International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Applications of RFID Systems in Healthcare Management: A Simulation for Emergency Department

Onur Deryahanoglu, Batuhan Kocaoglu

Abstract*: Emergency Departments are the most complex and busiest locations for patient flow in hospitals. Treatment of acute diseases, accidental injuries, heart attacks or different medical applications are performed in these centers. At this point, patients should receive effective treatments as soon as possible. Additionally, they can include in medical procedures such as triage, registration, treatment, transfer or hospitalization when they apply of this departments. There are many problems in these services due to their complex structure. For instance; long waiting times, leaving the hospital without excuse or without payment, lack of bed or medical staff, long staying times. For these reasons, patient cares and treatments will be affected. It is thought that using of RFID Technology will be expanded in the Emergency Departments that it may decrease long waiting times, improve the quality of treatment processes and increase patient satisfaction also. In this study, it is aimed to improve patient safety and quality with sustainable tracking system. In addition, a real-time warning mechanism will be created by determining the number of optimum medical staff due to this technology. As a result, length of stay of the patients will be reduced and patient satisfaction will be increased in Emergency Departments.

***Index Terms*: RFID Systems, Healthcare Management, Simulation, Patient Safety.**

I. INTRODUCTION

In the current understaffed and high population flow healthcare industry, it is not surprising to hear that patients suffer from medical care errors. According to recent World Health Organization (WHO) publication regarding patient safety (2009), tens of millions of patients around the world are injured or dead every year as a result of incorrect medical care. Roughly 10% patients admitted to hospital in developed countries suffered some forms of medical care errors or medical adverse events. From the statistics of the WHO in 2006, around 1.4 million people worldwide were injured due to medical care error [1]. At this point; to reduce critical errors, medical information technologies are used by healthcare workers to enhance operation efficiency and reduce their workload such as *Electronic Recording Systems, Automations, Smartphone Applications or RFID Technologies*. Today, RFID Technology is successfully implemented in many industries such as airports, banks, productions, retails and storages. However, research and development processes of this technology in the healthcare sector are slower than other industries. RFID Technology applications are recommended especially in the processes related to patient safety such as drug control, patient tracking, patient identification, equipment monitoring, injection management, doctor orders monitoring, medical errors prevention, sterilization issues, inventory management and operating room workflow regulations in hospitals. The emergency room is the most complicate and busiest place in a hospital. It is the center for treating patients with accident injuries and/or acute sicknesses of different levels of medical needs on a daily basis that the patients must receive the most adequate treatment and care in the shortest possible time from both the physicians and the nurses. Upon the arrival at an emergency room a patient goes through a medical operation procedure, including triage, registration, treatment, cashier, pharmacy, and admission, which require seamless collaboration with the medical treatment team.[2] Due to this complexity and busyness, patients may disappear or leave from Emergency Departments without informing any reason or without any treatment. Particularly while waiting in queue, they leave the department without informing the hospital. Therefore, hospital management has difficulty in following up the number of the patients in the hospital. Patient planning is also a challenging process in Emergency Departments. Besides, it is very important to check the patient locations information in real time. ED crowding is a major concern that affects the efficacy of the ED workflow, which often is challenged by long wait times, overuse of observation units, patients either leaving without being seen by a provider and non- availability of inpatient beds to accommodate patients after diagnosis [3]. Evaluating ED workflow is a challenging task due to its chaotic nature, with some success using time-motion studies and novel capacity management tools are nowadays becoming common in ED to address workflow related issues [4]. There are many factors affecting patient satisfaction like behavior of healthcare providers, hospital factors, waiting times, level of experience of physician, perception of care and cost of treatment. For this reason, using of RFID Technology will be expanded in the Emergency Departments that it may decrease long waiting times, improve the quality of treatment and care processes, and increase patient satisfaction also. Sustainable tracking system and a real-time warning mechanism may be created by determining the number of proper medical staff due to RFID Technology. That's why, this study will focus on this improvement.

