Agent-Based Modeling of IoT Electric Meters

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Abstract

Internet of Things (IoT) is the connection of objects using the internet that are equipped with sensors and communication technology. IoT Technology is a new paradigm envisioned as a global network of machines and devices capable of communicating with each other. This project presents using the agent-based model to simulate the behaviors of IoT electric meters. A case study was proposed to investigate the applicability of utilizing IoT technology in Saudi Electricity Company (SEC). The agent-based model was built using AnyLogic software. Two different scenarios were applied, and simulation outputs were analyzed to recognize the importance of adopting IoT technology at SEC.

Keywords
Internet of Things (IoT), Agent-Based model, Saudi Electricity Company.

1. Introduction

The main activity of the Saudi Electricity Company (SEC) is producing and distributing electricity within Saudi Arabia. SEC was established in 2000. The company is considered the principal generator of electricity and the only holder of the entire distribution network throughout the country, helping all kinds of clients. However, the current electric meter used widely in SEC has many flaws such as reading errors and delay in issuing electric bills since the reading of the meter is operated manually. Therefore, IoT technology can be applied to overcome these difficulties. This technology provides real-time data on electricity and helps to optimize the distribution of energy. The IoT electric meter can enhance the client service through the valuable insights and information obtained from the meter data. The purpose of this research is to investigate the applicability of applying IoT technology in SEC by simulating the behaviors of the electric meter using agent-based modeling.

This paper has four sections. Section 1 includes the introduction and Section 2 covers some background of agent-based simulation. Section 3 presents a case study from SEC. Finally, the limitation and the future works are addressed in the last section.

2. Agent-Based Modeling

Agent-based simulation is an approach to solve difficulties of systems consist of objects (Gilbert, 2007). In the beginning, it was applied in the study of cellular automata (Richiardi, 2014). Agent-based simulation has gained more interest in the last decade (Macal & North, 2009). Agents can be used to study the behaviors of different objects such as markets and customers which makes this type of simulation very helpful nowadays (Railsback & Grimm, 2019).

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Recently, agent-based modeling has been applied in many fields such as economics ((Farmer & Foley, 2009), (Samanidou et al., 2007), and (North et al., 2010)) biology ((An et al., 2009), (Bauer et al., 2009), and (Hinkelmann et al., 2011)), and social sciences ((Bruch & Atwell, 2015) (Macy & Flache, 2009), (Kennedy, 2012), (Billari & Prskawetz, 2012), (Grimm & Railsback, 2006)). Moreover, another new application of agent-based modeling is to examine the spread of COVID-19 (Rockett et al., 2020), (Silva et al., 2020).

3. Case Study

The Saudi Electricity Company (SEC) was chosen in this case study. The scope of the study is limited to: One main center of SEC and 13 buildings (each building has one electric meter). Agent-based model is built to model the existing system and study the effect of utilizing IoT technology. Figure 1 shows the workflow diagram to illustrate the methodology followed in this research. Before building the model, Unified Modeling Language (UML) was developed. UML is a visual paradigm that helps the developers to understand the system. There are many types of UML. One of them is the sequence diagram (Figure 2) which was developed in this study before building the simulation model. This diagram helps to model the logic of a sophisticated procedure, function, or operation and understand the interactions between objects.

