EMERGENCY DEPARTMENT SYSTEMS ENGINEERING: MODELLING AND EVENT SIMULATION

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THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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Name of Degree: PhD in Computer Science – Modelling and Simulation.

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EMERGENCY DEPARTMENT SYSTEMS ENGINEERING : MODELLING AND EVENT SIMUALTION

ABSTRACT

Emergency department systems are meant to ensure the timely delivery for essential healthcare services through complex systems. (ED) offers various services and have several components in its parts. Examined long previous research on system engineering and quality of healthcare resulting on these are influenced by operational management. Real time data are very helpful for decision making for any systems.

Patient output feedback and satisfaction can be ensured with engineered management. EDs have become evident particularly in current scenario when the world is in the grip of the deadly COVID-19. All this implies that analysis is significant for improvement of services in the emergency department. Digital health has become an essential feature of the healthcare sector specifically in present situation of COVID-19 pandemic.

Capacity of ED resources are over-utilized and insufficient. Capacity management is less quality and poor specially in devolving countries. Overcrowd patients' arrival put resources at high usages, Management readiness is not capable to mobilize available resources at very minimum time. Performance of ED is failed due to huge volume of unexpected patients.

Absence of a model for simulating the KPIs of ED based on real time events to enhance advance decisions. Operational effective management is

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absent within Patient ambulance transfer. Abstraction of research from 2000 to 2019 to understand emergency department processes was involved to create taxonomy on emergency services and its operations management. The last twenty years methods, problems, solutions allocated with emergency department were abstracted.

The assessment of service quality of emergency departments improved significantly with the development of new tool of system performance indicators. In this context, the formulation of sensitive assessment proved to be appropriate for simulation experiment. The new tool was validated and showed the value of Kappa to be 0.763 and reliability Cronbach's alpha to be 0.827. a reduction of patient waiting time at emergency department specially in Saudi Arabia as 38.57 percent less than current actual waiting time at medium hazard scenarios for door-to-door service time and with 61.63 percent of ED possessing time in Malaysia. Ninety percent of simulated cases was found to be within optimal range for data was collected before COVID-19 pandemic.

Key Words: Healthcare, Emergency Department, System Engineering, Modelling and Simulation, Quality Service and Waiting Time.

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SISTEM JABATAN KECEMASAN KEJURUTERAAN: PEMODELAN DAN SIMULASI

ABSTRAK

Sistem jabatan kecemasan (SJK) diciptakan untuk memastikan perkhidmatan kesihatan penting berlaku secara cekap dan tepat pada masanya melalui sistem yang kompleks. Jabatan kecemasan menawarkan pelbagai perkhidmatan dan merangkumi beberapa komponen dalam bahagian perkhidmatannya. Penelitian yang telah dilakukan dalam kajian pada masa lampau mengenai kejuruteraan system dan kualiti perkhidmatan kesihatan yang dihasilkan dipengaruhi oleh pengurusan operasi. Data masa nyata sangat membantu untuk proses membuat keputusan sebarang sistem. Maklumbalas dan kepuasan hati pesakit mampu dipastikan dengan pengurusan yang diciptakan. Dengan ini, SJK dengan jelas telah menjadi sesuatu yang penting terutama dalam senario semasa ketika dunia berada di dalam cengkaman membunuh COVID-19. Semua ini menunjukkan bahawa analisis penting untuk peningkatan perkhidmatan di jabatan kecemasan. Kesihatan digital telahpun menjadi ciri-ciri yang penting dalam sektor kesihatan, khususnya dalam situasi pandemic COVID-19 sekarang.

Kapasiti sumber SJK terlalu banyak digunakan dan tidak mencukupi. Pengurusan kapasiti kurang berkualiti dan tidak bagus terutamanya di negara-negara yang mundur. Ketibaan pesakit yang terlalu ramai meletakkan penggunaan sumber pada tahap yang tinggi. Kesediaan pengurusan tidak mampu menggerakkan sumber yang tersedia pada waktu yang minima. Prestasi SJK gagal disebabkan oleh jumlah tinggi pesakit yang tidak

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dijangka. Ketiadaan sesebuah model untuk menjalankan simulasi KPI SJK berdasarkan situasi dalam masa nyata untuk meningkatkan pembuatan keputusan yang lebih awal. Pengurusan operasi yang berkesan tiada dalam pemindahan Pesakit ambulans.

Pengambilan kajian dari tahun 2000 ke 2019 untuk memahami proses perkhidmatan jabatan kecemasan terlibat untuk mewujudkan taksonomi dan kaji urutan pada perkhidmatan kecemasan dan pengurusan operasinya. Kaedah, masalah dan penyelesaian yang diberikan selama dua puluh tahun yang lalu berkaitan dengan perkhidmatan jabatan kecemasan telah diklasifikasikan. Penilaian kualiti perkhidmatan jabatan kecemasan meningkat dengan ketara dengan perkembangan alatan baru yang merupakan petunjuk prestasi sistem. Dalam konteks ini, rumusan penilaian sensitif terbukti sesuai untuk menjalankan eksperimen simulasi. Alatan baru ini disahkan dan menunjukkan nilai Kappa menjadi 0.763 dan kebolehpercayaan alpha Cronbach menjadi 0.827. Ini adalah pengurangan masa pesakit perlu menunggu di jabatan kecemasan terutamanya di Saudi Arabia sebagai 38.1 peratus kurang daripada masa menunggu sebenar sekarang pada situasi kecemasan tahap sederhana. Sembilan puluh peratus kes simulasi didapati berada di dalam jarak optimum untuk data dikumpulkan, sebelum pandemik COVID-19. .

Kata kunci: Penjagaan kesihatan, Jabatan Kecemasan, Kejuruteraan Sistem, Pemodelan dan Simulasi, Perkhidmatan Kualiti dan Masa Menunggu Pesakit.

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صدق الله العظيم

To my beloved ones......

My Father, My Mother, My Daughters: (Alzahraa, Alpatool and Alkawther) and to My Son Zayed.

"I can't thank you enough".

To all my friends, and to my country..

"I thank you kindly".

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Salman Ben Zayed

"God Doesn't Play Dice with Universe"

Albert Einstein

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LIST OF ABBREVIATIONS

ABF	:	Activity-Based Funding
ACR	:	Ambulance Call Record
ANN	:	Artificial Neural Network
ATS	:	Australian Triage Scale
CCI	:	The Charlson Comorbidity Index
CTAS	:	Canadian Emergency Departments Triage and Acuity Scale
EBP	:	Evidence-Based Practice
EDs	:	Emergency Departments
EMS	:	Emergency Medical Services
ESI	:	Emergency Severity Index
ICD	:	International Classification of Diseases
IEEE	:	Institute of Electrical and Electronics Engineers
IPO	:	Input-Process-Output
LOS	:	Length-of-Stay
LWBS	:	Left-Without-Being-Seen
MAC Layer	:	Media Access Control (Data Link)
NPs	:	Nurse Practitioners
PIA	:	Physician Initial Assessment
POF	:	Patient outcome feedback
QI	:	Quality Index
QIPS	:	Quality Improvement and Patient Safety
RQ.s	:	Research Questions
SAE	:	Serious Adverse Event
SLR	:	Systematic Literature Review
SMR	:	Systematic Mapping Review
TQM	:	Total quality Management
UST	:	Unified System Theory

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LIST OF DEFINITIONS

- **Emergency Departments**: Is a system of people (patients, healthcare workforce, engineers and administrative staff) including processes and medical advancement and technologies in forms of hardware and software connected together with a network (cables, Wi-Fi, etc) to produce outputs that's is immediate quality care in other words, The production of outputs with the help of network of hardware and software, like cables, Wi-Fi etc.
- **Dynamic Capabilities**: The Lean Six Sigma is widely recognized as a TQM concept which employs service engineering to conduct process redesign initiatives and efficient process management systems. These systems are beneficial in the IT departments. They utilize these systems to refabricate or automate the processes. The organizational performance can immensely benefit and conquer positive milestones from the PDCs (Process Oriented Dynamic Capabilities) that the system engages.
- **Process Modelling**: Computers are used to conduct Input Process Output (IPO). The process should have enough room for specific adjustments so that the employs can tailor fit it to their requirements. Uncertainties are likely to occur therefore the employees must take efficiency into account when modelling new systems.
- **Service** Engineering: During the process, the services are developed and modified along each production unit. Services are typically a process but have been widely considered as a product. The service world requires a unified theory to be presented with so as to efficiently engage the services. For this purpose, the Unified service theory (UST) is brought to service through the I/O process model. An appropriate technique for transitioning input into output is only possible when the I/O model is analyzed in the light of certain features.
- **Simulation Method**: Organizations are applying a wide variety of simulation methods. The discrete-event—simulation is the primary method that is used for the modelling of a company's operation systems—queening systems.

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- **Simulation Model**: There are various complex computer models present but the simulation method can be used as a real-world phenomenon to establish a model that would help study the target simply rather than actually studying the target.
- **Utilization**: To bring something to use in its optimum capacity is known as utilization. This includes evaluating daily tangible assets, equipment, proceeds and success rate of workload and acquired milestones.
- **Optimization**: A real function can be capitalized or diminished by making calculated choices between pre-determined ranges of input values. The optimum value of the function is achieved through the substituting from the range of alternate values offered.
- **Emergency Preparedness**: Is collective actions for immediate relief and hazardous effective operation management before, during and after force of nature, human actions including a plan will help with safety, security and comfort regardless disaster type. In other words, it's a strategy for risk reduction before, during and after crises for known capacity that requires the necessary tools and steps to assess hazards; it must be followed by vulnerable resources and work and activities of people at local, regional and national level in which need development and strengthening services of emergency in form of large scale emergency, disaster response and relief or recovery program.
- **Management**: The capacity to recognize complicated issues to forecast disasters/hazardous with appropriate knowledge is related with the effective recognition of change, employing relative programs, calculating the operational efficiency in application to assess possible malfunctions in the system in other words, identifying change, utilizing strategies, evaluating the operational capacity in real world.

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CHAPTER 1: INTRODUCTION

ABSTRACT

A system comprising of persons (administrative and healthcare staff, patients and engineers), processes, techniques and equipment (software as well as hardware) connected to form a network that allows delivery of care to patients immediately is called Emergency Department (ED). For achievement of national goals, the Saudi Vision 2030 stresses upon economic diversification and this can be done through focusing on performance and sustainable strategies which are in agreement with the governance model of Saudi Vision 2030. An important target of the Saudi Vision 2030 is to ensure high quality and efficient healthcare delivery to Saudi citizens through improving quality of the healthcare services, making it more accessible and amplifying the efficiency of the system. With better ED systems, economic stability, improved utilization of resources and delivery of high-quality care is made possible and all these factors affect the organization and the service in the long run

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1.1 Introduction and Motivation

The second biggest city of the Kingdom of Saudi Arabia was substantially influenced by the 2009 floods. It caused a business loss of one billion and over 350 individuals were missing after the floods. It all occurred 2 days before the Eid ul Adha festival. In 2009, 123 individuals were killed by the floods in the Red Sea city. Two years after this, floods killed around ten individuals again. This spurred the need for responsive disaster planning and especially for the aspect of evacuation. Until 2004, the Kingdom of Saudi Arabia offered emergency services through only four organizations. However, 70 emergency departments were delivering emergency services in 2013. Development of improved strategies for EDs is still a challenge faced by the Health Department (Ministry of Health, 2013). At present, the constituents of EDS in Saudi Kingdom are not organized properly and the network is quite complicated. This study is aimed at minimizing or removing the factors which negatively affect the efficiency of the EDs. Main aspects considered in this study include the unnecessary waiting time leading to delay in delivery of care, decision response time and patient's flow in the ED.

In most of the countries especially developing states of the world, the healthcare organizations put great emphasis on emergency services. In this connection, quality analysis is of crucial importance for improving the emergency services. Debate is still in progress about measurement of quality of a service. Researchers are unable to find a method for accurate measurement of quality of a service or operation. Quality of the healthcare delivery can be analysed in a number of ways including consideration of the degree of satisfaction of the individuals receiving care. In other words, patient's experience speaks a lot about the quality of healthcare delivered in a setting. During this study, not only the patient's experience is analysed but issues related to key performance indicators (KPIs) in the EDs are also examined. This study can be split in four sections.

A technical aspect is considered in the first step. In particular, the EDs are not utilizing advanced monitoring and operation measurement technologies. This research aims to analyse different factors involved in development and implementation of an e-quality system for the EDs. In the second section, different factors involved in improving efficiency of the emergency service will be analysed. For this purpose, key performance indicators and key quality indicators are specified for the emergency services. In the third section, the descriptive model is utilized as a platform. The Discrete Event Simulation (DES) modelling platform is capable of managing the complicated and unorganized network that constitutes the EDs. This model facilitates application of various quality

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measurement models. An innovative strategy is put forward in the last section which focuses on the significance of utilizing operation research methodology in emergency departments.

1.2 Problem Statement

Efficiency of EDs is negatively influenced by the unanticipated admission of a large number of patients. In many emergency situations, resources and capacity of the EDs become very limited to cope with the situation. hidden causes of excessive waiting time severed as a tool for assessing the impact of major output on key performance indicators and was also used as effective method for testing defriend scenarios for possible system improving based on real data collected from emergency department sites (Komashie and Mousavi,2005). Ten percent of detailing a simulation experiment is key indicators for a general picture on a system behavior (Robinson et.al 2010). EDs capability may not be sufficient to support the requirements. There may not be capability assessment nor effective management therefore, the discrete-event simulation technique was considered is the most widely utilized technique in use in EDs, particularly from 2000 to 2009 in the UK healthcare system (Lim et.al, 2012). Resource optimization and reduction in waiting periods were the basic objectives behind the implementation of simulation method (Gul, M et.al, 2015).

Considering the complicated nature of the EDs, operational effective management is absent within Patient ambulance transfer. It is important to devise a model for improving the efficiency of the EDs. A crucial component of the EDs is the ambulance system. Transference of the patient from the ambulance to the ED is the first step in delivering care at ED and unluckily no strategy is at work which could ensure patient's satisfaction at this particular step. proper, operational, and effective management helpful for mangers

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of emergency departments in making appropriate decisions. to improve the overall patient experience through development strategies and quality evaluation in EDs. A critical element of the healthcare system is EDs (Alharethi et al., 2019). Typically, these sub-departments are operational 24-hours-a-day so that immediate treatment and care can be offered to patients suffering from extremely critical conditions (Zayed et al., 2018). It is therefore important to enhance ED resources as well as the healthcare system.

From long observation and previous studies (Komashie and Mousavi,2005), (Robinson et.al 2010), (Lim et.al, 2012), (Gul, M et.al, 2015), (Zayed et al., 2018) and (Alharethi et al., 2019), it was proofed that there is real problem facing patients who admit to EDs in devolving countries specially in Saudi Arabia as well as Malaysia like many worldwide countries concerning EDs. Furthermore, non-urgent visit, overcrowding, waiting time, preparedness, modelling operations and simulation in healthcare are worldwide phenomena. Waiting in ques too long increases the probability of worsen the patient conditions and may result in death. Automation and simulation are not expensive compare to other old fashion methods applied in EDs. The importance of automated solution to change and update current EDs system and subsequently, advance the healthcare service quality will provide patient with a timely fashion service and lower cost of resource for hospitals therefore, for governments and business. It will also bridge the gap of knowledge in the field to grate deal poor of operation management in healthcare in developing countries. ED is a complex system includes parts and interactions between its components; Capacity of ED resources are over-utilized and insufficient. Capacity management is less quality and poor specially in devolving countries. Overcrowd patients' arrival put resources at high usages, Management readiness is not capable to mobilize available resources at very minimum time. Performance of ED is failed due to huge volume of unexpected patients. Absence of a

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model for simulating the KPIs of ED based on real time events to enhance advance decisions.

1.3 Preliminarily Studies

Before conducting the research, relevant literature was reviewed through selecting a particular topic. The review involved examination of different issues related to our research problem, suggested solution and its analysis. Methods of extracting data are discussed in Chapter 3. Chapter 4 discusses EDs management and operation in EDs. Finally, Chapter 5 discusses the event simulation of operations at EDs. In general, the literature review is conducted in three steps. These are planning for the review, executing the review and reporting the findings all systematically. Methods which are used for conducting the systematic review are described in the review protocol. Main aspects of a process under study are analyzed through analytical review.

1.4 Gap of Knowledge

The EDs mapping discussed in 4th and 5th chapter was used to categorize the topics under study. 38,1860 articles published during the period between 1864 and 2017 were chosen for the review. Abstracts of these articles were collected. Basic processes and issues related to EDs were categorized.

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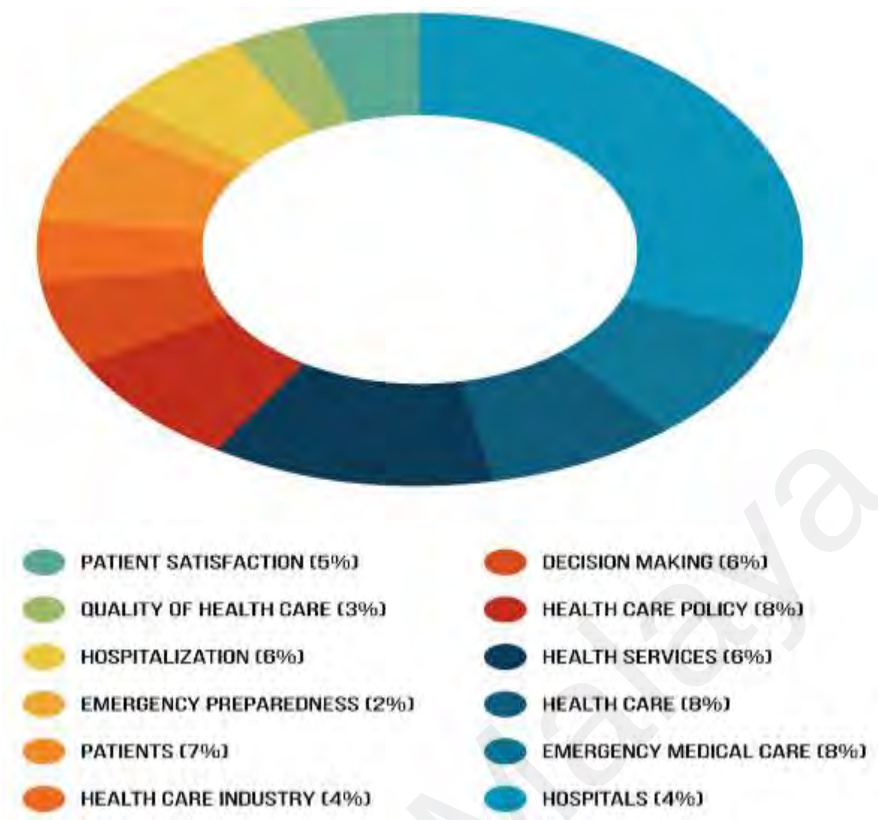

Figure 1.1 EDs Topics Gap of Knowledge

Review of preliminary studies allowed identification of knowledge gaps and questions which remain unanswered. Information gaps were identified in relation to emergency preparedness, performance measurement and quality of healthcare delivery as indicated by Figure 1.1 given above.

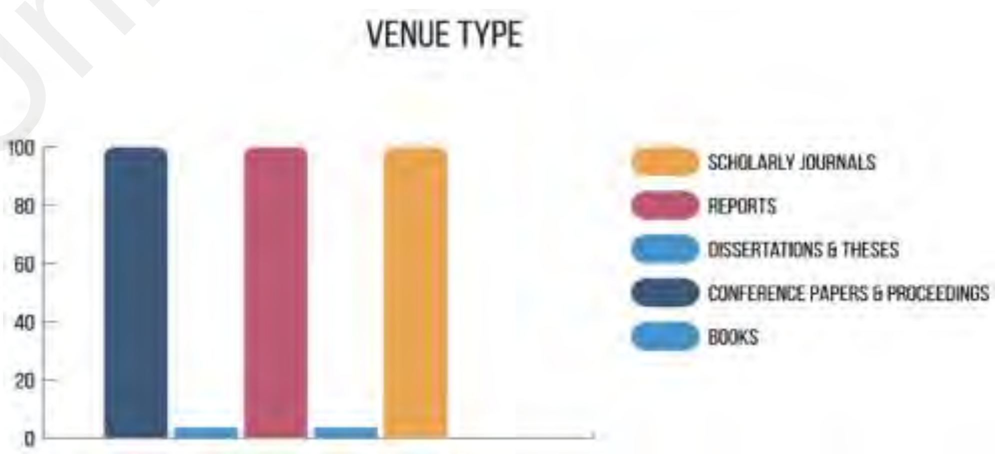

Figure 1.2 Classification of studies

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The volume of all studies in this field from 2000 to 2019 were classified based on venue type and no dissertations nor books were introduced as shown in Figure 1.2. Gaps were found in the health care industry, emergency preparedness, quality of health care, performance measurement, and others, as shown in Figure 1.3.

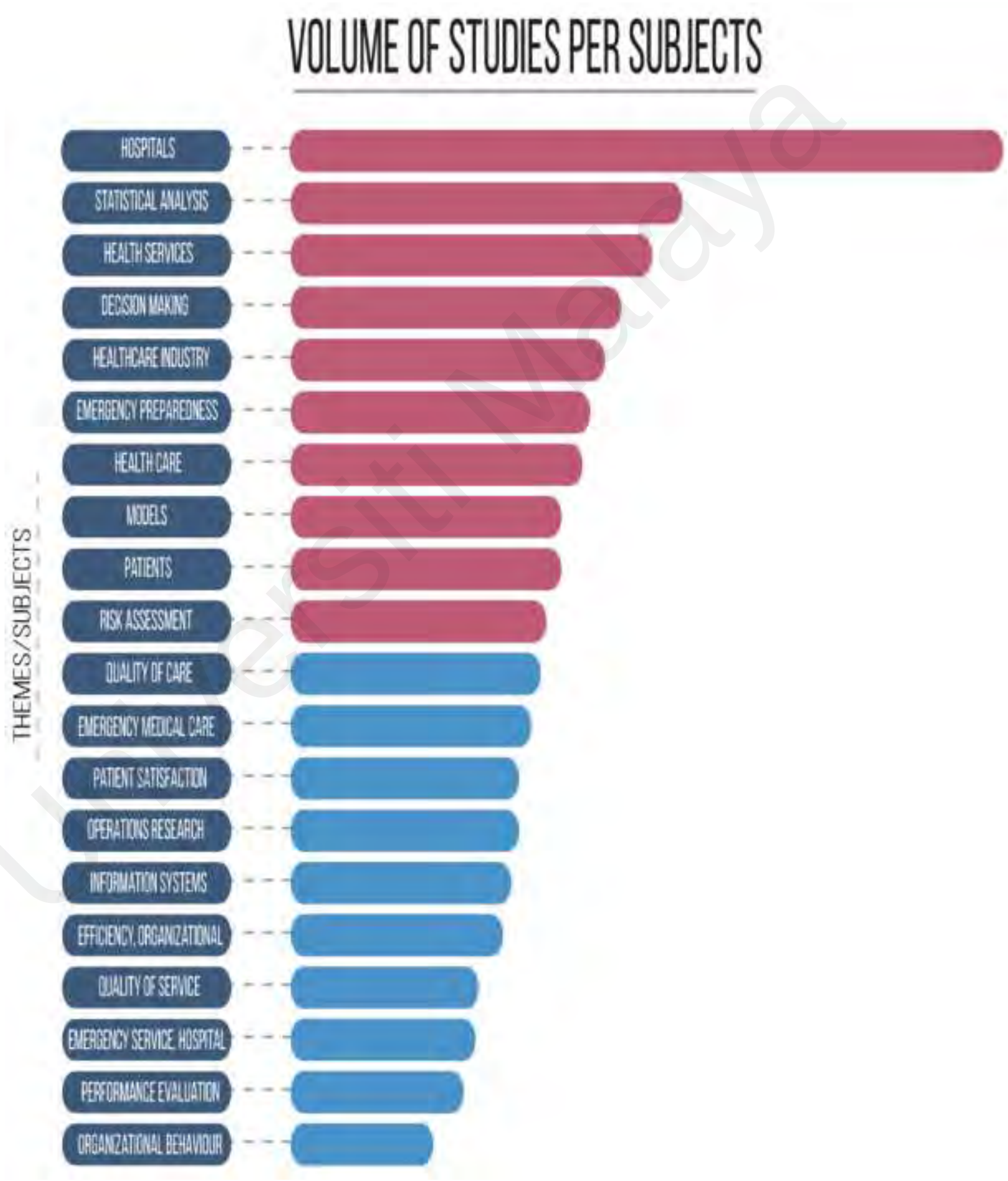

Figure 1.3 Classifications of Studies by Themes/Subjects before study

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1.5 Research Contribution

This thesis adds to the existing knowledge about the EDs and quality analysis and improvement by providing research-based data and years of track presented in Chapters 3, 4 and 5. Following are the ways through which this research adds to the existing literature.

This research puts forward an innovative framework for the EDs and this framework allows measurement of the efficiency and quality of healthcare delivery at EDs thereby allowing improvement in the ED system. Several knowledge gaps have been identified in this study and bridged. Data was collected from well devolved instrument that allows gathering data from actual cases that occurred in developing countries e.g. KSA and MY as well as developed states of the world e.g. USA. This data was then compared with literature and information provided by the government. The qualitative and quantitative data obtained from questionnaire studies, preliminary studies and questionnaire study were used to develop a model and framework. Development of validated theoretical framework was followed by development of a conceptual framework. Finally, a prototype of a web-based application for ED was developed which makes use of KPIs. Moreover, a research validated tool was developed which allowed measurement of the efficiency of EDs. This tool therefore allows improvement in ED using two different languages i.e. Arabic and English. Lastly, an innovative toolkit is developed for ED managers which presents a summary of the best operation management in the field of healthcare reported during the period between 2000 and 2019. To sum up thesis contribution as follows:

- Scientific models physical and mathematical computer model of EDs processes.
- Two theoretical models on EDs and its operations management.
- Conceptual model of EDs.
- Simulation model of real-world data.

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- Abstracted Taxonomy on EDs Problems occurred within the last two decades.
- Abstracted Taxonomy on EDs research methods used within the last two decades.
- Abstracted Taxonomy on EDs and Abstracted Taxonomy on its operation management.
- List of important definitions on EDs systematically defined.
- EDs KPIs instrument tool developed.
- Prototype of a real time EDs application that is capable of predicting its performances
- Updated EDs toolkit for EDs decisions-making personal.
- Bridging the gap of knowledge on EDs operational management and EDs event simulation.

1.6 Research Framework

The In this study, different gaps present in the literature have been identified and illustrated. It also elaborates why the issues addressed in this study do exist. The first step of constructing a conceptual framework is presented in Chapter 4 that contains SMR and SLR. This study links different studies conducted in this context and enlists different variables investigated by different studies. Research questions which have been specified in Chapter 6 have been developed accordingly. The entire framework is developed for investigating and analyzing different phenomena related to and system behavior and events relating to ED. This type of research has been conducted for the first time in connection to developing states like Malaysia and Saudi Arabia and implementing E-Systems for healthcare in these states.

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An Over 50,000 research papers published in peer reviewed journals during the period between 1915 and 2017 have been investigated previously. Chapter 3 outlines the conceptual model and working structure is given below.

Table 1.1 Research Theoretical Framework

Elements of framework	Issue Identified
Quality Care	Patient Record
EDs Operational Management	EDs Capacity and layout.
	Waiting time.
	Crowding and flow
	Efficiency
Healthcare Workforce	Skills
	Knowledge
	Effectiveness
Emergency Preparedness	Exposer to radiations.
	Disaster response.
Quality Engineering	Automatic segmentation
Simulation and Utilization in Healthcare	Structure and frequencies.
	Reduction of LOS

1.7 Advantage of the Thesis

Through literature review it was found that no research has been conducted in the past for utilization of simulation model in the Kingdom of Saudi Arabia (KSA) and Malaysia for bringing improvement. Direct comparison of results from various operational techniques for minimizing waiting time in EDs and improving patient's experience has not been considered in the past as well. Hence, this study is considered to be the first to consider implementation of simulation model in Malaysia and KSA. Key words ["emergency department" OR "emergency medicine" AND "operations" AND "waiting time"] were used for searching the relevant peer reviewed articles in the literature published during the period between 1882 and 2018. 1,759,073 articles were generated through this search and only 2994 publications were from the Middle East. Only ten articles were excluded from the study because they were found to be irrelevant. Hence

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this study can be considered to be original and unique; however, it can be re-evaluated and validated. Same search results were generated by using the IEEE database. All studies in this domain from 2000 to 2019 were classified based on venue type, with zero dissertations, thesis, or books introduced, as shown in Fig 1.2 therefore, this thesis is original and unique to the body of knowledge.

