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Agent Based Model to Analyze Consumer Behavior in Consuming the Electricity Energy

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Graphical abstract

Abstract

Several studies have been conducted regarding save energy in consuming the electricity through the simple changes in routines and habits. In the case of electricity consumption, consumer behavior might influenced by several factors such as consumer profession, season, and environmental awareness. In this paper, we developed an Agent Based Model (ABM) to analyze the behavior of different agents in consuming the electricity energy for each type of profession (agent) as well as their interaction with the environment. This paper demonstrated a prototype agent based simulation model to estimate the electricity consumption based on the existing condition and some scenarios to reduce the electricity consumption from consumer point of view. From the scenario results, then we analyze the impact of the save energy to increase the electrification ratio.

Keywords: agent based model, electricity consumption, consumer behavior, save energy

1.0 INTRODUCTION

Agent-Based Model (ABM) is a new approach to modeling systems containing agent interaction with the system or the environment. ABM is a tool for decision makers in implementing new policies that can improve the system performance. According to Macal and North [1], there are several stages in developing Agent-Based Model (ABM) as depicted below:

(1) Identification of agents and agent behaviors
(2) Identify relationships between agents
(3) Related data agents retrieval
(4) Agent behavior model validation
(5) Run the model and analyze the model output

In this paper, an agent-based modeling (ABM) is developed based on autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules [2]. Agents are either separate computer programs or, more commonly, distinct parts of a program that are used to represent social actors—individual people, organizations such as firms, or bodies such as nation-states [3]. Some agent characteristics can be seen in Fig. 1 and can be described as follows [1]:

- An agent can be identified, discrete individuals with a set of characteristics and rules that organize behavior and decision-making ability
- An agent may be directed to the purpose, and has a specific purpose
- An agent is located in a neighborhood where it can interact with other agents. Agent has the ability to recognize and distinguish the characteristics of the other agent
- An agent can function independently in its environment
- An agent has the ability to learn and customize the behavior based on experience. This requires some form of memory. An agent may be able to modify the rules.

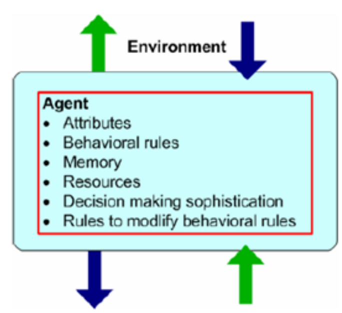

Figure 1 Agent Characteristics [1]

In this research, we conduct a survey to disseminate the questionnaire for obtaining a reality portrait of energy consumption patterns, in order to understand consumer behavior. In general, the type of profession can be classified into farmers, traders and fishermen, government officer, and private sector labors. Each type of profession (user) has a specific stereotype, e.g. for traders and fishermen have two stereotypes, those are normal and extravagant users (big users). The list of the number of user percentage and user stereotypes can be seen in Table 1.

To determine the electricity consumption for each type of user (agent), we need to have the list of electricity equipment use by user and power consumption for each equipment. The use of equipment and power consumption for each equipment and agent can be seen in Table 2.

Table 1 The list of user stereotypes.

No.	User	User Percentage (%)	Stereotype	
1	Farmers	40	Normal	Energy saver
2	Traders/Fishermen	20	Normal	Big User
3	Government officer	30	Normal	Big User
4	Private sector workers	10	Normal	Big User

Table 2 List of Equipment and Electricity Consumption Usage for Each User.

