Advances in Economics, Business and Management Research, volume 144
23rd Asian Forum of Business Education(AFBE 2019)

Improvement in Emergency Medical Services using Internet of Things (IoT). Hospital Emergency Department Case: a BPR Approach

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ABSTRACT
The operational process in an emergency situation becomes a very critical process in saving the lives of patients. A well-integrated emergency medical services (EMS) can be an important role in reducing the risk of death or disability. The implementation of Internet of Things (IoT) to the EMS can help integrate operational processes so that emergency physicians (EPs) can more quickly and accurately treat patients. The purpose of this paper is to design operational process improvements by applying IoT to the EMS process using Business Process Reengineering (BPR) approach. Failure Mode and Effect Analysis (FMEA) method is used to prioritize failure modes in the process that will be recommended for corrective actions using IoT implementation. This study improves 2 failure modes in the prehospital process and 10 failure modes in the hospital process by implementing IoT. The results of this study indicate an improvement in the reduction of prehospital processing time by 19% and hospital processing time by 22% based on EMS process simulations.
Keywords— Internet of Things (IoT), Healthcare, Emergency Medical Services, Business Process Reengineering (BPR).

1. INTRODUCTION

Emergency medical service (EMS) events have a high degree of complexity. In emergency situations, emergency physicians (EPs) are required to treat various types of patients with various types of diseases with different levels of emergency. EPs should be able to treat patients quickly and accurately in order to reduce death and disability in patients. EPs are required to be able to think quickly, have extensive knowledge of various medical conditions and abilities that can perform life-saving procedures [1].

During EMS events, the connection between pre-hospital and hospital service systems is important. Both systems must be integrated in order to exchange information easily. However, the hospital can only find out the details information about the patient's condition after the patient arrives at the hospital. EPs in the emergency department (ED) must first do an assessment to obtain the information.

Information technology (IT) can integrate information between the pre-hospital and hospital systems. IT has an important role in improving the speed and accuracy of emergency services to patients in critical conditions [2].

Internet of Things (IoT) in healthcare can make hospitals easier to process various information collected by ubiquitous devices. In EMS events, IoT can be an intermediary that connects pre-hospital and hospital systems in providing information about patient. In some countries, IoT has been implemented to assist in the operational process during the EMS event. There are several hospitals that have successfully implemented IoT on EMS [3]–[5]. This study designed the implementation of IoT in emergency services to improve the operational process of ED in hospitals.

2. LITERATURE REVIEW

2.1. Emergency Medical Service (EMS)

EMS is a comprehensive system that manages personnel, facilities, and equipment for the provision of effective, collaborated, and timely health and safety services to sufferer of sudden illness or injury [6]. EMS event begins when the patient calls the dispatcher and ends when the patient released from care, refused by the care provider or died [7]. There are four EMS main functions that are to access emergency care, to give care in the community, to give care on the way to healthcare facilities, and to give care on arrival at healthcare facilities.

To make decisions in an EMS event, EPs need information regarding patient information, surveillance data, current

diagnostic, and interventional. Information systems must provide a mechanism for retrieving and storing information about EMS events in the form of medical records. The EMS information system should be able to integrate data taken from various sources. The available information must be visible to every healthcare provider to be accessed before or during patient care [8].

2.2. IoT Implementation in EMS

Internet of Things (IoT) is a new paradigm that has the concept of how various objects interact with each other and work together to achieve desired goals [9].
IoT in healthcare allows health professionals (doctors or nurses) to monitor patients remotely by analyzing sensor output with big data analytics [11]. The sensor will send information to computers or other devices owned by health professionals [12]. There are several other studies that have also discussed the application of IoT in hospitals [13]–[15].
Several papers have also conducted research on the application of IoT in EMS. In EMS, connected devices play an important role in smart ambulances. The instrument in the ambulance is connected to the hospital through a telemedicine system [13]. Other examples, in pre-hospital EMS, emergency service providers get information about events on the scene and on the ambulance in the form of Electronic Patient Care Report (ePCR). EPCR provides information about patients at the scene, medical history and pre-hospital care provided by paramedics at the scene to staff at the hospital. Information in ePCR can be shown to get emergency care and better outcomes [2]. IoT implementation in EMS also can avoid the occurrence of errors during patient care [1].