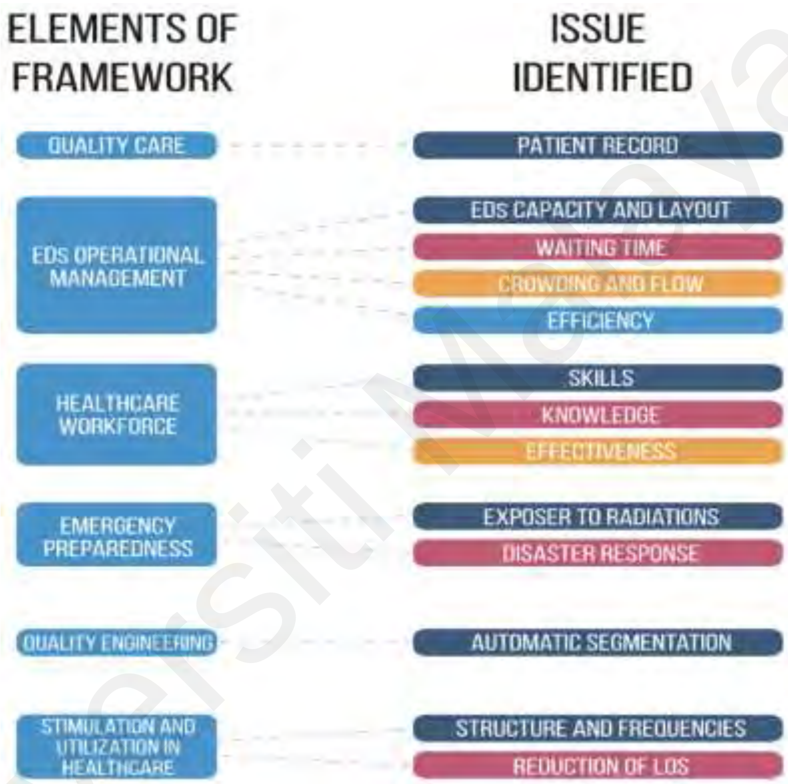

Figure 1.4 Research Conceptual Model

1.8 Research Roadmap

Building a research roadmap is the first step for approaching an investigation and for conducting research planning. Research management involves collection of evidences and its utilization for improving outcomes. Certain research articles were extracted based on the time period of publication. Research road map presents an extensive view of the research framework and different issues linked with the research conceptual model.

Classification of simulation in healthcare is presented in Figure 1.5. It is evident from the figure that this simulation is categorized into groups and subgroups. Simulation is first categorized into management, optimization and characterization of EDs. EDs are characterized by structure, patient flow i.e. frequency of patients and timing of various processes occurring at ED. These processes include admission, LOS and discharge of patients. Management involves skills and expertise for implementation of the simulation and optimization involves utilization of real-time algorithm. Chapter 4 and zayed et.al, 2018 presents detailed roadmap of the research.

Figure 1.5 Simulation in Healthcare Cluster

1.9 Research Scope

Scope of this study covers the topics related to e-Quality in the EDs of the healthcare settings particularly with reference to the utilization of simulation model. Different aspects identified by researchers for improving quality of the emergency services will be considered with the aim to improve level of satisfaction of patients as well as staff members in the healthcare setting thereby improving the efficiency of the entire emergency system.

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Figure 1.6 EDs in Healthcare Flow Chart

1.10 Research Questions

Research question was developed as part of research objectives of this study to solve the research problem and divided into three research questions:

- R.Q.1 What are the main and current problems of Emergency Department in Healthcare?
- R.Q.2 What type of research methods available and common to solve and overcome those problems?
- R.Q.3 How can we better harness our knowledge to execute tasks and missions to improve the overall process and outcomes of emergency department systems flow and experiences of patients and their satisfaction level?

1.11 Research Objectives

Certain research objectives are to be achieved through this research once answers to above mentioned questions are found. In other words, this thesis is basically conducted to:

- To Analyze the quality of services and patient's experience at EDs in a healthcare setting. RQ1
- To Formulate an innovative model which addresses the complicated nature of ED and relevant process. RQ1 and RQ2

- To Test the designed model of EDs of developing and developed countries. RQ2
- To Verify the results with the help of real-world data and simulation data of ED. RQ3

1.12 Significance of the Results

The statistical analysis of the results is important so that it can be validated that the results are correct. For instance, when two variables are found to be connected, it is tested statistically to make sure that they are actually connected, and the relationship is not caused by some other factors that is theoretical implications. Only statistically significant results are worth reporting. Results are first validated through instrumental validation that involves logical and statistical methods that is practical implications. In terms of the reliability of the instrument/tool designed in this study, Cronbach's Alpha was found to be 0.827. As per the findings of normality test, sample size was normally distributed. Strong and significant correlation ($p<0.01$) was detected between items and instrument score. The instrument items were evaluated by five experts and as per their analysis that involved determination of Kappa statistics, fair to excellent content validation is demonstrated by the instrument. A moderate to high loading was found through the factor analysis of various items of the instrument. This research is unique in terms of originality, collection of real world data and introduction of an innovative model which is discussed in Chapters 3, 4 and 5 in detail. One of the practical implications of this research, a reduction of patient waiting time at emergency department specially in Saudi Arabia as 38.1 percent less than current actual waiting time at medium hazard scenarios. Ninety percent of simulated cases was found to be within optimal range for data was collected before COVID-19 pandemic.

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CHAPTER 2: LITERATURE REVIEW

ABSTRACT

The emergency department (ED) setting within the healthcare system is quite complex, and it is imperative to perform mathematical modelling to examine the challenge of long waiting times and the ways in which it can influence EDs and patients experiencing conditions that need to be urgently addressed.

In addition, the ways in which certain mathematical models could help in assessing solutions to issues like waiting time and ensure that suitable care is offered to patients at all times is also analyzed. Various studies have been carried out in the last decade that examine the challenges faced by EDs to offer research evidence that can help in enhancing the ways in which health providers offer care to their patients.

2.1 Introduction

The mathematical modelling techniques employed during the planning stage of industrial engineering and operational processes provide a simple structure for practical implementation. Emergency departments (EDs) do not have indefinite measures; however, they provide critical care to a large number of patients. To evaluate ED systems, resource utilization, volume/number of patients, and waiting times need to be analyzed. A large number of information and data is available on hospitals through emergency department or patient files, which can be reviewed to facilitate management decision-making (Almozayen et.al, 2018). Moreover, different applications can be used to further support decision-making processes, with a stress on its application in E-Systems, such as ED systems in the field of healthcare. To specifically manage extensive data in the healthcare domain, data mining methods are essential and include clustering, classifications, sequential patterns, and decision trees. These techniques are supported by the datasets and allow the researcher to use extensive data from the search results in a more effective manner. In general, content mining includes searching for information available within a database. Similarly, there are different uses of search clustering. On the other hand, when there is substantively searched strings, bring together data to group information according to subjects, in which are employed for developing enhanced applications.

2.2 Emergency Departments

A critical element of the healthcare system is EDs (Alharethi et.al, 2019). They serve as a setting in which high-quality, instant care and service are offered to patients by care providers. Typically, EDs face challenges like overcrowding and lengthy waiting times. This is due to certain demand- and supply-side factors that have an impact on the ways through which patients are provided care in various settings. A review of previous studies revealed, for example, that problems like overcrowding and extensive waiting times can be managed by hospitals when there is adequate planning, resource allotment, effective patient management, and adequate staffing. Furthermore, the examination and assessment of the effect and cost-effectiveness of different interventions and approaches used to handle the issues experienced at EDs can be facilitated by mathematical frameworks. It is also important to perform additional evaluations to identify the technologies that can be employed by hospitals to decrease waiting times and overcrowding in their emergency departments.

A vital role is played by EDs in the provision of high-quality and well-timed care to patients suffering from various conditions. Typically, these sub-departments are

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operational 24-hours-a-day so that immediate treatment and care can be offered to patients suffering from extremely critical conditions and illnesses. Patients visit the ED at distinct times with the intention of receiving critical care for life-threatening conditions. Moreover, different kinds of injuries and complications brought about by accidents and chronic diseases, like cardiovascular disease, are managed by the ED (Hoot & Aronsky, 2008). In addition, all individuals are served in this department, regardless of background, or race. To ensure that the best possible care is provided to patients, various health professionals comprise ED staff, such as nurses, doctors, etc. (Lim et al., 2012). Much effort is made to ensure patients are given immediate care after their arrival at the ED (Hoot & Aronsky, 2007). The process may be different for each hospital or each case; however, usually, registration is the first step that is carried out, followed by placing of the patient on an ED bed and performing an examination, including diagnostic and laboratory tests. Following this, the patient is treated (Lim et al., 2012). Since this process involves some degree of uncertainty and complexity, various issues can arise, such as medical errors, lengthy waiting times, and resource wastage. Sometimes, due to factors like poor staff scheduling, testing delay, and incorrect results, the ED team is unable to provide effective care to its patients, and, often, the operational models used to perform various procedures can create barriers that inhibit providers from providing high-quality services. This is why efforts are being made to assess the challenges faced by EDs and determine solutions for enhancing the ED process, through which care is provided to patients.

Countries all over the world face different types of disasters, which, in turn, have negative implications on health, including serious injuries and casualties. In various parts of the world, natural calamities like avalanches, landslides, earthquakes, and volcanic eruptions have led to several deaths and loss of life's (Hoot & Aronsky, 2008). In certain situations, the extent to which EDs are reliable and suitable has been examined through the increase in the number of cases of infectious and chronic diseases reported. The ED is usually the primary point of care for patients experiencing complex problems (Lim et al., 2012) and also serves as the initial point of contact between victims and care providers during natural calamities (Hoot & Aronsky, 2008). Hence, it is important to enhance the ways in which units function and develop plans that will ensure appropriate care is provided to patients. Training is also being offered to care providers regarding the ways in which patients can be triaged and registered without delay as well as how to communicate with them upon their arrival, analyze their condition, and offer services to ensure they recover quickly. In the past decade, various studies have been carried out that examine the challenges faced by ED departments in order to identify evidence that can help enhance the ways in which health providers offer care to their patients (Hoot & Aronsky, 2008; Lim et al., 2012). In this paper, evidence from three previous studies, which concentrates on the activities occurring in ED settings, was examined.

2.2.1 Non-urgent-visit

It was shown in the study carried out by Hoot and Aronksy (2008) that there are several themes related to the reasons behind crowding in emergency care settings. These themes were typically classified as input, throughput, and output factors, with issues relevant to the source and components of patient inflow as some of the input factors. It was shown in an analysis of the data gathered by the researchers that the major factor were non-urgent visits. The researchers asserted that a few patients visited the ED when suffering from conditions that did not require urgent treatment. Specifically, sometimes, complaints were brought by frequent ED visitors that could probably have been treated in other settings, like inpatient or outpatient facilities. Lastly, patients experienced complex issues

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during the influenza season that needed to be treated immediately. Furthermore, there was a negative effect of these input factors on the process through which services are provided by healthcare professionals to manage these urgent ED cases. In contrast, the throughput factors were related to ED bottlenecks, and it was determined that its major influencing factor was insufficient staffing that led to negative effects like lengthier waiting times. Furthermore, it was asserted by the authors that due to insufficient staffing, caregivers in certain hospitals were compelled to manage multiple patients at once (Hoot & Aronsky, 2008). Lastly, overcrowding related to bottlenecks observed in other areas of the healthcare system that may influence ED operations were brought about by certain output factors. Inpatient boarding and hospital bed shortages were recognized by Hoot and Aronsky (2008) as the main output factors involved in resolving overcrowding issues in EDs.

2.2.2 Overcrowding

Outcomes from previous studies were used by Hoot and Aronsky (2008) to demonstrate the ways in which overcrowding affects EDs and summarize the negative health outcomes. According to the Hoot and Aronsky (2008), patients visiting the ED experienced several complications that could call for immediate and specialized treatment. When these patients were not offered the urgent care needed due to overcrowding, they faced a greater chance of experiencing negative effects, which could eventually even lead to their demise. Therefore, hospitals need to manage ED overcrowding to decrease the number of deaths they experience. The other issue discussed in the review involved the decreased quality of services. Overcrowding can compel care providers to treat multiple patients at once and work longer hours, because of which low-quality services are provided that do not fulfil patient requirements. This

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problem can also lead to less access to critical services since patients must face lengthy waiting times. Sometimes, there is also apprehension that the patients are likely to leave the ED without being examined by doctors because of the large number of patients already present. Because of lengthy waiting times, patients may move to other facilities; however, it is likely that those not checked by an ED doctor or care provider will exhibit worse conditions in comparison to those who were provided emergency care. Overcrowding can also cause financial losses for the hospital and produce a higher cost of care. It has also been shown in previous studies that, because of the large number of patients present at EDs, there may be delays in the provision of care, medical errors, extended pain, death, and the use of irrelevant processes. Relevant methods need to be determined by hospitals to manage issues and ensure that the best possible care is offered to their patients.

Further information was obtained by Hoot and Aronsky (2008) in regard to the potential solutions to crowding in EDs. three key themes were determined. In the first one, it was suggested that it is important to enhance ED resources as well as the healthcare system. The authors stated that further physical resources should be offered in hospitals to help employees react to the rising demand for emergency services. In addition, it has been asserted in other studies that the number of ED staff should increase, and support resources should be offered so they are able to provide treatment to patients in the shortest possible time and achieve positive clinical results. It was also suggested that the strategies, procedures, and techniques used to address the requirement for emergency services in the ED should be enhanced. Specifically, it was suggested by Hoot and Aronsky (2008) that the correct use of emergency services should be encouraged by hospitals, which should also reorganize patients in a way that positive health outcomes are attained and the number of patients at the ED at any specific point in time decreases.

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Finally, it was suggested that operational research should be carried out by hospitals to determine management and process changes required to ensure that patients are provided services just on time. In this process, partnerships should be established with external organizations, and researchers should formulate methods that make ED units and teams more effective and efficient.

Hoot and Aronsky (2008) carried out a systematic analysis of studies that examined the degree to which ED operations have been influenced by crowding, leading to unfavorable health outcomes. It was further asserted by the authors that a complex group of factors are responsible for bringing about this problem, which has an impact on patient flow and the tasks of healthcare professionals in these departments. Regardless of the reasons for its occurrence, crowding brings about several unfavorable outcomes that further worsens the health of patients. This is why various targeted solutions, like the recruitment of additional staff, has been carried out in the ED setting. Although important information is offered could bring about enhancements in the health sector, the ways in which overcrowding influences the provision of healthcare services was shown by Hoot and Aronsky (2008), and possible solutions that could be used to address this issue were determined.

2.2.3 Waiting time

Mathematical modelling was used by Lim et al. (2012) to analyze the issue of waiting time in EDs. The authors stated that novel opportunities are offered by analytical modelling for examining various healthcare issues, technologies, and interventions that have an impact on the process of providing care to patients. Due to developments in the healthcare setting, there has been an increasing need to establish relevant modelling methods that can offer high-quality data pertaining to care pathways and interactions

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among patients and healthcare providers in different settings. An example of assessing processes was put forward by Lim et al. (2012), which allowed for identifying the existing and subsequent demands for simulation and the way it affects the provision of high-quality care. System analysis techniques were formulated by the researchers in certain situations, which employed mathematical models to signify and evaluate an extensive variety of queries and factors. In addition, various hypothetical situations could be simulated by the models to enable care providers identifying areas that require adjustments to enhance patient care (Lim et al., 2012). The challenge of ED waiting times has been analyzed by mathematical modelling techniques. Due to lengthy waiting times, EDs become overcrowded and practitioners are unable to manage severe and chronic conditions that have an impact on patients (Lim et al., 2012). Since the ED setting within the healthcare system is quite complex, it is imperative to perform mathematical modelling to examine the issue of waiting time and the ways in which it can influence the health and welfare of patients in urgent condition.

There are several factors causing lengthy ED waiting times, including, for example, the complicated nature of the care provision process. According to Lim et al. (2012), urgent care is required by patients visiting the ED in order for them to regain their health. In contrast, healthcare professionals depend on management systems, care provision techniques, and equipment to manage their patients. Sometimes, lengthy waiting times are caused by demand factors like volume of beds, poor scheduling, hospital capacity, sub-optional management, and variations in the extent of patient acuity.

2.2.4 Preparedness

In some previous studies, the readiness of EDs to manage some of these healthcare issues often experienced by individuals has been examined. In addition, studies have been

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carried out to examine the issues faced by these departments and the ways in which they influence the provision of healthcare services. For example, a study was carried out by Hoot and Aronsky (2008) to assess the problem of overcrowding experienced by EDs. In this study, the authors sought to examine the reasons behind the problem and its consequences and then determine potential solutions for its mitigation. It was asserted by the researchers that overcrowding is a critical problem experienced by EDs throughout the world and has an impact on the quality of care offered to patients and their access to critical services. In addition, the authors claimed that, since a unique role was played by the ED in the provision of services, the researchers and practitioners gained encouragement to assess the safety characteristics of the contemporary healthcare system. It was shown that because of the high extent of overcrowding taking place in emergency care units, the quality of care provided to patients has been failing, with a breaking point identified that could cause negative health effects, like medical errors (Hoot & Aronsky, 2008). In previous studies, the ways in which hospital staff comprehend the problem of crowding and the interventions that have been formulated to manage its negative effects were analyzed, revealing evidence that could help in modifying the ways in which ED units work; however, according to Hoot and Aronsky (2008), more studies need to be carried out regarding the cause and effects of these issues so that relevant, long-term solutions can be formulated and executed in various care settings. It has been additionally observed by the Institute of Medicine that it is vital to comprehend the reasons behind overcrowding results as well as its impact to enable healthcare professionals in establishing methods for enhancing routine procedures and operations. This would ensure that, in the long-term, facilities are more capable of more rapidly managing the complex healthcare requirements of patients and produce positive health outcomes.

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The systematic review method was chosen by Hoot and Aronsky (2008) to accomplish their research objective. A comprehensive review of PubMed database was carried out to find articles that could present data regarding the required topic. For the purpose of this study, the author was looking for articles that had reviewed the cause, impact, and solutions related to the overcrowding problem in EDs. In addition, articles that used unambiguous data collection and analysis techniques were identified by the authors, while concentrating on the typical ED setting. Crowding was explained by Hoot and Aronsky (2008) as an issue arising when the requirements of patients in the ED setting become greater than the resources available. The researchers worked alongside two unbiased reviewers to review the articles and identify those that fulfilled the inclusion criteria. In case conflicts arose, consensus was reached on the basis of the pre-established standards for inclusion. After identifying the studies, data extraction was carried out. During this process, information pertaining to the objective, techniques, and findings of each study as collected. In addition, to analyze the methodological nature of the studies included in the review, a 5-level instrument was used (Hoot and Aronsky, 2008) with the purpose of collecting data that could help in understanding the issues faced by emergency departments all over the world and determine their solutions. The search process led to the selection of 93 articles that fulfilled the inclusion criteria (Hoot and Aronsky, 2008).

2.3 System Engineering

Various types of severe emergencies can be managed by EDs by their offering critical emergency care within and without the hospital. Moreover, the examination of health operations requires a decision-analytical model (Zayed, Gani, & Othman, 2018). It is important for hospitals to update these processes as modelling approaches are applied when carrying out communications among patients and ED staff as well as patient care

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pathways and supervision. It is vital to examine the system, as EDs are inherently complicated and face specific issues. Previous studies have employed mathematical healthcare frameworks; however, studies on EDs have quite infrequently used these models. However, a critical role has been performed by such models in decreasing the lengthy waiting times faced by ED patients.

It has been found that, in the healthcare sector, especially in EDs in less developed countries, improvements in quality measures and facilities are extremely valuable in assessing the quality and effectiveness of the care provided to the patients. These assessments involve collecting the perspectives of patients. Identifying a conceptual measurement of EDs facilities in EDs is not a simple task, since EDs in these countries do not employ certain existing operation and monitoring approaches to determine service quality. From the technological point of view, the factors bringing about the successful creation of an e-quality observational mechanism for emergency services can serve as a standard.

2.3.1 Modelling System Operations

Efforts have been made throughout the years to develop distinct mathematical models that can help in evaluating healthcare procedures. Nonetheless, there has been limited focus on the issue of ED waiting times. Due to the rising need to decrease the extent of overcrowding and time spent by patients in the ED altogether, a mathematical assessment of emergency department operations was carried out by Lim et al. (2012) to obtain information that would enable the enhancement of clinical outcomes. The study essentially sought to determine the latest mathematical modelling techniques that had been employed by researchers to examine the ways in which waiting times can be decreased in emergency departments. In addition, the modelling methods were compared by the authors to determine their impact on the process of offering urgent care to patients.

A well-defined and reliable technique was employed by Lim et al. (2012) to examine and produce data that could help in enhancing health outcomes in emergency care units. During this process, a systematic search was carried out to identify and determine studies that had employed mathematical models to assess the issue of ED waiting times. Different databases were used these included peer-viewed studies written in English from the years 2000 to 2010. Conference proceedings were also chosen by the researchers if they included information on the given topic. After identifying these studies, an abstraction form was generated by Lim et al. (2012) to note all important information. During this process, information was collection regarding the modelling methods employed as well as the aims, techniques, measures, and outcomes of each study. In contrast, the modelling techniques were compared by assessing their performance, ability to perform multiple types of processing, the type of software used, the extent of data abstraction, and memory. Based on the data collected, it was observed by Lim et al. (2012) that the discrete event simulation (DES) was used in 20 studies that fulfilled the inclusion standards to examine the problem of lengthy waiting times in EDs. An enhanced version of DES was used in two studies to formulate information pertaining to performance measures relevant to ED operations (Lim et al., 2012) also studies employed the system dynamics modelling to produce qualitative and quantitative data regarding the processes and systems employed by EDs.

It was shown in the review that DES, optimized DES, and system dynamics modelling were employed in previous studies to examine different performance measures that could increase ED waiting times. The impact of scheduling was one factor that was evaluated. It was asserted by Lim et al. (2012) that DES-based studies have assisted in determining

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scheduling factors like operational hours and staff shifts that had an impact on the number of hours spent by patients at the ED. It was also observed by Lim et al., (2012) that, in the studies chosen, appropriate scheduling could considerably enhance throughput and decrease patient waiting times. It was claimed in this study that, when fast-tracking of ED patients occurred, waiting times could decrease and better resource usage and management could ensue (Lim et al., 2012). Other factors that brought about positive clinical outcomes included sufficient staffing, enhanced planning, and bed registration. It was also demonstrated in mathematical model studies that waiting times in emergency care units could be decreased due to resource sharing and process timing (Lim et al., 2012). Hospitals with sufficient rooms, staff, beds, and equipment would be more capable of timing and planning their operations in an efficient manner. Consequently, there could be a decrease in ED length of stay and negative outcomes associated with overcrowding, like mortality, could be avoided in the long-term.

Due to pressure to make effective use of resources and enhance the quality of care offered to patients without producing any impact on budget, decision0makers have been compelled to concentrate on the different ways in which time spent in the ED can be decreased. Various supply- and demand-side factors are currently being understood by researchers and decision-makers that can increase waiting times as well as the degree to which care providers will treat patients in emergency departments. It was observed by Lim et al. (2012) that critical data has been offered by mathematical models that help decision makers in comprehending the systems and approaches that influence the provision of high-quality ED services in the shortest possible amount of time. It was also demonstrated in the study by Lim et al. (2012) that mathematical instruments have been used to illustrate the ways in which to manage the issue of lengthy waiting times through appropriate scheduling, resource usage, and management in addition to process planning.

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Furthermore, these models have been used to generate simulations that help in testing solutions to waiting times and identifying areas that caregivers should concentrate on in order to attain favorable results.

It was stressed in a systematic review carried out by Lim et al. (2012) that hospitals need to identify the ways in which the quality of ED services are enhanced by a decrease in waiting times. In addition, the ways in which mathematical models could help in assessing solutions to long waiting times and ensure that suitable care is offered to patients at all times was analyzed (Lim et al., 2012). Nonetheless, there were some limitations to the review that should be considered before the results are generalized. First, because of the cross-disciplinary character of mathematical modelling, the researchers were compelled to consider methods that have employed in various fields, such as industrial engineering and healthcare research (Lim et al., 2012). Secondly, the review findings may be influenced by biases in the modelling procedure, like temporality. Thirdly, a standard quality assessment instrument for the mathematical modelling methods was not available, which may have affected the validity and quality of the findings presented by Lim et al. (2012). Fourth, non-English studies that analyzed the role of mathematical modelling in addressing problems inherent in EDs, for example, lengthier waiting times, were not included in the study. Lastly, the researchers decided to restrict their search to articles issued between 2000 and 2010; because of this, older studies that offered high-quality evidence relevant to the subject of interest may have been excluded. However, despite these limitations, evidence was provided in this study that could bring about improvements in ED operations by highlighting the ways in which the issue of lengthy waiting times can be managed.

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2.3.2 Event Simulation in healthcare

When performing the operational management of an emergency, it should be noted that various complex features are involved. Specifically, efficient methods should be adopted to make sure that patients are responded to in a rapid manner. An issue that has been extensively observed in EDs is emergency preparedness in respect to lengthy waiting times and overcrowding, especially during calamities. Due to overcrowding, mortality and re-admission rates increase and there is a greater possibility of patients leaving the ED altogether without ever being checked. In addition, a greater number of patients are not taken care of in a proper manner due to a lack of prioritizing the offering of care to a large number of patients that could be suffering from minor to major conditions. The patient is first admitted to the hospital, after which, a doctor examines their conditions and offers treatment with appropriate medical care.

Due to extended waiting times, EDs become overcrowded, thus increasing the risk of patient mortality. In addition, since patients often leave the ED without being checked, ED re-admission rates could increase. The organizational, human, and physical features of patient monitoring in ED settings needs to be taken into account; therefore, it is necessary to consider the operational management system, real-time information regarding patients and their families and equipment. The key requirements include waiting areas and other places in which overcrowding is not allowed during times of high strike. The commands below are usually followed when managing patients: triage, registering patient name, examination, blood tests, X-rays, pharmacy, assigning ED bed location, management, ED staff, allocation, and, ultimately, discharge.

The most extensively used method by EDs has been the discrete-event simulation method, particularly within the UK Healthcare system from 2000 to 2009. The purpose of the ED is to attain critical healthcare objectives; hence, they are considered the most

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important component of hospitals. Thus, logical solutions and procedures should be developed by EDs in normal as well as unlucky situations. Simulation software can also be used to address issues regarding prevention, decreased waiting times, and forecasting variables in normal and unfavorable situations in EDs (Lim et al., 2012). Simulation modelling has been used to identify issues experienced in practical settings and those in terms of patient flow and supervising, arrival patterns, and inconsistent removal of optimal methods in emergency response domains (Gul & Guneri, 2015).

Data collection in the simulation model distinctly occurs in normal and hazard situations. Direct sampling, hospital records, historical data, patient tracking cards, questionnaires, and observations are used for gathering data. To increase resources and decrease waiting times, simulation approaches are used by employing cost monitoring and establishing planned guidelines (Gul & Guneri, 2015).

A simple structure for real-world implementation is offered by the mathematical modeling methods that are used in planning industrial engineering and operational procedures. Although EDs do not have unlimited means, they offer critical treatment to a large percentage of the patient population. The assessment of ED systems involves the examination of resource consumption, quantity, and waiting times.

In the case of extensive wait times, overcrowding can occur in EDs, which can result in the increased risk of patient death. Furthermore, patients could depart without ever being seen by a physician, which leads to their ultimate readmission. Therefore, it is essential to consider the organizational, physical, and human aspects of patient monitoring in ED environments; hence, the operational management system, equipment, buildings, and real-time information about patients and their families must also be considered. Moreover, primary prerequisites include waiting areas and other areas in which overcrowding is prohibited during the hours of highest risk. Patients are then

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managed according to the following guidelines: listing the name of the patient, triage, inspection, X-rays, blood tests, assessment, pharmacy, ED bed location, ED staff, management, allocation, and, finally, discharge. Overcrowding can result in increased waiting times at an ED. Furthermore, the capacity may not be sufficient to fulfill the requirements. For instance, there might not be enough beds, capacity management might not be effective, and patient acuteness and service requirements may differ (Lim et al., 2012). The discrete-event simulation technique has been considered the most widespread technique utilized in EDs, particularly in the UK healthcare system from 2000–2009 (Lim et al., 2012). System dynamics have also been used to some extent to reduce waiting times in EDs (Figure 2.1).

Because EDs aim to achieve significant healthcare goals, they are perceived as the most vital component in hospitals. EDs are required to formulate logical solutions and processes in both normal and adverse circumstances. Issues that pertain to prevention, minimizing waiting times, and predicting variables in normal and adverse circumstances at EDs can be addressed by simulation software. Additionally, problems occurring in real settings as well as issues related to patient flow and monitoring, arrival patterns, and the irregular withdrawal of optimal means in emergency response areas (Gul & Guneri, 2015) are determined by the simulation model (Table 2.1 and Figure 2.2).