Manuscript published on 30 August 2019.
***Correspondence Author(s)**
Onur Deryahanoglu, Logistic and Supply Chain Management, Maltepe University, Istanbul, Turkey
Batuhan Kocaoglu, Management Information Systems, Piri Reis University, Istanbul, Turkey

II. PROBLEM OVERWIEV

Waiting time in outpatient departments have become a long time complaint of patients more especially in high population society. Patients are unsatisfied with length of waiting time in the outpatient department. Many outpatient departments throughout the world have long waiting times for treatment followed by short consultations which are the major complaint of patients. Several researches have been carried out to reduce cost and improve the efficiency in outpatient services. Most researchers have concluded that the major reason for long waiting time is poor scheduling system put in place. Outpatient departments scheduling is considered as one of the important factors that bring efficiency to the health care sector, with the aim of providing an excellent service to reach patients satisfactions and use the available resources effectively [5]. Otherwise, patient beds can usually be considered as servers as they usually provide the limit on number of people in service. The service time is essentially the patient's length of stay in the hospital bed, although a short turnover interval is needed to prepare the bed for the next patient [6].

The main problems related to Emergency Departments in hospitals are as follows: 1) Long waiting times between stations. After the registration and triage procedures, patients can wait so long times for the medical examinations. 2) In cases of epidemics or natural disasters, a large number of patients can apply to the Emergency Departments. During this complex period, patients are prioritized by physicians and these results cause longer waiting times for other patients. 3) On the other hand, the physicians in the Emergency Department may not be an expert for the patient's condition. For example, an urgent problem in the patient's eye requires an ophthalmologist and this case affects the waiting time of the patient. 4) After final controls of patients who stay in bed in observation department, doctors can decide to hospitalization for continue their treatment. During this period, it may cause long waiting times for other patients if not to been found a proper patient bed. This situation will affect patients to be dissatisfied with the doctors and other health staffs, and even from the hospital, and they will leave the hospital. 5) Patients can leave from the hospital without any excuse after registration or triage processes. 6) Patients may leave from the hospital without any payment after treatment due to the financial difficulties.

In this study is aimed that a sustainable and effective capacity planning which will be able to prevent the above mentioned problems by including RFID Technology in the processes.

III. MATERIALS AND METHODS

A. RFID Technology

The most RFID systems consist of tags that are attached to the objects to be identified. Each tag has its own *read only* or *rewrite* internal memory depending on the type and application. The RFID reader generates magnetic fields that enable the RFID system to locate objects (via the tags) that are within its range. The high frequency electromagnetic energy and query signal generated by the reader triggers the tags to reply to the query; the query frequency could be up to 50 times per second. As a result, communication between the main components of the system i.e. tags and reader are established in this way, large quantities of data are generated [7].

The RFID reader retrieves data from the RFID tag through an antenna, which is either integrated or discrete. The reader stores the raw data, and then transmits them to other application systems. The RFID tag, either active or passive, has an integrated transmitter. When it receives a particular radio frequency signal, it sends a confirmation message to the RFID reader. Passive RFID tags do not have a power supply. Active RFID tags have a power supply, enabling them to transmit data over longer distances [8]. Both types of labels contain a chip for moving and processing information. In passive labels, the reader is triggered by the induced current when entering the electromagnetic field. After, transmission of the information on the chip is started. In active labels, chip information is transmitted to the reader in real time and continuously. After receiving the content on the chip, the reader sends the relevant information to a center for data processing or further applications In addition, various hardware and software are needed to support RFID applications. RFID tags can be different shapes and sizes.

The use of RFID technology in the healthcare industry is rather new compared to its use in other industries such as libraries, retail, manufacturing, logistics and supply chain. The adoption of RFID in the healthcare industry, is generally seen as *the next disruptive innovation in healthcare* various researchers have asserted that RFID technology can have a number of benefits in the healthcare system, specified that RFID technology has a great capability to considerably reduce cost, improve patient safety and medical service as well as improve the business process. Although RFID technology has lots of benefits to the healthcare industry, RFID adoption in healthcare has not been as striking as anticipated Therefore, in the present study the factors that may affect the adoption of RFID technology in hospitals were investigated [9].