2.3. Business Process Reengineering *(BPR)*

Business Process Reengineering (BPR) is an approach of business management strategy that focuses on analyzing and designing workflows of the information and materials within an organization [14]. BPR aims to achieve a dramatic increase in company performance measures by using the latest information technology (IT) to fundamentally and radically redesign business processes [15]. There are several studies that have used the BPR method in hospitals [16]–[18].

2.4. Failure Mode and Effect Analysis *(FMEA)*

FMEA a risk assessment method used to identify potential failures of high-risk processes and to develop recommendations for corrective actions [19]. FMEA is also commonly used to assess the risk of failure in a hospital. The following are some studies that use the FMEA method in hospitals [20]–[23].

3. METHODS

Data collection started with observing the flow of EMS processes and interviews with emergency ambulance staff and ED staff. After understanding the processes, the next step is to make the As-Is process model in the software to be simulated. FMEA is used to identify potential failures of EMS process and to generate corrective actions. The corrective action that will be recommended is using IoT platform. The process that is improved using IoT platforms will be modeled and simulated in business process software.

3.1. Mapping EMS Process

Before making an As-Is process, the EMS process is mapped using a flow process chart (FPC). FPC is used to represent step by step of the process using symbols that indicate the type of activity carried out and provide details of the process. The FPC in this study was divided into pre-hospital and hospital processes.
The time of each process is recorded which will be reference time for the simulation of the As-Is process in the next stage. The pre-hospital process time is known by conducting interviews and indirectly simulations by ambulance staff. The measurement of hospital process time is done by direct observation in the hospital ED.

3.2.Modeling Current Process (As-Is Process)