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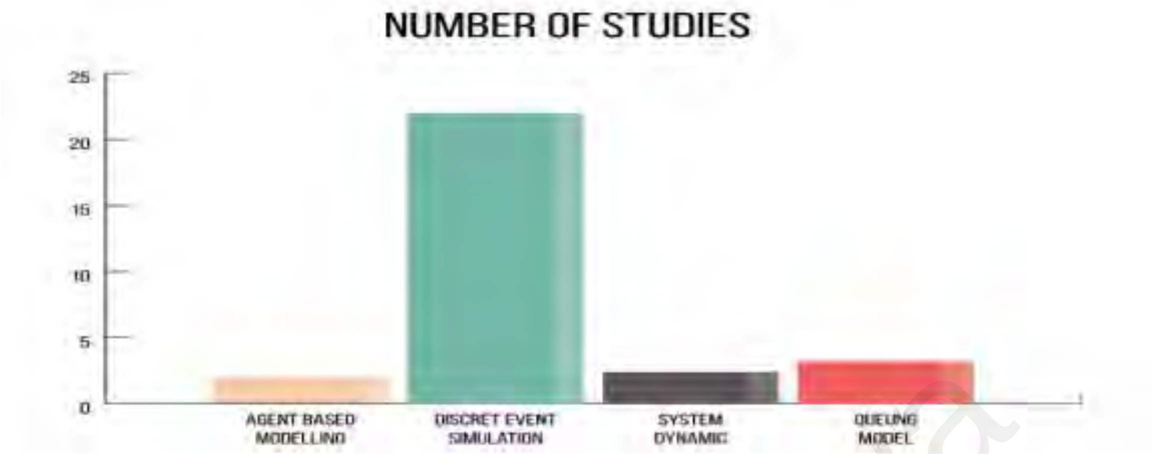

Figure 2.1 Simulation modeling type utilized from 2000–2009

Table 2.1 Simulation model in normal mode 1974–2015

Country	Publications Rate	Country	Publications Rate
USA	49%	Israel	2%
UK	14%	Ireland	2%
Turkey	1%	Iran	3%
Taiwan	3%	Hong Kong	1%
Sweden	1%	Germany	1%
Spain	3%	France	2%
Singapore	2%	Finland	1%
Norway	2%	Chile	1%
Kuwait	1%	Canada	5%
Jordan	2%	Australia	1%
Italy	2%	Total	100%

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Figure 2.2 Countries using the simulation model in hazard mode 2006–2012

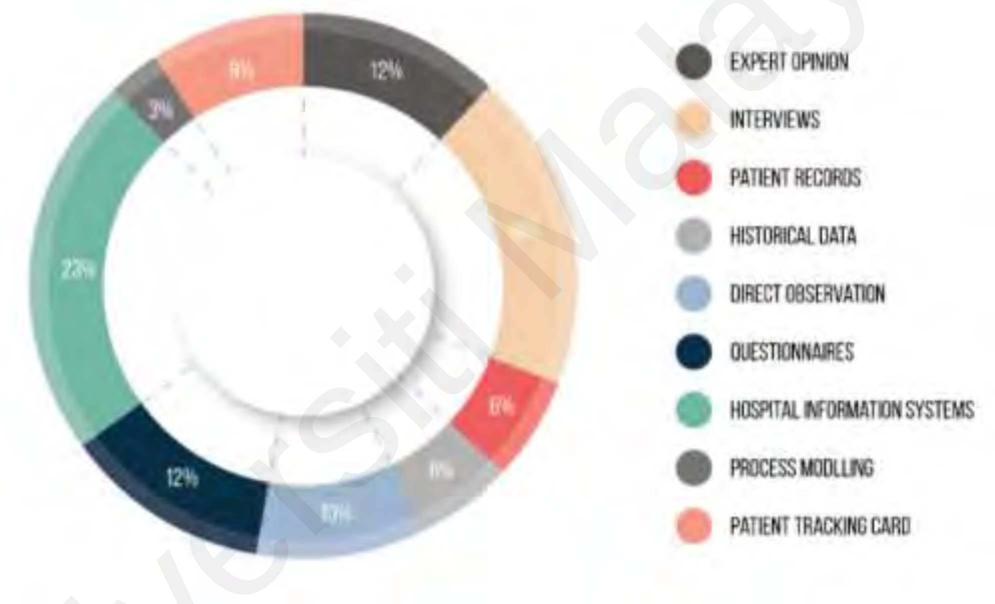

Figure 2.3 Data collection types in a simulation model with a normal mode

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Figure 2.4 Data collection types in a simulation model with a hazard mode

In the simulation model, data is collected differently depending on normal or risky mode. Data is also collected from direct sampling, historical data, hospital databases, questionnaires, patient tracking cards, and observations (Figure 2.3 and Figure 2.4). Moreover, simulation techniques are implemented to improve resources and minimize waiting times through the application of cost scrutinization and the presentation of planned policies (Gul & Guneri, 2015).

2.4 Data Mining

Different applications can be used to further support decision-making processes, with a stress on its application in E-Systems, such as ED systems in the field of healthcare. To particularly manage extensive data in the healthcare domain, data mining methods are needed, which include clustering, classifications, sequential patterns, and decision trees. These techniques are supported by the datasets and allow the researcher to use extensive data from the search results in a more effective manner.

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2.4.1 Data warehousing

To eliminate data repetition that emerges from web mining-derived clustering methods, a cluster-optimizing method that is identical to the inherent capability of ants to identify their nest mates can be employed, The cluster optimization method was considered to eliminate crawlers, there should be accessibility to the graphics in the web log. A cleaned web log was used to carry out the pattern analysis (Alphy & Prabakaren, 2011). The algorithms used most often, like PageRank, Weighted, and PageRank, were evaluated against each other (Jain & Purohit, 2011). When an influential web mining tool was used, the information from the traditional user patterns could be examined. In this technique, a vital role is carried out by web structure mining. Various web structure mining algorithms were used to rank the compatible and relevant pages, with the same treatment was provided by HITs, PageRank, and Weighted PageRank to each link while simultaneously presenting the ranking score (Jain & Purohit, 2011). The two levels of the prediction model will be explained by the author to conceptualize achieving enhanced hit ratios. The first level seeks to filter the categories that are highly likely to bring about a visitor hit. The next level is used particularly for achieving the greatest web page probability. Nonetheless, it is not possible to disregard the issues of heterogeneous user behavior (Khanchana & Punithavalli, 2011). To enhance the customization of web content, data mining instruments were used to examine web logs (Mukherjee, Bhattacharya, Banerjee, Gupta, & Mahanti, 2012). The effectiveness of the documents from the perspectives of the users were examined with the search tool by allocating higher ranks to clusters that were similar to the chosen keyword. The systems that just used content-based searching were deemed of lesser value in respect to their specificity (Mukherjee et al., 2012). In another study (Papadopoulos, Zigkolis, Kompatsiaris, & Vakali, 2011), a distinct concept that was presented involved automatically determining

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landmarks and events in tagged images. When a large amount of user-shared images need to be aligned, landmark and event detection are critical instruments.

2.4.2 Web mining

used to obtain a more extensive understanding of the support requirements of web- and programs uses several techniques to identify usage patterns present in web data. It comprises three key phases: pre-processing, pattern identification, and pattern assessment (Srivastava, Cooley, Deshpande, & Tan, 2000). While being used extensively in web, mining data has also grown its use throughout the web. Through this method, an increased understanding of existing information can be obtained, which can be applied more effectively to end users. This is why this kind of analysis has been employed by various organizations. In contrast, some challenging questions have surfaced in regard to web mining, and it is imperative to respond to them before formulating robust instruments (Srivastava et al., 2000). There have also been studies on the adoption of data mining with respect to management systems, and adaptive systems. Certain requirements exist with respect to the integration of data mining within systems. (Romero & Ventura, 2007).

2.5 Conclusion

Relevant methods need to be determined Almozayen et.al, 2017, by hospitals to manage issues and ensure the best possible care is offered to their patients. Overcrowding can compel care providers to treat multiple patients at once and work longer hours, resulting in low-quality services being provided to patients that do not fulfil their requirements. It has been found that, in the healthcare sector, especially in emergency departments in less developed countries, improvements in quality measures and facilities are extremely valuable in assessing the quality and effectiveness of the treatment provided to patients.

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Preparedness In a few studies carried out previously, the readiness of emergency departments to manage a few of the healthcare issues often experienced by researcher were examined. In contrast, healthcare professionals depend on management systems, care provision techniques, and equipment to manage their patients. It was suggested that the correct use of emergency services should be encouraged by hospitals, which could reorganize patients in a way to attain positive health outcomes a decrease in the number of individuals at the ED at any given point in time.

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CHAPTER 3: EMERGENCY DEPARTMENTS: A SYSTEMATIC MAPPING REVIEW

ABSTRACT

Emergency services are essential to everyday life in that any person may require these services at some point in their life. Emergency services operate through a complex management structure composed of many different parts. It is essential to establish effective procedures to ensure that patients are treated in a timely fashion. Collecting real-time information is also a necessary precursor to intelligent decision-making. Hence, thorough analysis of problems concerning appropriate, operational, and effective management could help prevent patient dissatisfaction in the future. Mapping studies are utilized to configure and explore research themes, whereas systematic reviews are utilized to combine proofs. The use of improvement strategies and quality measurements in the health care industry, specifically in emergency departments, is essential in value patient satisfaction levels as well as the quality of health care services based on patient experiences. This paper explores and creates momentum with all the methodologies utilized by researchers from 2010 and beyond that place stress on the subject of patient fulfillment in the emergency services segment.

3.1 Introduction

Emergency services, or emergency departments (EDs), manage various types of severe emergencies through acute, out-of-hospital medical care. It is essential to include a decision-analytic model in any assessment of health care technology. This type of technological analysis must be updated in hospitals, as modeling methods are required to manage interactions between patients and ED staff as well as patient care pathways.

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System analyses are also required due to the complex nature of EDs and the various issues involving them. Various studies have explored mathematical models in health care, but these studies did not explore mathematical models in EDs even though such models are vital in reducing the long waiting periods experienced in Eds

3.1.1 Study Motivation

The second biggest city of the Kingdom of Saudi Arabia was substantially influenced by the 2009 floods. It caused a business loss of one billion and over 350 individuals were missing after the floods. It all occurred 2 days before the Eid ul Adha festival. In 2009, 123 individuals were killed by the floods in the Red Sea city. Two years after this, floods killed around ten individuals again. This spurred the need for responsive disaster planning and especially for the aspect of evacuation. Until 2004, the Kingdom of Saudi Arabia offered emergency services through only four organizations. However, 70 emergency departments were delivering emergency services in 2013. Development of improved strategies for EDs is still a challenge faced by the Health Department (Ministry of Health, 2013). At present, the constituents of EDS in Saudi Kingdom are not organized properly and the network is quite complicated. Saudi Vision 2030 focuses on economic diversification to achieve national goals by valuing performance and measuring sustainable action. One of the main goals of Saudi Vision 2030 is to implement "efficient and high-quality health care" to improve the quality of health care services by boosting the accessibility and effectiveness of health care services. Within heath care services, improvements to ED systems will optimize resource use, assets, and economic stability, all of which have long-lasting effects on patient wait times, quality of care, and satisfaction.

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3.1.2 Knowledge Gap

The topics examined in the present study were classified based on the ED mapping of 381,860 articles that were published from 1864–2017 in a method similar to (Almozayen et.al, 2017). The main problems and methods associated with EDs were classified to determine a theme. This analysis revealed gaps in the emergency preparedness, quality of care, performance measurement, and other qualities of the health care industry, as shown in the answers to research questions RQ2, RQ3, and RQ6.

3.2 Background

Mathematical modeling techniques exist to map industrial engineering and operation processes or systems to provide a simple structure for real-world applications. Although EDs have limited resources, they provide acute care for a large percentage of the admitted patient population. Resource use, throughput, and wait times are parts of what is included in ED system as behavior measurements.

Overcrowding can occur in EDs if waiting periods are long, and this may increase patient mortality risks. In addition, long waiting periods may cause patients to leave EDs without being checked, resulting in readmission to EDs later. Organizational, physical, and human factors must be considered for the patients and environments of EDs. For instance, management systems, equipment, buildings, real-time patient information, and patient relatives must be considered. One basic requirement for avoiding overcapacity during hazardous times is the inclusion of adequate waiting areas. The following order is typically used to deal with patients: registration, triage, examination, X-rays and blood tests, evaluation, pharmacy, ED bed location and ED staff, handling, allocation, and discharge.

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ED wait times may be long due to overcrowding. In addition, the patient demand might exceed the EDs capacity; the number of beds might be insufficient, capacity management might be suboptimal, and patient acuity and service demand may vary (Lim et.al, 2012). From 2000–2009, the discrete-event simulation method was the most commonly used method in EDs, especially in the United Kingdom health care system (Lim et.al, 2012). To a minor degree, system dynamics have also been used to improve wait times in EDs (Figure 3.1).

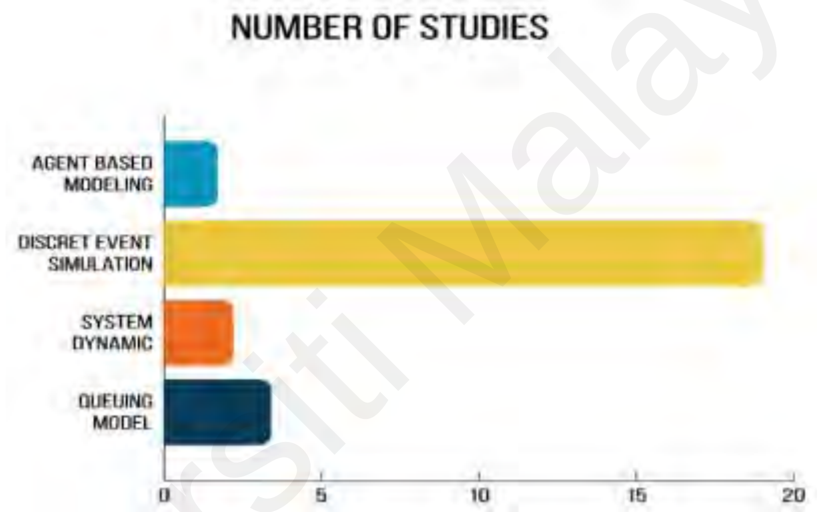

Figure 3.1: The different types of methods and frequency they were employed to solve the problems of EDs from 2000–2009.

Emergency Departments aim to meet an important health care objective; therefore, they are considered the most critical type of health care unit. It is necessary for EDs to develop rational solutions and procedures for both normal scenarios and disaster scenarios.

The simulation software used in this study aims to address prevention-related issues, reduce wait times, and predict variables related to disaster situations in EDs. The simulation model identifies issues that occur in real situations, including those pertaining to patient flow, arrival patterns, and the infrequent extraction of optimal resources in

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emergency response domains. The sources used for gathering data included direct sampling, historic data, hospital databases, and observation. The simulation method was applied to enhance resources and reduce wait times by implementing a cost analysis and introducing strategic policies (Gul et.al, 2015).

3.3 Methods

A system is only mapped as a starting point to evaluate and classify existing studies by subject with the goal of conducting a thematic evaluation. A systematic mapping study is used to summarize a research area and detect gaps in the preexisting research. Systematic mapping is used in preliminary studies to allow researchers to review papers related to a certain theme, classify research, and conduct thematic evaluations (Elberzhager et.al, 2012). The systematic review process characterizes and summarizes existing research following a predefined protocol (Petersen et.al, 2008). The final result of the mapping study distinguished the gaps in the related research.

3.3.1 Research Questions

The intelligence of this study, the monitoring strategies used in (Petersen et.al, 015), [3–6], [8], and [32] were used to define the problems of EDs. The following research questions (RQs) were addressed:

- RQ1: What techniques do research studies on EDs typically use?
- RQ2: What topics do studies of EDs typically introduce?
- RQ3: When and where have previous studies of EDs been published?
- RQ4: How do studies of EDs typically visualize their results?
- RQ5: What problems have preexisting studies of EDs addressed?
- RQ6: How are studies of EDs typically classified?

Management of the present study's research area was carried out through mapping studies. The RQs of this study were developed to systematically meet the following aims: a) to obtain a general idea of the issues that must be addressed in EDs, and b) to review the approaches used in existing research on EDs.

3.3.2 Search for Primary Studies

The search for primary studies was conducted in the following databases: ABI/INFORM [9–10], Emerald [15–16], IEEE Xplore [17–21], and ProQuest Dissertations and Theses Global [22–27]. These databases were chosen because they are comprehensive databases containing millions of publications, especially those related to EDs, engineering, and computer science.

The following keywords were identified: *emergency department*, *emergency medical care*, *emergency clinics*, and *methods*. These keywords were used to develop the following search strings:

- Set 1: Search terms related to scoping research on EDs (i.e., *emergency department*).
- Set 2: Search terms related to strings (e.g., *emergency medical care* and *emergency clinics*).
- Set 3: Search terms related to techniques (e.g., *methods*).

The keywords were classified based on the RQs and grouped into sets. Each set was identified in the databases (Table 3.1). This study was systematized based on the period of time during which it was conducted: early 2017 to late 2016 (Table 3.2).

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Table 3.1: Database Searches

Database	Command Search
ABI/INFORM	("emergency department" or "emergency medical care" or "emergency clinics") and ("methods")
Emerald	("emergency department" or "emergency medical care" or "emergency clinics") and ("methods")
IEEE Xplore	("emergency department" or "emergency medical care" or "emergency clinics") and ("methods")
ProQuest Dissertations	("emergency department" or "emergency medical care" or "emergency clinics") and ("methods")

Table 3.2: Number of Studies Per Database

Database	Search Results	Date
ABI/INFORM	103,025	1864–2017
Emerald	12,313	1898–2017
IEEE Xplore	891	1924–2016
ProQuest Dissertations & Theses Global	265,631	1897–2017

3.3.3 Study Selection

Based on several database features (Figure 3.2). Quality assessment was based on each article's citations at first place, and articles without citations were excluded in certain cases. The following inclusion criteria were considered: studies focused on the research methods involved in studying EDs, studies published between 2010 and 2016, and studies in the field of EDs. Finally, the following exclusion criteria were considered: studies not presented in full text, studies that had not been reviewed, studies duplicating other work, and non-English studies. The numbers of articles included and excluded in the search process for each database are listed in Figure 3.2, and the final list of selected studies is presented in Table 3.4.

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3.3.4 Data Extraction

The extracted data form used the modified template provided by [32], which was updated to suit this study (Table 3.3). Each space included the item and value. Data extraction was completed by the first author and reviewed by the second and third authors for validity and quality control.

Table 3.3: Adapted Data Extraction Table

Item	RQ Result	RQ
Study ID	Number	
Author Name	Name(s)	
Year of Publication	Calendar year	RQ3
ED Area	Area of knowledge related to EDs	RQ2, RQ6
Venue	Journal name	RQ3
Method	Method used	RQ1
Problem	Problem identified	RQ5
Visualization Type	Style of presentation	RQ4

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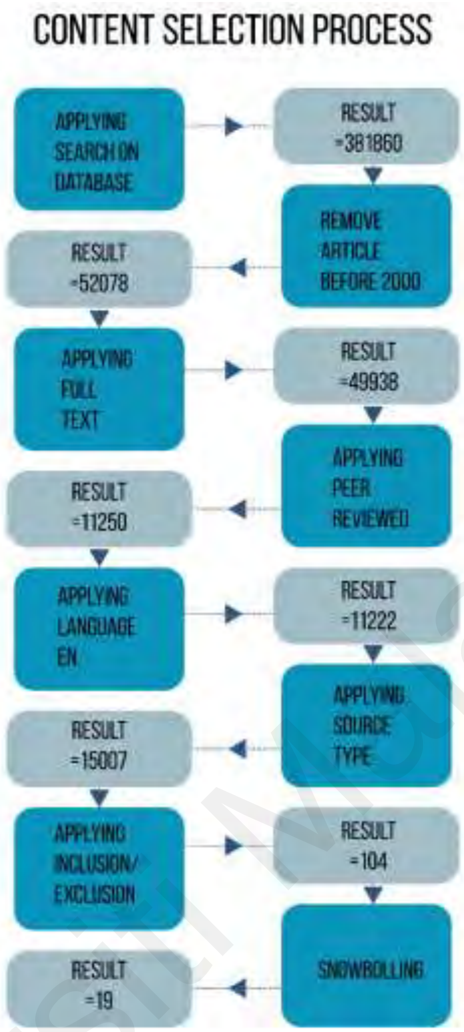

Figure 3.2: Flowchart for the content selection process.

3.3.5 Validation and Verification

The data collection process used in this study has a strong degree of objectivity. The validity of data collected this way is exposed to less risk than data obtained from quantitative analysis. To reduce this risk, a data compilation table was adapted to back the documented data; this table was used in data mining [32] to allow for reexamination. Data collection tables are used to document data and reduce risk. Further risk reduction can be done by rechecking the data extraction. When two different authors carried out these steps independently and arrive at a common understanding, as was done in the present study, further reinforcing the objective stance and reproducibility of the methods [3].

3.4 Results

Several publications from 2010–2017 were identified and reviewed for each database (Table 3.4).

3.4.1 RQ1: What techniques do research studies on EDs typically use?

More than eight different methods and techniques were found to have been used in research on EDs. The main methods used in the ABI/INFORM database included literature reviews, interviews, and questionnaires [9–14]. The main methods used in the Emerald database included queuing theory and focus groups or interviews (problem trees) [15–16]. The main methods used in the IEEE Xplore database included image processing/machine learning, neural network machine learning, and clustering and logistic regression algorithms [17–21]. Finally, the main methods used in the ProQuest Dissertations and Theses Global database included mixed methods, descriptive research, experimental research, and qualitative research [22–27].

3.4.2 RQ2: What topics do studies of EDs typically introduce?

The screened topics were categorized based on ED-related research topics. All ED-related activities were well presented. The main problems that arise in EDs and the methods used to study them can be covered by mapping and are not influenced by any specific topic [9–27]. Thus, gaps were found in the research related to emergency preparedness, health care quality, patient satisfaction, performance measurement, and the overall health care industry (Figure 3.3 and Figure 3.4).

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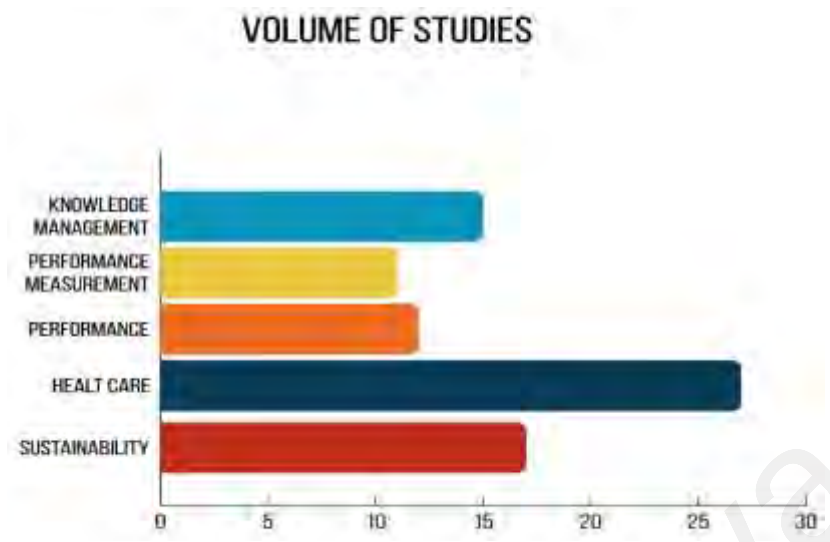

Figure 3.3: Subjects with a research gap in performance measurement.

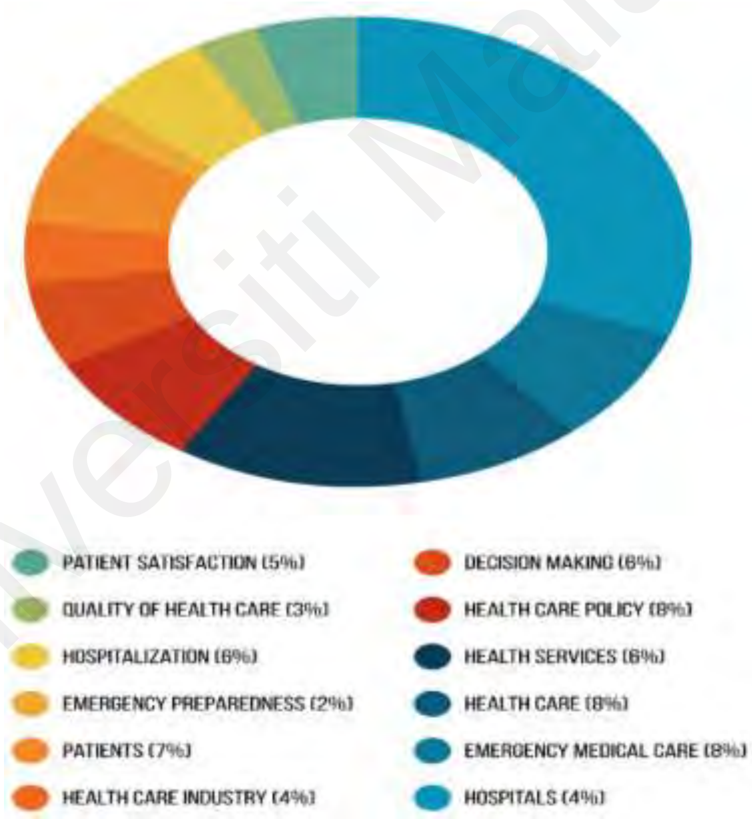

Figure 3.4: Overview of topics with research gaps in emergency preparedness and health care quality.

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3.4.3 RQ3: When and where have previous studies of EDs been published?

Many documents published between 2010 and 2016 were identified in each database. The earliest identified study was published in 1864. Interest in this field increased between 2010 and 2014 and significantly dropped in 2016.

In the present study, only peer-reviewed journals, conferences, and materials were included to answer the research questions. Studies related to engineering, simulation, and process management only accounted for 2% of the total studies on EDs published between 2010 and 2016 (Figure 3.4, Figure 3.5 and Figure 3.6).

3.4.4 RQ4: How do studies of EDs typically visualize their results?

In this study, the visualization approaches of previous studies were identified (Table 3.4). Most commonly, figures or graphs and tables were used to visualize data.

3.4.5 RQ5: What problems have preexisting studies of EDs addressed?

Dynamic and iterative processes that decrease risks and exposure may be uncontrolled in some emergency management structures. Active and repetitive processes, which include parallel computing, dissemination, exchanges, and ethically sound knowledge applications in health care systems, can result in decreased service quality or inappropriate crisis management. Crisis management requires simulation, focus, memory, exceptions, people, authorities, and resources to be brought together at a specific time for a specific purpose. ED problems can be classified into major concerns, as shown in Table 3.4 and Figure 3.3, Figure 3.4, and Figure 3.8.

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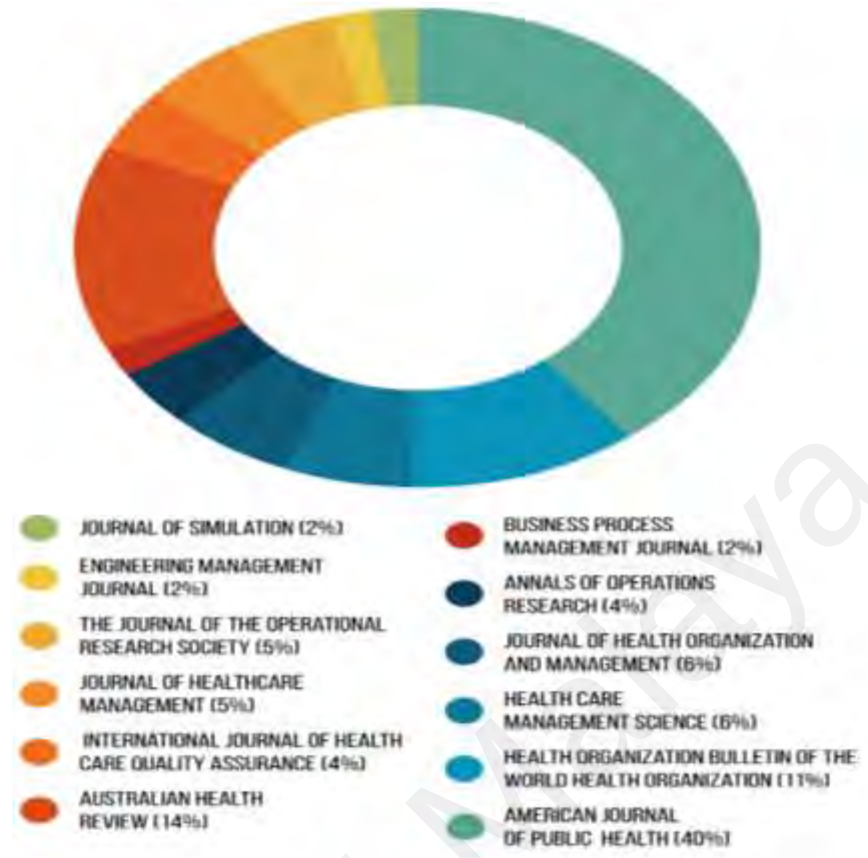

Figure 3.5: Journal where retrieved studies were published.