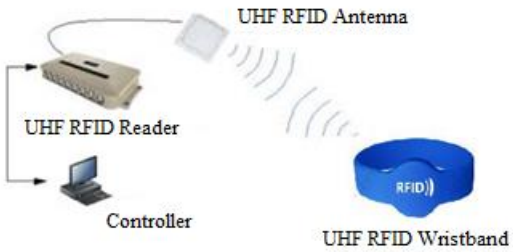


Figure 1. RFID System Design in Emergency Department

Retrieval Number: J89040881019/19©BEIESP
DOI: 10.35940/ijitee.J8904.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

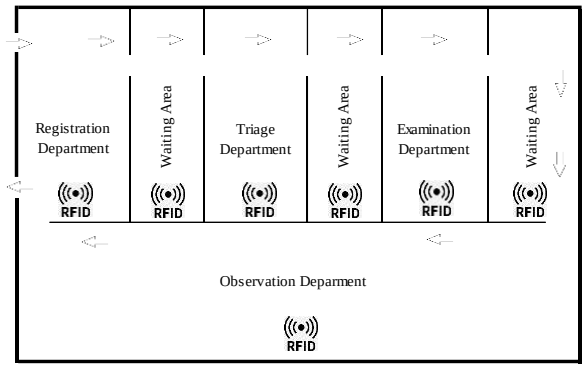


Figure 2. Patient Flow in Emergency Department

In this study, active UHF patient wristbands, UHF RFID reader, UHF RFID antennas are preferred for real-time analysis of patient processes. Because, active UHF RFID technology have much more accurate results due to having an average 50 meters signal coverage.

B. Arena Simulation Software

Simulation is an analysis tool that uses the computer model of the system in order to estimate and evaluate the performance of models within a certain time period in related operating conditions. Rockwell Arena is a simulation and automation software released by Rockwell Automation.It is possible to simulate a company's production or service processes and measure their performance as using this program. By simulating these processes, companies can track the results of scenarios, obtain feasibility, effective time and resource planning or with savings. It helps to the managers for effective decisions. It's easy to organize the process blocks that represent in Arena : Create process block, Dispose process block, flow control process block (Decide, Separate, Batch, Delay), information import and export process block, etc. It is also easy to connect them by lines for building a model. A process block may be a simple function or a sub-model in which a detailed sub-process will be built in the same way as a subprogram. The creation of entities and the availability of resources are controlled by calendar schedule patterns, from which a complex schedule including exceptions can be precisely defined.. Remarkably, the entity can carry integrated or customized attributes that simplify modeling and enhance flow control. Integrating Crystal Report, Arena can offer various statistics ratios and results, such as activity statistics, entity statistics, process statistics, queue statistics, and resource statistics [10]. Rockwell Arena 14. version is used in this study.

C. Data Analysis

It will be simulated of an Emergency Department (a public hospital in Turkey) in this study. The duration of all procedures between stations and mean waiting times of the patients will be analyzed. Total length of stays in Emergency Department and utilizations will be seen. A 24-hour database was created as a result of the Hospital Information and Management System, the measurements taken from the observations and face-to-face interviews with the department's professionals. In this way, the existing structure and improvement processes of the system (total waiting times, total staying times, optimum number of employees, or leaving the hospital without payment or without any excuse) will be planned. In this database, there are lots of information such as time of arrival to the Emergency Department, duration of the prosses in registration, duration of the prosses in triage, level of triage, duration of prosses in examination and duration of occupancy in observation room. In addition, it will be occurred waiting times between stations as a result of simulations (Sim-1 and Sim-2).

Table 1. Current Database of Emergency Department

Patient	Patient Arrival Time	Registration Department Process Time	Triage Department Process Time	Triage Level	Examination Department Process Time	Observaiton Department Residence Time
1	8:00:24	0:00:55	0:03:45	1	0:12:00	2:05:02
2	8:01:53	0:00:54	0:03:00	2	0:09:45	1:35:06
3	8:01:57	0:00:48	0:03:00	3	0:10:00	1:39:13

Table 2. Number of Entities in Each Station

	Number of Entity
Doctor	7
Triage Nurse	3
Observation Nurse	9
Registration Staff	2
Patient Bed	60

C.I. Data Analysis of Registration Department and Design with Arena Simulation Program

