CHAPTER V
IMPLEMENTATION

5.1.   System Implementation

The simulation software is called Simulate Mall (SIMMAL) and is built with Unity3D Game Engine. The computer's specification used to build this software is as follow.

1) Gigabyte P2542 Intel i7-3630QM
2) 2 x 4GB RAM
3) 2GB Nvidia GTX 660M
4) 1920 x 1080 screen

The simulation software can be executed in windows environment. The minimum resolution for the simulation software is 1280 px X 1024 px, with 1920 px X 1080 px as the best resolution for viewing. The software is built with C# and iTween library for animation purposes.

5.1.1. Welcome Screen

The welcome screen loads all mall layouts that have been saved. The saved layouts can be shown by clicking which layout to be loaded. It also has an option to create a new layout with user-defined floor number. The implementation of welcome screen can be seen below.

Figure 5.1. Simmal Welcome Screen

5.1.2. Simulation Screen

The simulation screen contains a multi-level grid-based layout which can be placed with buildings. The screen also contains several user interfaces for variable controls, statistic window, builder panel, and status bar. User can also navigate around the 3D environment by using keyboard controls listed below.

1) W, S, A, and D to move forward, backward, left, and right.

2) Q and E to move up and down

3) Move mouse to rotate camera

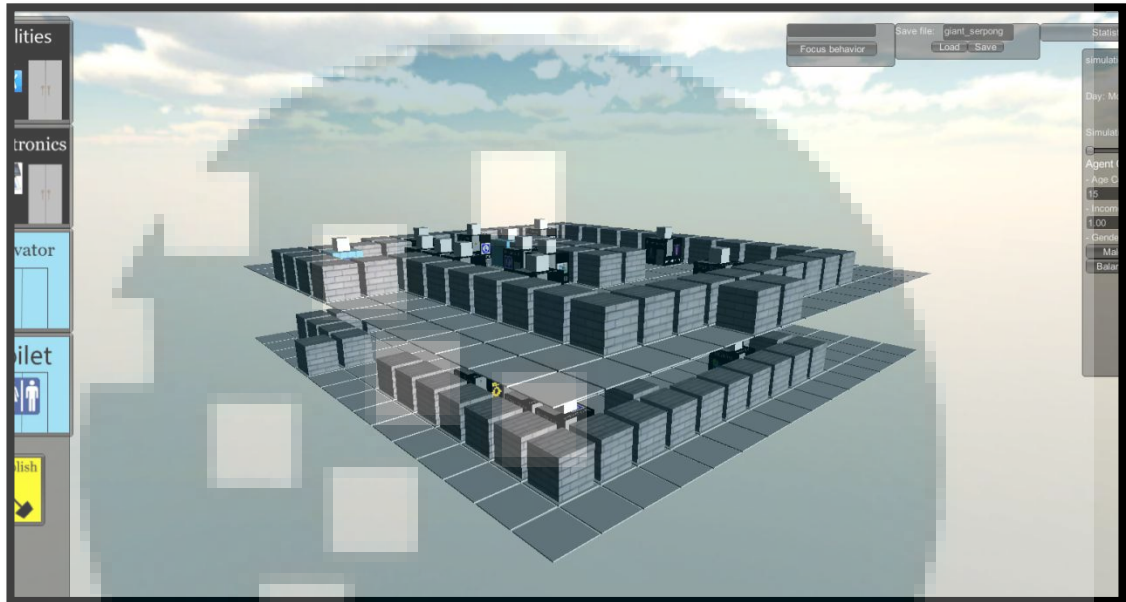The implementation of the simulation window can be seen below.

Figure 5.2. Simmal Simulation Window

5.1.3. Builder Panel

The builder panel is the part of the GUI from the simulation windows. It features nine categories of buildings that can be built in the environment. There's also a demolish button to destroy an unwanted building. The user can click the desired building icon and click an empty cell to build it. Additionally, walls can be built multiple times by dragging it in empty cells. The implementation of builder panels can be seen below.

Figure 5.3. Simmal Builder Panel

5.1.4. Variable Control Panel

This panel is placed on the left sidebar of the simulation screen. It features shopper agent's attribute editors which are implemented in a form of textbox. It also has a slider for increasing or decreasing time steps up to 8x. The attribute's changes will immediately take effect in the simulation property. This panel is useful for market segmentations. The implementation of the variable control panel can be seen below.