Figure 3.6: Year of publication by the number of studies published

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Table 3.4: Extraction Table

ID	Author Name	Year	ED Area	Venue	Method	Problem	Visualization Type
1	Allnutt et al.	2010	Skills and Competencies	Australian Health Review	Survey conducted as part of a quantitative research study using an information sheet and consent forms sent through email	Assessment of the nurse practitioner's role as observed by the client along as well as the client's satisfaction with their nurse practitioner's education, care, skill, and knowledge	Tables
2	Fulop	2012	Skills and Competencies	Journal of Health Organization and Management	Qualitative research using interactive interviews to present accounts in which health care professionals describe leadership	Investigation of how hybridity can be utilized to re-speculate authority in services, as it identifies change strategies that address initiative projects to grasp the utilization of various approaches	Tables
3	Hanson	2011	Quality	Australian Health Review	Qualitative research using a literature review	Demonstrated that health care centers need a structured strategy to enhance data quality and create a robust information culture that harnesses health information	Process map
4	Morgans and Burgess	2012	Emergency Department or Ambulance Utilization	Australian Health Review	Qualitative research using a comprehensive literature review	Defined and measured inappropriate emergency health service use in Australia	Text: Percentages and classification
5	Rosenberg and Hickie	2013	Skills and Competencies	Australian Health Review	Qualitative research using a literature review	Provided an ideal approach to community and home mental care	Text: Percentages and classification
6	Scott	2010	Management	Australian Health Review	Qualitative research on planning, hospital discharge, patient discharge, and discharge processes to conduct a systematic meta-review of controlled trials	Determined the relative efficacy of pre-discharge interventions to reduce post-discharge problems in adults	Tables and text: Percentages and classification
7	Lantz and Rosén	2014	Management	Health Organization and Management	Queueing theory to study the time of arrival, exact time of triage, total number of patients, patient arrival rates, system capacity measures, and average queueing times as well as the theoretical relations between them	Developed a technique based on a queuing model to evaluate the operational capacity of health services without process observation by appraising Skaraborg Hospital's operative capacity during the triage process in the emergency department	Mathematical equations, figures (graphs), and tables

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ID	Author Name	Year	ED Area	Venue	Method	Problem	Visualization Type
8	Buttigieg et al.	2016	Quality: Process reengineering	Journal of Health Organization and Management	Multiple case study on effective strategic planning and the project management methodologies of three units in Malta's health care system, all of which are popular methods for improving the quality of health care services	Determined the root causes of quality issues specific to the three settings; objective trees were formed to suggest solutions to these quality issues	Tables, figures, and charts
9	Esfahani et al. 1	2016	Quality: Engineering	38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society	Segmentation methods, neural network/deep learning, and convolutional neural networks classified into three groups as tracking-, model-, and filter-based	Described vessel segmentation to ensure that the images obtained were of high quality by reducing their noise and enhancing their contrast	Figures, tables, and mathematical equations
10	Esfahani et al. 2	2016	Quality: Engineering	38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society	Neural network and deep learning methods	Proposed a method to enhance the detection of melanoma through the analysis of enhanced images	Figures, tables, and mathematical equations
11	Jafari et al.	2016	Quality: Engineering	38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society	Algorithms for digital image magnification of details and extraction features to detect surfaces	Proposed an efficient pre- screening mechanism for pigmented skin lesions	Graphs, figures, and mathematical equations
12	Jamali et al.	2016	Utilization	38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society	Experimental use of the robust watermark method in advanced image processing and diagnostic/discrete Fourier transform	Proposed a robust watermark method wherein the watermark data is hidden to prevent the distortion of the region of interest	Graphs, figures, and mathematical equations
13	Kadkhodaei et al	2016	Quality: Engineering	38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society	Experimental algorithm with a method to join hybrid clustering and logistic regression	Minimized problems in brain MR images	Graphs, figures, and mathematical equations

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ID	Author Name	Year	ED Area	Venue	Method	Problem	Visualization Type
14	Clark	2010	Emergency Preparedness: Operations.	University of Baltimore Ph.D. Thesis	Mixed quantitative and qualitative examination of data from the year 2008 using action research	Evaluated public administration in a real-world setting to identify failures and weaknesses associated with systems and to reduce hazards	Tables
15	Donnelly	2013	Management	Queen's University Ph.D. Thesis	Multiple-method case study of systematic, scientific, systematic, and empirical knowledge	Co-produced knowledge about a complex problem	Tables and graphs
16	Gautam	2000	Management	Southern Illinois University Ph.D. Thesis	Quantitative, cross-sectional, descriptive, correlational survey	Examined health beliefs and knowledge to determine the factors that predict demographic variables	Tables
17	Nikolai	2014	Emergency Preparedness: Disaster Response	University of Notre Dame Ph.D. Thesis	Mixed-method study using quantitative research to observe, collect, and analyze key documents including past-situation reports, after-action reports, and exercise documents as well as qualitative research to classify informal and formal interviews with emergency managers	Coordinated new forms of collective action to solve critical problems in crises at a specific time for a specific purpose to prioritize recommendations Proposed a method to determine problem severity and used classification in the analysis of data collected during evaluation Activities	Tables and charts
18	Cheung	2011	Utilization Geometric Optimization	The University of Texas at Dallas	Algorithm to simulate the process	Proposed a method to simplify problems, allow for their observation at different angles, and find the shortest path to the solution with the fewest amount of obstacles	Figures and mathematical equations
19	Pandit	2013	Utilization: Resource Allocation	The University of California	Experimental use of Webster's algorithm, real-time optimization methods, multi- user resource allocation (content-aware networking), the adaptive Webster's method, and simulation methodology	Determined resource allocation and job scheduling with processors using real-time data and proposed an online scheduling algorithm to maximize the quality of patient Care	Graphs, figures, and mathematical equations

a. Extraction Table IV with column including ID, Author Name, Year of Publication, Area of Knowledge in EDs, Venue of Publication, Method, Problem and Visualization Type.

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3.4.6 RQ6: How are studies of EDs typically classified?

Classification of content in Figure 3.7 as scanned, but Figure 3.8 represents a systematic cluster built through the taxonomy of content extracted from Table 3.4 (i.e., Skills and Competencies, Management, Quality, Emergency Preparedness, and Utilization of EDs). The process of classifying scanned content showed that review papers were rare. Thus, systematic mapping and systematic review papers are appropriate to be conducted.

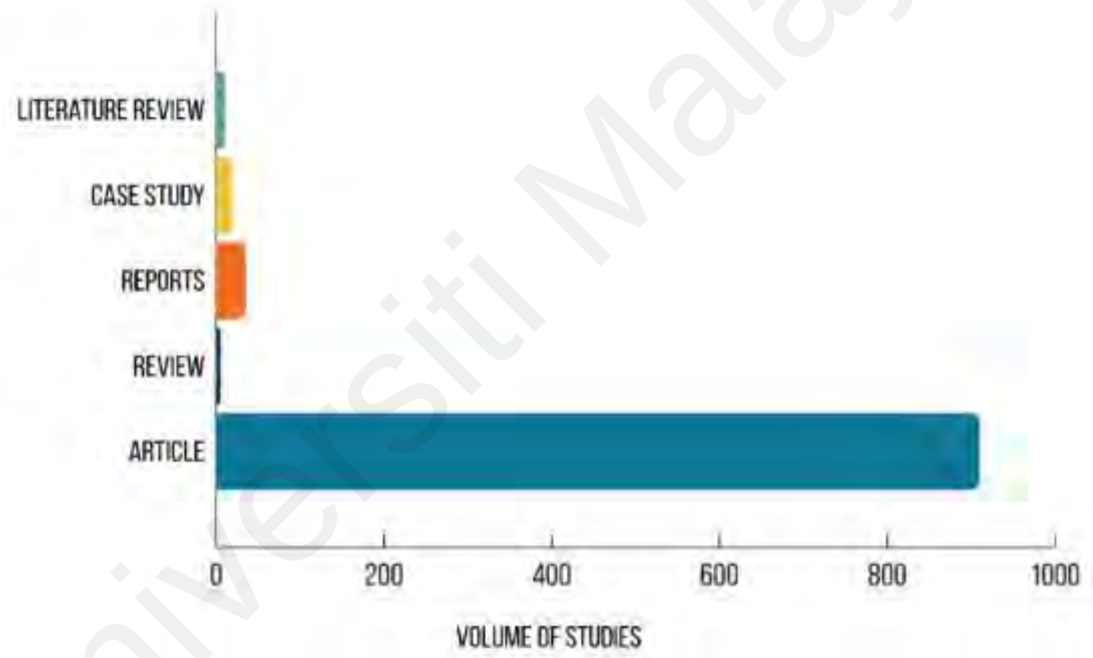

Figure 3.7: Classification of studies type by the number of studies produced.

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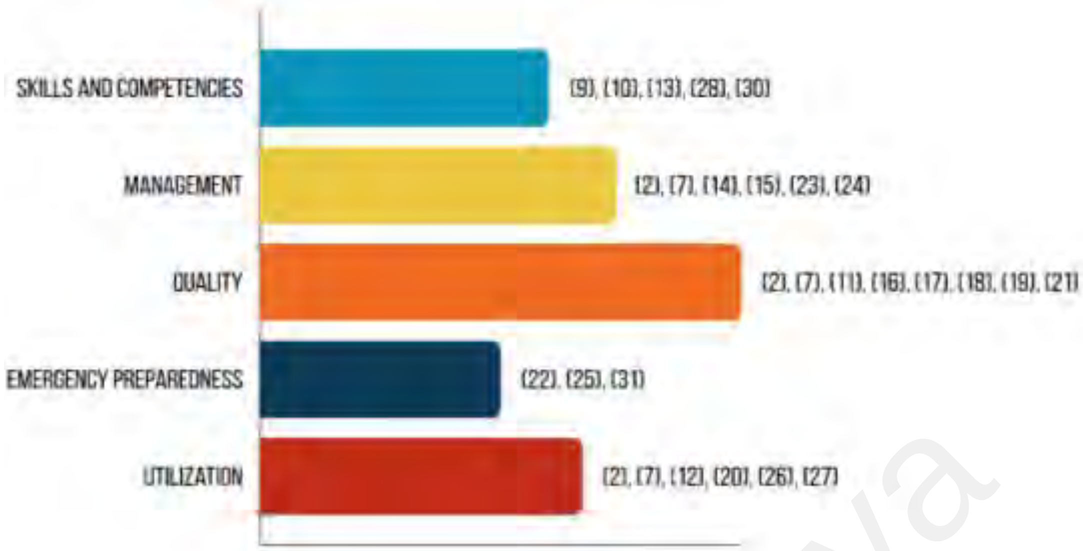

Figure 3.8: The thematic studies cluster.

3.5 Discussion

Various complex factors are present in the management of an emergency. It is necessary to use an analytical decision-making process so that a health technology can be evaluated based on its performance. This analytical system needs to be regularly updated since modeling procedures are essential for the management of patient and staff interactions and patient care systems in hospitals. This need is essential due to the complicated nature of EDs and the problems that arise in EDs.

Many studies have been conducted on mathematical models; however, few have been conducted pertaining to mathematical models in EDs. Such studies are vital to reduce wait times in EDs. Mapping research extracts vital issues and methods to devise solutions [2]. Some mapping studies are currently being conducted [7]; however, less are being conducted on EDs research [17]-[21]. Important aspects for analysis include the study selection quality and continuous research updates [8]. We have defined and explained the dynamic problems in EDs and approaches to manage these issues to attain positive outcomes from our mapping study. The objective of this research was to present the brief foundation of a systemic literature review input [8]. It is only to be used as secondary research.

3.6 Conclusion

In developing nations, health care systems are quite poor, so it is important to manage issues and meet demands for the acute hospital-based health care. It is also necessary to manage the implementation risks of activity-based funding. The following are the solutions derived in this study. Emergency preparedness systems require continuous training and simulations with thorough information assessments. The primary factors are the people involved in, authorities of, and assets to be used during emergency conditions. Patient experiences, patient satisfaction levels, effective procedures, patient safety, and quick response programs should be major focuses.

For ED simulation modeling, researchers should assess the present scenario and the research gaps [7]. Multi-label case studies of health care personnel should be carried out to determine workforce competence in terms of skills and capabilities [30]. EDs require leadership [10] within management [28] to ensure control in EDs [29]. Managing EDs and providing personnel with knowledge regardless of the ED"s policies, structure, capacity, network, etc. is important to ensure informed decision making and the effective management of emergency cases in normal and disaster situations with decreased and controlled crowding. Analyzing techniques and utilizing the correct one to practice emergency procedures allow for their efficient implementation.

Health care quality standards must be updated according to this systematic review. Figure 3.8 presents the features of and insights to the theme of the research to be conducted in the future within the context of emergency and risk management [31].

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Future research should focus on the sustainability of implementing real-time data monitoring in EDs as well as the performance measurement of emergency systems.

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CHAPTER 4: DECADES TREND OF EMERGENCY DEPARTMENT SYSTEM OPERATIONS

ABSTRACT

Emergency services are meant to ensure the timely delivery of essential healthcare services to people using complex systems. If emergency services use real-time patient information to select the most suitable emergency option, it will allow the service provider to more quickly conduct a detailed physical examination to diagnose the problem and to determine a treatment plan that will suit the patient. Emergency departments offer various services and have several components that are conducted under complex management.

This study examined previous research on engineering systems and the evaluation of the quality of healthcare systems. These studies considered the level of patient satisfaction and investigated how healthcare is influenced by operational management. The research also indicated that real-time data are very helpful for mangers in emergency departments to help them make appropriate decisions. This finding implies that patient satisfaction can be ensured through the extraction of data about the issues related to proper, operational, and effective management. Patient satisfaction and the quality of services and care delivered can be enhanced to improve the patient's overall experience by using development strategies and quality evaluation in EDs.

The previous research conducted on the management and processes of emergency departments was systematically reviewed and classified. This study reviewed research conducted between 2000-2019 to understand how emergency departments used processes, addressed issues, and resolved issues when considering the patient in an ideal

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healthcare setting with a high standard of operation management. Emergency services are significant for everyone because anyone may need these services at any time. This study uses the data from the last 20 years to investigate the methods employed during that time in emergency department operations.

4.1 Introduction

The introduction of new tools and performance evaluation systems in EDs in underdeveloped countries resulted in a positive impact on the measurement of the quality of care and services delivered to patients. In particular, the patient's perspective is considered in this kind of performance evaluation. The process of evaluating the efficiency of the facilities and the services offered by an ED is complex, and there is no specific theoretical formula for this evaluation. The supervising system and functional strategies that serve as criteria for evaluating the efficiency of any ED's facilities are not presently implemented in developing and underdeveloped countries, which makes it difficult to evaluate the performance of ED facilities in these countries. When considering technology, such countries can use factors that ensure a high standard observational system for an emergency department as criteria for evaluating emergency medical services.

The operational management of an emergency department is a complex job and involves various complicated factors. Quick and immediate responses to patient queries must be provided through effective strategies. The main prevailing issue in EDs is the attentiveness of the emergency staff and the readiness of the processes, which allow smooth operations and prevent prolonged waiting and overcrowding in the case of catastrophic events. Overcrowding may also occur with higher casualties, readmissions and when patients cannot see the doctor because of prolonged wait times. Moreover, since

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all kinds of patients with minor to major illness come to the emergency department, the patients must be categorized on the basis of the severity of their condition so that the more serious patients can be treated first to prevent them from being deprived of the timely services and care they need. The treatment process involves a patient's admission, examination by the doctor and provision of a suitable treatment.

The available research was explored to detect the correspondence between the search systems and data collection Almozayen et.al 2018 and Alhareth et.al 2019. Emergency departments (EDs) impart emergency services to patients in urgent need of care by providing acute, out-patient care. The evaluation of the technologies used for care and services must be accompanied by a decision-analytic model. The hospitals must make efforts to introduce and improve this technological analysis because it facilitates effective patient-staff interaction and regulates the procedures involved in patient care. As EDs operate multiple systems and impart multiple services to patients, they may face numerous issues; therefore, it is imperative to conduct system analyses. Although mathematical models have been investigated by numerous studies in the context of healthcare, no work has been conducted to investigate these models in the context of EDs, although the mathematical models could help reduce prolonged wait times in the EDs.

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4.2 Background

A critical element of the healthcare system is the emergency department (EDs). EDs serve as a setting in which high-quality, instant care and services are offered to patients by care providers. Typically, EDs face challenges, such as overcrowding and lengthy wait times. These challenges are due to certain demand and supply-side factors that have an impact on the ways in which patients are provided care in various settings. Problems such as overcrowding and extensive wait times can be managed by hospitals when there is adequate planning, staffing, and resource allotment and effective patient management. Furthermore, the examination and assessment of the effect and cost-effectiveness of different interventions and approaches used to address the issues experienced at EDs can be facilitated by mathematical frameworks. It is also important to perform additional evaluations to identify the technologies that can be employed by hospitals to decrease waiting and overcrowding in their EDs.

A large amount of information and data on hospitals are available through the emergency department or patient files, which can be reviewed to facilitate management decision-making [1]. EDs are a critical element of the healthcare system [2]. Typically, these sub departments operate 24-hours-a-day so that immediate treatment and care can be offered to patients suffering from extremely critical conditions and illnesses [3]. It is important to enhance ED resources and those of the entire healthcare system.

4.3 Material and Methods

The systematic review employed the approaches mentioned in [1 - 3]. The review starts with a systematic analysis of the research to classify the studies and create a thematic assessment. The available literature is discussed in detail in this research. The systematic approach presents the outline of the research area and the drawbacks of the research [3]. The most recent sources of data are employed in this research. This study is quite significant because it is focused on the standard of healthcare and contributes to the present literature by investigating the concept of emergency preparedness, system operations and services reengineering in the context of the ED, which has not been previously explored.

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4.3.1 Research Questions (RQs)

The systematic review employed the approach in [1–3] to identify the problems faced by operations of the ED system and gave rise to the following questions:

- RQ1: When and where was the research published?
- RQ2: What problems/objectives were addressed in the research?
- RQ3: Which methods were utilized in the ED operations research?
- RQ4: What measurements and KPIs were used?
- RQ5: What were the findings?
- RQ6: What are the shortcoming and deficiencies that were addressed?
- RQ7: What themes were introduced in the ED operations research?
- RQ8: How was the research categorized?

4.3.2 Search for Strings

Databases were searched with the help of international web trends based on the following keywords: emergency department, emergency medical care, emergency clinics, management, preparedness, quality, reengineering, and health care as shown in Figures (Figure 4.1–Figure 4.8). The search strings mentioned below were obtained using the search strings:

- Set 1: Search terms related to research on EDs (i.e., emergency department, healthcare).
- Set 2: Search terms related to strings (e.g., emergency medical care and emergency clinics).
- Set 3: Search terms related to themes (e.g., management, preparedness, quality, reengineering).

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Figure 4.1 Comparison of three strings worldwide by time.

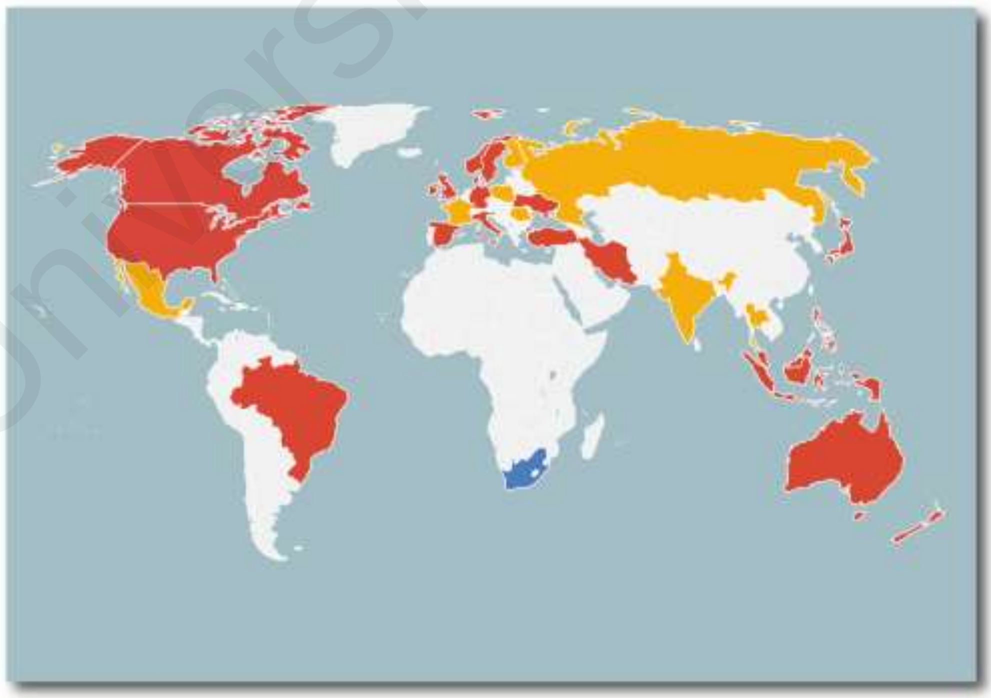

Figure 4.2 Comparison of three strings worldwide by region.

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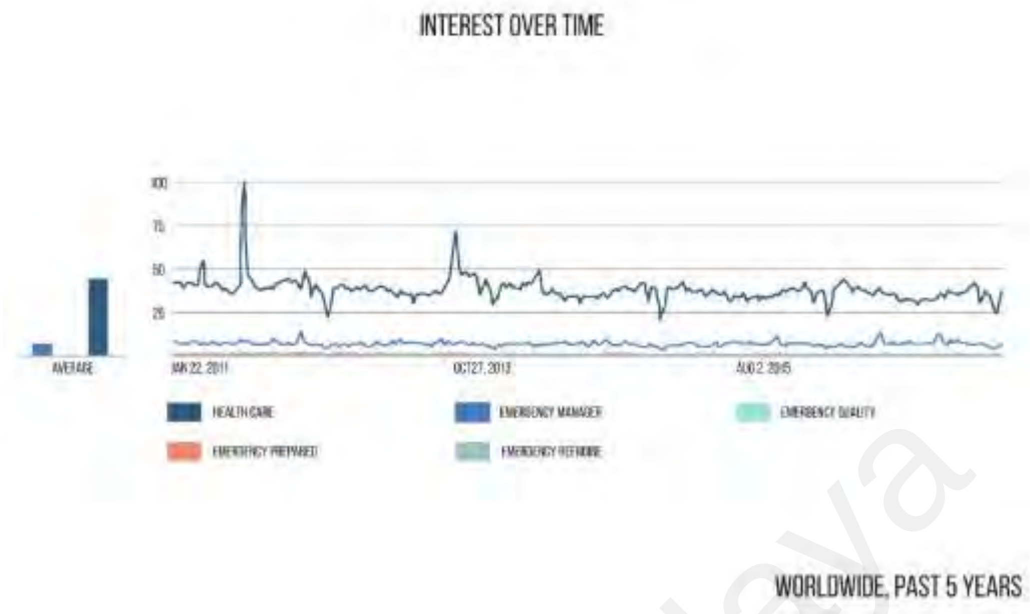

Figure 4.3 Worldwide trend of other search strings by time.

The keywords were divided into different groups based on the research questions. Table 4.1 shows all of the search strings that were searched in the databases. This study was classified based on the time it was mined (i.e., from 2018 to 2019). The search results obtained from each database are shown in Table 4.2.

Table 4.1 Search Strings

Database	Search Strings
1	(Emergency Department OR Emergency Medical Care OR Emergency Clinics) AND (Emergency Management OR healthcare) AND (Emergency Preparedness OR healthcare) AND (Emergency Quality OR healthcare) AND (Emergency Reengineering OR healthcare)
2	(Emergency Department OR Emergency Medical Care OR Emergency Clinics) AND (Emergency Management OR healthcare) AND (Emergency Preparedness OR healthcare) AND (Emergency Quality OR healthcare) AND (Emergency Reengineering OR healthcare)
3	(Emergency Department OR Emergency Medical Care OR Emergency Clinics) AND (Emergency Management OR healthcare) AND (Emergency Preparedness OR healthcare) AND (Emergency Quality OR healthcare) AND (Emergency Reengineering OR healthcare)

Table 4.2 Primary Studies

	Search results	Date
Databases	631,957	2000-2019

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Figure 4.4 Emergency Management worldwide trend of other search strings by region.

Figure 4.5 Emergency Preparedness worldwide trend of other search strings by region.

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Figure 4.6 Emergency Quality worldwide trend of other search strings by region.

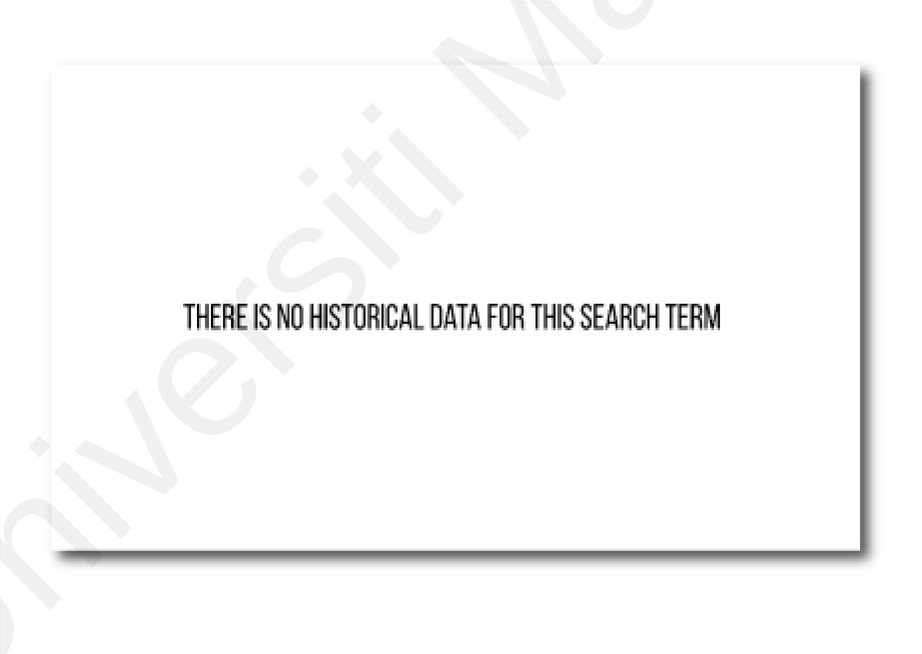

Figure 4.7 Emergency Reengineering worldwide trend of other search strings by region.

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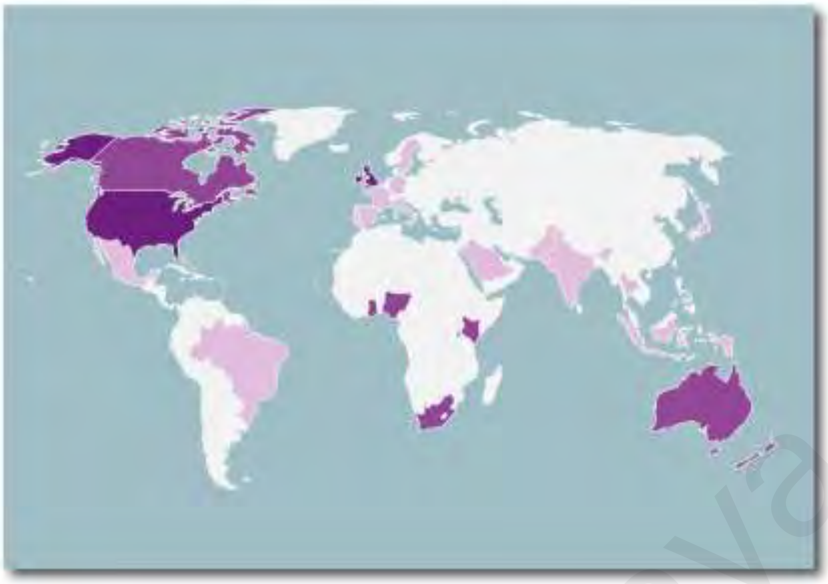

Figure 4.8 Health care worldwide trend of other search strings by region.

4.3.3 Search for Primary Studies

The search for primary studies was conducted in the following databases. These databases were chosen because they are comprehensive and contain millions of publications, especially those related to EDs, engineering, and computer science. Moreover, these databases are user friendly and have advanced search features e.g., IEEE Xplore, ABI Inform, Google Scholar, etc.

4.3.4 Study Selections

Figure 4.9 shows that some of the studies were not considered in our study because of certain characteristics of the database. The studies were mainly selected based on their relevance and citations. The studies that did not include proper references or citations were not included. In addition to references, the studies were selected based on the following features: the study must be related to the management, the ED and attentiveness of the ED staff and services, and the quality of healthcare; the study must consider reengineering and healthcare associated with Eds; and the study must have been

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conducted between 2000 and 2019. Moreover, the selected studies were evaluated and excluded because of the following features: the study did not meet the criteria of full text; the study was not reviewed; the study was a duplicate study, and the study was in a language other than English. Figure 4.9 shows the quantity of the studies that were selected for inclusion and exclusion from the database search. Moreover, Table 4.3 represents the model for studies that required further data extraction for research.