Equipment	Farmers		Traders/Fishermen		Government Officer		Private Sector	
	Continuous On (Watt)	Stand by (Watt)	Continuous On (Watt)	Stand by (Watt)	Continuous On (Watt)	Stand by (Watt)	Continuous On (Watt)	Stand by (Watt)
Big Refrigerator	0	0	0	0	57.5	6	57.5	282
Medium Refrigerator	0	0	11.25	3	0	0	0	0
Magic jar + rice cooker	29.06	90	116.25	180	232.5	360	232.5	360
Small Lamp	360	0	800	0	800	0	800	0
Big Lamp	180	0	360	0	360	0	360	0
Iron	300	0	450	0	450	0	600	0
Washing machine	0	0	31.25	0	31.25	0	37.5	0
Microwave	0	0	0	0	0	0	0	0
TV	272	6	340	0	340	0	340	0
Computer	0	0	0	0	200	25	100	12.5
Water pump	1300	0	1625	0	1625	0	1625	0
Fan	80	0	150	0	80	0	100	0
AC	0	0	0	0	215	0	215	0
Total Consumption (watt)	2,521.063	96	3,883.75	183	4,391.25	391	4,467.5	654.5
Total Consumption (kW)	2.521	0.096	3.883	0.183	4.391	0.391	4.467	0.655
Average usage per user per month (kWh)	2.6170625		4.06675		4.78225		5.122	

2.0 LITERATURE REVIEW

Agent-based modeling is used to study social phenomena such as human behavior and the processes that occur in the business. The agent-based simulation has been used extensively by researchers and visualized phenomena such as the interaction of individuals in ecosystems, chemical reactions and insect behavior [4]. The benefit of agent-based modeling lies in its ability to model complex real-world systems. Agent-based modeling also can produce complex system behavior as results from the agent interaction [5].

Bonabeau denotes that agent-based modeling can model the system with a set of entities for decision making autonomously and this entity are called as "agent" [2]. Every agent acts and behaves based on certain rules in the environment. In Agent-Based Modeling, observation and research can be done toward interactions that occur between agents [6]. Agent-Based modeling also can be used to model business process [6-7]. Business process entities are modeled as an agent and business processes are modeled as the interaction between agents. Some advantages of agent-based modeling are:

a. Able to capture the phenomenon appears, as a result of the interaction of individual entities.
b. Able to provide an overview of the system: able to make the model closer to reality.
c. Flexible: easy to add the agent, providing a natural framework for tuning the complexity of agent-like behavior, the level of rationality, the ability to learn and evolve, and interaction rules.

ABM models can be applied in the social sciences, politics, and economics. In a business context, a situation in which the phenomenon appears to be classified into four areas, namely: flows, markets, organization, and diffusion.

3.0 MODEL DEVELOPMENT

ABM models which are used to simulate the electricity consumption, is divided into four sections based on types of users, namely traders and fishermen, farmers, private sector workers, and government officer. For each part of the model will also be divided based on the type of usage, the use of normal, big, or energy saver. In this model, the agent is a representation of household electricity consumption.

ABM models will also consider certain activities in a predefined, which will result in the increase or decrease in the electricity consumption. Several events that influence the electricity consumption can be seen in Table 3.

Table 3 List of Events That Affect Electricity Consumption

Month: January 2012		
Events	Date	Persentage
New Year	1	10%
Istighotsah	2	9%
Khitan	7	9%
Maulid Nabi	26	10%

State charts in ABM models are constructed for analyzing the behavior pattern of electrical energy consumption according to the type of profession in general can be seen in Figure 2.

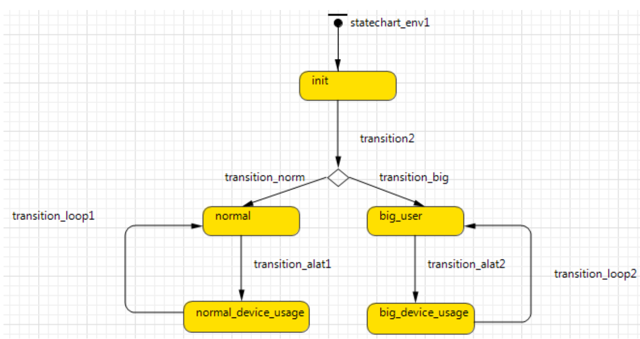

Figure 2 ABM Statechart

State chart descriptions are as follows:

init

init : To initialize the variables that will be used in the simulation.

decision/branch : To determine the each type of agent consumption, whether normal or big user.

normal : Represents agent consumption with normal behavior

big_user/energy_saver : Represents agent consumption with wasteful behavior / energy saver.

normal_device_usage : To calculate the power consumption for each agent with normal consumption.

big_device_usage : To calculate the power consumption for each agent with extravagant consumption.

