Using Agent-Based Modeling for IoT Application: A Case Study of Retail Pharmacy in Saudi Arabia

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Abstract

Internet of Things is the connection of objects using the internet that are equipped with sensors, actuators and communication technology. IoT, also called the Internet of Everything or the Industrial Internet, is a new technology paradigm envisioned as a global network of machines and devices capable of interacting with each other. Nowadays, this technology is recognized as one of the most important areas of future technology and is gaining vast attention from a wide range of industries. This paper presents a conceptual study of using IoT technology in one of the leading chains of Saudi Arabia retail pharmacy (Al-Nahdi). Agent-Based Simulation (ABS) was used to simulate the refrigerators behaviors of Al-Nahdi. Three different scenarios were applied and simulation outputs were analyzed to recognize the importance of adopting IoT technology.

Keyword
Agent-Based Simulation, Internet of Things, Refrigerators Behaviors, Al-Nahdi Pharmacies.

1 Introduction

Al-Nahdi Pharmacies is a leading chain of Saudi retail pharmacy. It operates a network in 125 cities in Saudi Arabia, which makes it one of the top dominant and the fastest increasing companies in KSA. It has 1131 branches around Saudi Arabia. Al-Nahdi has an approximate annual cost of SR 2.5 Million due to refrigerator failure and medicine waste. The main reason for this problem is the lack of having an efficient checking system to monitor Al-Nahdi's refrigerator failure constantly. This paper proposes a conceptual study to solve Al-Nahdi's problem by applying the Internet of Things (IoT) technology.

The Internet of Things (IoT) is a new technology paradigm envisioned as a global network of devices capable of interacting with each other (Lee & Lee, 2015). Nowadays, IoT is recognized as one of the most important areas of future technology and is gaining vast attention from a wide range of industries (Whitmore, Agarwal, & Da Xu, 2015). In the early 2000s, Kevin Ashton was laying the groundwork for what would become the Internet of Things (IoT) at MIT's AutoID lab. Ashton was one of the pioneers who conceived this world as he searched for ways that Proctor & Gamble could improve its business by linking RFID information to the Internet (Ashton, 2009). The concept was simple but powerful. If all objects in daily life were equipped with identifiers and wireless connectivity, these objects could be communicated with each other and be managed by computers.
The main objective of this paper is to propose a conceptual study of using IoT technology in Al-Nahdi Pharmacies to reduce the waste of medicines and Increase the response of the maintenance team. This paper is organized into four sections including the introduction. Section 2 provides a brief review of the literature of Agent-Based Simulation (ABS). Section 3 shows a case study to demonstrate the application of ABS to simulate refrigerators behavior of Al-Nahdi in Saudi Arabia. Finally, Section 4 discusses the future works of this paper and concludes the research.

2 Related Work

The first appearance of Agent-Base Simulation (ABM) was in the 1940s when John von Neumann invented the idea of cellular automata (Xu, He, & Li, 2014). Primarily, computer scientists were more interested than others in ABM because of its powerful use for artificial intelligence. "However, In the 1990s, social scientists discovered the potential benefits of Agent-Based Simulation (ABS) when they started to form research groups that investigated the use of ABS for modeling individuals' behaviors" (Brailsford, 2014; Macal & North, 2009). Recently, ABS was applied in areas where human behavior is important due to its powerful capability of capturing human behavior in detail and imitating system interactions and dynamics" (Basingab, 2019; Brailsford, 2014).

3 Case Study of AL-Nahdi Pharmacies

In this case study, 12 pharmacies, 10 trucks and 1 warehouse of Al-Nahdi Pharmacies in Jeddah city were selected. The Agent-Based simulation was built using AnyLogic software to simulate refrigerators failures. There are 4 types of agents in our ABS model shown in Figure 1.