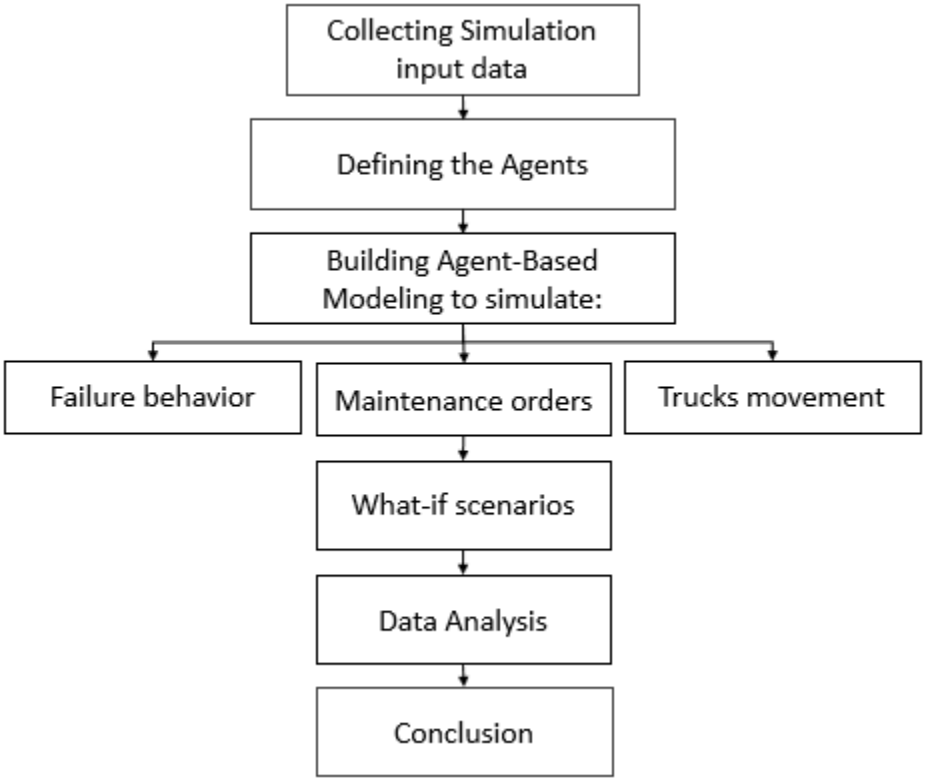

Figure 1. Workflow diagram

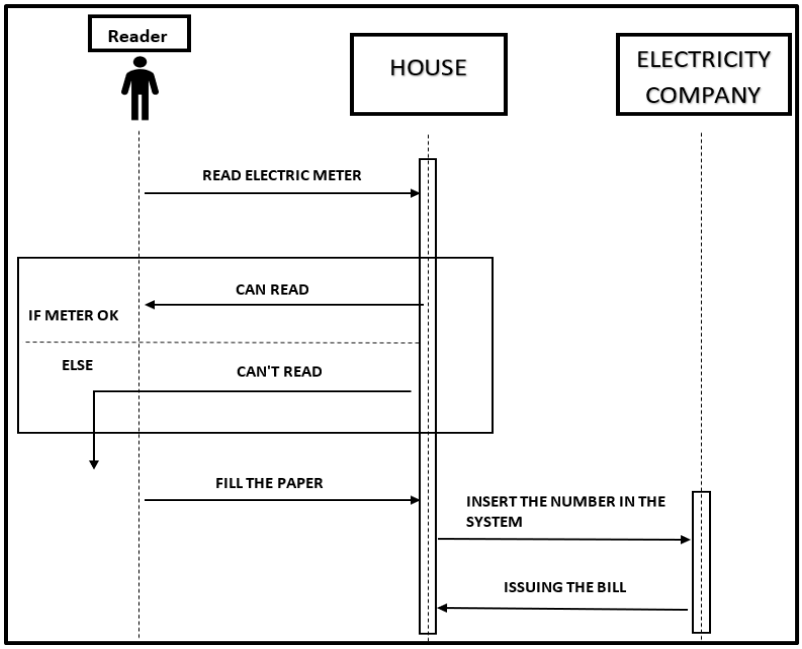

Figure 2. The sequence of objects instructions

3.1 Input Data

Agent-based model requires sufficient data to demonstrates the mechanism of the real system. The simulation input data are shown in Table 1. Moreover, the exact physical locations of 13 buildings were collected (Table 2) to reasonably estimate the transfer time between different locations using GIS functionality inherited in AnyLogic software.