Figure 5.4. Simmal Builder Panel
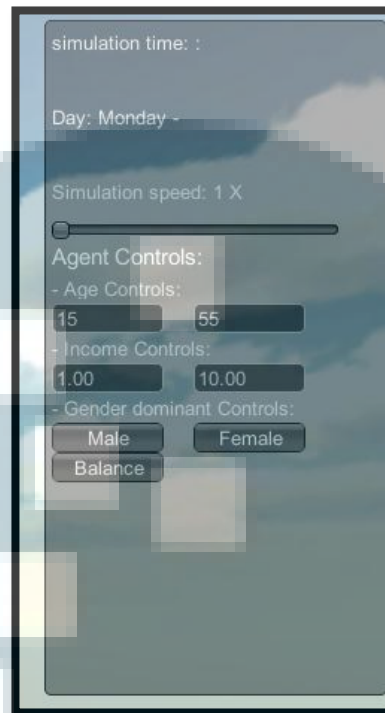
5.1.5. Statistic Window

The statistic window can be shown by clicking the "Statistic" button at the top left of the simulation window. It will bring up a full screen window which is made up of two tables. The first table shows the list of all buildings built in the simulation environment and some of their attributes and another table shows the list of shopper agents in the environment.
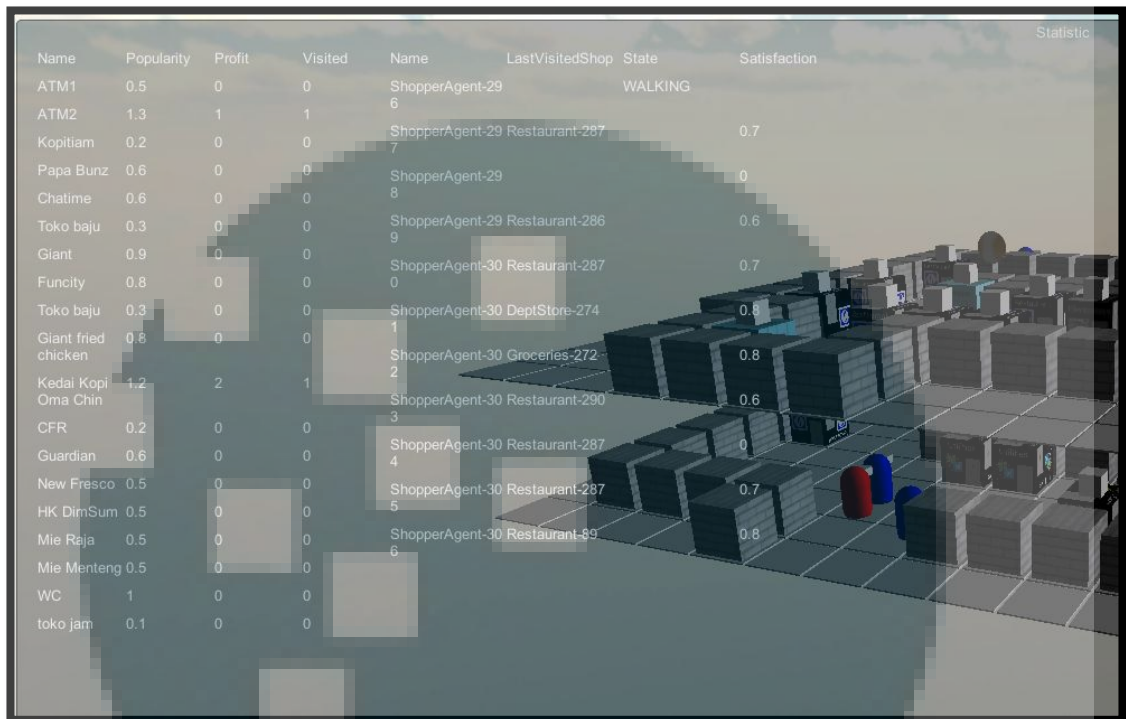
Figure 5.4. Simmal Statistic Window