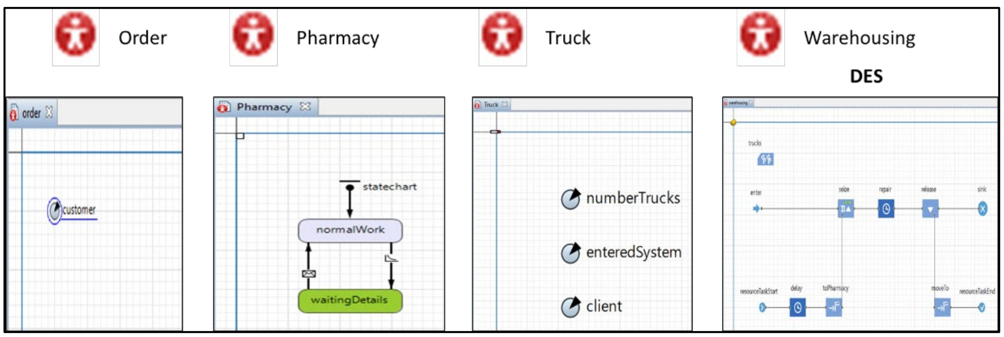

Figure 1. The four agents in ABS

Figure 2 shows the Unified Modeling Language (UML). UML is a diagram visually representing a system to understand and document information with its main actors, roles and action. Sequence diagram, the most popular type of UML, describes the sequence of instructions and messages that happen between agents. The Figure shows the sequence of communication between pharmacy and warehousing agents. Once the technical issue happened, it turns from Normal Work into Waiting Details and sends a maintenance order to the warehouse to send a back-up maintenance truck to solve the problem. Once the problem is solved, waiting details will send a delivered message to normal work and get back in a normal situation.

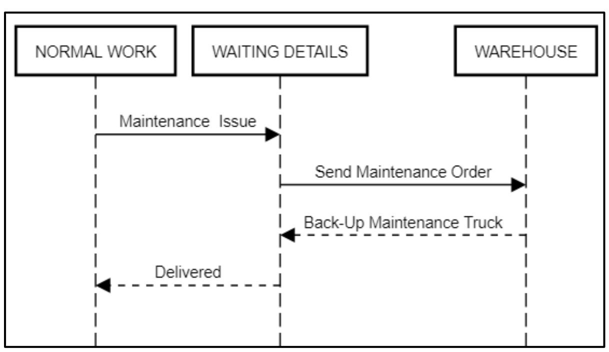

Figure 2. The Unified Modeling Language (UML)

3.1 Data Collection Method

ABS modeling requires data that represent the dynamic environment of the real world. In this paper, all the data collected from Al-Nahdi specialist is shown in Table 1.

Table 1. Simulation Input Parameters

#	Parameter	Value	Unit
1	Number of Trucks	10	Truck
2	Trucks Speed	70	Km/h
3	Number of Al-Nahdi Warehouse	1	Warehouse
4	Number of Al-Nahdi Stores	12	Store
5	Failure Rate of Refrigerator	Triangle (5,7,10)	Refrigerator
6	Maintenance Response Time	Uniform (1,2)	Hour
7	Queue Capacity	100	Truck
8	Repair Time of Refrigerator	Uniform (2,3)	Hour
9	Distance between Manufacturing Facility and Al-Nahdi stores	GIS Functionality	GIS
10	Repair Cost / Failure	50	Saudi Riyal
11	Out of Service / Day	20	Saudi Riyal

The geographical data (Longitude and Latitude) of the 12 Al-Nahdi stores and the warehouse is shown in Table 2.

Table 2. Geographical Data

#	Longitude	Latitude
Warehouse	39.25031	21.51589
Store 1	39.15542	21.59468
Store 2	39.13148	21.59764
Store 3	39.23951	21.51747
Store 4	39.23941	21.51284
Store 5	39.23009	21.52764
Store 6	39.22284	21.51971
Store 7	39.22615	21.51232
Store 8	39.21296	21.48603
Store 9	39.20554	21.482
Store 10	39.19677	21.49728
Store 11	39.1974	21.49167
Store 12	39.20527	21.48507

3.2 Simulation Model

The developed ABS in this paper was considered for pilot testing to help us understand how a system reacts due to different inputs. It enabled us to realize the effect of specific parameters such as the failure rate of the refrigerators. Figure 3 shows how the geographical data was inserted in AnyLogic software using *collection* feature.