Table 1. Simulation input data

#	Item	Value	Unit
1	# of trucks	5	#
2	Speed of the truck	40	Km/h
3	# of SEC center	1	Center
4	# of buildings	13	Building
5	Delay	Uniform (5,10)	Hour
6	Distance between SEC facility and buildings	GIS	GIS

Table 2. Locations of the 13 building

#	Building	Longitude	Latitude
1	gisPoint1	39.16576	21.50982
2	gisPoint2	39.16524	21.51063
3	gisPoint3	39.16618	21.51144
4	gisPoint4	39.16647	21.50996
5	gisPoint5	39.16433	21.51183
6	gisPoint6	39.16349	21.51205
7	gisPoint7	39.16487	21.50941
8	gisPoint8	39.16443	21.51349
9	gisPoint9	39.1637	21.51389
10	gisPoint10	39.16555	21.5122
11	gisPoint11	39.16476	21.51121
12	gisPoint12	39.16499	21.51288
13	gisPoint13	39.16399	21.51257

3.2 Agent-Based Simulation Model

First, all the different locations were inserted in the model (Figure 3). Then, modeling the behaviors of the system was done by defining four different agents (Figure 4) and then establishing the process of reading the electric meter in each of the 13 buildings. Lastly, the simulation model investigates three different scenarios of utilizing IoT technology.

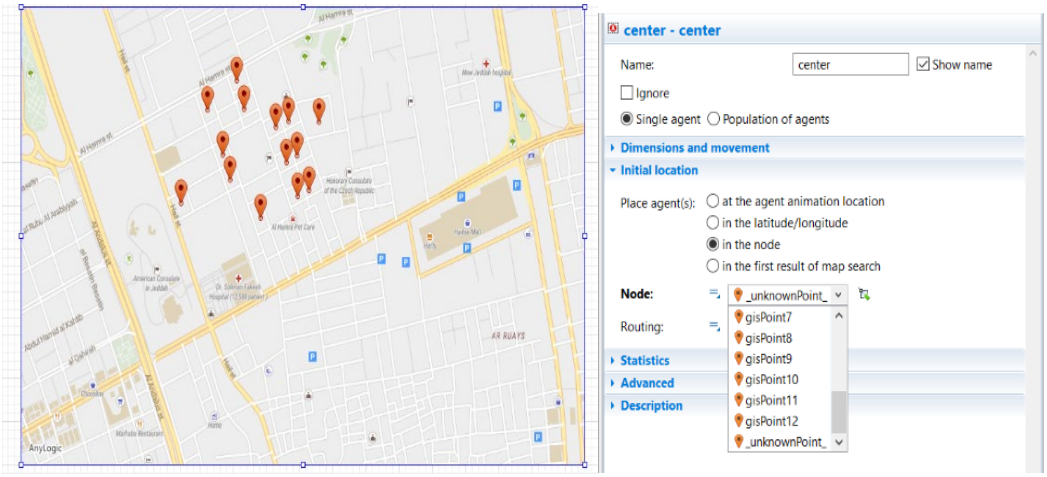

Figure 3. Sitting the building locations in the simulation model

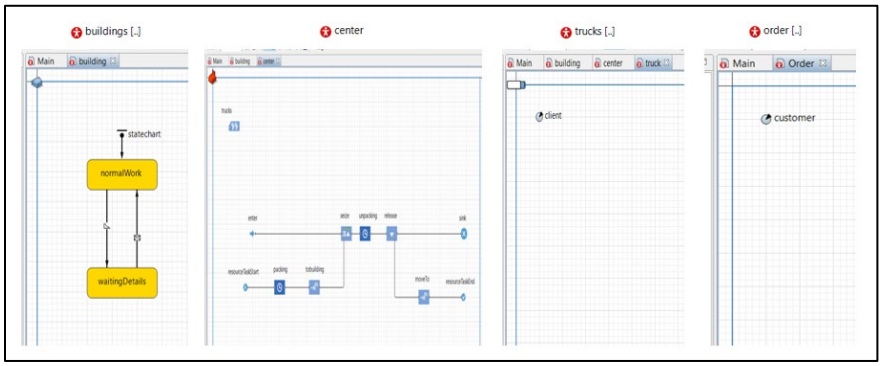

Figure 4. The four agents of the simulation model

The interactions between the *Order* agent and the *Truck* agent using the java code is shown in Figure 5. Moreover, two different kinds of simulations were needed to mimic the system. The agent-based model was used to simulates the behaviors of the electric meter in the *Building* agent while the discrete event was used to simulate the process of reading the electric meter in the *Center* agent

