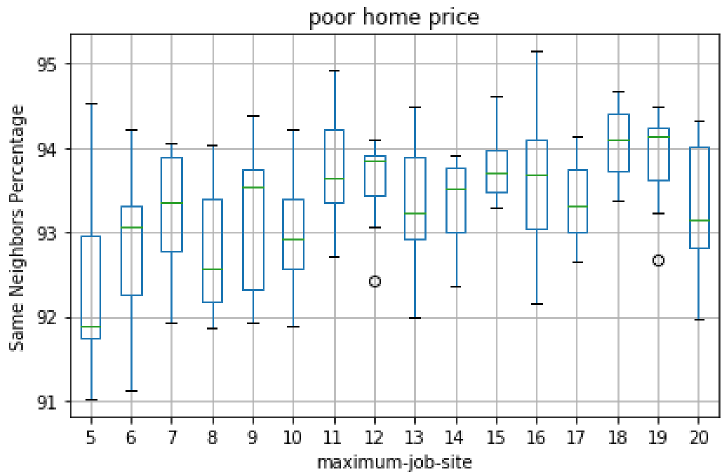


Figure 12 – Same Neighbors Percentage and Maximum Job Site

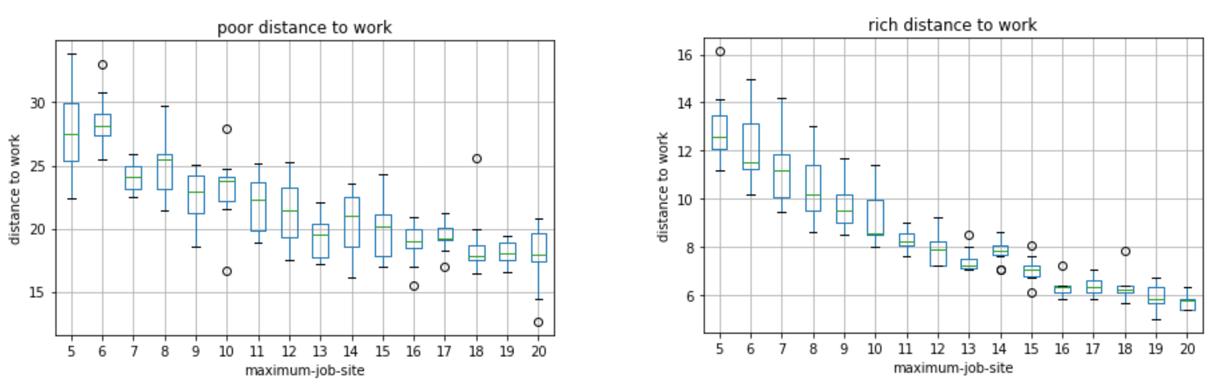


Figure 13 - Distance to Work and Maximum Job Site

IV. Conclusion

Based on the experiment that was conducted during this project, here is several conclusions about the residential segregation in the city of Jakarta:

1. When the traffic congestion level is high and the risk of flood is high, the segregation level is reduced. But when the traffic congestion level is low and the risk of flood is low, the segregation level is increased.
2. When the traffic conditions are low and the flood risk is low, the city of Jakarta will be dominated by the rich and most of the poor people will live outside of Jakarta (in the satellite cities).
3. Severe traffic congestion in Jakarta will make more poor people live inside the city, but they need to pay more for their homes price.
4. The distance to work is not affected by the traffic conditions and the flood risk.
5. It is not worth it for the poor people to move in inside the city because they need to pay more money but the distance to work is not decreasing significantly.
6. When the number of choices is high, the segregation level is high too. Based on this finding, we could predict that segregation will get worse in the future because in this Information Age the choice for people is in abundance.
7. It is preferable to have a large number of jobs in the city. Based on our experiment, the overall distance to work decreases as the number of job increase, and the increase in home price for the poor is only a little. There is also some potential for reducing the segregation level if the number of jobs is high enough.
8. In this extended model, the flood risk has only little effect on the overall model result. The reason for this may be the tolerance threshold of flood risk for the rich people is not fit the reality. Another possibility is that using a tolerance threshold is not suitable for this case. Finding the best tolerance value or including the flood risk level in the utility function could fix this situation.

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VI. Appendix

The source code for this extended model could be downloaded in this link:
https://github.com/toribukit/ABM_ResidentialSegreationInJakarta