The Department of Registration is the area where patient's identity information is entered into the Hospital Information and Management System by the registration staff at the entrance of the Emergency Department. Patients who are with critical conditions (such as traffic accident, heart attack, injury) as a result of an ambulance or visual examination their triage is determined as Level 1 (Red Code) are directed directly to the Medical Examination Department in order not to lose time. However, registration procedures are completed by patient's companion for this patient. Therefore, a dummy patient companion has added to the program. Statistical distribution analysis has performed as using Arena Input Analyzer Program according to database (in seconds). As a result of this analysis, it was seen that the registration staffs processing times belonged to *Beta Distribution* (Chi-Square Test p-value = 0,357> 0,05). *Simulation 1;* The number of employees in the Registration Department (Registration Staff : 2 Person) and the processing times are defined to the Arena Simulation Program according to the statistical data analysis obtained from database. Through this simulation, the existing workflow and waiting times of the department will be evaluated and then improvement works will be planned. *Simulation 2;* After registration is completed, *an RFID Wristband* which works with *Active Tag Technology*, is attached to the patient's arm. Thus, real time patient tracking is provided in each station.

Figure 3. Arena Model of Registration Department

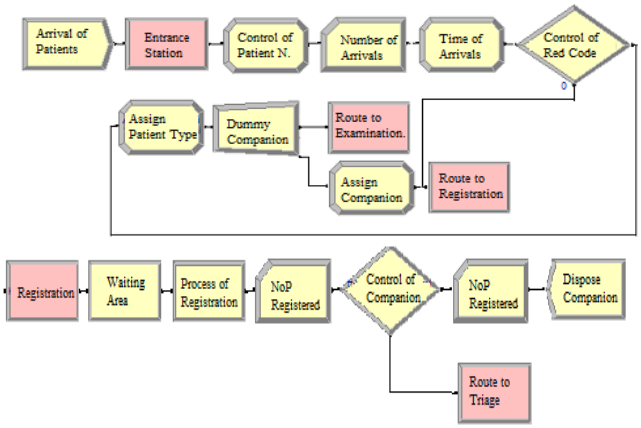
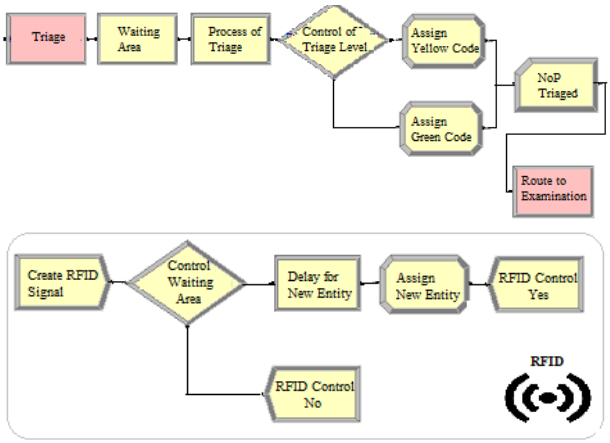


Figure 4. Arena Model of Triage Department



Time of patient arrivals in Emergency Department is another important issue. In this direction, statistical distribution analysis has performed as using MS Excel Program according to database (in minutes). As a result of this analysis, it was seen that arrival times of patients belonged to *Poisson Distribution* (Chi-Square Test p-value=0,44>0,05). There is a link between the Poisson Distribution and Exponential Distribution. In this way, time between two patients; EXPO (1/α) : 1/0,65988 : 1,515 (in minutes).