5.1.6. Summary Window

The summary window is brought up every day in simulation time. It compiles and shows the gathered data from each agent in the simulation in one day, such as the most visited shops, shopper agent's traits of certain shop category, and other information. The implementation of summary window can be seen below.
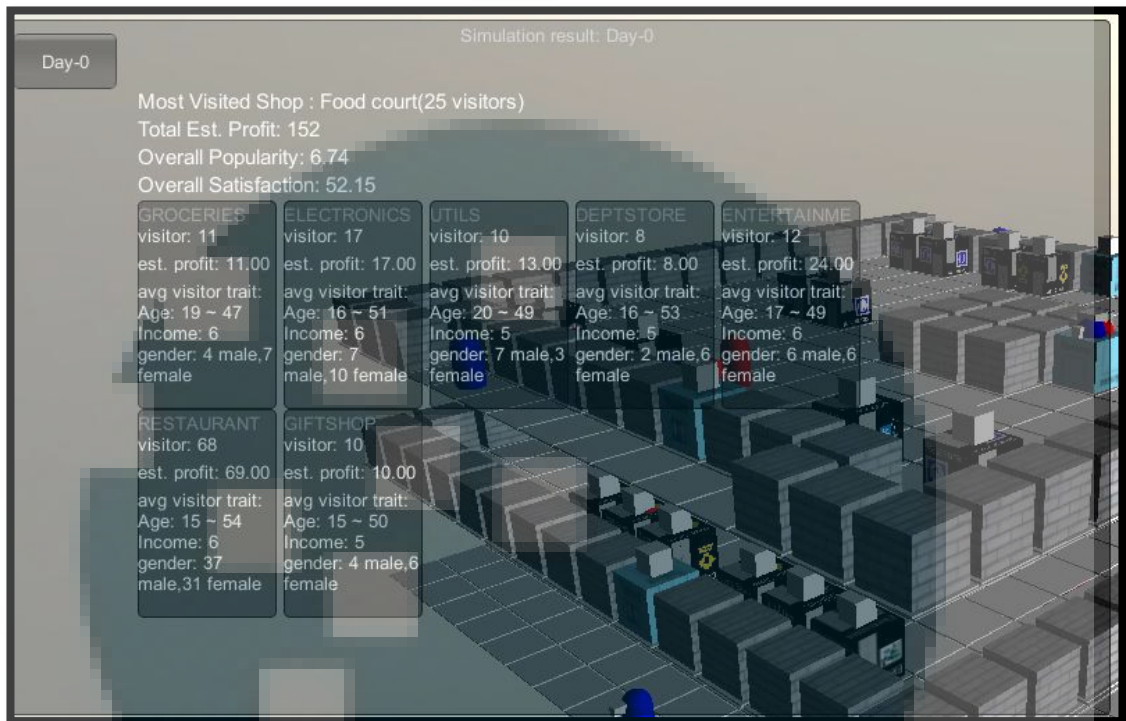
Figure 5.5. Simmal Summary Window

5.1.7. Agent Panel

Agent panel differs between shop agents and shopper agents. It can be shown by clicking an agent in the simulated environment. The shop agent window enables the user to change the level of popularity, name, and the level of price. The shopper agent window shows information about its history of actions and attributes. The implementation is shown below.

Figure 5.6. Simmal Shopper Window
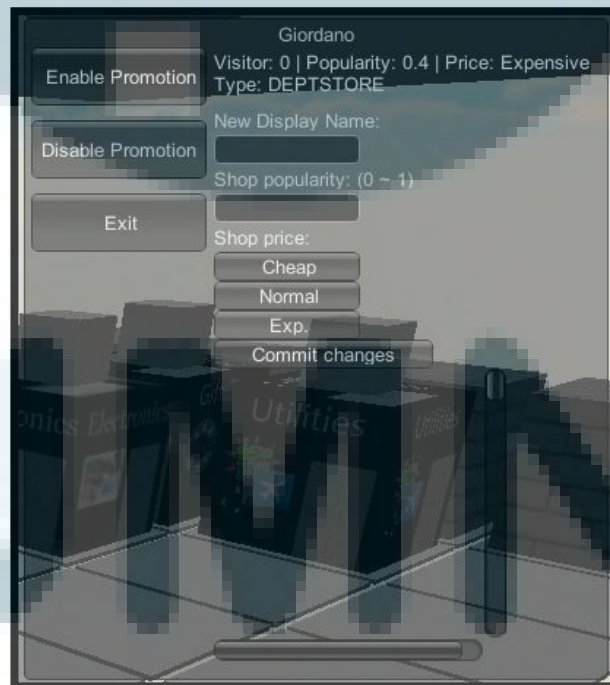
Figure 5.7. Simmal Shop Window