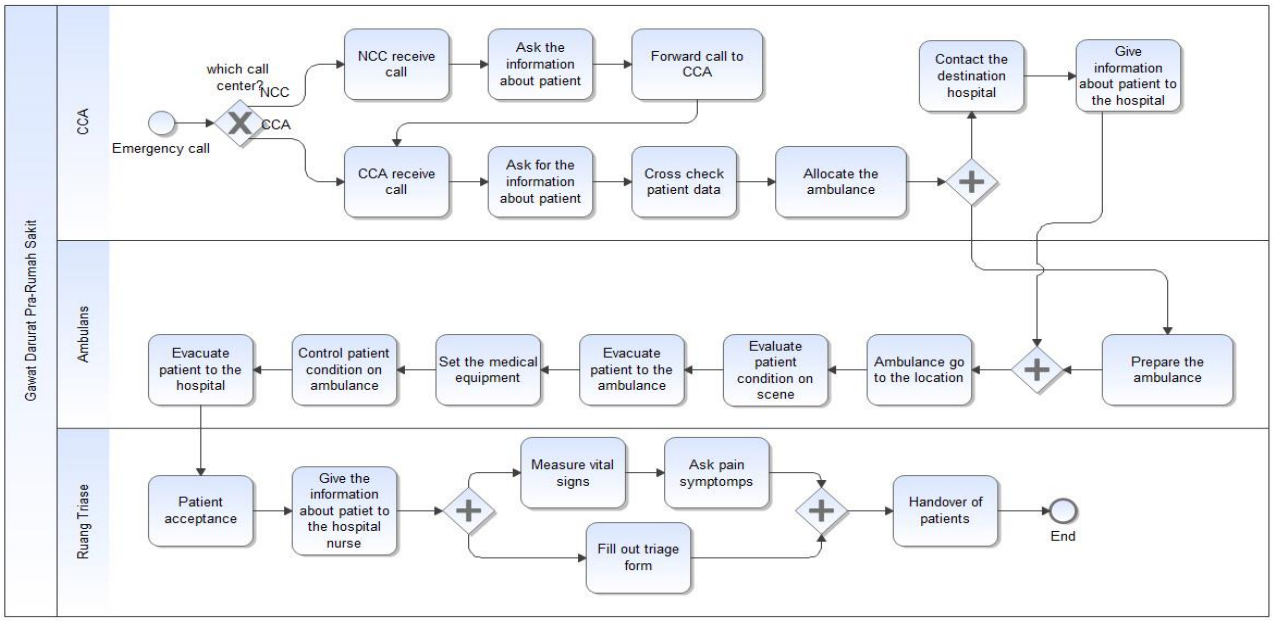

Figure 1. Prehospital As-Is Process Model

The As-Is process model was created using Business Process Model and Notation (BPMN). BPMN is used to represent the overall business process so that the flow can be seen from the beginning to the end. The BPMN model was created using iGrafx software to be simulated and obtained results. The As-Is process model for pre-hospital and hospital can be seen in Fig. 1 and Fig. 2.. The input time in the BPMN model is the result of previous observations. The data for each process was taken as many as 30 samples which were then processed statistically to determine the form of distribution. The results of the pre-hospital and hospital As-Is process simulation can be seen in Table 1.

Table 1. As-Is Process Simulation

Transactions Statistics (Hours)		
Process	**Detail Lane**	**Avg Process Time**
Pre-hospital	Total	1,69
	Ambulance	1,28
	CCA	0,34
	Hospital (Triage Room)	0,18
Hospital	Total	5,36
	Administration	0,79
	Pharmacy	0,04
	Nurse Station	2,64
	Triage room	0,05
	Emergency room	1,97

3.3.Analysis of As-Is Process

The As-Is process was analyzed using the FMEA method. Failure mode is assessed based on severity (S), occurrence (O) and failure detection (D) level to determine the value of Risk Priority Number (RPN).

FMEA of the pre-hospital was conducted by group discussion and interviews with two ambulance staffs. Based on the result of the discussion and interviews, 9 failure modes were obtained from several processes. FMEA of the hospital process was done by group discussion and interviews with four EPs consisting of two doctors and two nurses. The results of the hospital process analysis are 25 failure modes were obtained. Severity, Occurrence, and Detection of each failure mode will be assessed by weighing from 1 to 10. RPN value is calculated from each failure mode using predetermined SOD weights.

Geometric mean used to obtain weighted average number of RPN value. Geomean value is used as the threshold to find out which failure mode is more important to be improved using IoT. IoT platform recommendations acquired by literature review. The recommended IoT platform can be seen in Table 2..