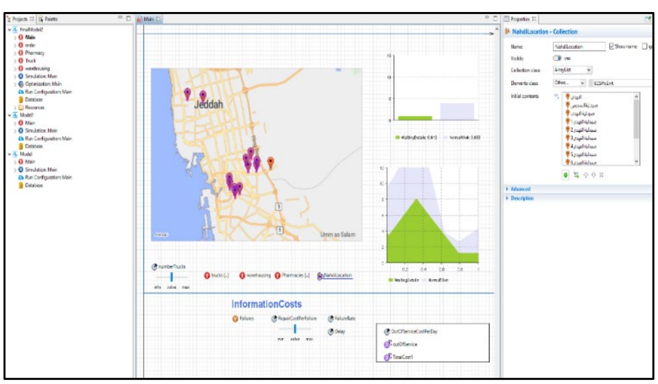

Figure 3. ABS Model

The model simulates 12 pharmacies in Jeddah and one warehouse. There are two states in the Pharmacy agent statechart. The first one is the normal condition which means that the pharmacy is in a normal situation. The second condition is the failure condition which means that the pharmacy is waiting for the truck with the maintenance team from the warehouse to make the repair. The ABS model uses the integrated Geographic Information System (GIS) functionality to locate the agents in the model as well as automatically determine the routes based on the roads from the GIS provider in AnyLogic software. Orders are created by the Pharmacy agent and received by the Warehouse agent. These orders are represented as agents and communicate between the Pharmacy agent and the Warehouse agent. After receipt of an order, loading the truck is simulated with a process logic embedded within the Warehouse agent. Once the truck is loaded, the order is delivered to the requesting pharmacy and unloaded and sent back to the warehouse.

Figure 4 shows the structure of the discrete model and truck movements from the Wearhouse agent to the different stores in the Pharmacy agent. In the discrete model, if any refrigerator fails, orders (notifications) will be sent to the warehouse. In the Warehouse agent, there is a delay time (that includes when the refrigerator is going out of service status and the pharmacist does not know about it). After noticing the failure by the pharmacist, the truck with the maintenance team will move to the pharmacy using *Seize*, *Delay*, and *Release* modules. After that, Pharmacy agent state will be changed to normal and the truck goes back to the warehouse.

The discrete model inside the Warehouse agent (Figure 4) is connected with the statechart inside the Pharmacy agent using the *Order* JAVA code shown in Figure 5 (Hybrid model). Hybrid System is a large class of systems being developed has both agent time and discrete time behavior.

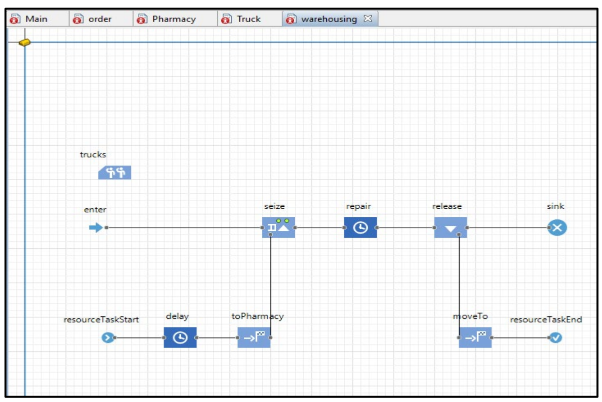

Figure 4. Discrete Model

Figure 5. Hybrid Model

One of the challenging parts in ABS was to calculate *out of service* time for each refrigerator. Using the JAVA code shown in Figure 6, we were able to determine how much time each refrigerator was not working. Figure 7 shows the visualization of ABS animation for the agents in Saudi Arabia after running the simulation for 1 year. There are two states in the Pharmacy agent. The first one is the normal condition with a lavender color which means that the pharmacy is in a normal situation. The second condition is the failure condition with a green color which means that the pharmacy is waiting for the truck with the maintenance team from the warehouse to make the repair.