5.2.   Mall Implementation

The implementation of the mall layouts is done after the simulation tool is made. By using the builder panel, the mall stores are placed in the environment, with the arrangements as close as possible to the real layout. To achieve that, direct observation layout searching is conducted in the malls themselves to gather store locations and attributes. After the observation is done and the mall layout is sketched, the layout and the number of floors will then be implemented in the simulation tool by using the builder panel.

Figure 5.8. Layout of Giant Serpong

For shopping centers which are very large in size, the layout will be implemented by cutting down several distances between shops and aisles, making the layout more

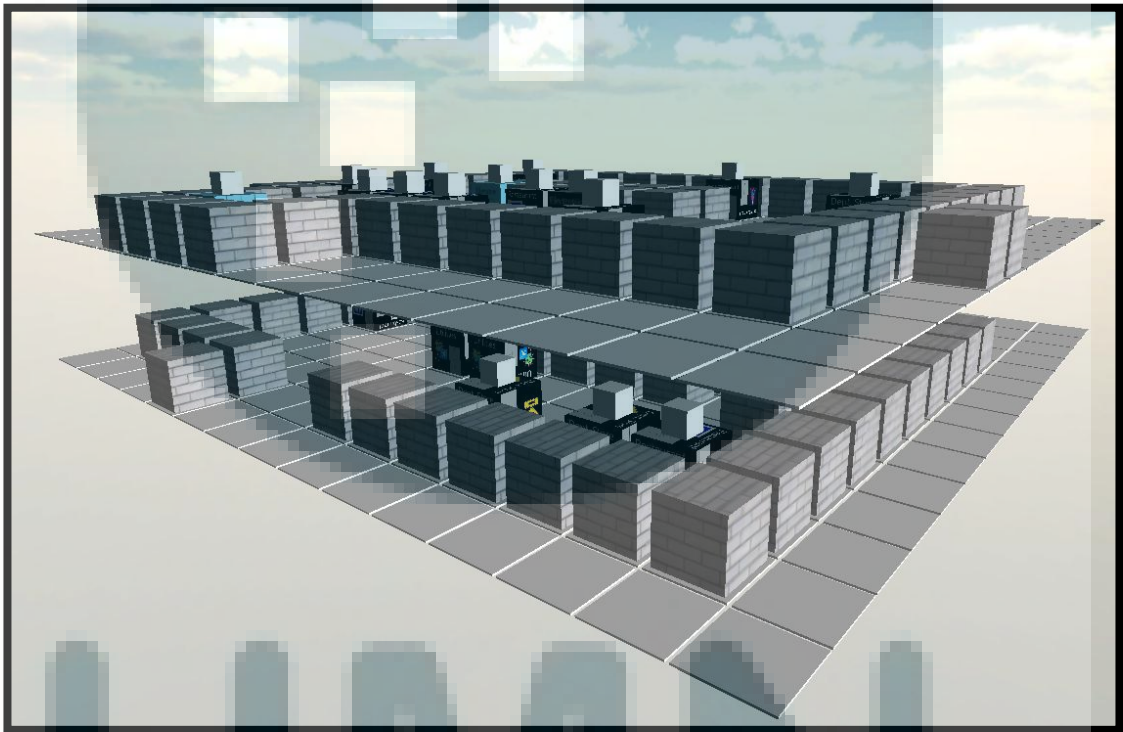compact. For example, the layout of Summarecon Mall Serpong and Karawaci, which are presented below.
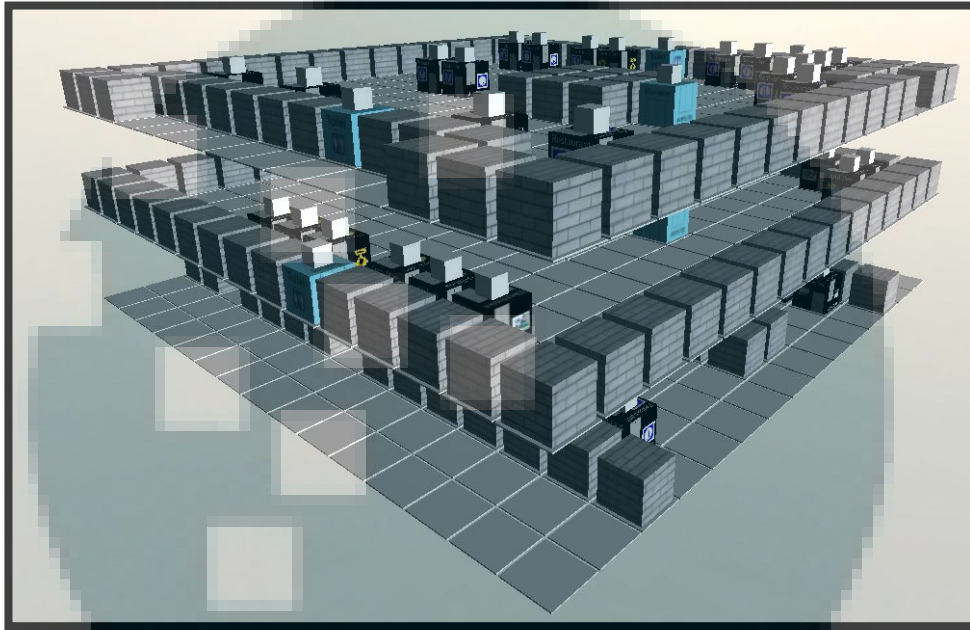
Figure 5.8. Layout of Summarecon Mall Serpong
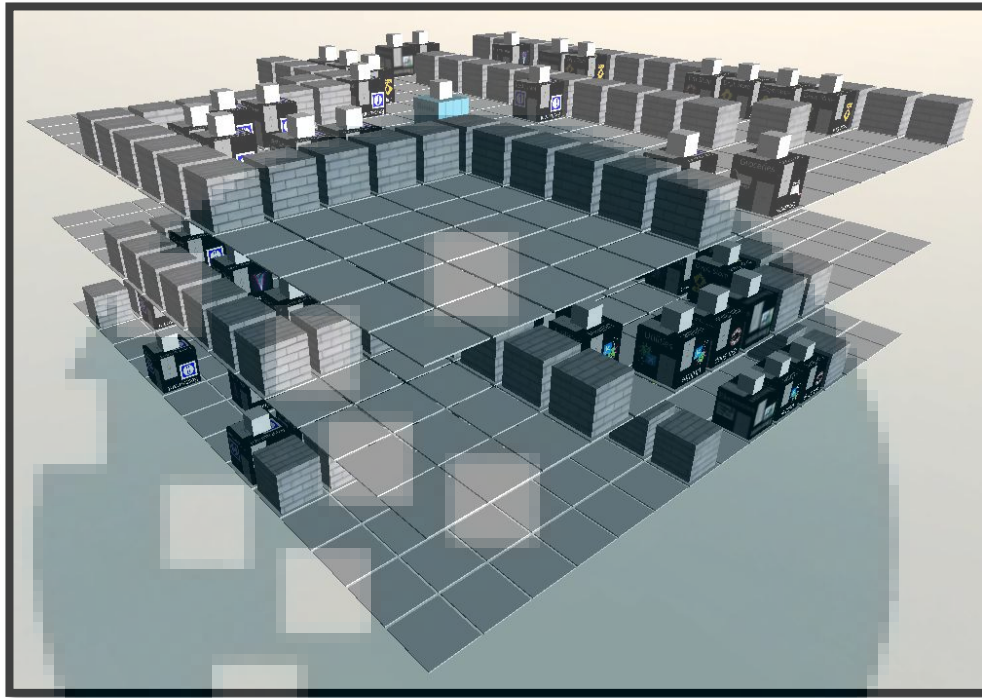
Figure 5.9. Layout of Supermall Karawaci

Each shopping center is chosen because of the difference they have with each other. The Giant Gading Serpong is not a fully grown shopping center because of the Giant supermarket, which is the main reason of why people go there. Summarecon Mall Serpong and Supermall Karawaci are the biggest shopping center in Serpong and Karawaci. Those 3 shopping centers will serve in the testing phase of the simulation tool.