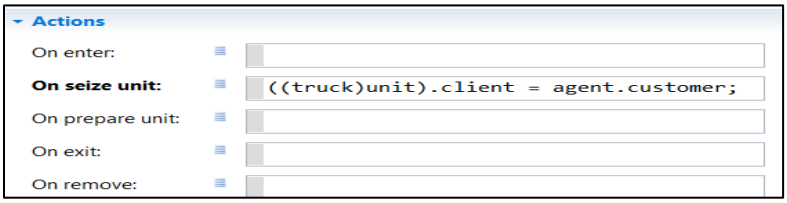

Figure 5. Java code used to connect the *Order* agent with the *Truck* agent

3.3 Simulation Results

Two important parameters in the simulation model were used as system performance measurement: *Required Time to Read* & *Waiting Time Cost*. Java codes were used to calculate these parameters (Figure 6). The lateness cost of reading the meter was assumed to be SR 100 per day based on SEC expert opinion.

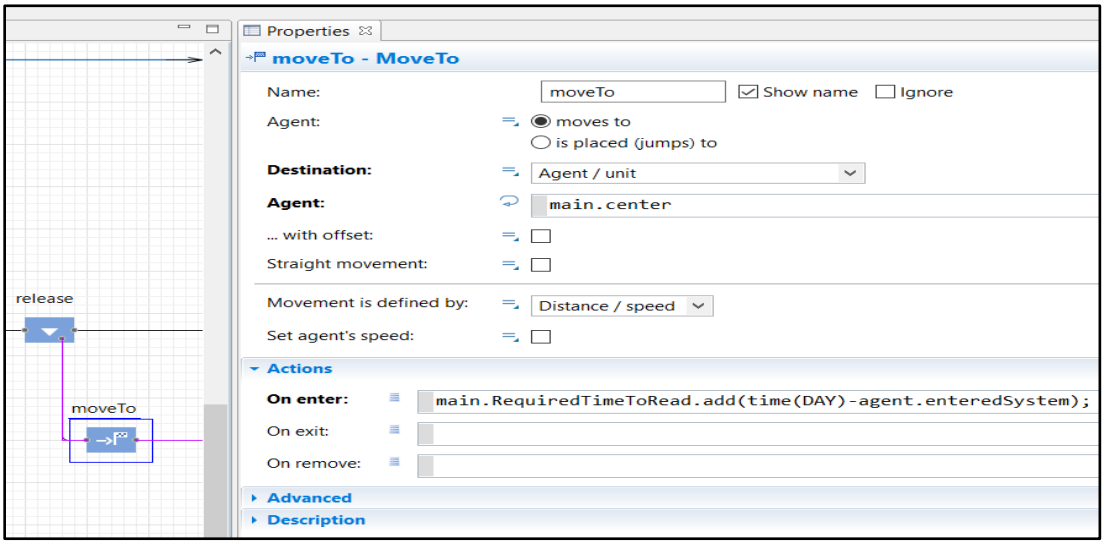

Figure 6. Java code used to calculate Required Time to Read

The simulation model was run for 1 year. The results of *Required Time to Read* & *Waiting Time Cost* are shown in Figure 7 and Table 3