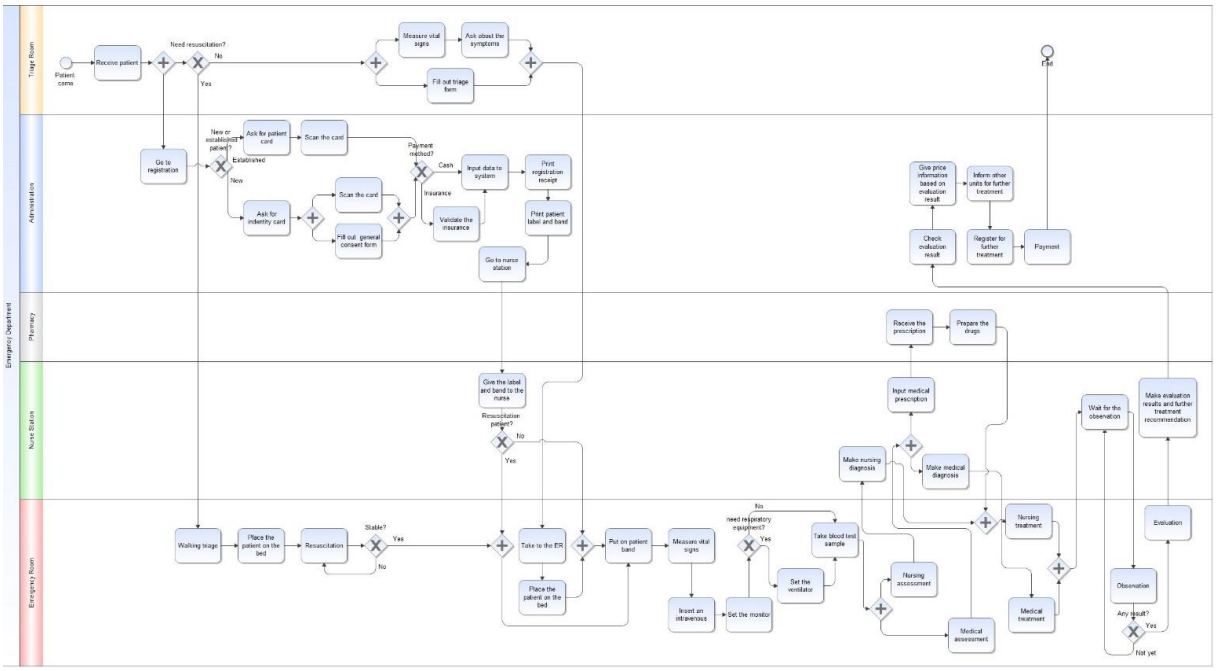

Figure 2. Hospital As-Is Process Model

Table 2. IoT Platform Recommendation

IoT Platform	Reference
Remote medical scribe using FMT	[24]
Smart ambulance	[25], [26]
Vital signs sensor	[27]
Smart medical bed	[28]
Medical access case	[13]

Based on the geomean value, the failure mode in the pre-hospital process which has RPN values less than 195 will be eliminated. The number of failure modes in the chosen pre-hospital process is 2. For the hospital process, the failure mode will be eliminated if the RPN values less than 387. After eliminating the failure mode of hospital process, 10 failure modes are chosen. The chosen failure mode will be recommended for improvement by implementing the IoT platform obtained from the literature review. Improvements in each failure mode will be suited to the functions of each IoT platform. The results of the improvement recommendations for each chosen failure mode can be seen in Table 3.

Table 3. Improvement Recommendation Using Iot Result

Process	Failure Mode	RPN	Improvement recommendation using IoT
Pre-hospital	Patient's condition is not recorded properly	270	Smart ambulance, medical access case
	Patient's condition is not conveyed clearly	360	Smart ambulance, vital signs sensor
Hospital	Error interpreting measurements	400	Vital signs sensor
	Inaccuracy in determining triage level	500	Vital signs sensor
	Delay in triage process	560	Vital signs sensor
	Delay in assessment	560	Smart medical bed
	Incomplete primary and secondary survey	500	Smart medical bed, remote medical scribe using FMT
	Differences in results from digital and manual tools	500	Smart medical bed
	Inaccurate diagnosis	400	Remote medical scribe using FMT
	Not immediately writing a diagnosis	600	Smart medical bed, Remote medical scribe using FMT
	Not immediately writing a diagnosis	700	Remote medical scribe using FMT
	Inaccuracy in determining the early warning score	450	Smart medical bed

3.4.Process Improvement Design (To-Be Process)