5.3. System Evaluation

5.3.1. System Interoperability

The simulation system has managed to implement a string-based rule for the fuzzy logic system. The rules are implemented in a list data structure which will be

evaluated when calculating fuzzy and crisp values. The knowledge base of each agent is successfully implemented based on the variable control set.

The fuzzy logic system is successfully built to determine agent's actions in the simulated environment. The fuzzy logic system manages to derive the values from agent's attribute and turn it into a graph which measures the tendency of the agent's actions.

Each agent's knowledge base is successfully implemented in a hash table. For values in a form of number, the system will parse the value, do the operation and revert it back to the string. The hash table is also used to show the agent's attribute in the simulation GUI.

The pathfinding algorithm is successfully implemented in the system. The algorithm manages to find paths through a multi-level shopping mall. The algorithm also sends feedback to the agent for successful or failed attempts of pathfinding. The pathfinding utilizes threads, so that the operation can be concurrent and decrease processor's load. Some of the failed pathfinding is caused by synchronization between agents in the virtual environment, which are already handled by message-passing.

The simulation system manages to simulate different type of visitors, in this case agents, based on their demographic attribute. The system also successfully implemented a messaging system based on the message format mentioned above. The agents manage to communicate through the message-passing system, which is implemented in a queue.

5.3.2. System Validation

To validate whether the simulation system can simulate the real-world occurrence, the face validation method is used by visiting the mall managers or developers in several shopping malls listed above. The validation steps are:

1) Drawing mall layouts. The layout of the target shopping centers are implemented in the simulation software. The category of each tenants are based on nine shop categories which are implemented in the simulation.

2) Validating input data. The input data, knowledge base, and rules for shopper and shop agents are shown to the experts to be validated.

3) Running the simulation. The simulation and its output are shown to the experts, which will be validated whether it is similar to the real world or not.

4) Interface testing. In this phase, the expert is allowed to try designing a custom mall layout, which determines the simulation's usability for different scenarios.

5) Questionnaire. Each expert is given a questionnaire to evaluate the simulation requirements, outputs, behaviors, and advices for future researches.

The validation of the simulation software is done in three different shopping centers which are listed below.

Table 5.1. Target Shopping Centers

Mall	Experts	Position
Giant Paramount Gading Serpong (**A**)	Andry Dicky P.	Complex Manager
Summarecon Mall Serpong (**B**)	Medy Suteja	General Manager
Supermall Karawaci (**C**)	Mira Virgona	Senior Manager Leasing and Exhibition

Before the validation is conducted, the mall managers are given a certain survey, which state about the general mall visitor's preferences towards the tenants. The output of the simulation will be generated several times and sampled. The result will be crosschecked by the experts' opinion to validate the accuracy and reliability of the simulation. The result is shown below:

Table 5.2. Mall visitor's activity index

No.	Activity
1	WALKING
2	WINDOW_SHOPPING
3	EATING
4	ENTERTAINMENT
5	APPAREL
6	GADGET
7	GROCERY
8	SOUVENIR

Experts from Giant Serpong are required to fill the most common activity done by shopping mall visitors given their age, gender, and income. The accuracy value is calculated from how similar the output of the system and the experts' point of view. For example, 2 points of similarity means 2 of 3 activities mostly done, whether in reality or from the system itself, is similar. For this purpose, the system will samples 7-8 shopper agents and their output to gain the most common activities done according to the tuned attributes. The crosscheck result between the system and expert's point of view can be seen below.

Table 5.3. Crosschecked result between system and experts

Age	Gender	Income	Activities			System			Similar
Teen	Male	Poor	4	1	3	3	4	7	2
		Normal	4	3	8	3	5	4	2
		Rich	4	3	6	8	1	6	1
	Female	Poor	3	1	4	1	2	3	2
		Normal	3	4	7	7	6	2	1
		Rich	4	2	3	3	5	4	2
Adult	Male	Poor	1	2	4	3	1	7	1
		Normal	3	4	8	3	5	6	1

Table 5.3. Crosschecked result between system and experts (continued)

Age	Gender	Income	Activities			System			Similar
		Rich	5	6	7	4	6	1	1
	Female	Poor	1	3	4	5	4	1	2
		Normal	2	3	7	4	2	1	1
		Rich	5	6	7	3	6	2	1
Elder	Male	Poor	1	2	7	5	6	7	1
		Normal	1	3	7	7	1	2	2
		Rich	3	7	8	4	7	8	2
	Female	Poor	1	2	7	3	4	2	1
		Normal	1	3	7	3	8	4	1
		Rich	3	7	8	4	8	3	2
Average Percentage									48.14%

Each expert is also given a questionnaire to validate the simulation input, process, and output. The questionnaire and the survey is also enclosed along with this report. The result of the questionnaire is shown in the table below.