Total electricity consumption can be determined by multiplying the electrical consumption (watt), ignition time, and the number of electrical equipment. The formula can be seen at Equation (1).

$$electricity\ consumption = \sum(electric\ watt \times ignition\ time \times number\ of\ device) \quad (1)$$

Ignition time and the number of electrical equipment owned by each agent varies depend on the type of profession and type of usage. Electrical consumption is also influenced by month / season of usage, which in this model, is calculated with the following algorithm;

```
if(time=1&26)
{       usage = usage+( usage*0.1);
}
else if(time=2&7)
{       usage= usage+( usage*0.09);
}
```

As we can see in the above algorithm, when the simulation timing t1 and t26 (1st and 26th of January), the consumption will increase by 10%. Meanwhile at t2 and t27 (2nd and 27th of January), the consumption will increase by 9%.

After the definition of parameters, variables, and formulation for all stages, model simulation can be performed.

3.1. Traders and Fishermen Model

From the simulation results we can see that the total average power consumption of traders and fishermen per month is around 50,946 + 23,381 = 74,327 kWh as seen at Figure 3.

Figure 3 Simulation Model Result for Traders and Fishermen

From the simulation results obtained total usage and average usage for normal and big consumption as seen at Table 4.

Table 4 Simulation Result for Traders and Fishermen

Type of usage	Total consumption (kwH/ month)	Average usage (kwH/ month)
Normal User	1,579,322	50,946
Big Consumption	724,804	23,381
Overall	**2,304,126**	**74,327**

3.2. Farmers Model

From the simulation results can be seen the total average power consumption of farmers per month is 113,936 + 9,590 = 123,526 kWH as seen at Figure 4.

Figure 4 Simulation Model Result for Farmers

From the simulation results obtained total usage and average usage for normal and energy saver as seen at Table 5.

Table 5 Simulation Result for Farmers

Type of usage	Total consumption (kwH/ month)	Average usage (kwH/ month)
Normal User	3,418,070	113,936
Energy Saver	287,719	9,590
Overall	**3,705,789**	**123,526**

3.3. Private Sector Worker Model

From the simulation results can be seen the total average power consumption of private sector worker per month is 10,971 + 35,747 = 46,718 kWH as seen at Figure 5.

Figure 5 Simulation Model Result for Private Sector Worker

From the simulation results obtained total usage and average usage for normal and energy saver as seen at Table 6.

Table 6 Simulation Result for Private Sector Worker

Type of usage	Total consumption (kwH/ month)	Average usage (kwH/ month)
Normal User	340,091	10,971
Big Consumption	1,108,158	35,747
Overall	**1,448,249**	**46,718**

3.4. Government Officer Model

After the definition of parameters, variables, and formulation for all stages, model simulation will be performed. From the simulation results can be seen the total average power consumption of private sector worker per month is 76,156 + 34,428 = 110,584 kWH as seen at Figure 6.

Figure 6 Simulation Model Result for Government Officer

From the simulation results obtained total usage and average usage for normal and energy saver as seen at Table 7.

Table 7 Simulation Result for Government Officer

Type of usage	Total consumption (kwH/month)	Average usage (kwH/month)
Normal User	2,360,844	76,156
Big Consumption	1,067,283	34,428
Overall	**3,428,127**	**110,584**

We demonstrate the overall of the simulation results for all user type in Table 8.

Table 8 Simulation Results for All User Type.