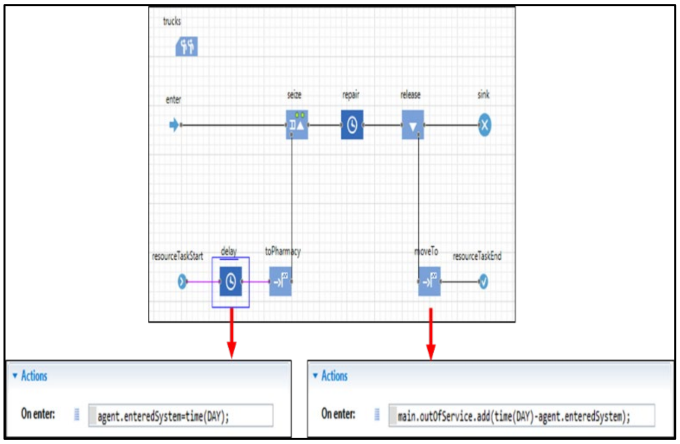

Figure 6. Calculating Out of Service Time

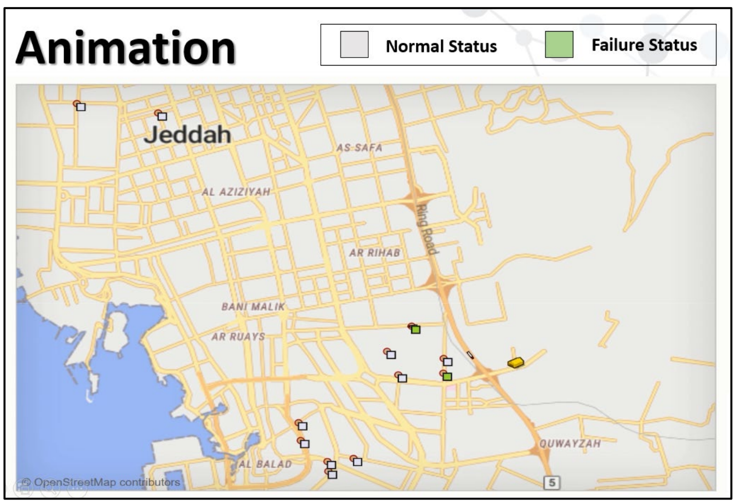

Figure 7. Model Animation

3.3 Simulation Results

We run the ABS model for one year and our main focus to know how many days the refrigerators were out of service in each pharmacy. Also, we concern about the total cost which includes both repair and out of service cost. The simulation results are shown in Figure 8 and summarized in Table 3.

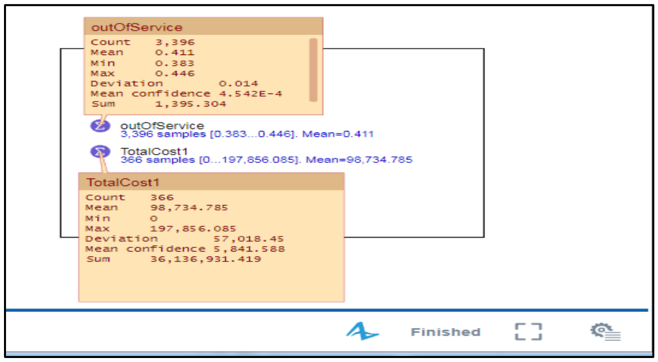

Figure 1. AnyLogic Results

Table 1. Summarized Results

Simulation Output	Value
Out of Service (DAY)	1395.304
Total Cost (SR)	197,856.085

3.4 What-if Scenarios

We selected three different scenarios randomly and manipulate the data to understand the effect of applying IoT technology in Al-Nahdi stores. The delay time (which was explained in section 3.2) is changed in each scenario. The first scenario represents the current situation of Al-Nahdi with a delay time of uniform distribution between 5 and 10 hours. In the second scenario, we (arbitrarily) cut the delay time to half with a uniform distribution between 2.5 and 5 hours just to know how this will affect our simulation result. The third scenario represents applying IoT technology with no delay time (when the refrigerator fails, the maintenance team will know about the failure immediately because of the IoT immediate notifications) (Figure 9). The results of each scenario are shown in Figures 10,11, and 12 and summarized in Tables 4,5 and 6.