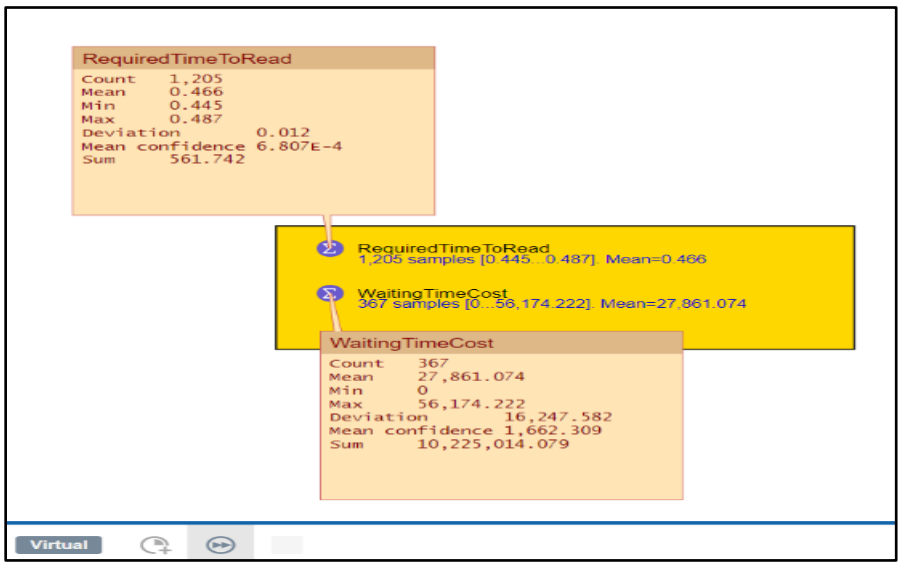

Figure 7. Simulation results

Table 3. Simulation results

Simulation Output	Values
Required Time to Read (DAY)	561.742
Waiting Time Cost (SR)	56,174.222

The simulation results show that the existing system has an approximate delay of 562 days in reading the electric meter per year. The reason behind this delay is that the current reading process is operated manually. This lateness generates an unnecessary approximate cost of SR 56,000 per year. The SEC management decided to reduce this cost by adopting IoT technology. Two different scenarios were tested in this study.

3.4 What-if scenarios

Two different scenarios were tested. The first scenario when the Delay of reading the electric meter was reduced to half and the second scenario is when IoT is utilized and therefore the Delay equals 0. In the second scenario, IoT sensors will be connected to each electric meter to advance its functionality. Figures 8, 9, and 10 show the simulation results for each scenario, and these results are summarized in Table 4.