C.II. Data Analysis of Triage Department and Design with Arena Simulation Program

The priority levels (1-Red Code, 2-Yellow Code, 3-Green Code) of the patients are determined according to their urgency status in Triage Departments. Patients are directed to there after the patient information is entered into the system. In this area, Triage Nurses follow the vital signs (pulse, blood pressure, fever, diabetes level) of patients and evaluate their past stories and make prioritization. Statistical distribution analysis has performed as using Arena Input Analyzer Program according to database (in seconds). As a result of this analysis, it was seen that the triage nurses processing times belonged to *Weibull Distribution* (Chi-Square Test p-value = 0,396> 0,05). *Simulation 1;* The number of employees in the Triage Department (Triage Nurse : 3 Person) and the processing times are defined to the Arena Simulation Program according to the statistical data analysis obtained from database. Through this simulation, the existing workflow and waiting times of the department will be evaluated and then improvement works will be planned. *Simulation 2*; This area has been designed with RFID Technology and integrated into Arena Simulation Program as follows: A signal is generated every minute to measure the intensity of the patient queue with *Create Module*. After, the condition in the queue is checked with *Decide Module*. If the average waiting time of the patients in the Triage Department exceeds 15 minutes, increasing the number of Triage Nurses + 1 (min: 2 current capacity - max: 4 variable capacity), to reduce average waiting times. If the average waiting time exceeds 15 minutes, RFID Technology sends an alarm signal to the to the Management Center, so it provides real time monitoring. Then, the management center evaluates the processes for reducing average waiting intensity and they assign +1 Triage Nurse within *UNIF Distribution (1,5)* minutes.

C.III. Data Analysis of Examination Department and Design with Arena Simulation Program

Medical examinations are performed according to patients triage levels in Examination Department. In this way, patients are diagnosed and treatment plans are established. Statistical distribution analysis has performed as using Arena Input Analyzer Program according to database (in minutes). As a result of this analysis, it was observed that doctor processing times could not be used for simulation model because Chi Square Test was not positive (p-value <0.05). In this case, if a data set does not fit to any known standard distribution, an *Empirical Distribution* can be generated. So, doctors processing times generated by this distribution and defined to the Arena Simulation Program such as : CONT (0.000, 8.210, 0.000, 8.505, …etc.). *Simulation 1;* The number of employees in the Examination Department (Doctor : 7 Person) and the processing times are defined to the Arena Simulation Program according to the statistical data analysis obtained from database. Through this simulation, the existing workflow and waiting times of the department will be evaluated and then improvement works will be planned. *Simulation 2;* This area has been designed with RFID Technology and integrated into Arena Simulation Program as follows: A signal is generated every minute to measure the intensity of the patient queue with *Create Module*. After, the condition in the queue is checked with *Decide Module*. If the average waiting time of the patients in the Examination Department exceeds 10 minutes, increasing the number of Doctors + 1 (min: 7 current capacity - max: 9 variable capacity), to reduce average waiting times. If the average waiting time exceeds 10 minutes, RFID Technology sends an alarm signal to the to the Management Center, so it provides real time monitoring. Then, the management center evaluates the processes for reducing average waiting intensity and they assign +1 Doctor within *UNIF Distribution (1,5)* minutes.

Retrieval Number: J89040881019/19©BEIESP
DOI: 10.35940/ijitee.J8904.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