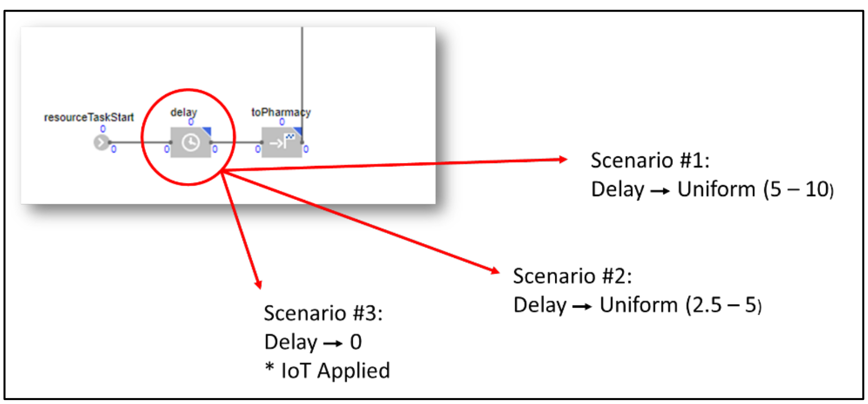

Figure 2. Summary of the Three Scenario

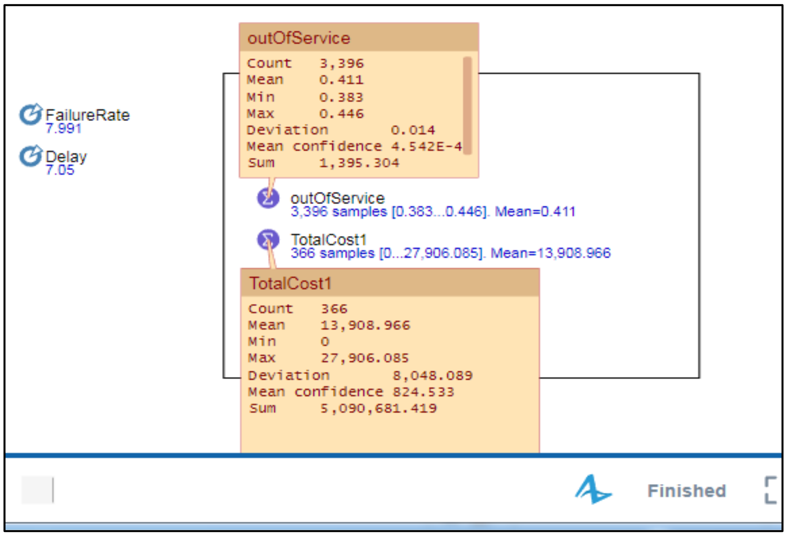

Figure 10. Scenario 1 (Current Situation of Al-Nahdi)

Table 2. Results of Scenario 1

Simulation Output	Value
Out of Service Cost	27,906.085
Delay	Uniform (5 – 10)

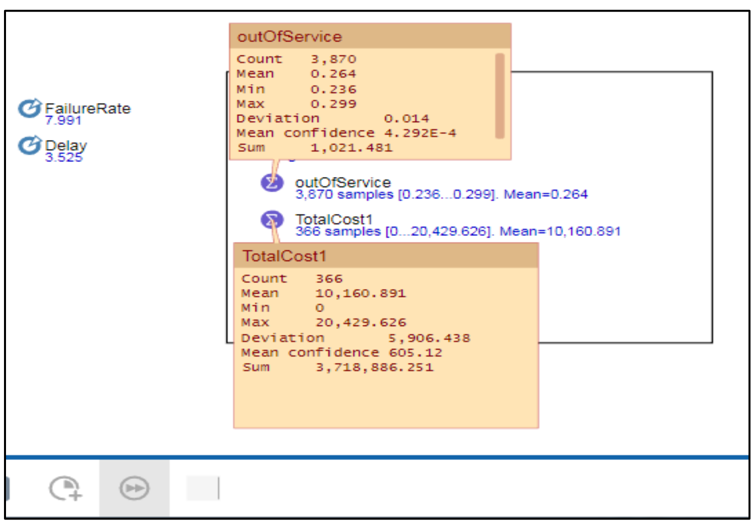

Figure 11. Scenario 2 (Cut Delay Time to Half)