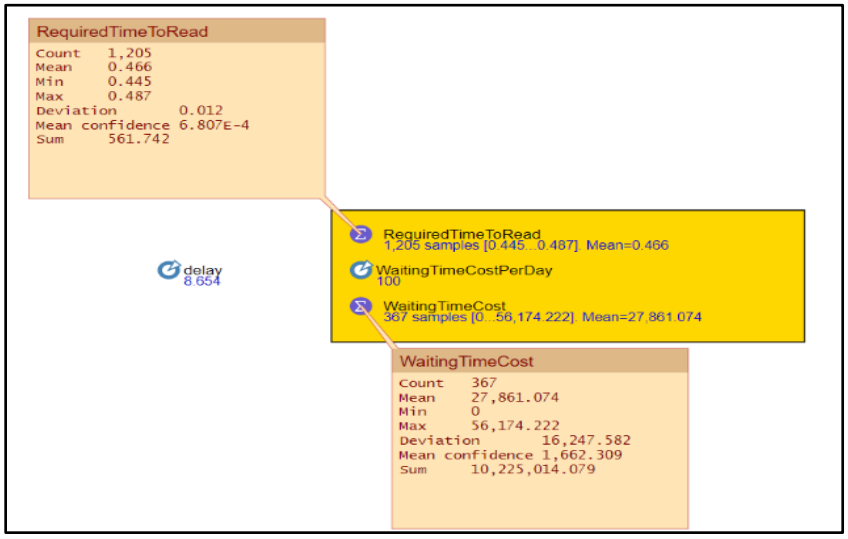

Figure 8: Base scenario results

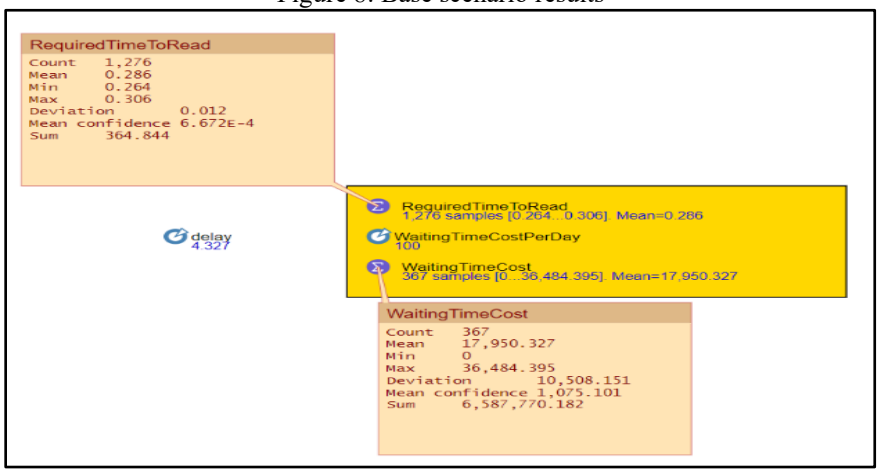

Figure 9: Second scenario results

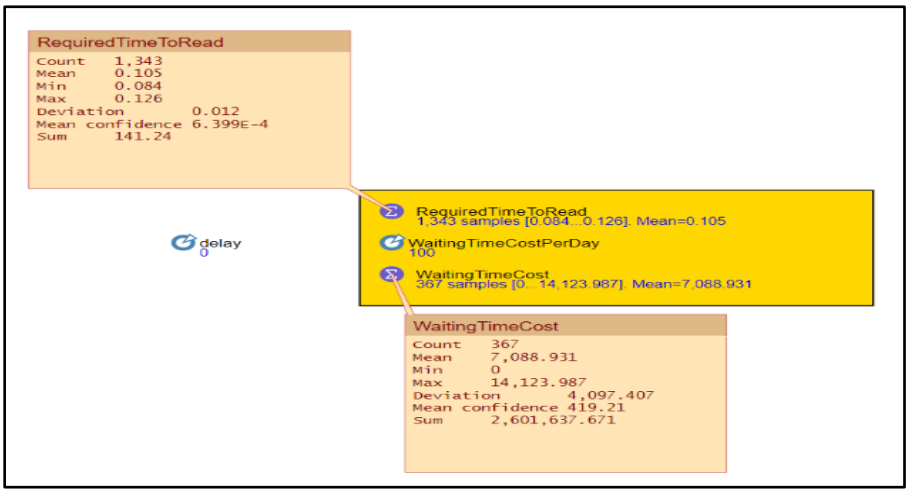

Figure 10: Third scenario (IoT applied) results

Table 4. The summarized result for each scenario

Scenario	Delay (Hour)	Waiting Time Cost
Base Scenario	Uniform (5 – 10)	56,174.222
First Scenario	Uniform (2.5 – 5)	36,484.395
Second Scenario (IoT applied)	0	14,123.987

As shown in Table 5, the cost of the waiting time was reduced by 35% (SR36,484.395) in the First scenario while in the Second scenario (Where IoT applied) the cost was reduced by 75% (SR14,123.987) with ZERO delays.

4. Limitations and future works

The limitation and some of the suggestions for future work are summarized in Table 5

Table 5. The limitation and the future work

Limitation	Future Work
Agent-based simulation model was not validated	Validation of the simulation model
The project sample size was limited to 13 buildings and 1 center of SEC	Increase the project scope (Include more buildings, trucks, and centers)
The truck movement information and utilization were not used in this model	Apply Transportation Optimization model
The cost of Installation of Internet of Things (IoT) technology was not calculated	Calculate the ROI of IoT technology
Simulation parameters have assumptions of constant values such as Delay, Cost of waiting per day	Run for multiple replications and more analysis on the data (Probability Distribution

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Biography

Mohammed Basingab is an Assistant Professor in the department of Industrial Engineering at King Abdulaziz University, Jeddah, Saudi Arabia. He received his PhD in Industrial Engineering and Management Systems from the University of Central Florida, Orlando, the USA in 2017. His research interest includes but not limited to Quality Management, Six Sigma applications, Big Data Simulations, Agents Based Simulation, Internet of Thing (IoT) applications, and Supply Chain Management. Dr. Basingab has published in many journals and conferences including International Journal of the Computer, The Internet and Management, Second International Conference on Internet of Things, Data and Cloud Computing, and IX International Symposium of Industrial Engineering: news and trends. He also published two book chapters in “Artificial Intelligence: Advances in Research and Applications” regarding Managing Overcrowding in Healthcare using Fuzzy Logic and Utilization of Case-Based Reasoning and Simulation Modeling in Healthcare Sector.