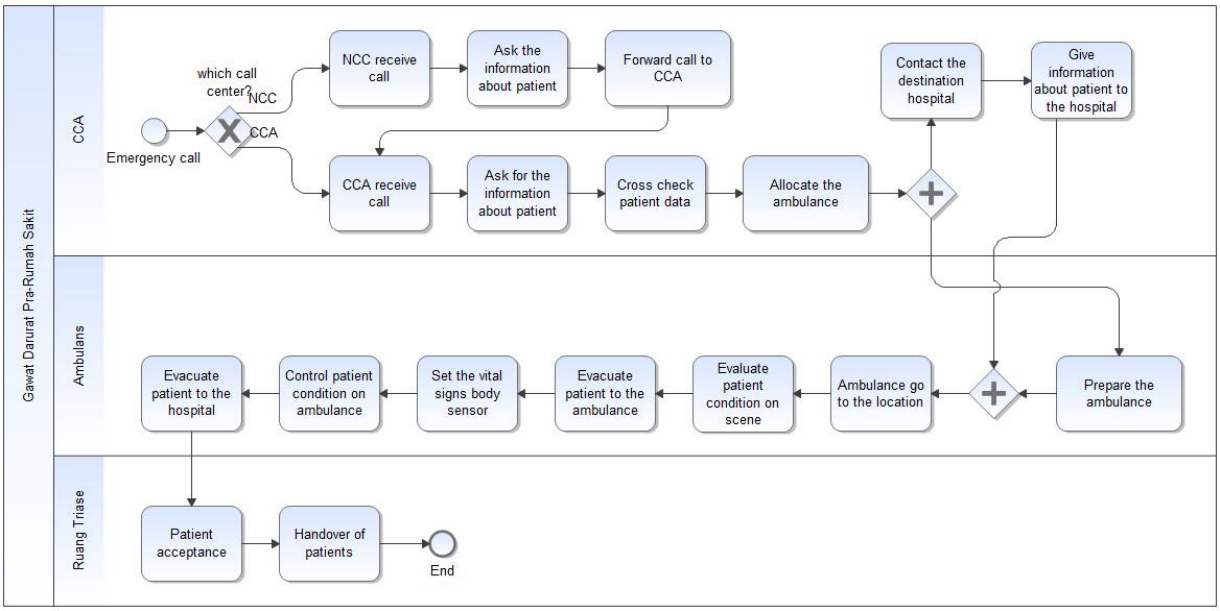

Figure 3. Pre-Hospital To-Be Process Model

The design of IoT device implementation in EMS is divided into two strategies. Strategies are grouped into pre-hospital processes and hospital processes. Combination of strategies can be seen in Table 4. The improvement design is made a To-Be process model to be simulated.

Table 4. IoT Implementation Combination Strategies

IoT Platform Implementation	Process	
	Pre-hospital	Hospital
Smart ambulance	✓	
Medical access case	✓	
Vital signs sensor	✓	✓
Smart medical bed		✓
Remote medical scribe using FMT		✓

Pre-hospital process model needs to be made several changes to implement IoT. A new improved model that has made several changes can be seen in Fig. 3. IoT implementation in each pre-hospital process makes the following changes.

– The health access case makes a reduction in time when evaluating the patient's condition at the scene.
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– Vital signs sensor changed the process of “set medical equipment to patients” became “put on vital signs sensor”. Vital signs sensor also made a reduction in time when putting on the sensor.
– Smart ambulances eliminated the process of providing information about patients, measuring vital signs, asking symptoms and filling out triage forms.

Hospital process model also needs to make some changes to implement IoT. The improved model can be seen in Fig 3. The impact of changes that occur in the hospital process are as follows.

– Vital signs sensor eliminated the process of measuring vital signs and filling out the triage form. Vital signs sensor also made new processes which are “put on vital signs sensor” and “check vital signs sensor results".
– Smart medical bed eliminated the process of measuring vital signs and repeated observations to the patient’s bed.
– Remote medical scribe using FMT reduced time in making nursing diagnoses and medical diagnoses.