Table 3. Results of Scenario 2

Simulation Output	Value
Out of Service Cost	20,429.626
Delay	Uniform (2.5 – 5)

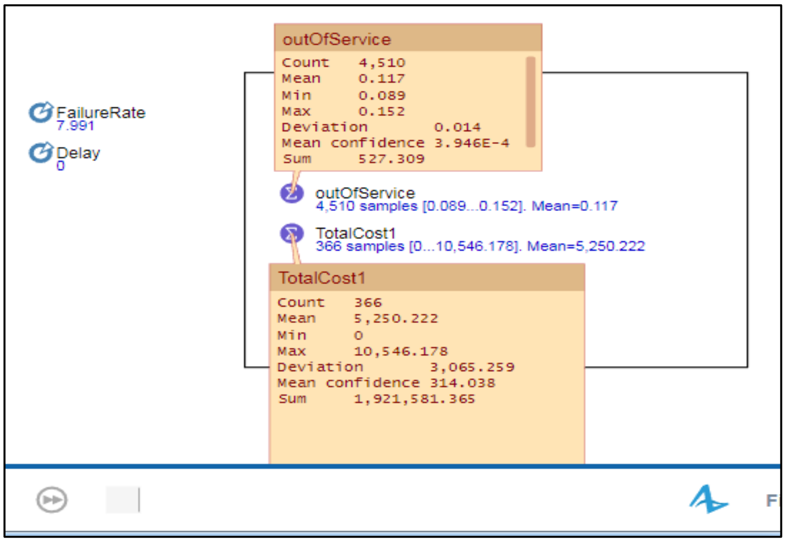

Figure 12. Scenario 3 (IoT applied)

Table 4. Results of Scenario 3

Simulation Output	Value
Out of Service Cost	10,546.178
Delay	0

As mentioned before, the delay time is changed in the three different scenarios. Scenario 2 and Scenario 3 (IoT applied) show a significant reduction in Out of Service cost by 37% and 65% respectively.

4 Conclusion, Limitations and Future Works

Nowadays, IoT is recognized as one of the most important areas of future technology and is gaining vast attention from a wide range of industries. This paper suggests using IoT capability in Al-Nahdi to monitor the failure constantly. However, Table 7 shows the limitations and future works of this paper.

Table 7. Limitations and Future Works

Limitation	Future work
The Project scope was limited to 10 trucks, 12 pharmacies and one warehouse	Increase the project scope (more stores, trucks and warehouse)
Repair cost / Failure = SR 50 Out of Service cost / Day = SR 20	More analysis of the cost data (Probability Distribution)
More information about the Sensor installation cost	Apply Optimization experiment and calculate the Return on Investment (ROI)
The truck movement information and utilization were not used in this model (Truck movement information-Table 8)	Apply Transportation Optimization model

ABS was not validated	Collect more data related to Out of Service time and compare the real data output with ABS output