User Type	Normal Consumption	Big Consumption /Energy Saver	Total
Traders and Fishermen	1,579,322	724,804	2,304,126
Farmers *)	3,418,070	287,719	3,705,789
Private Sector Worker	340,091	1,108,158	1,448,249
Government Officer	2,360,844	1,067,283	3,428,127

4.0 MODEL VALIDATION

Validation is a process to determine whether the model has made an accurate representation of the real system from the perspective of the usefulness of the model [8]. However, the valid model is not the perfect model, because the perfect model is the real system itself [9]. The model will be checked for its accuracy by calculating error rate for average usage and total electricity consumption of all types of users. A model can be stated to be valid if it has an error rate of less than or equal to 5% [10]. The model accuracy level can be calculated by dividing the difference between simulation results and the existing data with the existing data as can be seen in the Equation (2).

$$\text{Error rate}=\frac{(\text{simulation result-data})}{data} \quad (2)$$

Error rate for the average usage and the total electricity consumption for all types of users are described as follows:

a. Traders and Fishermen
   E (average) = (74,327 – 74,748) / 74.748 = 0.0056
   E (total consumption) = (2,304,126– 2,317,173) / 2,317,173 = 0.0056

b. Farmers
   E (average) = (123,526 – 121,020) / 121,020 = 0.0122
   E (total consumption) = (3,705,789 – 3,751,614) / 3,751,614 = 0.0207

c. Private Sector Workers
   E (average) = (46,718 – 46,272) / 46.272 = 0.009
   E (total consumption) = (1,448,249 – 1,434,441) / 1,434,441 = 0.009

d. Government Officer
   E (average) = (110,584 – 113,901) / 113,901 = 0.029
   E (total consumption) = (3,428,127 – 3,530,931) / 3,530,931 = 0.029

6.0 SCENARIO DEVELOPMENT

In this research, scenario is developed by considering the weather to see a decrease or increase in electricity consumption during the dry season and the rainy season.

6.1. Dry Season Scenario

In this scenario, the models are simulated by considering the weather conditions that could affect the electricity consumption. Indonesia has two kinds of season, dry and rainy season. The electrical devices usage that is affected by this scenario are fan and Air Conditioner (AC). The fan and AC usage increase three times from normal condition (based on survey), as shown in Table 9. The calculations obtained by changing the average ignition time of a fan and air conditioning.

Table 9 Ignition Time of Fan and AC for Each Type of User.

User	Electrical Device	Ignition Time			
		Minimum	Maximum	Average	Standard Deviation
Normal User	Fan	0,55	10	9	1,8
	AC	0,55	6	5	0,33
Big User	Fan	0,55	12	11	0,55
	AC	0,55	7	6	0,55

Besides the season, the power consumption is also influenced by several events in a certain month. In this research, we consider August (dry season) as a month that has several events such as Idul Fitri, Istighotsah, Khitan as seen in Table 10.

Table 10 Events that Affect the Electricity Consumption Based on Dry Season Scenario.

Month: August 2012		
Event	Date	Increase By
Idul Fitri	1	10%
Istighotsah	6, 13	9%
Khitan	20, 27	9%

Based on this this scenario, the total power consumption = 18,758,648 kWH/month

6.2. Rainy Season Scenario

According to National Environmental Education Foundation Climate, Weather, and Energy Consumption [11], in rainy season, the power consumption will decrease by 5%-20%. In this scenario, we assume that the electricity consumption for each user will decrease as follows:

a. Traders, fishermen and private workers = 15%
b. Farmers = 20 %
c. Government officer = 15%

These assumptions have been made by considering the historical data that we obtained from the electricity company. Events that occurred in January that represent rainy season can be seen in Table 11.

Table 11 Events that Affect the Electricity Consumption Based on Rainy Season Scenario

Month: January 2012		
Event	Date	Increasement
New Year	1	10%
Istighotsah	2	9%
Circumcision	7	9%
Maulid Nabi	26	10%

The results of this scenario is, the total electricity consumption = 14,296,581 kWH/month

■7.0 CONCLUSION

In developing ABM, system understanding is crucial for the development and model formulation. We assume that the increase in electricity consumption caused by certain events that may happen within the year. Determination of total power consumption for each household (agent) depends on the number of electricity device, ignition time, and the device power (Watts). The number of electricity device and ignition time relied on the behavior of users such as normal user, big consumption users, or energy saver.

In the rainy season scenario, power consumption will be reduced by 17.9%, so that the total consumption would be around 14,296,581 kWH. Meanwhile, based on dry season scenario, the power consumption will be increased by 7%, so that the total consumption would be around 18,758,648 kWH.

Acknowledgement.

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