Figure 5. Arena Model of Examination Department

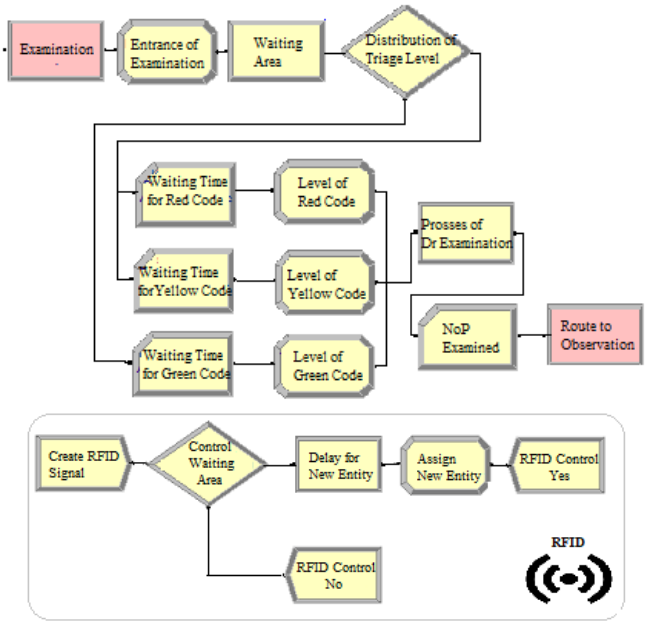
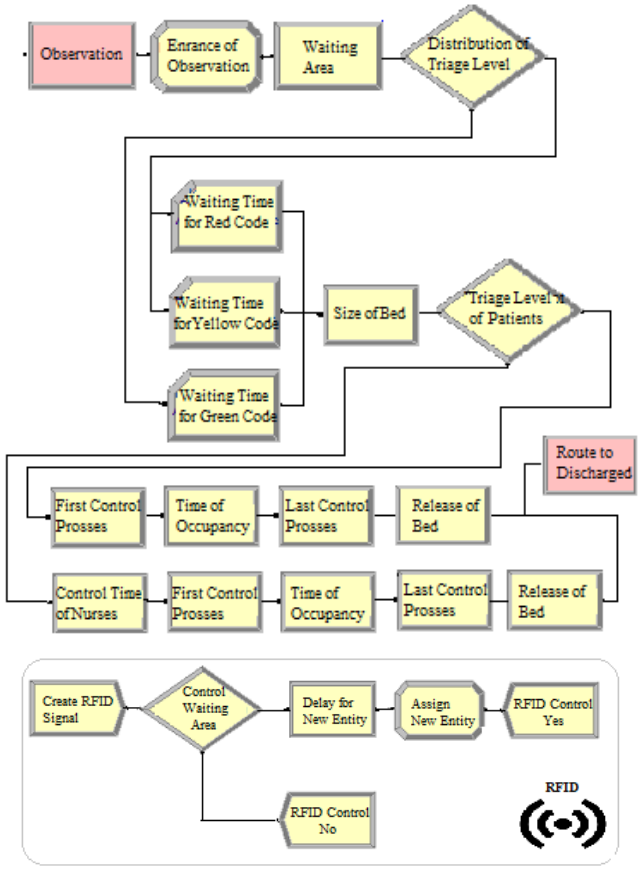


Figure 6. Arena Model of Observation Department



C.IV. Data Analysis of Observation Department and Design with Arena Simulation Program

A short-term care of patients according to treatment plans are performed in Observation Departments. Patients who have level of Red Codes, are prioritized in the waiting area. Observation Nurses start to perform the first controls *immediately* which determined by the doctors for this patient. It can take *30 minutes* for level of Yellow or Green Codes. Statistical distribution analysis has performed as using Arena Input Analyzer Program according to database (in minutes). As a result of this analysis, it was seen that the observation nurses processing times belonged to *Normal Distribution* (Chi-Square Test p-value = 0,07> 0,05). *Simulation 1;* The number of employees in the Observation Department (Observation Nurse : 9 Person) and the processing times are defined to the Arena Simulation Program according to the statistical data analysis obtained from database. Through this simulation, the existing workflow and waiting times of the department will be evaluated and then improvement works will be planned. *Simulation 2*; This area has been designed with RFID Technology and integrated into Arena Simulation Program as follows: A signal is generated every minute to measure the intensity of the patient queue with *Create Module.* After, the condition in the queue is checked with *Decide Module*. If the average waiting time of the patients in the Examination Department exceeds 5 minutes, increasing the number of Observation Nurse + 1 (min: 9 current capacity - max: 13 variable capacity), to reduce average waiting times. If the average waiting time exceeds 5 minutes, RFID Technology sends an alarm signal to the to the Management Center, so it provides real time monitoring. Then, the management center evaluates the processes for reducing average waiting intensity and they assign +1 Observation Nurse within *UNIF Distribution (1,5)* minutes. So, it is prevented that patient's long term waiting without any treatment.

IV. RESULTS

The simulations of the Emergency Department (Sim: 1 and Sim: 2) have been realized with the Arena Simulation Program according to the 24-hour database. They were repeated 1000 times in terms of the accuracy and reliability of the information. Detailed analysis of the simulations is listed below:

A. Number of Patients

The results of simulations are given below for number of patients.