Table 8. Truck Movement information

	type	agent	start_date	stop_date
1	Truck	trucks[0] : 143	02-02-2019 08:36:04	02-02-2019 08:44:19
2	Truck	trucks[1] : 144	02-02-2019 09:43:25	02-02-2019 09:52:34
3	Truck	trucks[0] : 143	02-02-2019 11:29:11	02-02-2019 11:38:50
4	Truck	trucks[2] : 145	02-02-2019 12:05:48	02-02-2019 12:25:06
5	Truck	trucks[1] : 144	02-02-2019 12:15:22	02-02-2019 12:27:46
6	Truck	trucks[3] : 146	02-02-2019 12:58:07	02-02-2019 13:16:49
7	Truck	trucks[4] : 147	02-02-2019 14:10:10	02-02-2019 14:43:33
8	Truck	trucks[2] : 145	02-02-2019 14:37:37	02-02-2019 14:57:45
9	Truck	trucks[3] : 146	02-02-2019 16:13:31	02-02-2019 16:30:57
10	Truck	trucks[5] : 148	02-02-2019 16:45:03	02-02-2019 17:00:28
11	Truck	trucks[4] : 147	02-02-2019 17:28:22	02-02-2019 18:01:17
12	Truck	trucks[5] : 148	02-02-2019 19:56:47	02-02-2019 20:09:52
13	Truck	trucks[6] : 149	03-02-2019 00:54:36	03-02-2019 01:03:45
14	Truck	trucks[7] : 150	03-02-2019 03:28:09	03-02-2019 03:44:32
15	Truck	trucks[8] : 151	03-02-2019 03:51:43	03-02-2019 04:07:08
16	Truck	trucks[6] : 149	03-02-2019 03:52:53	03-02-2019 04:05:17
17	Truck	trucks[7] : 150	03-02-2019 05:57:25	03-02-2019 06:13:54
18	Truck	trucks[8] : 151	03-02-2019 06:22:29	03-02-2019 06:35:34
19	Truck	trucks[9] : 152	03-02-2019 07:54:48	03-02-2019 08:34:07
20	Truck	trucks[0] : 143	03-02-2019 08:46:46	03-02-2019 09:05:28
21	Truck	trucks[9] : 152	03-02-2019 11:22:14	03-02-2019 11:59:29
22	Truck	trucks[0] : 143	03-02-2019 11:33:09	03-02-2019 11:50:35
23	Truck	trucks[1] : 144	03-02-2019 14:45:14	03-02-2019 14:54:23
24	Truck	trucks[2] : 145	03-02-2019 17:14:18	03-02-2019 17:23:00

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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.

Amr Saleh Bachelor of Science in Industrial Engineering / KING ABDUL-AZIZ University, he is a fresh graduate he had a cooperation training in SAUDIA Airlines for six months, he had more than three years of experience in sales assistant, he has certificates in: Project Management Professional – PMP700, Supply Chain, Data Mining and Root Cause Analysis Familiarization. He worked on the KPIs of Flight Operations Standards department at SAUDIA Airlines. He created a License Privileges and Validity of Ratings Record Card to Flight Operations; his Senior Project was 'Using Agent-Based Modeling for IoT Application in Al-Nahdi Pharmacies'.

Bader Bugshan is a fresh graduate with an honor class in Industrial Engineering from King Abdulaziz University. Currently, he is applying "Cooperative Training Program" in Total Productive Manufacturing (TPM) Department in SAVOLA International Group. He is responsible to improve productivity and efficiency of oil production lines and involved in different main projects.
Bader is certified in Lean Six Sigma Master Black Belt and Certified Data Analyst. He has different certifications and very knowledgeable about KAIZEN, Project Management, Business Intelligence and Continuous Improvements techniques. He has successfully completed the Graduate Project with his colleagues in a very promising trend of projects which is the Internet of Things (IoT) by utilizing the most modern simulation technology and techniques.

Khalid Al-Ghafeer obtained his bachelor degree in Industrial Engineering from King Abdul Aziz University, Saudi Arabia. Currently, he is an assistant team member in the production department at Saudi Air-Conditioning Manufacturing Company (Juffali-Carrier). He is responsible to develop process improvement to achieve higher productivity, cost effectiveness and higher utilization of organization resources by using industrial engineering tools and techniques. He has certificates in: Unilever The Quest (Business Competition), PMP700 - Project Management Professional, Data Mining and Business Intelligence (Data Analysis), Adopting PDCA Cycle in Kaizen and Lean Six Sigma Yellow Belt. His scope of research is wireless sensor network, communications, monitoring, Anylogic Simulation, Agent-Based Model, Internet of Things.

Abdulkareem Alshammari Bachelor of Science in Industrial Engineering / KING ABDUL-AZIZ University, he's fresh graduate, he had a summer training in SAUDIA Airlines for two months, He has certificates in: Decision Analysis and Entrepreneurship, his Senior Project was 'Using Agent-Based Modeling for IoT Application in Al-Nahdi Pharmacies'.