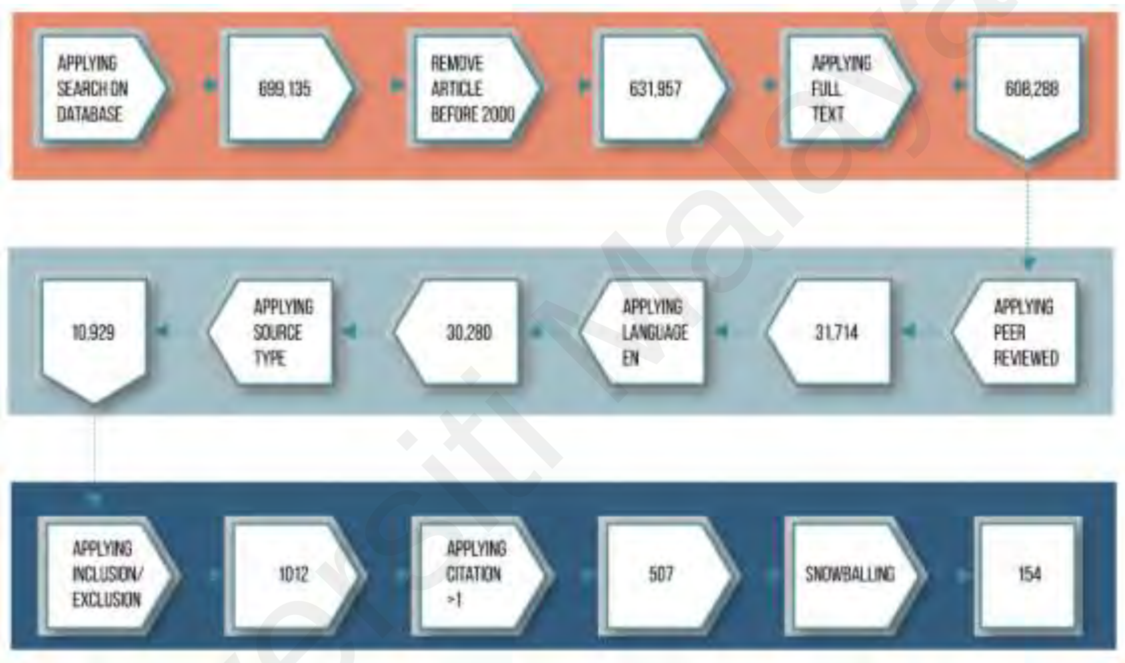

Figure 4.9 Study Selections Process.

4.3.5 Data Mining

The data obtained was used to present the model given in [1-3]. Table 4.3 shows that the model was customized according to the research requirements. The factors are shown in the table along with their corresponding quantity. One of the experts extracted the data while two others reviewed the data to ensure the validity and standard of the mined data. Moreover, another expert evaluated the data for further verification.

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Table 4.3 Data Mining Table

Item	RQ Result	RQ
Study ID	Number	Coding
Author Name	Name(s)	Reference
Year of Publication	Calendar year	RQ3
Country	Location of research.	RQ3
Objective/Problem	Problem or objective of research	RQ2
Method	Method used	RQ3
Measurements/KPIs	Items used or measured	RQ4
Findings/Conclusions	Result of research	RQ5
Shortcoming/Deficiency	Limitation of research	RQ6
Venue	Journal name	RQ7 & RQ8

4.3.6 Verification and Validation

The data collection procedure followed in this research was highly objective. This data collection method ensures greater validity of the data compared to the quantitative analysis method. The data obtained were recorded in a data-collection table [Table 4.1-Table 4.3] to support the data and to ensure greater validity of data, since tables can be reviewed to evaluating the extracted data. The risk to data validity was reduced to a significant extent due to the involvement of three experts who independently reviewed the data to prevent any risk of invalidation [2]. Therefore, the collected data were found to be accurate and objective with an insignificant degree of risk [1-3].

4.4 Results

In this review, the approaches in [1- 3] were used to identify the issues encountered in ED systems operations. Based on these issues, eight research questions were developed:

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4.4.1 When and Where Were the Research Published

Several journals that were issued between 2000-2019 were included in each database. The earliest study was published in 1998. The importance of this field peaked in 2013 and significantly declined afterwards. The present study considered only peer-reviewed journals, materials, and conferences that answered the research question. The volume of the articles is shown in Figure 4.10, when researches were published in Figure 4.11 and where shown in Figure 4.12 and Figure 4.13. Studies on engineering, simulation and process management constituted only 9.92% of the total studies on EDs published from 1998 to 2018.

Figure 4.10 Number of Studies Per Year.

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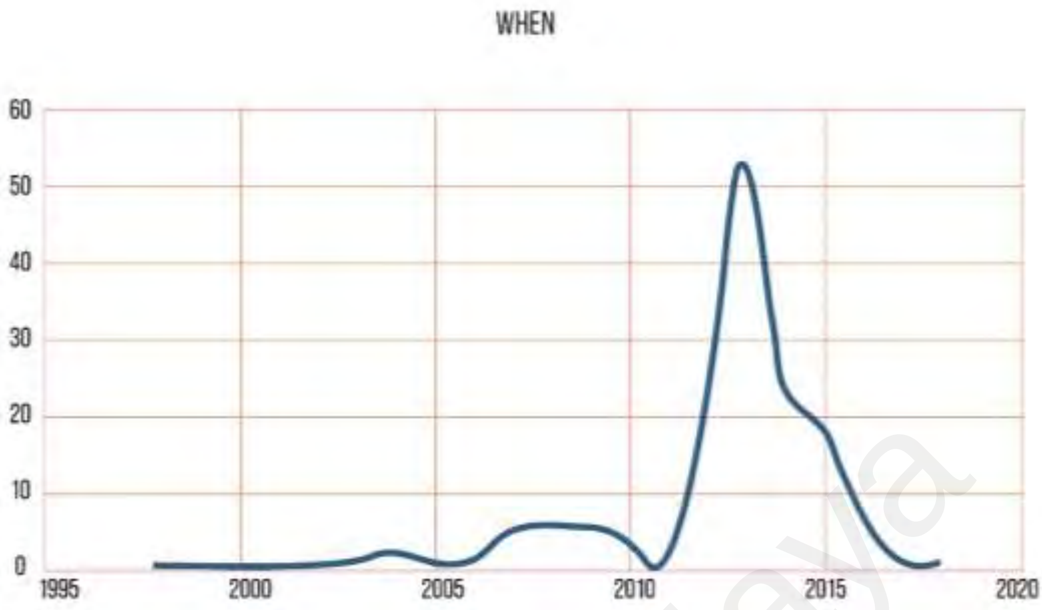

Figure 4.11 When Studies Were Published.

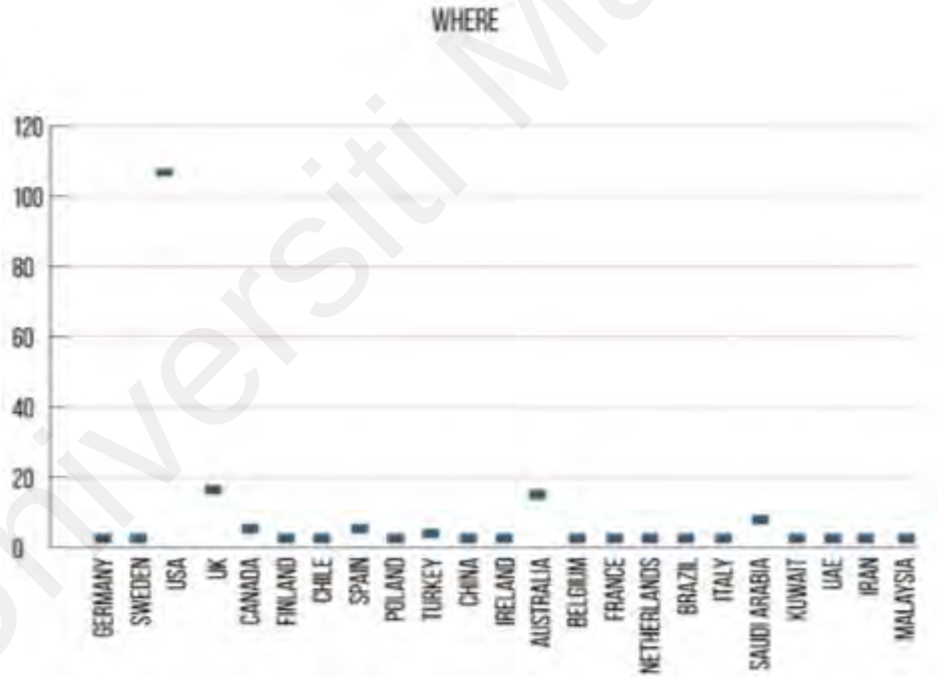

Figure 4.12 Where Studies Were Published

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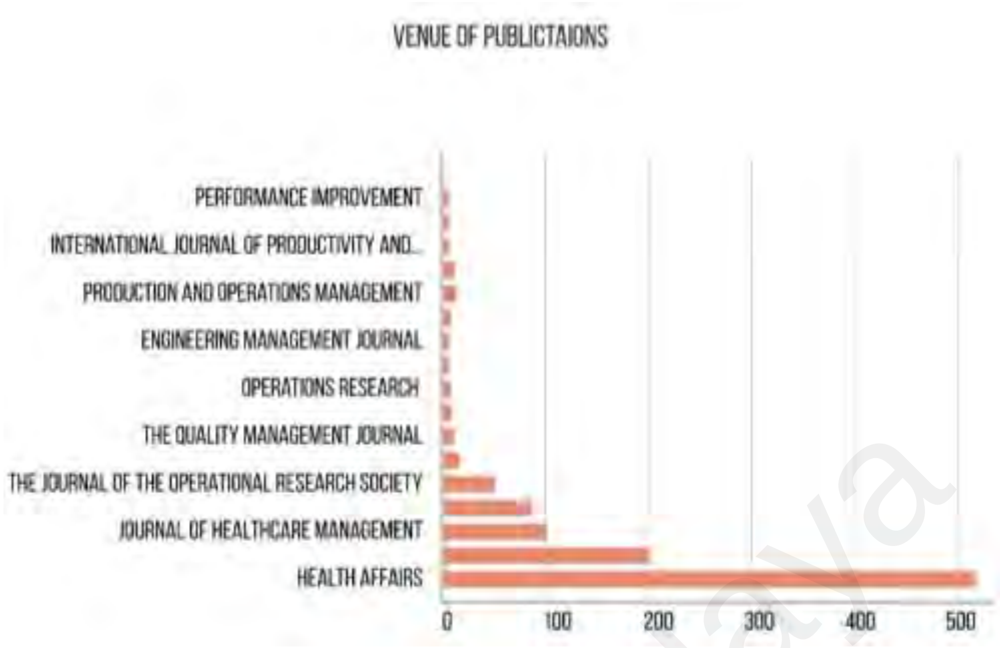

Figure 4.13 Venue of Publications.

4.4.2 What Issues Were Addressed in the Research

The current hospital systems need to be removed and replaced with new systems. Not only the systems but also the hospitals themselves, which can be considered systems that included separate parts, especially emergency departments, need to be replaced. The issues that arise include the cost of quality, medical data, service improvement, overcrowding, management, high number of visits, wait times and collective skills. Experts are needed to research, explore, and investigate these problems and to improve the processes of service to create a better mechanism and medical reform for each part.

Table 4.4 EDs Problems

Issue Addressed	References
Cost of Quality	[41, 83, 87, 109, 111, 112, 133, 137]
Medical Data	[41, 44, 51, 67, 89, 126, 130, 139]
Service Improvement	[9, 12, 30, 38, 41, 81, 90, 96, 106, 112, 128]
Overcrowding	[26, 27, 51, 57, 58, 125, 144, 145, 148]
Management	[4, 6, 16, 49, 86, 89, 95, 141]
High Number of Visit	[24, 51, 57, 102, 119, 127, 131, 147]
Waiting Time	[5, 9, 12, 19, 27, 48, 113, 126]
Collective Skills	[25, 45, 56, 67, 106, 151]

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4.4.3 Methods Were Utilized in Ed Operations Research

The data analysis is capable of producing a model that handling services, improves organization, and influences new healthcare. The various number of studies used different approaches that focused not only on patients but also on the healthcare workforce. Various research tools have been utilized mainly including surveys, interviews, observation checklists, questionnaires, and literature reviews. The data used in the studies were either primary or secondary data. The methodologies include analyzing the empirical data, meta-analysis, and simulation. The statistical models utilized include mainly linear regression, logistic regression, correlation, and mean differences.

4.4.4 What Measurements and KPIs Were Used?

Many ED studies tend to measure a wide range of factors in the context of health care within emergency departments. The main key points researchers focus on are health care quality versus the cost of the medical service provided by the system, time spent serving the patient, patient satisfaction, patient length of stay, clinical information, health care services provided to patients, accessibility of the health care system, performance of the health care providers such as physicians.

4.4.5 What Were the Findings

Quality care is a vital initiative that must be pursued by healthcare providers to affect the high number of visits and the time of services. The implementation of these targeted processes using simulation data to build a significant system will improve services and increase satisfaction for both providers and patients. Therefore, this approach will result in low cost but quality care and an effective emergency system where optimal decisions are made. General findings can be found by looking at Tables [Table 4.5 – Table 4.11].

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Table 4.5 EDs Data Types

Data Type	References
Primary	[10], [146]
Secondary	[9], [14], [43], [142], [148], [153]

Table 4.6 EDs Studies Types

Studies Type	References
Empirical	[35], [38], [62]
Observation	[6], [10], [12], [20], [34], [38], [52], [63], [107], [116], [133], [136], [151]
Simulation	[2], [3], [7], [17], [23], [37], [87], [125], [132], [135], [154]
Case study	[9], [89], [151]

Table 4.7 EDs Method Types

Method Type	References
Interview	[2], [6], [12], [36], [39], [45], [62], [79], [83], [96], [99], [106], [115], [122], [151]
Survey	[3], [13], [31], [37], [68], [72], [80], [82], [83], [92], [96], [105], [106], [108], [116], [118], [126], [128], [141], [143], [146]
Review of literature	[48], [53], [54], [86], [103], [110], [134]
Questionnaire	[6], [38], [45], [46], [104], [120], [146]

Table 4.8 EDs Analysis Types

Analysis Type	References
Meta-analysis	[33], [35], [36], [59], [60], [64], [66], [80], [85], [93], [94], [95], [97],
Correlation	[27], [109], [111], [114], [129], [130]
Linear / Nonlinear Regression	[1], [26], [31], [57], [77], [100], [112], [118]
Logistic/ Multinomial regression	[32], [34], [132], [152]
Mean differences	[34], [73], [112], [152]

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Table 4.9 EDs KPIs Types

KPIs	References
Health care quality	[8], [18], [28], [33], [34], [36], [38], [41], [55], [61], [65], [77], [84], [85], [88], [89], [95], [106], [108], [136], [139]
Medical Cost	[3], [33], [34], [35], [37], [39], [41], [52], [54], [58], [63], [69], [76], [84], [88], [94], [97], [98], [100], [106], [107], [108], [109], [111], [112], [129], [133], [137], [139], [140], [149]
Services' processing time	[7], [15], [17], [19], [20], [24], [27], [44], [51], [116], [117], [120], [122], [126], [144], [145], [148], [149]
Satisfaction	[16], [54], [76], [77], [107], [108], [113], [115]
Length of stay	[6], [24], [49], [52], [78], [114], [145], [148], [154]
Efficiency of ED services	[23], [113], [139], [144]
Access to health care	[106], [114], [115], [116], [136]
Performance	[2], [10], [41], [62], [142],[150]
Admission	[6], [34], [52], [102], [107], [109], [119], [124], [125], [133], [140]
Demographic characteristics	[11], [57], [123], [127], [148], [152]

Table 4.10 EDs Expected Results

Expected Result	References
Quality Care	[8, 33, 36, 38, 41,55, 59, 76, 84, 132]
Process Simulation	[2, 10, 17, 23, 99, 125,141]
Good Decisions	[43, 58, 65,69, 80, 98, 108]
Savings	[37, 58, 69, 101]
Improved service	[2, 12, 55, 76]
Better Experience	[49, 53, 77, 86, 94, 126, 141]

Table 4.11 EDs Shortcoming/Deficiency Types

Shortcomings and Deficiencies	References
Data Availability	[11, 12, 13, 20, 31, 34, 48, 71, 125]
Errors	[21, 22, 48, 54, 55, 71, 111, 117]
Assumptions e.g., Traffic	[26, 35, 52, 56, 61, 67, 93, 97, 114, 135, 149]
Cost	[37, 41, 69, 111,

4.4.6 Shortcoming and Deficiencies that Were Addressed

One of the major limitations of ED systems is the availability of accurate data and research. A weak analysis and the wrong tools for analysis will lead to large amounts of incorrect decisions. Errors can be divided into human errors and systems errors. Another issue is data collection during ED research. Very few studies have considered patient characteristics and demographics in their decisions. Observations that are connected and investigations that result in strong evidence provide better information, a strong model and useful information that is exclusive to the ED system. Another deficiency in EDs is traffic including volume, emissions, and noise. A significant number of patients suffer from traffic congestion during their transportation to EDs.

4.4.7 Themes Were Introduced in the Ed Operations Research

The classification of themes as shown in Figure 4.14 shows that there is a general gap in the knowledge about organizational behavior, performance, and quality of service in healthcare, especially in EDs. A more specific gap is introduced in Figure 4.15.

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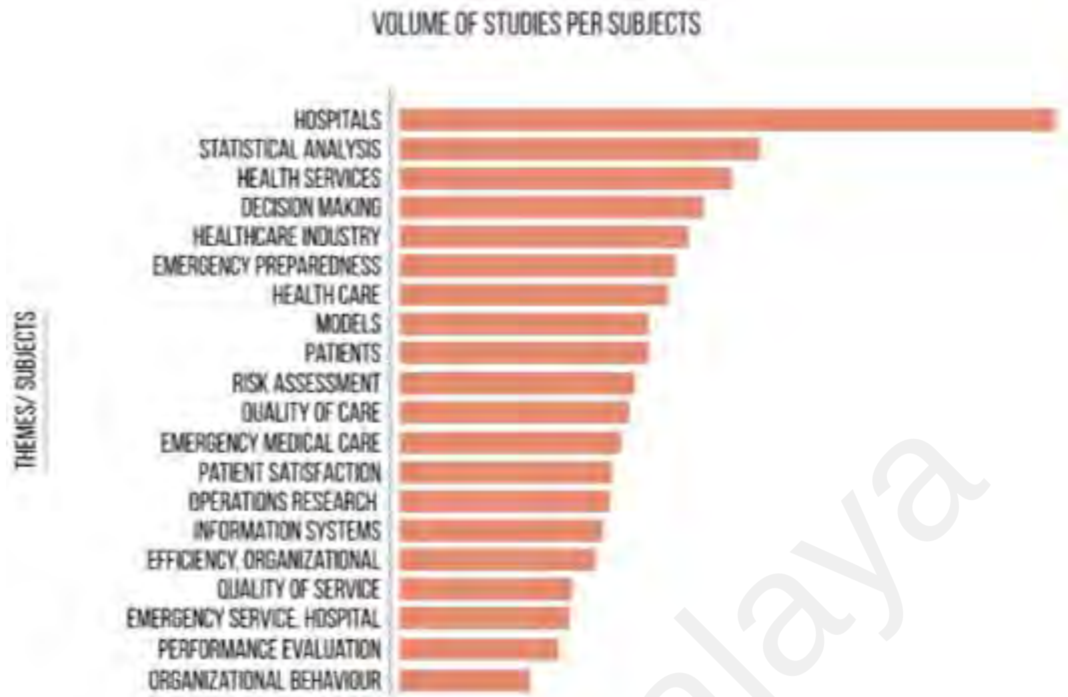

Figure 4.14 Classifications of Studies by Themes/Subjects Before Study.

Figure 4.15 Classifications of Studies by Themes/Subjects After Study

4.4.8 How was the Research Categorized

The volume of all of the studies in this field from 2000-2019 were classified based on venue type, and no dissertations, theses or books were introduced as shown in Figure 4.16 and Figure 4.17.

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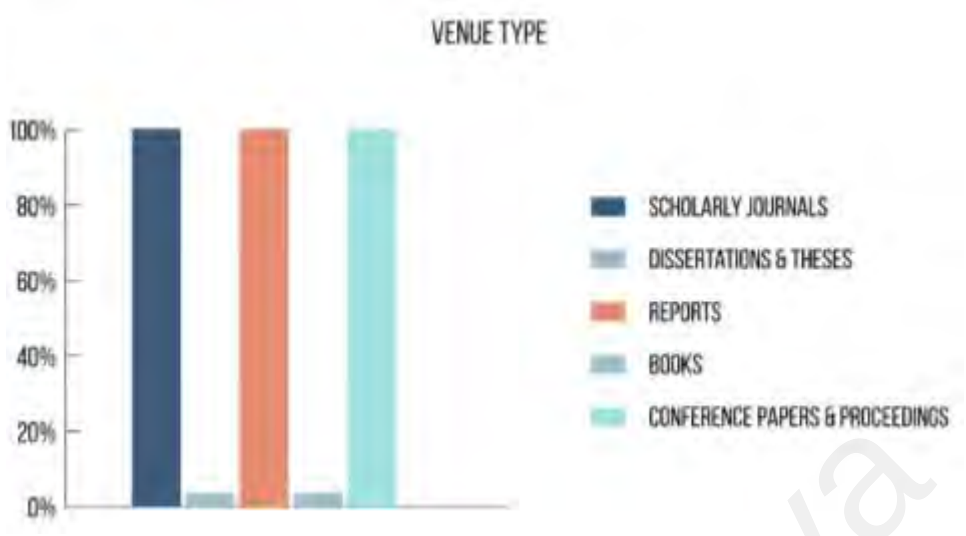

Figure 4.16 Classifications of Studies by Source Before Study

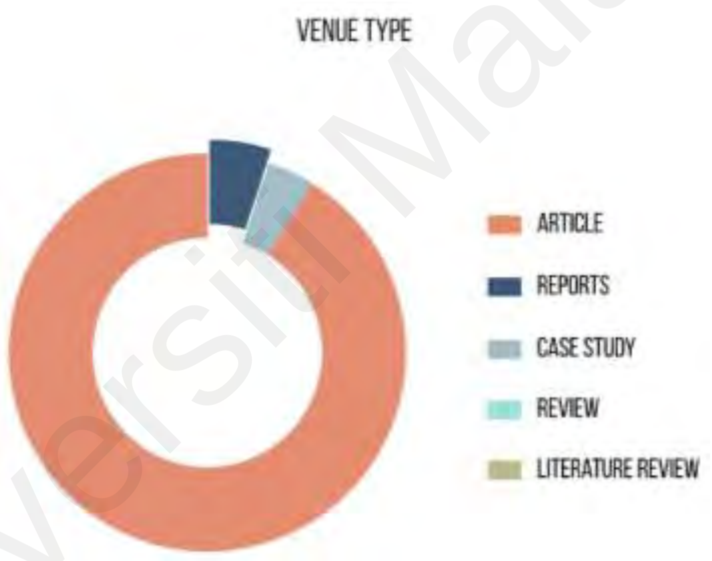

Figure 4.17 Classifications of Studies by Source After Study.

4.5 Discussion

The trends of the problems that have existed in healthcare emergency system operations for the past decades include the cost of quality, medical data, service improvement, overcrowding, management, high number of visits, wait times and collective skills.

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4.5.1 Emergency System Problems

4.5.1.1 Cost of Quality

The task of improving the efficiency of an elderly patient's treatment is a significant research problem [83]. The Medicare Essential program is presented to improve the effectiveness and efficiency of services [87] and reduce costs. There is a wide variation in admission rates for U.S. hospitalizations due to variations in effectiveness [109]. The Medicare agencies are asked to determine whether for-profit home health agencies are more effective than nonprofit home health agencies [111]. The prices for health care services vary significantly across different hospitals, and experts determine the likelihood of a patients' choice of a lower-price facility based on whether or not they are aware of the alternatives [112]. The implementation of a readmission reduction program would cause significant financial penalties for hospitals that do not meet the requirements, and policy makers are considering an expansion and modification of the readmission reduction program [133]. The health care industry is facing increasingly complex challenges, such as new regulatory requirements.

4.5.1.2 Medical Data

The clinical information about patients in a facility is vital to increase the quality of healthcare services, especially in the EDs of hospitals [41]. The major issue that was helpful in the data collection, storage, analysis and near real-time availability of the ED was an improvement in the methods for recording data in health care facilities where technology was lacking [44]. It is necessary to pay more attention to the problem of an administration's effectiveness [89].

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4.5.1.3 Service Improvement

The quality of an ambulance service is related to the wait time as determined by the possibility of all ambulances being busy [9]. It is necessary to address reducing the patient wait times and enhancing the overall system throughput and service delivery at this stage [12]. Bed capacity at hospitals in the U.S. is at a premium and improving of service capacity is more feasible than increasing the physical capacity to respond to increasing patient volumes [30]. The issue of controlling costs under new reforms still has not yet been studied in detail [41]. Problem of measuring the throughput of services is traditionally considered to be a complicated issue [81].

4.5.1.4 Overcrowding

Overcrowding is a challenge for hospitals and requires strategic tools [26]. A contributing factor to the challenge of overcrowding and increased wait times in the ED is created [27]. Overcrowding in some hospitals and longer wait times for minor and major issues has increased by 32% from 1999-2009 [51], with unnecessary visits being one factor [57]. A substantial part of Medicare beneficiaries could have reduced the overcrowding of emergency departments [58]. Overcrowding, particularly in the late afternoon, is made worse by the ED's lack of ability to move patients who need to be admitted due to lack of inpatient beds [125]. Emergency department operations are becoming outdated due to overcrowding, and new communication methods should be used to advance the system [144]. Overcrowding in EDs affects the quality of care [145], and therefore, resolving the issue of overcrowding in the emergency department and the imbalance between the need for emergency care and the available resources requires an evaluation of the triage process [148].

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4.5.1.5 Management

The Saudi national guidelines provide a comparison of the recorded management of acute bronchial asthma in the ER [4] for example. The UK is searching for a way to improve operation processes in hospitals, and there is substantial pressure to provide processes to improve the system that will be cost effective [6]. Spanish hospitals concentrate on shift management [16]. Simulations create a decision support system for EDs that help the heads of EDs establish management guidelines that improve their operations [49]. It is of critical importance to find a way to develop mechanisms of management that would simultaneously focus on effectiveness and efficiency, with more attention being paid to the problem of the administration's effectiveness [89]. It has been proven that patient engagement in decision-making, self-management and prevention activities improves health outcomes [95]. Effective management of health care in the U.S. is critically dependent on effective management [141].

4.5.1.6 High Number of Visits

In the U.S., at the hospital-level, the ED performance on visit length and wait time are major issues [24]. The number of visits to the ED increased by 32% from 1999-2009. Some of these increases in ED visits led to ED overcrowding and longer wait times [51]. Many frequent emergency department users do not have any serious diseases except for mental illness; however, they contribute to ED overcrowding by making unnecessary visits [57]. The New Mexico Health Information Collaborative is a newly invented e-porting project, which will collect a wider array of information about all ED visits in a timely manner in an effort to make changes in authority, mechanisms, design, and approach [102]. Over the past two decades, the number of visits to EDs has increased. However, ED visits for some conditions have decreased while others have demonstrated

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varying patterns [127], and this presents barriers to assessing primary care [131]. Furthermore, patients return to the ED for more, visits and, hence, there is need to solve this problem [147].

4.5.1.7 Waiting Time

The risk and suffering this are faced by patients while waiting in line needs to be modeled, and changes in the patient's condition while the patient waits need to be considered [5]. Ambulance services have drawn substantial attention in operations research, and a vital aspect of the ambulance service is the wait time [9]. A reduction of patient wait times can enhance the overall system throughput and service delivery [12]. Numerous effects on ED wait time, boarding, and treatment times have been shown across multiple acuity groups and sites [19]. The growing public demand for ED services contributes the challenge of increased wait times in the ED [27]. The ED is considered the front door of the hospital and wait times and inpatient experiences create the perceptions of patients regarding the ED [126].

4.5.1.8 Collective Skills

Expressing collective skills as a mathematical model that can allow emulation of the behavior of the facilities and workforce and its components, shape the optimization when a problem is faced and satisfy various requirements is required [25]. There is an effort regarding the effectiveness of teaching emergency medicine in terms of skills, knowledge, and attitudes outside the clinical environment [45]. Numerous reports show that emergency departments in the U.S. experience problems concerning behavioral disorders [56]. There is a shortage of studies that evaluate the influence of behavior [67]. A powerful driver of significant improvements in the field of health outcomes is the improvement of behavioral health conditions [106]. One of the most well-known

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mechanisms of achieving a reliable environment in which all workers look for, and report, small problems or unsafe conditions before those issues pose a substantial risk to the organization is seeking zero defects in outcomes quality and achieving high reliability [140], which are resilience skills [151].

4.5.2 Emergency System Tools

The tools used to research trends in the past decades in healthcare emergency system operations are primary and secondary data in the form of empirical, national, observation, case study and simulation research. Primary data are data that are collected (data that are collected by a researcher from first-hand sources) through observations [6], surveys [146], or other sources. Although most studies did not specifically mention that their source of data was primary, it could be inferred from the research tool used such as those listed in the research tools in the previous paragraph except for the literature reviews. In contrast, some studies used secondary data (data gathered from studies, surveys, or experiments that have been examined by other people or for other research) which include reviewing what other researchers have published about the same issue [9] [14], collecting data from a specific database [43], gathering information about patients who visited the emergency department from health record reviews [148], and collecting data from papers selected using a specific criteria [153].