Table 3. Comparison of Patient Numbers

	Results of Sim-1 (Current System)	**Results of Sim-2** (RFID System)	Improvement Rate
Number of Patient Arrivals	952	950	-0.21%
Number of Patient Registered	951	949	-0.21%
Number of Patient Triaged	926	935	0.97%
Number of Patient Examined	802	796	-0.75%
Number of Patient Discharged	602	830	37.87%
Number of Patient without Payment	9	0	100%

The number of patients who had completed the discharge procedure was improved by 37.87 % and the number of patients who left the hospital without payment was prevented by 100 % because of using RFID System.

B. Utilizations

The results of simulations are given below for capacity of utilizations.

Table 4. Comparison of Utilizations

	Results of Sim-1 (Current System)		Results of Sim-2 (RFID System)		
	Number of Entity	Utilization Rate	Number of Entity	Variable Entity	Utilization Rate
Doctor	7	0.96	7	2	0.91
Triage Nurse	3	0.97	2	2	0.86
Observation Nurse	9	0.64	9	4	0.87
Registration Staff	2	0.34	2	0	0.34
Patient Bed	60	0.95	60	0	0.86

According to the average waiting time of the patients, variable capacities are assigned to the stations because of RFID System. Therefore, capacities started to use more efficient.

C. Waiting Times According to Triage Levels

The results of simulations are given below for waiting times according to triage levels.

Table 5. Comparison of Waiting Times (Examination Department)

	Results of Sim-1 (Current System)	Results of Sim-2 (RFID System)	Improvement Rate
	Time (min/average)	Time (min/average)	
Red Code	1.26	0.87	-30.48%
Yellow Code	2.23	1.3	-41.64%
Green Code	37.04	12.87	-65.25%

Table 6. Comparison of Waiting Times (Observation Department)

	Results of Sim-1 (Current System)	Results of Sim-2 (RFID System)	Improvement Rate
	Time (min/average)	Time (min/average)	
Red Code	2.18	1.47	-35.57%
Yellow Code	204.41	3.39	-98.34%
Green Code	209.41	131.27	-37.34%

The average waiting times of the Examination Department (according to the patient triage levels) was improved by 46 % (averages of Red, Yellow, Green Code) and the average waiting times in the Observation Department was improved by 56 % (averages of Red, Yellow, Green Code) because of using RFID System

D. Total Length of Stays According to Triage Levels

The results of simulations are given below for total length of stays according to triage levels.

Table 7. Comparison of Total Length of Stays

	Results of Sim-1 (Current System)	Results of Sim-2 (RFID System)	Improvement Rate
	Time (min/average)	Time (min/average)	
Red Code	90.28	88.62	-1.84%
Yellow Code	343.1	128.29	-62.61%
Green Code	374.12	265.67	-28.29%

The average length of stays (the total time of period when the patient enters from the door of the Emergency Department and discharges from the Emergency Department) were improved by 31.15 % (average of Red, Yellow, Green Code) because of using RFID System.

V. CONCLUSIONS AND FUTURE DEVELOPMENTS

Simulations 1; simulations were performed with current database, number of patients, productivity of employees, triage levels, waiting times between stations were evaluated. Thus, the current processes of the hospital have been reviewed. The most important point here is the high waiting times (independent of patient triage levels) in the Departments of Examination and Observation (total average 76.08 minutes). Therefore, the total length of stays (independent of patient triage levels) in the Emergency Department have been affected also (total average 269.17 minutes). In addition, 9 patients left from the hospital with various reasons without any payment although they had treatment.

Simulations 2; RFID Technology has been implemented to the current database and variable capacities are assigned in the process. If the average waiting time of the patients in departments (Triage, Examination or Observation) exceeds 5,10 or 15 minutes (depends on departments), increasing the number of entities + 1, to reduce average waiting times. So, the capacities and costs will be at the optimum level and the number of additional employees will not need to be permanently allocated to the departments. On the other hand, total number of patient discharge increased by 37.87 % because of RFID Technology. Examination and Observation Departments (independent of patient triage levels), the waiting times were significantly reduced (total average 25.18 minutes - averagely improvement 50.94% in total). The total length of stays in the Emergency Department was reduced 31.15% (total average 160.86 minutes). In addition, the possibility of leaving the department without any payment is prevented. (If the patients leave from hospital without payment, the RFID System sends a warning signal to the management center and the patients exit are blocked at the exit of the department.)In the near future, RFID Technology can be implemented to all hospital processes with Emergency Department and an effective management model can be established in order to ensure patient safety and sustainability. For instance:

Retrieval Number: J89040881019/19©BEIESP
DOI: 10.35940/ijitee.J8904.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

- RFID Systems can send an automatic alarm to the management center with a motion sensor in case of a fall or any emergency situation.
- Patients & Doctors & Nurses & Equipment can be matched for traceability.
- It can provide sterilization processing tracking for highly usable and reusable materials.
- RFID System can provide sterilization process tracking for disposable or reusable materials.
- It can remind to patients for medication and meal times.
- It can analysis logistical problems of hospital and their bottlenecks in this way, managers can take right decision for redesign process.
- RFID Systems can track of all medical equipment's calibration process in real time for ensure patient safety.

REFERENCES

1. C. L. Yeung, S. K. (2011). An Investigation of an RFID Based Patient Tracking and Mobile Alert System. *International Journal of Engineering Business Management; Vol: 3, No:1*, 50-56.
2. Yen Chieh Huang, C. P. (2010). RFID Applications in Hospitals - A Case Study for Emergency Department. *Proceedings of the 16th International Conference on Distributed Multimedia Systems.* Oak Brook, Illinois, USA: ResearchGate.
3. Shivaram P. Arunachalam, A. S. (2017). Optimizing Emergency Department Workflow Using Radio Frequency Identification Device (RFID) Data Analytics. *Proceedings of the 2017 Design of Medical Devices Conference DMD2017-3402.* Minneapolis, Minnesota, USA: ResearchGate.
4. Anastasis C. Polycarpou, G. G. (2011). A Healthcare Application Based on Passive UHF RFID Technology. *EU CAP* (pp. 2814-2818). ResearchGate.
5. Aliyu Isah Aliyu, T. A. (2015). Modeling and Simulation Analysis of Healthcare Appointment System Using ARENA. *International Journal of Science and Advanced Information Technology*, 1-7.
6. Worthington, D. J. (1987). Queueing Models for Hospital Waiting Lists. *Operational Research Society*, 413-422.
7. Sima Ajami, A. R. (2013). Radio Frequency Identification (RFID) Technology and Patient Safety. *Journal of Research in Medical Sciences*, 809-813.
8. Chia Chen Chen, Y. F. (2012). Smart Healthcare Environment: Design with RFID Technology and Performance Evaluation. *Journal of Medical and Biological Engineering*, 427-432.
9. Suhaiza Zailani, M. I. (2014). Determinants of RFID Adoption in Malaysia's Healthcare Industry: Occupational Level as a Moderator. *Journal of Medical Systems*, 39-172.
10. Tao Wang, A. G. (2007). Modeling and Simulation of Emergency Services with ARIS and Arena – Case study: The Emergency Department of Saint Joseph and Saint Luc Hospital. *Production Planning & Control*, 1-27.

AUTHORS PROFILE

Onur Deryahanoglu received his BSc in Biomedical Sciences. He has MSc in Hospital and Healthcare Management and Ph.D. in Logistic and Supply Chain Management. He has more than 13 years of professional experience working as Biomedical Systems Manager, Project Manager and Operation Manager in healthcare sector. He has also consulting experience in Biomedical Engineering, Medical Device & Technology Investments, Hospital Planning & Design and Facility & Risk Management. He is currently working as a Project Manager in one of the global-leading healthcare company.

Batuhan Kocaoglu received his BSc, MSc, Ph.D. in Industrial Engineering. He has worked for more than 15 years as a Production Planning Manager and ERP Project Manager. He has consulting experience in SCOR processes, software selection, reporting needs analysis, SME projects, and MRP check-up. His main research areas are digital transformation, Industry 4.0 readiness, ERP, MRP, production planning, S&OP, and SCM. He has taught courses production inventory management, ERP, MIS, logistics information systems, supply chain design in Poznan Economics, Montenegro, Maltepe and Okan Universities. He is currently working as the Head of Management Information Systems Department at Piri Reis University