Table 5.4. Questionnaire result

Question	Score			Mean	Explanation
	A	B	C		
Is the limitation given in the simulation is enough to simulate the real world occurrence?	4	4	3	3.67	**A**: Limitation is enough, but the categorization is not exactly correct, need more shop categories. **B:** The input data should include the user's brand perception and awareness. **C:** Income can be replaced with the classes of visitor (mid, mid-up, mid-down). The shopper agent's location can also be added to input data.
Can the simulation tool be understandable and easily used?	4	4	2	3.33	**A:** The simulation tool needs to differentiate between eating places, food courts or food stands. **C:** The purpose of the simulation should be made clear and more complex.

Table 5.4. Questionnaire result (continued)

Question	Score			Mean	Explanation
	A	B	C		
Can the interface of the simulation be understandable easily?	4	4	4	4	**C:** The interface is easy to understand and the use of icons are clear.
What features of the shopping centers simulation are important to simulate?	-	-	-	-	**A:** The estimated level of visitor's satisfaction, profit in each tenant **B:** Visitor's traffic in a specific location **C:** Visitor data generation.
What features can be added to the simulation?	-	-	-	-	**B:** Brand awareness or estimated popularity of each brand. **C:** Visitor's estimated spending, visitor's geographic attribute.
Can the simulation prototype describe the real world phenomenon?	2	3	5	3.33	**A:** For a mall such as Giant, the visitor's focus is for shopping or doing grocery. The result is different from real world occurrence. **B:** Not accurate, because certain features such as brand awareness or shopping programs are not included. No event simulation. **C:** Fairly accurate given the output presented.
Do the agents behave similarly to the real world happenings?	4	3	4	3.67	**A:** Fairly accurate, it will be better if the agent can simulate its marriage properties, such as married or single. **B:** Average, the agents is ignorant of its lifestyle and level of education **C:** Fairly Accurate. The customer's behavior should be divided into more parts, not only from its demographic attribute.

Table 5.4. Questionnaire result (continued)

Question	Score			Mean	Explanation
	A	B	C		
Is the result of the simulation can be used to support decision-making process?	4	2	4	3.33	**A:** The method of deriving agent's behavior is good, but the result is not accurate. **B:** The level of accuracy is still low because of lack of attribute given above **C:** The result is fairly enough to portrait the summary of consumer's behavior.
Advices for future researches	-	-	-	-	**A:** Implement graphics in data visualization, simulate the needs of the mall visitors **B:** Surveys to identify visitor's preferences, more accuracy in simulating consumer's behavior. **C:** Implementing graphics for data output, more visitor's and shop's attributes simulated.
Average Score				**3.55**	

The analysis and result of the simulation tool and questionnaire are given below.

1) The simulation still lacks of variables or attributes, which are abstract or qualitative, such as consumer life styles, level of education, brand awareness, etc. The lack of such variables is one of the factors which decrease the accuracy of the simulation.

2) The output visualization must be made easier to understand. The use of business intelligence in data gathering inside the simulation becomes important. The use of tables, graphics, charts are important in visualizing output.

3) The initial data, rules, and knowledge base such as shopper attributes, fuzzy rules, and shop categorization still has not fully covered all of shopping center's attributes, because of the lack of historical data or statistic for shopping centers.

4) The visualization of the virtual shopping center is not very realistic, which means basic 3D shapes are not enough to draw the mall layout realistically.

5) Input data obtained from literatures are not enough. There's still a need of early surveys to determine the consumer's behavior in shopping centers.

6) The simulation should implement activities outside the usual visitor's behavior, such as events, construction works, etc.

7) The simulation interface, which are referenced from construction games, such as SimCity, and the grid-based environment model is proven to be easier to use and understandable by the users.