4.5.3 Emergency System Approaches

The approaches used to track the trends in the past decades in healthcare emergency system operations are interviews, surveys, reviews of literature, and analyses carried out using meta-analysis, correlation, linear/nonlinear regression, logistic/multinomial regression, and mean differences.

In addition to empirical data [35] [38] [62], meta-analysis was used as a methodology for various aims including the calculation of adjusted medical costs [33], determination of the process needed for transformation of the U.S. emergency care system [59], description of the regionalized trauma system, determination of the effectiveness of and provision of recommendations regarding the further development of the emergency health care system [60], or other purposes [93] [94] [97].

Computer simulation is one of the most widely used methods of evaluating, improving, and optimizing many types of processes because it is an imitation of an actual process over time [2]. System simulation is used in estimation of the target function and optimization to calculate and authenticate the optimal configuration of servers [3]. In addition, the simulation model is employed to test various process scenarios, assign resources, and complete activity-based cost analysis [7]. Simulation is also integrated with optimization to establish the optimal number of nurses, lab technicians, and doctors needed to reduce patient time in the system and maximize patient throughput [23].

The simulation model is used to study ED operations [125]. Some studies also simulate an existing ED system after collecting actual data from the system [154]. Finally, the case study methodology was rarely used with a Chilean ambulance firm [9] and with the EDs of two university hospitals in the United States and Brazil [151]. In most cases, various types of regression were used in analyzing the data. Linear regression was mainly used to assess goodness-of-fit [1], to predict a specific outcome [31] [57] [77], to estimate a specific outcome [100], and to assess the influence of a specific factor on the outcome, the influence of an insurer-initiated price transparency program on costs per unit [112], and the influence of comments on patients' intention to recommend the specific hospital and their rating [118].

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Moreover, a nonlinear regression model was rarely used [26]. Logistic regression [32] [34] [132] was used when the outcome variable was dichotomous, and multinomial regression [152] was used when the outcome variable was polytomous. A correlational analysis was used to assess the relationship between the variation in admission rates and national health expenditures [109], among the main cost variables of health care services [111], external consultants, system managers and the hospital team [114], between time and cost [129], and between community health centers and the Medicaid program using patient and insurance data [130]. The mean differences using t-tests [73] or other statistical tests [34] [112] [152] were also used in analyzing ED data. The type of factors included wait time, cost, registration process, number of visits and other medicals processes.

4.5.4 Emergency System KPIs

The emergency system KPI trends of the past decades in healthcare emergency system operations are health care quality, medical cost, services' processing time, satisfaction, length of stay, efficiency of ED services, access of heath care, performance, admission, and demographic characteristics.

4.5.4.1 Emergency System Quality

Health care quality was a main theme that researchers intended to measure. Health care quality was operationalized in terms of various variables such as quality and the type of processes and outputs involved in the health care system [8] [55], quality of the processes of service [18] [28], quality of care [33] [36] [41] [65] [77] [84] [85] [95] [108], clinical quality [34] [89], quality of teamwork [36], changes in health care quality [38], quality of medical services [61], quality of care delivery [88], medication administration

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quality [89], quality of behavioral health care [106], quality of plans [136], and service quality [139].

4.5.4.2 Emergency Medical Service Cost

The many issues related to cost were the main concern in ED research and included minimum cost configuration of servers that satisfy the user [3], overall medical costs [33] [35] [63] [111] [129], health care costs [98] [106] [107] [109] [139] [140], medical and pharmacy costs [34], cost savings [37] [52] [58], costs of care [41] [54] [69] [84], acute injury costs [69], ED costs [76], cost per beneficiary [88], out-of-pocket costs for health services [97], treatment costs [108], patient costs [100], benefit costs [111], cost per discharged patient [129], healthcare cost and utilization [133], cost of overtime [149], cost of increasing one-unit capacity in hospital [149], and cost of income of accepted patients [149].

4.5.4.3 Emergency Services Processing Time

Researchers were also concerned with measuring the time of medical service delivery including process time [7], time of initial registration at the ED, time until placed into an ED treatment bed, time of hospital bed request, time of discharge from the ED facility [15], cycle time [17], treatment and boarding time [19] [20], wait time [24] [27] [44] [51] [117] [126] [144], time to transfer a patient to a medical facility [116], time of assessment by nurse, time of assessment by doctor, consultation time, time of arrival to a specific area, time of arrival to a consulted specialty, time of laboratory investigation, time of radiological investigation, time of final disposition and time of physical disposition [120], doctor-patient contact time, delay time for lab results and doctor-patient contact, interarrival time and time spent at registration counter [122], processing time [145], time of triage [148], and cost of overtime [149].

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4.5.4.4 Emergency Patients Output Feedback

Patient output feedback includes a patient's satisfaction [54] [77] [107] [108] [113][115], the staff's satisfaction of hard and soft constraints imposed by the monthly schedule [16], and the staff's satisfaction in general [76] [107].

4.5.4.5 Emergency Patients Length of Stay

Researchers were also concerned with the length of stay and queuing times for patients with both minor and major illnesses [6], length of patient stay in the ED [49][52] [78] [114] [145] [148], length of queues [154], and visit length [24].

4.5.4.6 Emergency Services Efficiency

Measuring the efficiency of ED services provided to patients was an issue for some studies and included the effect of staffing levels on service efficiency [23], the efficiency of heath care services [113], the efficiency that reduces health care costs [139], and the ED efficiency [144].

4.5.4.7 Emergency Access of Services

A few studies aimed to measure a critical variable, such as accessibility of ED health care, which included access to behavioral health care [106] [116], access blocks [114] or barriers [115], and geographic access [136].

4.5.5 Emergency Services Performance

Some studies developed measures or indicators of performance in ED service including "output" performance measures such as daily work hours, personnel shifts, and lunch breaks [2], performance monitoring [10], physicians' performance on care quality

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[41], overall hospital performance [62], and indicators of work performance [142] such as the mean busy period [150].

4.5.5.1 Emergency Admission

Another important issue that attracted the attention of some studies was hospital admission. The studies in ED research were interested in measuring the impact of delayed admission [6], hospital admission [107] and readmission rates [34] [133] [140] and the probability of subsequent inpatient admission [52], ED admission rate [102] [119] [124] [125] and risk-standardized admission rates [109].

4.5.5.2 Demographic Characteristics

Demographic characteristics were also measured in order to test their relationship with factors involved in ED research including demographic characteristics of frequent ED users [11] [57] [127], demographic traits and ages of people who died from unintentional drowning [123], relationship between demographic characteristics and occupancy ratio, emergency department occupancy, length of stay, time of triage [148], and relation between demographic characteristics and specific vulnerability conditions, such as drug and alcohol abuse, psychological distress and chronic conditions [152].

4.5.6 Emergency System Expected Results

The results of the trends of the past decades in healthcare emergency system operations include quality care, process simulation, well decisions, savings, improved services, and better experience.

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4.5.6.1 Quality Care

The use of new technology would improve quality management with regards to processes and would be improved by enhancing staff ownership [8]. A collaborative accountable care initiative may improve the quality of care and decrease medical costs [33]. Teamwork in hospitals and health organizations would be an effective and efficient instrument to improve [36] the time for problem solving [38]. New payment incentives might be useful for ensuring better performance [41]. Integrated networks of emergency care have a potential to significantly increase the level of patient satisfaction and to improve the quality of services [55]. Quality of service and readiness for disasters do not meet the U.S. national requirements [59]. Modeling has a potential to improve service quality and reduce costs [76]. Customized information technology is a promising instrument to improve the quality and costs of care for seniors with multiple conditions [84]. The staff's insufficient knowledge and lack of understanding, along with low-quality training, were the main reasons blocking improvement [99]. Defining standards to promote quality improvement and identifying and removing any existing elements of quality measures that tend to increase the likelihood of patient behavior change could be helpful [132].

4.5.6.2 Process Simulation

Simulation modeling can allow several alternatives to be considered before any resources, especially human, are expended, and a simulation model imitates a system's behavior, which is referred to as "baselining." Simulation modeling evaluates possible changes in the system's structure, environment, or underlying assumptions in the form of a "what-if analysis [2]. It is clear that a simulation model is a very effective method for identifying solutions to resource levels [10]. A simulation of different scenarios of ED

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patient flow led to the acknowledgment that ED diversion could result in discharge of patient one hour earlier [17]. The optimization simulation model yields optimal staffing allocation that would facilitate an average reduction of 40% of patient wait time and a 28% increase in patient throughput [27]. Simulation tools have not been widely implemented [99]. Dynamic behavior in the ED can be acceptably modeled through simulation. [125]. A greater use of the processes positively influences patient experience and the quality of health care [141].

4.5.6.3 Optimal Decisions

Real time information can also be used to determine where to build a health care facility and to determine the density of these facilities in each area [43]. Good decisions can reduce expenses by millions of dollars annually [58]. There is universal pattern that would explain the connection between a decision and the analysis of the unique features of each situation in healthcare [65]. It is crucial to develop field triangle guidelines that would prevent EDs from transporting low risk injured patients, and this decision could save millions of dollars annually in the U.S. healthcare system [69]. Other factors influence decisions, such as delays in payments [80], shared decision-making tends to reduce medical costs [98]. A logical decision in the U.S. health care system was developed, and a model demonstrated its extreme effectiveness in ensuring a higher quality of care, in lowering treatment costs and creating a higher level of patient satisfaction [108].

4.5.6.4 Savings

Hospital observation units are very promising when considering how to reduce costs; in all U.S. hospitals the unit has generated $1,572 cost savings per patient [37]. The expected savings in Medicare is approximately $283-$560 million annually in the U.S.

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healthcare system if the guidelines are followed. It has been proven that the decision to prevent EDs from transporting low risk injured patients saves approximately $136.7 million annually in the U.S. healthcare system [69]. Mobile clinics have the potential to lead to significant cost savings [101].

4.5.6.5 Improved Processes

Healthcare is a dynamic service industry with high human involvement [2]. Shorter wait times increase the service level [12]. An increase in the level of patient satisfaction improves the quality of services [55]. Quality assurance has been proven to have the most effective potential to improve service quality and reduce costs [76].

4.5.6.6 Better Experience

The more experienced and the greater number of ED staff, the less the mean length of stay for a patient is [49]. The positive experience of Japan may be useful for the U.S. health response system [53]. A strong commitment to the community implies a high level of patient experience of care [77]. Patient outcomes can be improved by telephone-based coaching services [86]. Patient engagement has a positive impact on both health outcomes and care experiences [94]. There are important relationships that exist between a favorable ED experience and a favorable inpatient experience [126]. The patient experience is positively influenced by greater use of the process analysis [141].

4.5.7 Emergency System Deficiency and Shortcoming

The deficiency and shortcomings of the trends of the past decades in healthcare emergency system operations are data availability, errors, traffic conclusions and cost.

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4.5.7.1 Data Availability

The data set did not have a chief diagnosis or complaint, which made it difficult to adequately assess the reasons for patient visits. Nevertheless, it is also impossible to generalize the data from one hospital to other hospitals [11]. The data were collected over the summer which made it difficult to generalize the data to other seasons [12]. The database limited the ability of the researchers to extrapolate national estimates about the subgroups of interest that are reliable [13]. A substantial amount of data was required in order to make a good estimate of the input values [20]. The data were self-reported by patients, [31] and the risk of multiple biases was significant [34]. The searching tools that were used in the business and engineering databases were not as detailed [48]. The data sets do not exclusively contain information about hospitals [71], and there was a limited amount of data available [125].

4.5.7.2 Errors

The inaccurate data that were due to estimation may lead to inaccurate results and, therefore, errors [21]. Software limitations led to problems in weighting the medial wait time results [22]. The databases were not as detailed [48], and there was a risk of transforming the databases' errors and other scholars' biases into the eventual conclusions [54]. There were many errors and limitations from other sources [55]. There was a potential inconsistency between the data sets [71]. Many agencies may have misreported some of their quality parameters [111]. A single source of data may contain errors [117].

4.5.7.3 Desistance

The conclusions require confirmation, [35] but the conclusions regarding the extreme effectiveness should be verified [52]. Emergency departments can improve their services,

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but studies that support the conclusions about behavioral disorders and other parameters are required [56].

4.5.7.4 Cost

The costing method was employed for calculating savings [37]. There was a potential correlation between the variation in cost and the quality of physicians' performance that provided higher-quality care [41]. It is necessary to conduct a cost-effectiveness analysis [69], as there are some errors in many of the cost reports [111].

4.6 Conclusion

In conclusion, the issues faced by EDs can be resolved if the cost of quality is controlled and managed effectively, and patient data are recorded appropriately. Moreover, the managers in EDs are expected to prevent overcrowding and prolonged wait times by managing the patient visits and exploiting the skills and expertise of the staff. The managers must obtain primary and secondary data through interviews, surveys, and literature reviews and by conducting research at the clinical and national levels. The managers must interpret and process the data through meta-analysis and must be capable of noting similarities, disparities and weaknesses of the wait time, process of patient registration, costs, patient visits, and other aspects.

The ED manager is expected to conduct interviews, assessments, literature reviews and meta-analysis, and determine the correlation, various types of regression and average differences in order to investigate aspects such as wait times, the process of patient registration, costs, number of visits and others. The ED manager must pay attention to the standard of healthcare services, cost of treatment, time consumed by services, patient satisfaction, length of stay, quality of performance of the ED, access to health care, patient

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admission, and demographics. The effectiveness of healthcare services can be ensured if the manager prevents assumptions, biased conclusions, single step data collection, employment of meta-analysis for primary data-analysis, data collection from particular sources of data, employing a costly system and data recording errors as in case of self-reporting patients.

4.7 Future Work

The expertise and skills of the personnel involved in healthcare provision can be explored by conducting multilabel studies [2]. Emergency departments need a management [3] that provides leadership [2] to the employees that facilitates smooth operations in EDs. The management of the ED must ensure that the quality of the care and services is improved and revised with time [3]. Research regarding the performance appraisal of emergency systems and that ensures that the practice of obtaining real-time patient data in EDs is continued is necessary. Future studies must evaluate the performance of emergency departments in the context of a the demographic features of patients, the shift of a patient through the ambulance, the time acquired by the ED to provide for patient needs and evaluation of EDs processing time by simulation.

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CHAPTER 5: AMBULANCE TRANSFER AND EMERGENCY DEPARTMENT PROCESSING: MODELLING AND SIMULATION

ABSTRACT

Emergency services aim to use complex systems to ensure the provision of fundamental healthcare services to the patient at the appropriate time. Patients approaching the emergency department are examined in detail by healthcare providers. The care providers aim to obtain real-time data about the patients to detect the issues and quickly decide the appropriate treatment plan.

Emergency Departments (EDs) are run by complex management systems and render diverse healthcare services. The assessment of the service quality in the emergency departments has improved significantly with the development of tools and systems of performance assessment in underdeveloped countries. These assessments are based on the views of the patients. In this context, the aim of this study was to formulate a highly sensitive assessment tool that is appropriate for simulation experiments.

This assessment tool was validated and had a kappa value of 0.763 and a Cronbach's alpha value of 0.827. The use of this tool for the assessment of healthcare standards resulted in the collection of valid and reliable data. The probability density distribution was used to check the accuracy of the results of the simulation experiment data, and all data adequately followed a normal distribution. Furthermore, 90% of the simulated cases were found to be within the optimal range.

Key Words Emergency Department, Simulation, Waiting Time, Modelling, Patients, Utilization, Ambulance Transfer, Emergency and Services

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5.1 Introduction

It is imperative to adopt improvement strategies and to evaluate the quality of services rendered to patients in medical centers or hospitals, particularly in the emergency departments, to enhance the satisfaction of patients and the quality of medical services provided to them. The evaluation of a medical technology must be supported with a logical model. Such a system of technology evaluation must be modified frequently because the association between the patient, the care provider and the systems of care in hospitals are in need of modeling systems. Moreover, the complexity of emergency departments and the diverse issues associated with emergency departments call for system evaluation. The principal objective of the Saudi Vision 2030 program is to ensure the availability of effective and high-standard healthcare to Saudi Arabian citizens. This program aims to enhance the performance and outcomes of healthcare services and to ensure the availability of these healthcare services to all citizens. The ultimate goal behind these activities is the enhancement of the standard of medical services rendered to patients.

These improvements have a direct and long-term impact on the optimization of ED resources and cost savings. Emergency departments can plan the establishment and functioning of such systems by implementing statistical modeling strategies. This also enables the emergency department to practically apply such systems. Emergency departments render healthcare services to the majority of patients despite the limited resources available in the emergency department. The performance of EDs may be evaluated on the basis of resource management, patient arrival and discharge, and waiting period duration. ED management involves a number of complex aspects. The performance assessment of healthcare technology demands a logical decision-making system. Such a system must be modified frequently because the association among the patient, the care provider, and the systems of care in hospitals are in need of modeling systems.

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5.2 Background

A simulation model is imperative for the detection of real-life issues related to patient influx and discharge as well as the irregular optimization of resources in emergency departments. The data are obtained through direct sampling, patient history, hospital records, and observation. Resource optimization and waiting period reduction were the basic objectives behind the implementation of the simulation method. This process involved the execution of cost analysis and the adoption of appropriate strategies [1].

The consequences of the alterations in a system or process can be evaluated with the help of simulation models [2]. The basic aims of using these simulation models include testing the system's performance in different circumstances, optimizing resource allocation, and analyzing the entire cost profile. The simulation models provide a thorough explanation and analysis of the problem of overcrowding in emergency departments [3].

The optimization simulation model enables the hospital to make optimum use of its existing resources and staff to enhance the quality of healthcare rendered to patients by reducing the average waiting period of the patients by 40% and improving the patient flow by 28% [4]. The simulations are capable of efficiently modeling the active environment of emergency departments, which involves various procedures and practices specifically related to the emergency departments [5]. The simulation modeling system is imperative for the evaluation and management of the stability of patient care quality [6].

The simulation determines the optimum combination of the healthcare staff and evaluates the impact of this combination by merging field surveys, simulation processes, the optimization of resources and the identification of objectives [7]. Currently, basic simulation systems can be accessed easily from the market and can be directly implemented for basic applications and rearranged for complex applications [7]. The appropriate combinations of simulation,

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concentration, memory, human resources, power, and other resources at a specific time can help manage a specific crisis [8].

The predictions about the overcrowding in emergency departments and the real results showed high disparity, which declined gradually up to 8 hours in the future, while the disparity between the predicted and real ambulance diversion was found to be high and was maintained at this level in the future [9]. The model inputs were identified as the equipment's and facilities, staff allocation, and electronic record of patient information, tracking records, and comprehensive reconsideration of the ED registers [10]. This implies the significance of the simulation model for addressing the issues related to resource allocation and utilization in healthcare institutes to prevent bothersome and tiring waiting periods [11].

The evaluation, enhancement and optimization of healthcare systems are extensively performed with the help of computer simulation since this approach involves the representation of the systems, staff interviews and patient information [12]. In the context of operational research modeling, the highly recognized content available in the literature concerns the modeling of simulations with the help of Scenario Generator [13]. Various factors related to patient care in emergency departments must be considered, which indicates the need to reflect on hospital management, particularly ED management, facilities and equipment in the ED and hospital building, patient data, details about patients' relatives, the areas of the hospital that lead to the emergency department and the waiting areas that must not be overcrowded, particularly in situations when the patient influx is high [14].

5.3 Material and Methods

A questionnaire was adopted from [15] to develop an instrument that was completely modified to fit the simulation experiment. The instrument was logically and statistically validated after modifications; a series of questions to gather data on the characteristics of

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patients attending the EDs, ED system behaviors, and the required simulation data sheet items were included.

A logical validation, including the assessment of face validity and content validity, was carried out by five different experts; the process was similar to that in Figure 5.1. The kappa statistic was calculated and equal to 0.763, indicating that the items in the instrument were excellent. Statistical validity was carried out, and the instrument was valid and reliable; the data collected were normally distributed, and the sample size randomly from the United States, Saudi Arabia and Malaysia was over n=300. Simulation data sheet items were included in the instrument questions, and a random sample of 65 was selected to run the simulation experimenting. The instrument is shown in Table 5.1.

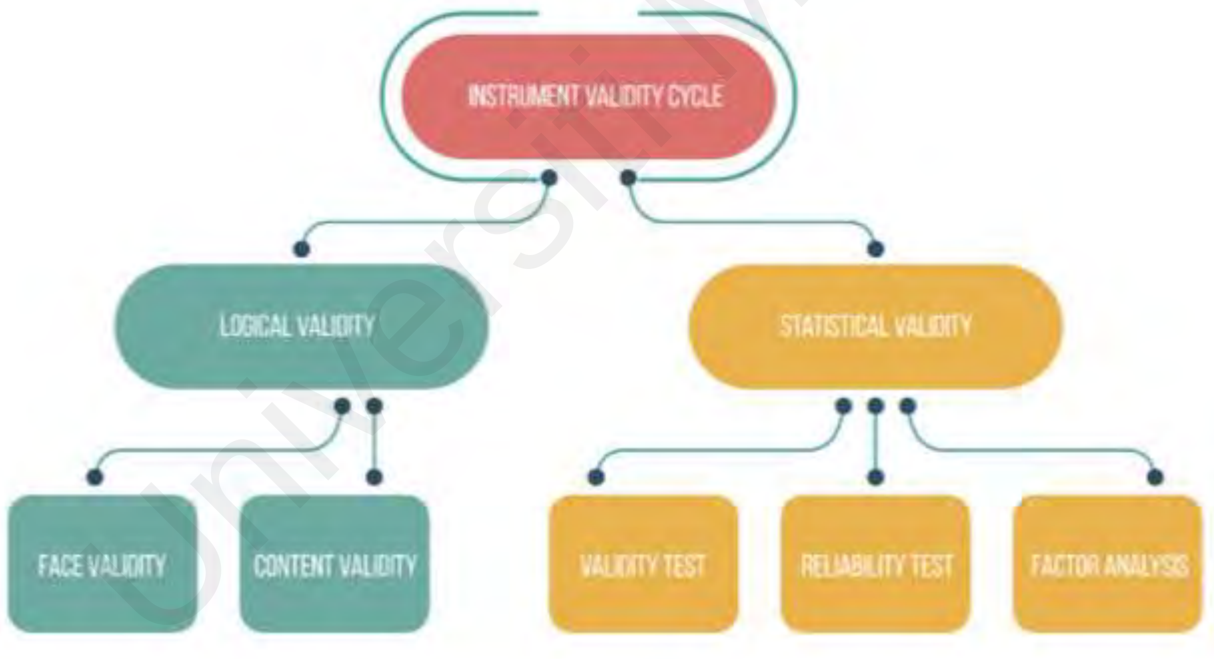

Figure 5.1 Validation Cycle for Instrument.

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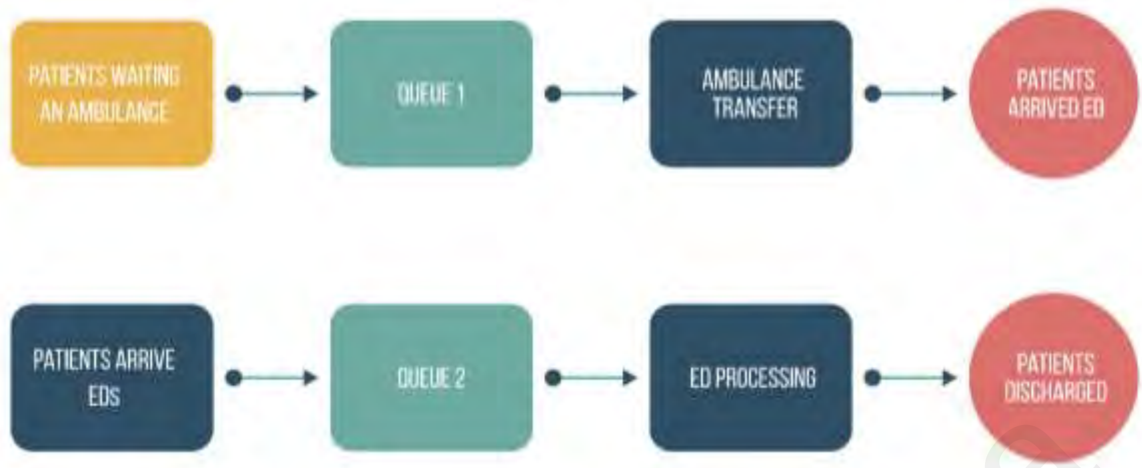

Figure 5.2 Logical Model of Patient Ambulance Transfer and ED Processing.

A simulation experiment was set to generate new data with new items based on logical model in Figure 5.2. A series of research questions was developed as follows for both the ambulance transfer process and the ED processing process:

- R.Q.1. What is the average wait time for patients waiting an ambulance?
- R.Q.2. What is the maximum wait time?
- R.Q.3. What is the average time that patients spent in ambulance transfer?
- R.Q.4. What is the total number of patients who used an ambulance or arrived in the normal mode?
- R.Q.5 What is the total number of patients serviced by an ambulance in the normal mode?
- R.Q.6 What is the number of patients remaining in the system or still in ambulance transfer?
- R.Q.7 What is the number of patients waiting in queues for an ambulance?
- R.Q.8 What is the utilization percentage for resources?

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Table 5.1 The Validated Instrument with Key Answers and Codes

Instrument in English, with Key Answers and Codes											
ID	**Item Name**	**Answer**									
1	Sex	Male	Female								
2	Age	18-24	25-34	35-44	45-54	55-64	65-74	75 and above			
3	Education Level	Foundation Degree	Graduate Diploma	BSc	PG Dip	Master	PhD				
4	Field of Education	Engineering	Computing	Health & Social Care	Sports Science	Social Sciences	Mathematics	Law	Information Technology	Business	Art
5	Marital Status	Single	Married	Divorced	Separated	Widowed					
6	Employment Status	Full-time student	Part-time student	Full-time employment	Part-time employment	Self-employed	Retired				
7	Nationality	American	Saudi Arabian	Malaysian							
8	Where do you currently live?	USA	Saudi Arabia	Malaysia							
9	Visited the ED in the past few weeks?	Yes	No	Maybe							
10	How did you arrive to the unit?	By myself	With help								
11	Easy task finding the nearest emergency department?	Yes	No	Maybe							
12	Time between needing emergency care to the	15 min	30 min	45 min	60 Min	90 Min	120 Min	More than 120 Min			

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Instrument in English, with Key Answers and Codes								
ID	**Item Name**	**Answer**						
	time of arrival at your destination							
13	How long did the ambulance take to respond to you?	15 Min	30 Min	45 Min	60 Min	90 Min	120 Min	More than 120 Min
14	Ambulance time from your location to destination	15 Min	30 Min	45 Min	60 Min	90 Min	120 Min	More than 120 Min
15	Traffic congestion impact?	Yes			No		Maybe	
16	Notice any delay caused by bystanders?	Yes			No		Maybe	
17	Admission desk or registration area noisy?	Yes			No		Maybe	
18	Admission desk or registration area busy?	Yes			No		Maybe	
19	Patient resistance that cause a delay?	Yes			No		Maybe	
20	Admission or registration process unfavourable?	Yes			No		Maybe	
21	Legal issues impacting admission?	Yes			No		Maybe	
22	Staff at admission or registration desk friendly?	Yes			No		Maybe	
23	Wait time until seen by doctor from the time you	Immediately	15 Min	30 Min	45 Min	60 Min	90 Min	120 Min

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Instrument in English, with Key Answers and Codes								
ID	Item Name	Answer						
	entered the ED							
24	What time did you arrive the ED?	Morning	Afternoon	Night	Midnight			
25	Time spend for door-to-door service (in Minutes)?	15 Min	30 Min	45 Min	60 Min	90 Min	120 Min	More than 120 Min
26	Been seen by a doctor and given full service?	Yes	No	Maybe				
27	Was the ED you visited public or private?	Public	Private					
28	How many times do you usually visit ED per year?	1	2	3	4	5	6	More than 6
29	Rate your condition	Nonurgent	Less Urgent	Urgent	Emergent	Severe		
30	Area you were transferred to after admission	Waiting Area	Triage Room	Emergency Bed	Doctor's Room			
31	How long did you stay in that area?	15 Min	30 Min	45 Min	60 Min	90 Min	120 Min	More than 120 Min
32	Rate your overall experience of visiting the ED	Very Poor	Poor	Acceptable	Good	Very Good		

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The patient's urgent care journey requires two different processes. In the first process, the patient feels unwell and then requests an ambulance transfer to the nearest ED, which is the ambulance transfer process. In the second process, the patient arrives at the nearest ED and enters the ED to obtain the necessary healthcare services as show early in Figure 5.2. This is the ED processing process, which accounts for 10% of the detailing in the simulation experiment [16] and [19].

The simulation environment was designed using Arena software [18]. The data generated from the data sheet included in the instrument are shown in Table 5.2 for the ambulance transfer process, and a similar table was designed for ED processing. Both new data sets were tested for their validity, reliability, and normality.