4. RESULTS AND DISCUSSION

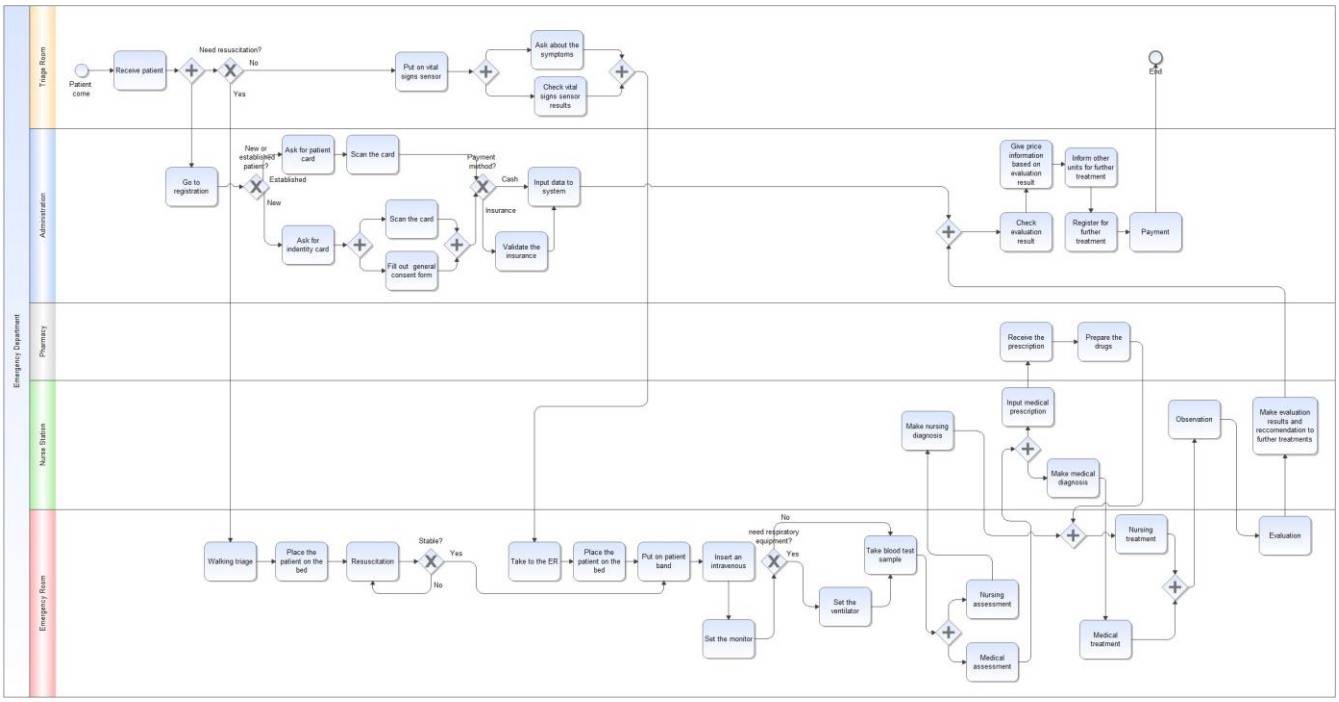

Figure 3. Hospital To-Be Process Model

Both the prehospital and hospital strategy models have the same basic model as the As-Is process model so the existing variables remain the same.

4.1. Pre-hospital To-Be Process Model

Pre-hospital To-Be process model was implemented three IoT platform which are smart ambulances, medical access case and vital signs sensors. The simulation results of the pre-hospital to-be process model can be seen in Table 5. The simulation results show that there is a change in time faster than the As-Is process. Average processing time changes by 19% after the IoT platform is implemented.

Average processing time in the ambulance lane has a time reduction of 13%. Time reduction can occur because the ambulance lane used an IoT device that is a medical access case. Medical access cases can speed up evaluation time at the scene because ambulance staffs do not need to assess patients using manual medical equipment. By using a medical access case, the ambulance staffs only need to put on the sensor to the patient's body then the sensor will immediately capture the patient's body condition data and send the results to the device owned by the staffs. Changes in the process of “set medical equipment” became “put on vital signs sensor” also made a reduction in the time on the ambulance lane. Attachment of the vital sign sensor to the patient's body takes a shorter time compared to the attachment of various medical equipment. Vital signs sensor also make the data obtained more accurate so that it can reduce the failure mode.