Table 5.2 Data Sheet Information for the Ambulance Transfer Process

Item Number	Item Name	Data Source
1	Sex	Gathered from Survey
2	Age	Gathered from Survey
3	Nationality	Gathered from Survey
4	Where do you currently live?	Gathered from Survey
5	Ambulance Response Time to Patient Location (Min)	Gathered from Survey
6	Ambulance Transfer Time from Patient Location to Emergency Unit (Min)	Gathered from Survey
7	Ambulance Utilization percentage	Simulation Data
8	Successful transfer	Simulation Data
9	Transfer in the Field or stuck in Traffic	Simulation Data
10	Min Number of Transfers	Simulation Data
11	Max Number of Transfers	Simulation Data

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Item Number	Item Name	Data Source
12	Utilization percentage	Simulation Data
13	Patient average Transfer Time (Min)	Simulation Data
14	Average number of Patient calls to request an ambulance (Patients Picked up)	Simulation Data
15	Average number of Patients served (Patients Dropped off)	Simulation Data
16	Average number of Patients not-served (Patients stuck in Traffic)	Simulation Data
17	Lower Ambulance Failure Range	Simulation Data
18	Upper Ambulance Failure Range	Simulation Data
19	Ambulance operations (Min per week)	Simulation Data
20	Patient Overall Experience	Gathered from Survey

5.3.1 Value of Data

Through a literature review, it was found that no research has been conducted in the past that involved utilization of simulation models to bring improvement in the Kingdom of Saudi Arabia (KSA) or Malaysia. The direct comparison of results from various operational techniques for Minimizing ED wait times and improving the patient experience has also not been considered in the past. Hence, this study is the first to consider the implementation of a simulation model in Malaysia and Saudi Arabia. Key words ["emergency department" OR "emergency medicine" AND "operations" AND "waiting time"] were used to search the relevant peer reviewed articles in the literature published between 1882 and 2018. A total of 1,759,073 articles were identified through this search, and only 2994 publications were from the Middle East. Only ten articles were excluded from the study because they were found to be irrelevant. Hence, while this study

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is original and unique, it can be re-evaluated and validated. The same search results were generated by using the IEEE database.

5.3.2 Ed KPIs and Performance Model

Factor analysis was carried out, and items were grouped to draw a unique conceptual model for the patient pathway from the time that they started feeling ill to their discharge time from the ED after receiving the required services, in this case, quality healthcare. The conceptual model incorporates the key performance indicators (KPIs) as shown in Figure 5.3.

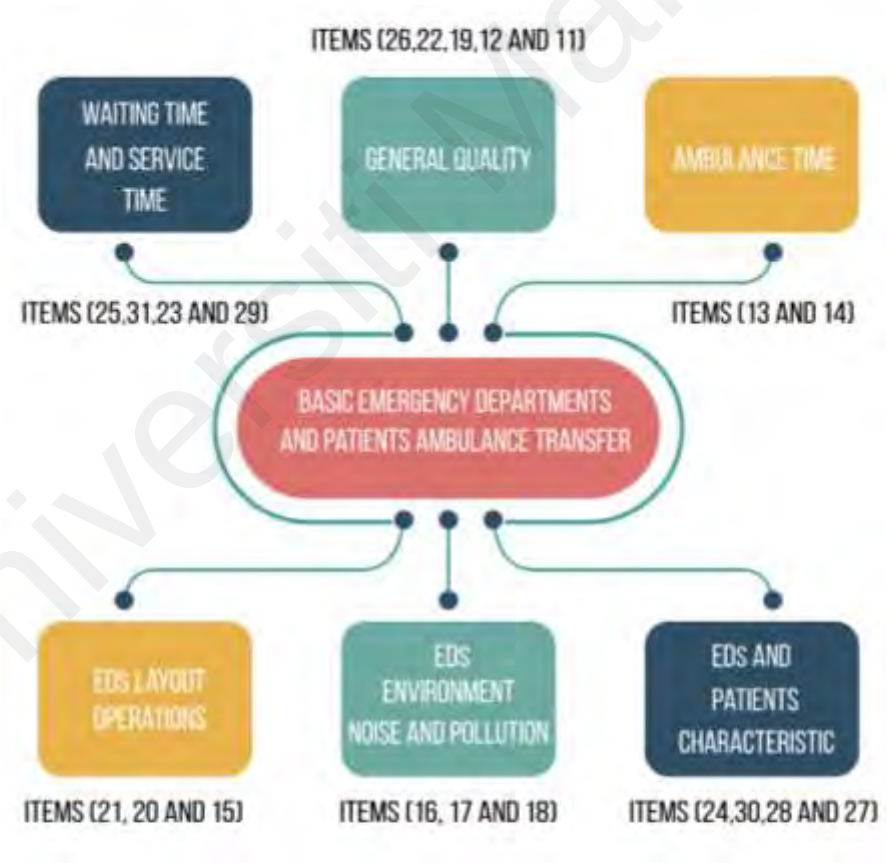

Figure 5.3 Conceptual Model of Emergency Department and Ambulance Transfer: A Quality KPIs

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5.4 Result

The results of this study were divided into three sections. Each section includes intensive analyses (descriptive, diagnostic, predictive and prescriptive analyses). The first section is the survey results. The second and third sections are the simulation experiment results, including ambulance transfer and ED processing simulation experiment results.

5.4.1 The Survey

5.4.1.1 Descriptive Analysis

The characteristics of the respondents in terms of sex, age, education, marital status, employment status, and nationality are presented in Figure 5.4, Figure 5.5 and Figure 5.6. Figure 5.4 demonstrates the respondent characteristics (n = 348) in terms of education, marital status, employment status, and nationality.

Table 5.3 ED Profile Distribution

ED type	Public 58.5%		Private 41.5%		
Patient arrival time	Morning 29.2%	Afternoon 24.6%	Night 32.3%	Midnight 13.8%	
Patient severity level	Nonurgent 12.3%	Less Urgent 16.9%	Urgent 38.5%	Emergent 26.5%	Severe 6.2%
Area after admission	Waiting Area 33.8%	Triage Room 23.1%	Emergency Bed 36.9%	Doctor's Room 6.2%	
Patient overall experience	Very Poor 7.7%	Poor 20.0%	Acceptable 30.8%	Good 24.6%	Very Good 16.9%

Figure 5.5 represents the sex distribution of the respondents. As shown in Figure 5.5, 54.9% of respondents were male. Figure 5.6 represents the age distribution of the respondents. As shown in Figure 5.5, 28.7% of respondents were between 25 and 34 years old. Table 5.3 details the distribution of the respondents according to ED type, patient arrival time, patient severity level, area after admission, and patient overall experience.

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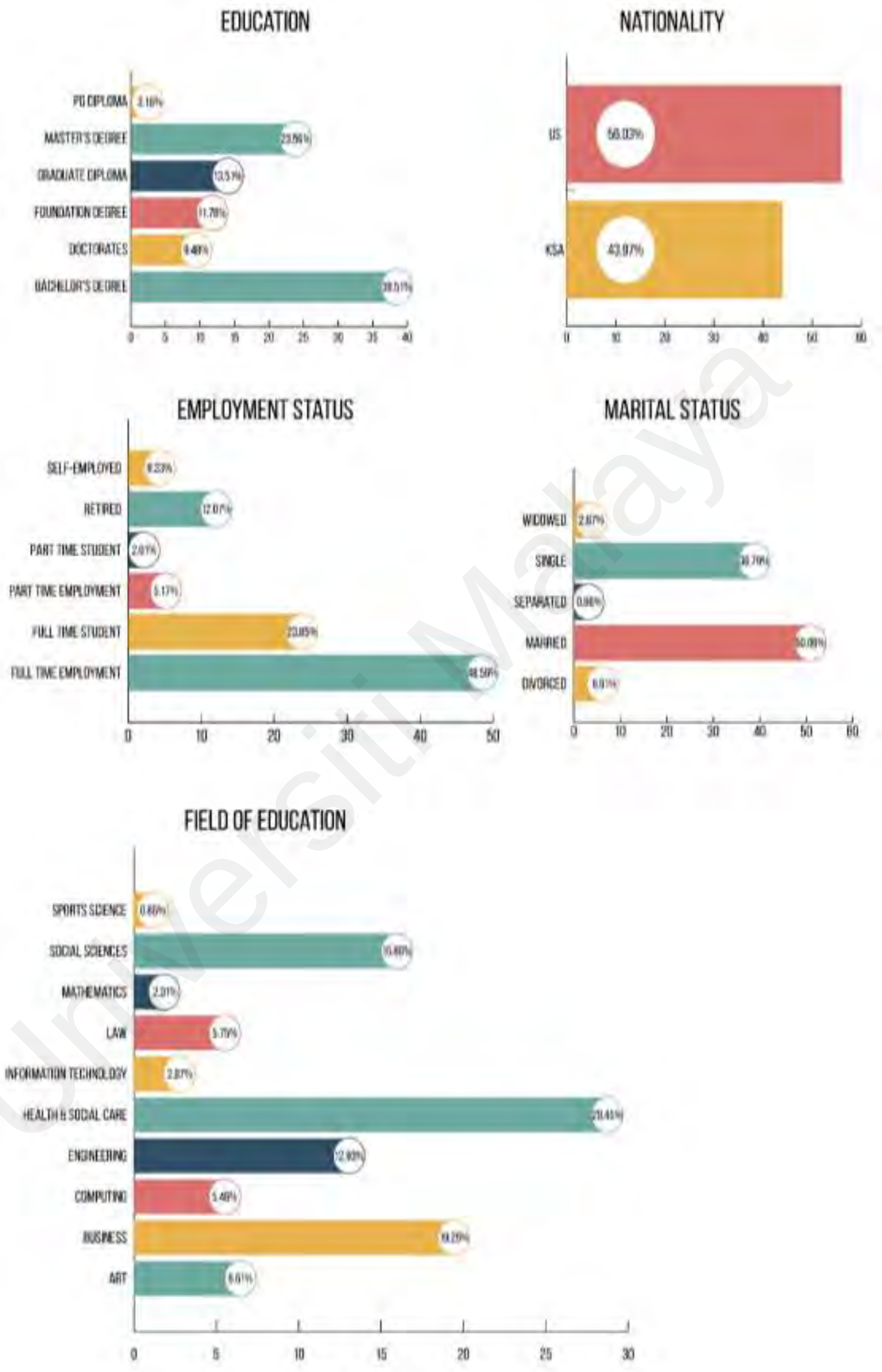

Figure 5.4 Characteristics of Patient attended an ED.

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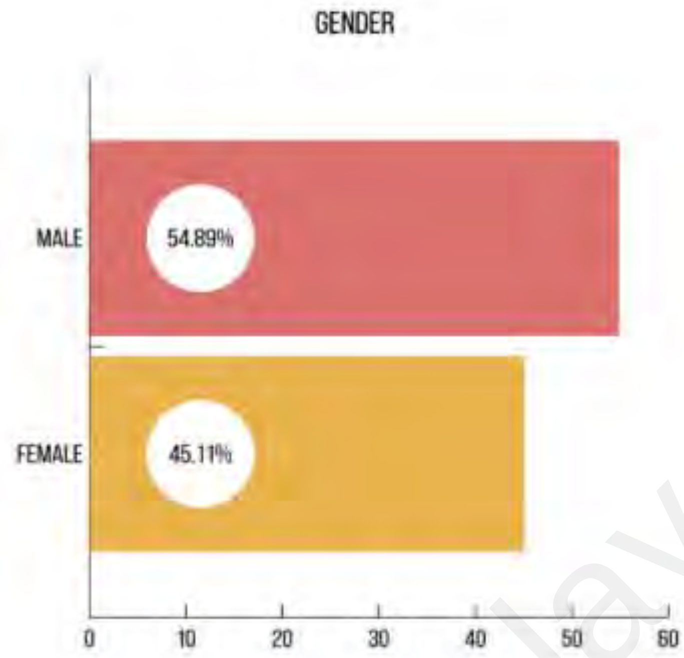

Figure 5.5 Sex distribution.

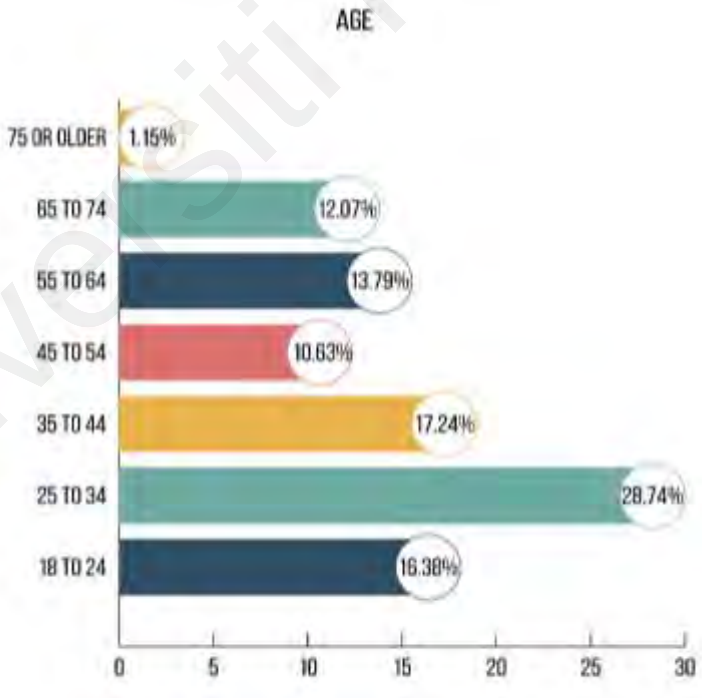

Figure 5.6 Age distribution.

A total of 58.5% of emergency departments visited by patients were public, and 41.5% were private. A total of 29.2% of patients visited the ED in the morning, 24.6% in the

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afternoon, 32.3% at night, and 13.8% at midnight. A total of 12.3% of patients visited the ED with a nonurgent severity level, 16.9% with a low severity level, 38.5% with an urgent severity level, 26.5% with an emergent severity level, and 6.2% with a high severity level. After admission, 33.8% of patients stayed in the waiting area, 23.1% went to the triage room, 36.9% stayed in an emergency bed, and 6.2% of patients went to a doctor's room. Overall, 7.7% of patients rated their ED visit as very poor, 20% rated their ED visit as poor, 30.8% rated their ED visit as acceptable, 24.6% rated their ED visit as good, and 16.9% rated their ED visit as very good.

5.4.1.2 Diagnostic Analysis

To investigate the factorial structure of the survey, factor analysis was performed using principal component analysis estimation methods with orthogonal rotation (varimax) and Kaiser normalization. The rotation converged in 14 iterations. Table 5.4 shows the results of the factor analysis for the final survey with kappa values and corrected item-total correlations. The items accumulated in six factors (Figure 5.3): general quality, wait time and service time, ED layout and operations, ED and patient characteristics, ambulance time and ED environment. All items showed high and significant correlations ($p < .01$) with the total instrument score. Five experts assessed the instrument items, and according to their evaluation of each item, kappa statistics were calculated (see formula 1). The kappa statistics showed excellent to fair content validation of the instrument. The factor analysis (principal components) of the instrument items showed moderate to high loading, as shown in Table 5.4. In addition, the instrument items showed high internal consistency, with a Cronbach's alpha of 0.827.

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Table 5.4 Factor Analysis

Item number	Item content	Corrected Item total Correlation	Kappa	Loading
Item 8	How long did it take from the time of feeling ill/needing emergency care to the time of arriving at your final destination (entering the emergency department; in minutes)?	.580**	0.763	0.448
Item 9	How long does an ambulance usually take to respond to you at your location (in minutes)?	.668**	0.763	0.452
Item 10	How long did the ambulance take traveling from your location to your final destination (entering the emergency department; in minutes)?	.657**	0.763	0.885
Item 11	Traffic congestion impact	.750**	0.763	0.843
Item 12	When you enter the emergency unit and before you seen by a doctor, did you notice any delay caused by bystanders or family members?	.716**	0.763	0.445
Item 13	Were the admission desk or registration areas noisy?	.501**	0.763	0.746
Item 14	Were the admission desk or registration areas busy?	.551**	0.763	0.636
Item 15	Did you notice any patient resistance that caused a delay?	.704**	0.763	0.464
Item 16	Was the impression of patients and their family about the admission or registration process unfavourable?	.742**	0.763	0.529
Item 17	Did legal issues or litigation proceedings interfere with the efficiency of admission?	.683**	0.763	0.641
Item 18	Was the staff at admission or registration desk friendly, and did they have trust and confidence when working with you?	.628**	0.763	0.839
Item 19	How long did you wait until you saw the doctor from the time you entered the emergency department?	.486**	0.763	0.751
Item 20	How long did you spend (in minutes) for door-to-door service?	.492**	0.763	0.622
Item 21	Were you seen by a doctor and given full service?	.470**	0.763	0.784

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Item number	Item content	Corrected Item total Correlation	Kappa	Loading
Item 22	How many times do you usually visit an ED per year?	.478**	0.418	0.799
Item 23	Severity level	.333**	0.418	0.819
Item 24	Area after admission	.695**	0.418	0.322
Item 25	How long did you stay in the admission area?	.647**	0.418	0.333
Item 26	Overall Experience	.599**	0.418	0.411
** $p < .01$				

The kappa statistic calculation is presented in Equation 1, where Po is the relative observed agreement among raters, and pe is the hypothetical probability of chance agreement. The reliability calculation is presented in Equation 2, where n is the number of items, Vt is the variance of the total scores and Vt is the variance of the item scores.

Equation 1 Kappa Theorem

$$K = \frac{Po - Pe}{1 - Pe}$$

Equation 2 Reliability Theorem

$$\propto = \frac{n}{n-1}\left(1 - \frac{\sum_i Vi}{Vt}\right)$$

Figure 5.3 represents a conceptual model operationalized from the factor analysis results. As shown in Figure 5.3, six factors were extracted from the patient responses: general quality (represented by items 11, 12, 19, 22, and 26), wait time and service time (represented by items 23, 25, 29, and 31), ambulance time (represented by items 13 and 14), emergency department layout and operations (represented by items 15, 20 and 21), emergency department environment noise and pollution (represented by items 16, 17, and

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18), and emergency department and patient characteristics (represented by items 24, 27, 28, 30).

A structural equation analysis model was specified using emergency department and patient characteristics as exogenous variables, general quality as mediating variables and wait time and service time as endogenous variables.

Equation 3 RMSEA Model fit

$$RMSEA = \sqrt{\max\left(\left[\left(\left(\chi^2/df\right) - 1\right)/(N - 1)\right], 0\right)}$$

The RMSEA calculation is presented in Equation 3, where N is the sample size, and df is the degrees of freedom.

Equation 4

$$CFI = if\ D = X^2 - df, then:$$
$$\frac{D(Null\ Model) - D(Proposed\ Model)}{D(Null\ Model)}$$

Equation 5

$$TLI = \frac{X^2/df(Null\ Model) - X^2/df(Proposed\ Model)}{X^2/df(Null\ Model) - 1}$$

The model was adequate with RMSEA = .07, TLI = .95, and CFI = 0.95. The equations for RMSEA, TLI, and CFI are presented above.

5.4.1.3 Predictive Analysis

A multiple regression analysis was performed, where the overall patient experience was used as an outcome variable, and all the other instrument variables were used as independent variables to explore which variables were highly related to the patients' emergency department experience. Only one variable showed a significant relationship

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with the outcome (patient experience), which was “How long did you wait until you saw the doctor from the time you entered the emergency department? “($\beta = -.48$, $t = 3.13$, $p < .01$). The coefficient of determination (R2) was equal to 0.52 ($F = 2.07$, $p < .05$). This indicated that as the time that the patient spent before seeing the doctor increased, the impression that patients had about their emergency department visit was less positive.

5.4.1.4 Prescriptive Analysis

Table 5.5 shows significant sex differences using the independent samples t-test for the equality of means. Five variables showed significant differences in favor of females: traffic congestion impact, noisy admission desk or registration area, patient resistance that caused a delay, seen by a doctor and given full service, and length of stay in the area following admission.

Table 5.5 Independent Samples T-Test for the Equality of Means by Sex

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Traffic congestion impact	-2.500	63	.015	-.435	-.783	-.087
Were the admission desk or registration areas noisy?	-2.884	63	.005	-.440	-.745	-.135
Did you notice any patient resistance that caused a delay?	-2.658	63	.010	-.385	-.674	-.096
Were you been seen by a doctor and given full service?	-2.169	63	.034	-.375	-.721	-.029
How long did you stay in that area?	-2.980	63	.004	-1.300	-2.172	-.428

Table 5.6 shows significant differences related to nationality (US versus KSA) using the independent samples t-test for the equality of means. Three variables showed significant

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differences in favor of US nationality: noisy admission desk or registration area, patient resistance that caused a delay, and length of stay in the area following admission.

Table 5.6 Independent Samples T-Test for the Equality of Means by Nationality

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Were the admission desk or registration areas noisy?	2.616	63	.011	.414	.097	.731
Did you notice any patient resistance that caused a delay?	2.703	63	.009	.409	.106	.712
How long did you stay in that area?	3.928	63	< .001	1.685	.826	2.544

Table 5.7 shows differences among the participants' responses for 9 selected variables using the chi-Square test of homogeneity.

Table 5.7 Responses of the Participants for Variables with Statistically Significant Differences (n = 65)

Item number	Item content	Rarely (%)	Most of the Time (%)	Always (%)	Chi-Square
Item 11	Traffic congestion Impact	20 (30.8)	32 (49.2)	13 (20.0)	8.52*
Item 12	When you enter the emergency unit and before you were seen by a doctor, did you notice any delay caused by bystanders or family members?	11 (16.9)	39 (60.0)	15 (23.1)	21.17**
Item 13	Were the admission desk or registration areas noisy?	22 (33.8)	36 (55.4)	7 (10.8)	19.42**
Item 14	Were the admission desk or registration areas busy?	27 (41.5)	27 (41.5)	11 (16.9)	7.88*
Item 15	Did you notice any patient resistance that caused a delay?	14 (21.5)	42 (64.6)	9 (13.8)	29.20**
Item 16	Was the impression of patients and their family about the admission or registration process unfavorable?	14 (21.5)	32 (39.2)	19 (29.2)	7.97*
Item 17	Did legal issues or litigation proceedings interfere with the efficiency of admission?	15 (23.1)	36 (55.4)	14 (21.5)	14.25**
Item 18	Were the staff at the admission or registration desk friendly, and did they have trust and confidence when	45 (69.2)	9 (13.8)	11 (16.9)	37.79**

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Item number	Item content	Rarely (%)	Most of the Time (%)	Always (%)	Chi-Square
	working with you?				
Item 21	Were you seen by a doctor and given full service?	49 (75.4)	8 (12.3)	8 (12.3)	51.72**
* $p < .05$, ** $p < .01$					

5.4.2 Ambulance Transfer

5.4.2.1 Descriptive Analysis

Figure 5.7-Figure 5.13 show the probability distributions of the ambulance transfer simulated data. As shown in Figure 5.7-Figure 5.13, most variables tended to be normally distributed. A typical normal probability distribution was found for the transfer failed or stuck in traffic variables. Ninety percent of the simulations had an ambulance response time to the patient location between 19.2 and 57.5 minutes. Ninety percent of the simulations indicated successful transfer of between 130 and 355 patients. Ninety percent of the simulations had ambulance operations of between 256 and 388 cases per minute per week.

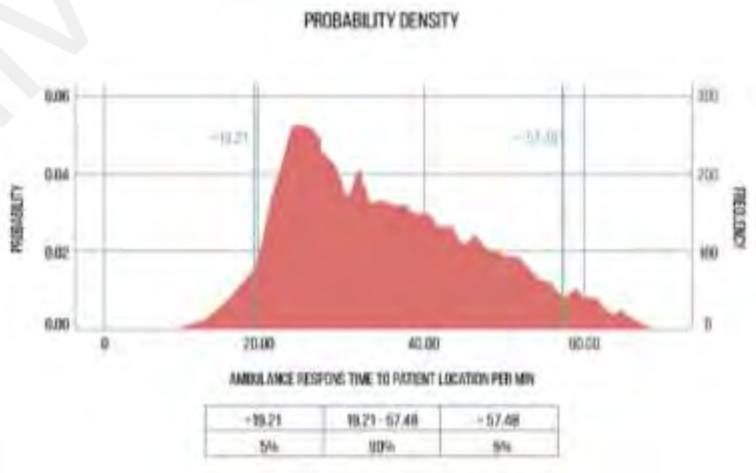

Figure 5.7 Probability Density of Ambulance Transfer Variable 1.

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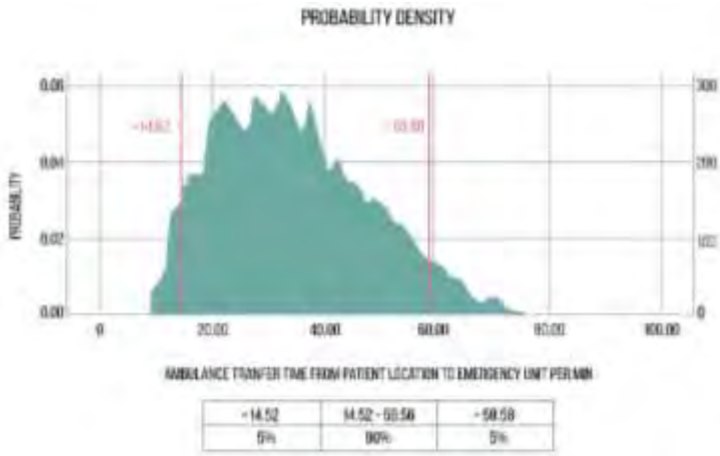

Figure 5.8 Probability density of the ambulance transfer variable 2.

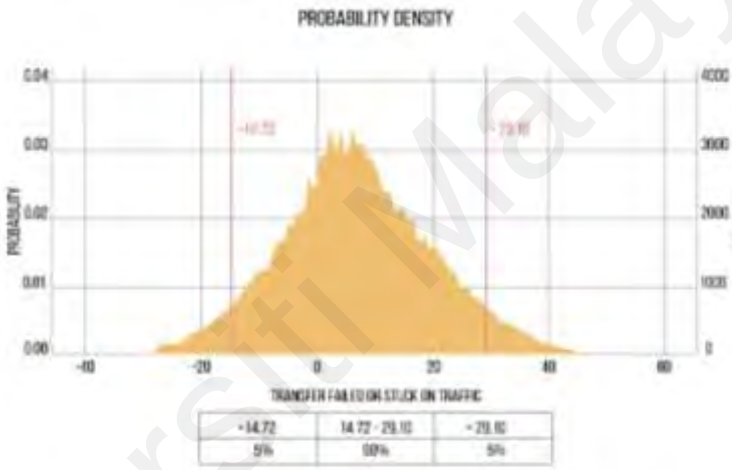

Figure 5.9 Probability density of the ambulance transfer variable 3.

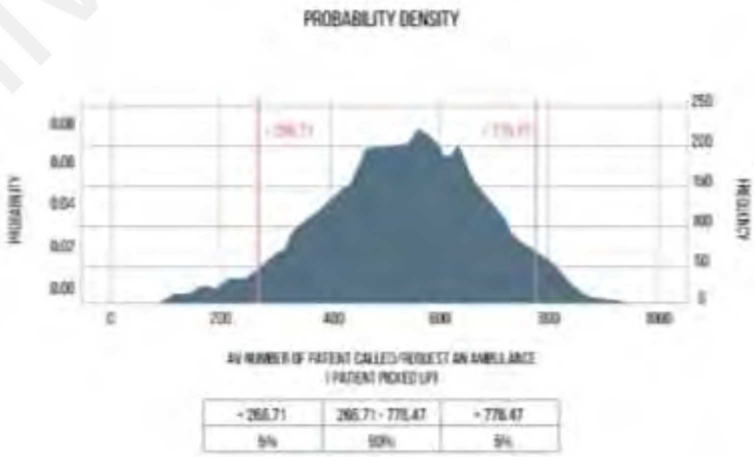

Figure 5.10 Probability density of the ambulance transfer variable 4.

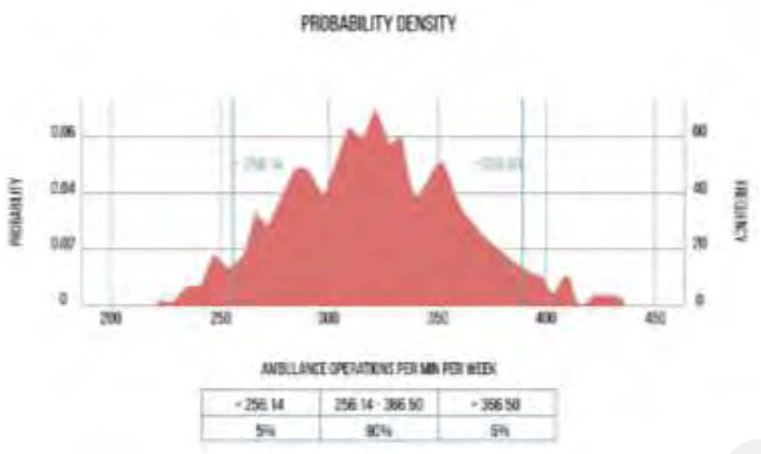

Figure 5.11 Probability density of the ambulance transfer variable 5.