Significant time reduction occurred in lane hospital at 86%. This time reduction can occur because by using a sensor on the patient's body, the patient's condition data can be sent directly to the hospital so that the nurse and doctor at the hospital can immediately make an initial diagnosis and prepare to take action when the patient arrives. The use of sensor can eliminate the triage process when the patient arrives so that the ambulance officer can immediately handover the patient to the EPs at the hospital. This improvement can make patients get treatment as soon as possible.

Table 5. Pre-Hospital To-Be Process Model Result

Transactions Statistics (Hours)				
Process	Detail Lane	As-Is Process	To-Be Process	% Change
Pre-hospital	Total	1,69	1,37	19%
	Ambulance	1,28	1,11	13%
	CCA	0,34	0,34	0%
	Hospital (Triage Room)	0,18	0,03	86%

4.2.Hospital To-Be Process Model

The pre-hospital To-Be process model was implemented three IoT platform which are vital signs sensor, smart medical bed and remote medical scribe using FMT. IoT implementation in the hospital process generally makes changes as much as 22% of the total average process time. The results of the simulation model of hospital To-Be process can be seen in Table 6.

The process in the administrative lane has improved by 4% if the hospital uses the EHR system because the administrative staff does not need to walk to the nurse station every time a patient has been registered. Administrative staffs only need to input data into the system and all data will be integrated through the EHR system.

The use of remote medical scribe using FMT can speed up the process in the emergency room (ER) lane. When EPs do an initial assessment to the patients using smart glass, the remote medical scribe will help them documenting the assessment results. The results of the assessment will be directly inputted to the EHR system by medical remote scribe so that when EPs making a diagnosis, they can immediately see it in the EHR system without having to record it again.

In the nurse station lane, the average processing time has increased significantly to reach 15%. The increase in the average processing time in a nurse station lane is due to changes in the process of repeated observation to the patient's bed become a patient observation from the nurse station. However, this change decreases the time in the ER by 29%. Observation process can be done by nurses through a computer at the nurse station because the patient's condition will continue to be updated in the system. Process of updating the data can also be done in real-time because of the implementation of smart medical bed that have a sensor of the patient's vital signs. The system also displays activity that may indicate a potential fall risk, a need to be turned, or vital signs outside the normal threshold to the device owned by EPs.

A very significant time change also occurs in the triage lane space. This decrease in time occurs because of the use of vital signs sensor that simplifies the triage process. With a faster triage process, patients get faster care from EPs at the ED. Vital signs sensor also make the data obtained from the triage process more accurate so as to reduce the risk of errors.

Table 6. Hospital To-Be Process Model Result

Transactions Statistics (Hours)				
Process	Detail Lane	As-Is Process	To-Be Process	% Change
Hospital	Total	5,36	4,19	22%
	Administration	0,79	0,76	4%
	Pharmacy	0,04	0,04	0%
	Nurse Station	2,64	3,03	-15%
	Triage room	0,05	<0,01	82%
	Emergency room	1,97	1,4	29%

5. CONCLUSION

In EMS events, emergency physicians must provide quick and accurate care to save patients from death or disability. IoT is a technology which can facilitate the EMS process in capturing, processing and analyzing information about patients. Based on the existing process, pre-hospital and hospital process has several failure modes that are selected for improvement with IoT implementation. The results obtained indicate that there is a reduction in time of 19% in the prehospital process and 22% in the hospital process. Results of both processes have the highest percentage change in the triage room. The reduction in time in this triage room is very important because it can accelerate patients to get treatment in the emergency room.

ACKNOWLEDGMENT

Authors wish to acknowledge the Universitas Indonesia that has been granted this research through PITTA B and would like to thank all the stakeholders who participated in this research.

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