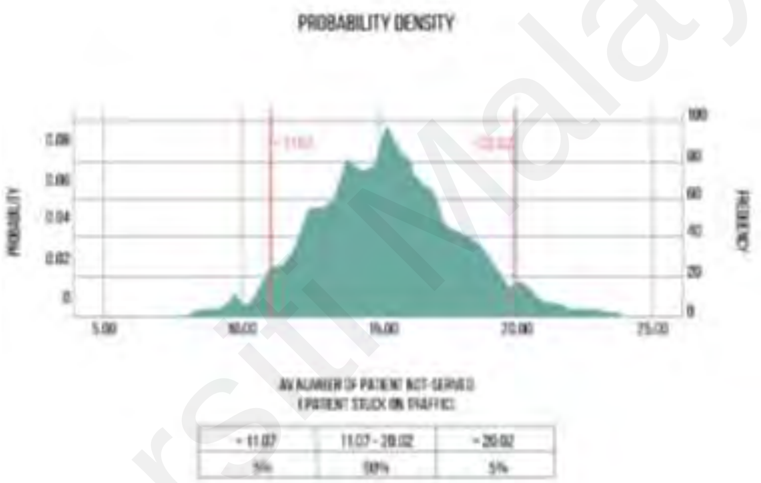

Figure 5.12 Probability density of the ambulance transfer variable 6.

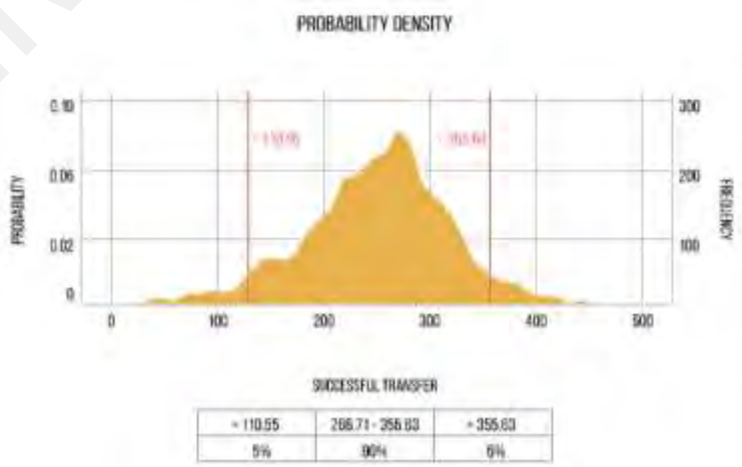

Figure 5.13 Probability density of the ambulance transfer variable 7.

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5.4.2.2 Diagnostic Analysis

Table 5.8 shows the minimum values, maximum values, means, and standard deviations for the ambulance transfer variables. In addition, Table 5.8 shows the bias statistics and bootstrap 95% confidence intervals for each variable. The bootstrap results are based on 1000 stratified bootstrap samples selected from the simulated dataset. The bias statistics showed small mean values and small standard deviations, indicating the accuracy of the simulated data. According to the bootstrap results, 95% of the time, ambulance response times to the patient location were between 18.9 (SD = 8.0) and 24.92 (SD = 19.7) minutes; 95% of the time, between 234 (SD= 71) and 280 (SD= 106) patients were successfully transferred, and ambulance operation was between 282 (SD = 64.4) and 321 (SD = 96.7) patients per minute per week.

Table 5.8 Bootstrap Statistics for the Ambulance Transfer Simulated Variables

					Bootstrap					
							95% Confidence Interval			
	Statistic				Bias		Lower		Upper	
Items	Min.	Max.	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ambulance Response Time to Patient Location (Min)	15	105	21.69	14.28	-.14	-.82	18.92	7.99	24.92	19.67
Ambulance Transfer Time from Patient Location to Emergency Department (Min)	15	75	21.23	12.96	-.11	-.42	18.69	8.77	24.00	15.91
Ambulance Utilization percentage	33.80	99.80	89.08	16.14	.0755	-.34	84.83	12.15	92.89	19.08
Successful transfer	31	403	259.43	90.65	.36	-1.42	234.4	71.33	280.47	105.7
Transfer Failed or stuck in Traffic	1	76	18.54	16.24	.06	-.35	15.18	10.49	22.43	20.64
Min Number of Transfers	2	607	433.08	236.6	1.47	-2.17	379.2	211.51	486.53	254.23
Max Number of Transfers	15	1042	610.60	274.4	1.98	-3.92	542.3	234.11	677.71	306.34

Items	Statistic				Bootstrap					
					Bias		95% Confidence Interval			
							Lower		Upper	
	Min.	Max.	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Utilization percentage	40.40	95.30	81.63	12.69	.0413	-.25	78.61	9.24	84.62	15.05
Patient average Transfer Time (min)	13.30	199.0	22.68	24.43	-.1797	-2.84	18.36	8.62	28.05	38.755
Average number of Patient calls / requests for an ambulance (Patients Picked up)	46	675	516.17	220.0	1.58	-2.60	462.1	191.09	569.65	241.95
Average number of Patients served (Patients Dropped off)	26	645	490.03	218.5	1.52	-2.67	438.1	185.53	542.57	244.23
Average number of Patients not served (Patient stuck in Traffic)	1	35	16.28	7.63	.04	-.12	14.47	6.23	18.18	8.685
Lower Bound of Ambulance Failure Range	.7	24.0	5.214	4.20	.008	-.12	4.327	2.70	6.24	5.34
Upper Bound Ambulance Failure Range	1.0	50.0	37.89	16.54	.110	-.27	33.82	13.06	41.90	18.89
Ambulance operations (patients per min per week)	58.56	585.0	301.52	81.70	-.2113	-2.05	282.0	64.40	321.00	96.69

Bootstrap results are based on 1000 stratified bootstrap samples

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5.4.2.3 Predictive Analysis

Multiple regression analysis was performed shown in Table 5.9 with ambulance operations per minute per week used as the outcome variable and all the other simulation variables used as the independent variables. Four variables showed significant prediction: ambulance transfer time from patient location to emergency department (minute) (β = .92, t = 10.93, p < .001), number of successful transfers (β = .92, t = 8.28, p < .001), transfer failed or stuck in traffic (β = .86, t = 7.82, p < .001), and utilization percentage (β = -.33, t = 3.90, p < .001).

Table 5.9 Regression Analysis for Ambulance Transfer Data

Variable	Standardized Coefficients (Beta)	t	Significance
Ambulance Transfer Time from Patient Location to Emergency Unit (Min)	.923	10.928	> .001
Number of Successful Transfers	.915	8.283	> .001
Transfer Failed or stuck in Traffic	.862	7.820	> .001
Utilization Percentage	-.328	3.900	> .001

5.4.2.4 Prescriptive Analysis

Table 5.10 shows the analysis of sex differences using the independent samples t-test for the equality of means. As shown in Table 5.10, no variable showed significant differences. Table 5.11 shows the analysis of differences among US, KSA, and Malaysia with regard to ambulance transfer variables.

Table 5.10 Sex Differences for the Ambulance Transfer Variables

Ambulance Response Time to Patient Location (Min)									
			15	30	45	60	More than 60	Chi-Square	Sig.
Sex	Male	Count	26	11	3	0	0	7.28	.122
	Female	Count	20	3	0	1	1		
Ambulance Transfer Time from Patient Location to Emergency Unit (Min)									
Sex	Male	Count	28	7	4	1	0	5.62	.230
	Female	Count	21	2	0	1	1		
Variable			Sex	N	Mean		SD	t	Sig.
Average Patient Transfer Time per min			Male	40	21.15		9.71	.639	.525
			Female	25	25.14		37.78		
Successful transfers			Male	40	260.90		101.20	.164	.870
			Female	25	257.08		72.54		
AV number of Patient served (Patient Dropped off)			Male	40	458.03		226.71	1.51	.136
			Female	25	541.24		198.52		
Transfer Failed or stuck in			Male	40	18.98		17.96	.272	.786

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Traffic	Female	25	17.84	13.34		
Average number of Patients not-served (Patient stuck in Traffic)	Male	40	16.03	8.426	.334	.739
	Female	25	16.68	6.310		
Ambulance Utilization percentage	Male	40	87.93	17.83	.727	.470
	Female	25	90.93	13.11		
Utilization percentage	Male	40	81.24	14.27	.315	.754
	Female	25	82.26	9.88		
Patient Overall Experience	Male	40	3.15	1.07	.694	.491
	Female	25	3.36	1.35		

According to Table 5.11, there were differences in favor of US with regard to ambulance response time to the patient location (minutes), average number of patients served (patients dropped off), and utilization percentage.

Table 5.11 difference Among Countries for the Ambulance Transfer Variables

Ambulance Response Time to the Patient Location (Min)									
			15	30	45	60	More than 60	Chi-Square	Sig.
Country	US	Count	27	1	0	1	1	21.05	.007
	KSA	Count	10	10	1	0	0		
	MY	Count	9	3	2	0	0		
Ambulance Transfer Time from Patient Location to the Emergency Department (Min)									
			15	30	45	60	75	Chi-Square	Sig.
Country	US	Count	26	1	0	2	1	13.15	.107
	KSA	Count	13	5	3	0	0		
	MY	Count	10	3	1	0	0		
Variable	Country	N	Mean	Std. Deviation				F	Sig.
Average Patient Transfer Time (min)	US	30	22.77	34.73				.098	.907
	KSA	21	24.12	9.06					
	MY	14	20.34	10.54					
Successful transfers	US	30	243.60	69.95				1.05	.358
	KSA	21	265.19	127.17					
	MY	14	284.71	57.82					
Average number of Patients served (Patients Dropped off)	US	30	558.90	201.47				5.12	.009
	KSA	21	374.29	225.11					
	MY	14	516.07	182.53					
Transfer Failed or	US	30	20.50	15.55				.676	.512

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stuck in Traffic	KSA	21	18.52	21.22		
	MY	14	14.36	6.14		
Average number of Patients not-served (Patient stuck in Traffic)	US	30	18.37	5.82	2.332	.106
	KSA	21	13.90	9.92		
	MY	14	15.36	6.28		
Ambulance Utilization percentage	US	30	83.91	6.87	2.003	.144
	KSA	21	77.15	18.78		
	MY	14	83.46	9.81		
Utilization percentage	US	30	93.33	9.29	3.152	.050
	KSA	21	82.25	22.69		
	MY	14	90.22	13.38		
Patient Overall Experience	US	30	3.47	1.30	1.414	.251
	KSA	21	2.90	1.13		
	MY	14	3.21	.89		

5.4.3 Ed Processing

5.4.3.1 Descriptive Analysis

Figure 5.14-Figure 5.21 show the probability distributions of the simulated ED processing data. As shown in Figure 5.14-Figure 5.21, the variable distributions tended to be almost perfectly normal. For example, wait time was normally distributed, with 90% of simulations having a wait time from emergency department admission to the first contact with a doctor between 5.99 and 279.08 minutes in the most extreme cases.

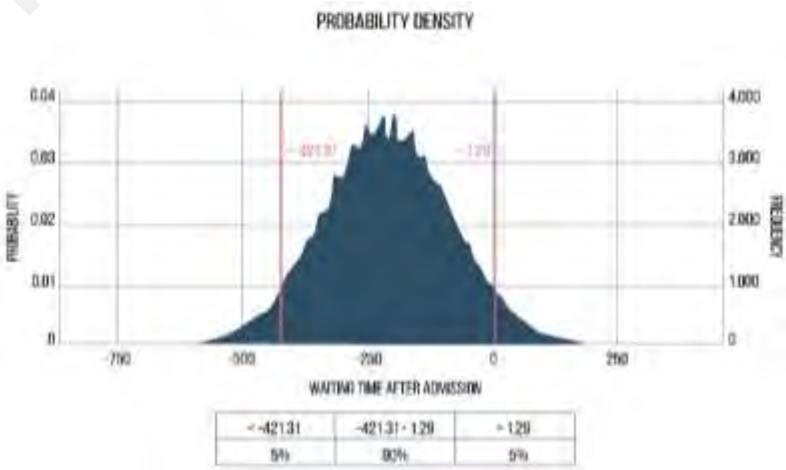

Figure 5.14 Probability density for the ED processing variable 1.

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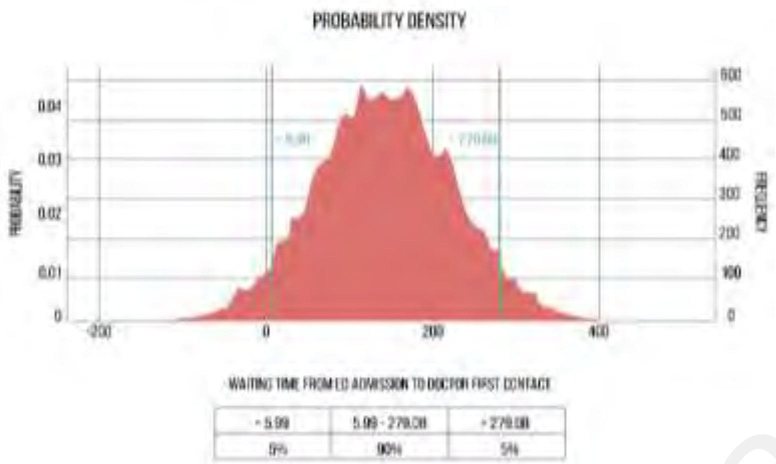

Figure 5.15 Probability density for the ED processing variable 2.

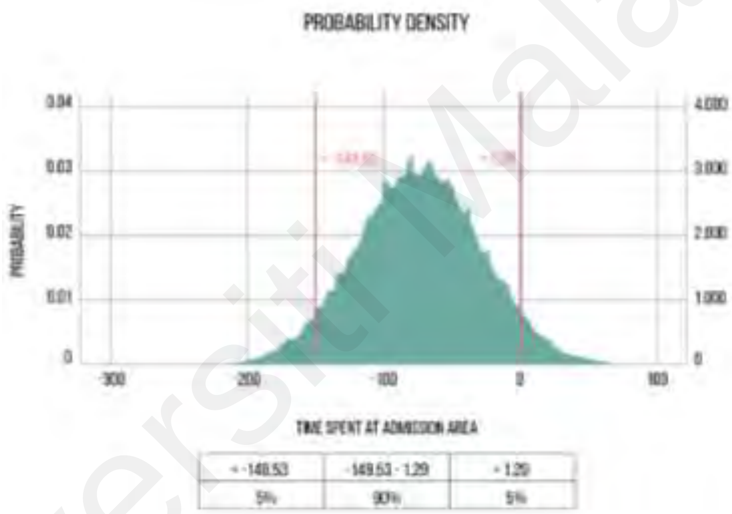

Figure 5.16 Probability density for the ED processing variable 3.

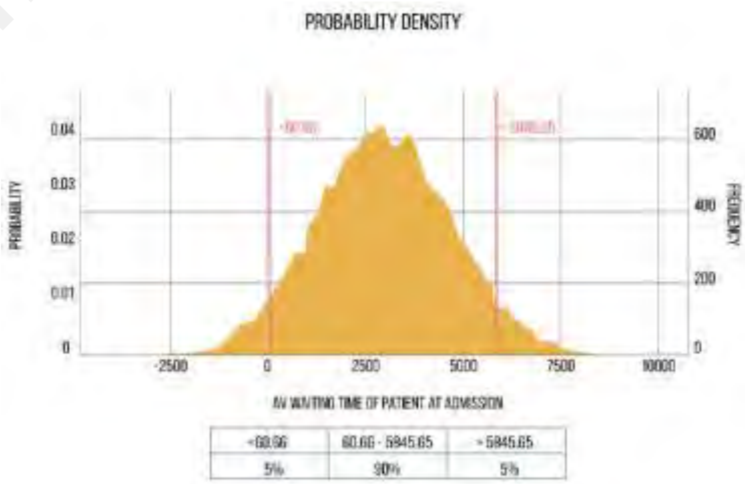

Figure 5.17 Probability density for the ED processing variable 4.

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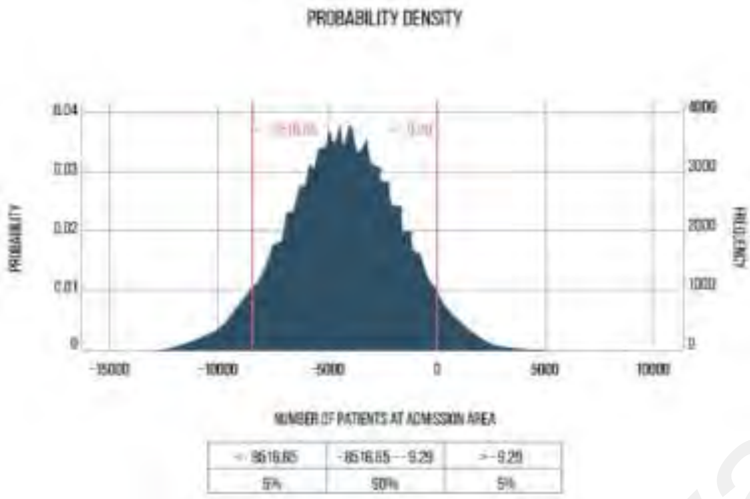

Figure 5.18 Probability density for the ED processing variable 5.

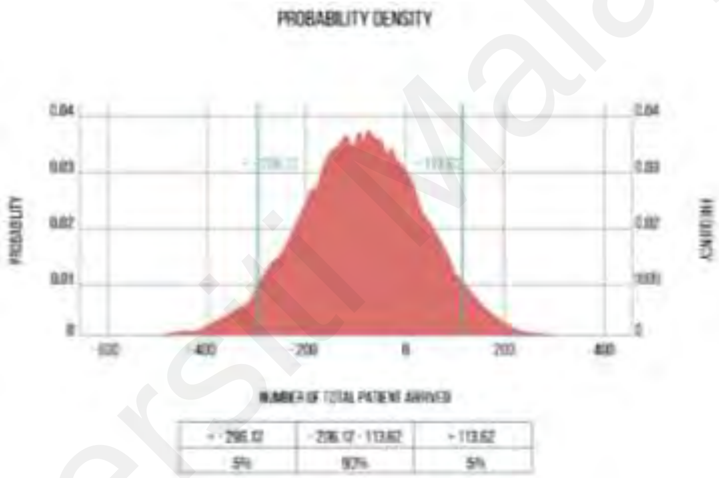

Figure 5.19 Probability density for the ED processing variable 6.

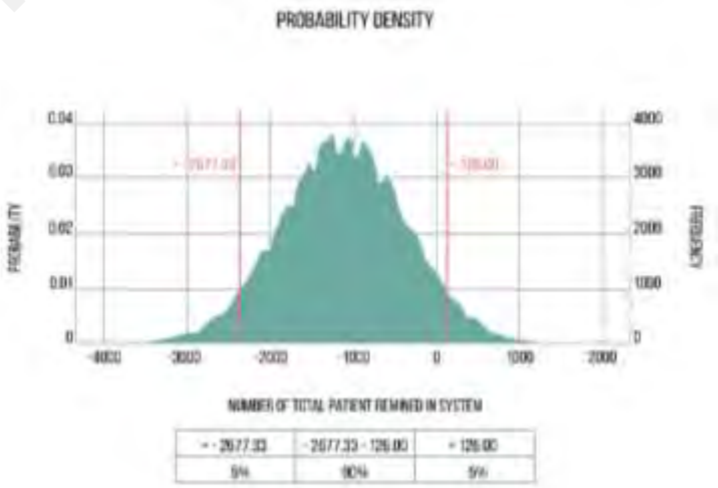

Figure 5.20 Probability density for the ED processing variable 7.

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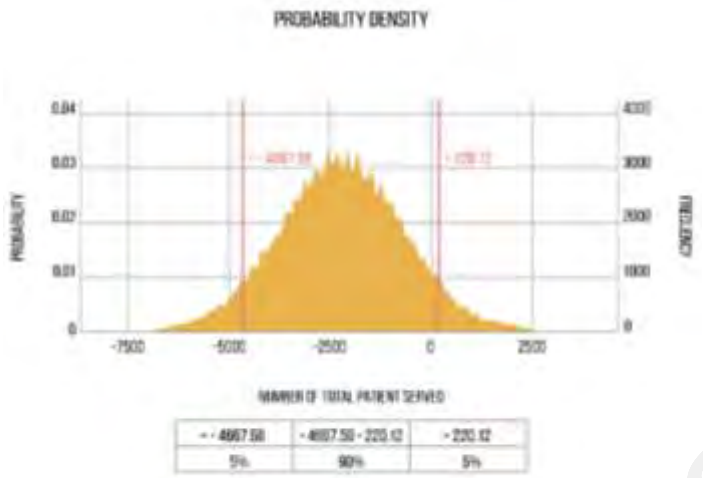

Figure 5.21 Probability density for the ED processing variable 8.

5.4.3.2 Diagnostic Analysis

Table 5.12 shows the minimum values, maximum values, means, and standard deviations for the emergency department variables. In addition, Table 5.12 shows the bias statistics and the bootstrap 95% confidence intervals for each variable. The bootstrap results are based on 1000 stratified bootstrap samples selected from the simulated dataset.

Table 5.12 Bootstrap Statistics for the Simulated Emergency Department Variables

					Bootstrap					
							95% Confidence Interval			
	Statistic				Bias		Lower		Upper	
Items	Min.	Max.	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Wait Time After Admission	1.00	6.00	2.83	1.54	0.01	-0.02	2.48	1.25	3.23	1.77
Wait time from ED Admission to First Contact with a Doctor	3.00	7.00	4.40	1.48	0.01	-0.02	4.03	1.29	4.80	1.62
Time Spent in the Admission Area	1.00	4.00	1.57	0.92	0.00	-0.01	1.35	0.69	1.78	1.10
ED Processing Time	1.00	6.00	2.97	1.43	0.00	-0.02	2.62	1.19	3.31	1.63
Utilization of the ED	50.29	99.92	88.62	19.41	-0.01	-0.23	83.85	15.12	93.28	22.07
Average Wait Time of Patients at Admission	15.00	126.3	50.44	29.43	0.00	-0.42	43.45	22.44	57.67	35.33
Number of Patients in the admission area	1.00	41.00	21.68	13.72	0.00	-0.12	18.45	11.91	24.77	14.93

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Items	Statistic				Bootstrap					
					Bias		95% Confidence Interval			
							Lower		Upper	
	Min.	Max.	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Average Door-to-Door Service Time (Simulated)	28.90	654.5	351.51	215.42	-0.13	-2.02	297.6	189.80	404.32	235.43
Total Number of Patient who Arrived at the ED	30.00	231.0	103.48	54.01	-0.02	-0.79	90.48	40.59	117.26	63.68
Total Number of Patients Served	12.00	340.0	96.75	112.55	-0.13	-1.42	70.08	90.37	125.37	129.34
Total Number of Patients who Remained in the System	1.00	340.0	64.77	104.61	-0.15	-2.06	41.90	68.47	92.46	129.65
Patient Door-to-Door Service Time (Actual/Real)	3.00	7.00	4.54	1.36	0.00	-0.01	4.20	1.20	4.85	1.49

The bias statistics showed small mean values and small standard deviations, indicating the accuracy of the simulated data. According to the bootstrap results, the wait time after admission ranged from 2.5 (SD = 1.3) to 3.2 (SD = 1.8) 95% of the time, the wait time from emergency department admission to the first contact with a doctor was between 4 (SD = 1.3) and 4.8 (SD = 1.6) minutes 95% of the time, the emergency department processing time ranged between 2.6 (SD =1.2) and 3.3 (SD = 1.6) 95% of time, the estimated number of patients in the admission area ranged from 18 (SD =12) to 25 (SD =15) 95% of the time, and the average door-to-door service time was estimated to be between 297.6 (SD = 189.8) and 404.3 (SD = 235.4) minutes 95% of the time.

5.4.3.3 Predictive Analysis

A multiple regression analysis was performed with patient door-to-door service time used as the outcome variable and with all the other simulation variables used as independent variables. Two variables showed significant prediction: average wait time of

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patients at admission (β = .96, t = 23.88, p < .001) and time spent in the admission area (β = .56, t = 13.96, p < .001). The results of the regression analysis for the emergency department processing data are presented in Table 5.13.

Table 5.13 regression Analysis for ED Processing Data

Variable	Standardized Coefficients (Beta)	t	Significance
Average Wait Time of Patients at Admission	0.964	23.884	> .001
Time Spent in the Admission Area	0.563	13.964	> .001

5.4.3.4 Prescriptive Analysis

Table 5.14 shows the analysis of sex differences using the independent samples t-test for the equality of means. As shown in Table 5.14, there were significant differences in the time spent in the admission area and the total number of patients served in favor of males; there were significant differences in ED processing time and utilization of the ED in favor of females.

Table 5.14 Sex Differences for ED Processing

Variable	Sex	N	Mean	SD	t	df	Sig.
Wait Time After Admission	Male	40	2.75	1.50	0.856	63	0.395
	Female	25	3.14	1.70			
Wait time from ED Admission to First Contact with a Doctor	Male	51	4.47	1.42	0.733	63	0.466
	Female	14	4.14	1.70			
Time Spent in the Admission Area	Male	51	1.73	0.98	2.75	63	0.008
	Female	14	1.00	0.00			
ED Processing Time	Male	51	2.76	1.38	2.28	63	0.026
	Female	14	3.71	1.38			
Utilization of ED	Male	51	85.60	20.95	2.487	63	0.016
	Female	14	99.61	0.32			
Average Wait Time of the Patients at Admission	Male	51	47.16	29.72	1.746	63	0.086
	Female	14	62.42	25.90			

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Variable	Sex	N	Mean	SD	t	df	Sig.
Total Number of Patients who Arrived at the ED	Male	51	105.92	60.87	0.694	63	0.49
	Female	14	94.57	0.85			
Total Number of Patients Served	Male	51	115.71	120.29	2.717	63	0.008
	Female	14	27.71	12.98			
Total Number of Patients who Remained in the System	Male	51	73.24	116.86	1.251	63	0.216
	Female	14	33.93	6.44			
Number of Patients in the admission area	Male	51	19.08	14.26	3.106	63	0.003
	Female	14	31.14	4.62			
Average Door-to-Door Service Time	Male	51	319.51	218.82	2.367	63	0.021
	Female	14	468.10	160.17			

Table 5.15 shows the analysis of differences among the US, KSA, and Malaysia with regard to the emergency department processing variables. According to Table 5.15, there were significant differences in the wait time from ED admission to the first contact with a doctor, the ED processing time, the average wait time of the patients at admission, the average door-to-door service time, and the total number of patients who remained in the system in favor of Malaysia.

Table 5.15 Differences In Ed Processing Variables Among Countries

Variable	Country	N	Mean	SD	F	Sig.
Wait Time After Admission	US	15	3.20	1.66	2.40	0.10
	KSA	38	2.95	1.56		
	MY	12	2.00	1.04		
Wait time from ED Admission to the First Contact with a Doctor	US	15	4.80	1.66	4.38	0.02
	KSA	38	4.58	1.45		
	MY	12	3.33	0.78		
Time Spent in the Admission Area	US	15	1.60	0.83	0.48	0.62
	KSA	38	1.63	1.05		
	MY	12	1.33	0.49		
ED Processing Time	US	15	2.60	0.83	11.07	< .001
	KSA	38	3.53	1.50		
	MY	12	1.67	0.49		

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Variable	Country	N	Mean	SD	F	Sig.
Utilization of the ED	US	15	92.41	12.16	0.79	0.46
	KSA	38	88.91	20.21		
	MY	12	82.97	23.97		
Average Wait Time of the Patients at Admission	US	15	45.29	12.63	7.50	< .001
	KSA	38	60.05	33.54		
	MY	12	26.48	8.48		
Number of Patients in admission area	US	15	18.00	12.09	1.85	0.17
	KSA	38	24.39	14.38		
	MY	12	17.67	12.31		
Average Door-to-Door Service Time	US	15	267.83	142.45	9.47	< .001
	KSA	38	436.00	223.01		
	MY	12	188.57	117.11		
Total Number of Patients who Arrived at the ED	US	15	112.00	64.57	2.40	0.10
	KSA	38	109.63	52.92		
	MY	12	73.33	32.00		
Total Number of Patients Served	US	15	74.60	80.82	1.35	0.27
	KSA	38	91.00	110.50		
	MY	12	142.67	145.74		
Total Number of Patients who Remained in the System	US	15	19.40	12.79	4.19	0.02
	KSA	38	61.87	97.51		
	MY	12	130.67	154.60		

5.5 Discussion

Emergency departments may experience different problems such as long wait times, inefficient use of ED resources, an unbalanced healthcare workforce and scheduling difficulties. This paper applied Arena simulation [18] as a first effort to model the operations of emergency departments the Saudi Arabian healthcare system and the Malaysian healthcare system. The model was based on real world data collected by a well- developed survey designed specifically for the purpose of the current study. Analysis of the responses to this survey revealed that public emergency department usage was higher than that of private emergency departments. The survey results also showed that the use of the ED was almost even during the day and night, with slightly more visits at night and slightly fewer visits at midnight. Urgent and emergent severity cases

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accounted for most of the cases received by the EDs. In addition, most patients stayed in the waiting room area or an emergency department bed after admission. Furthermore, most ED patients rated their experience as acceptable or good.

Factor analysis revealed that the evaluated items loaded onto six factors: general quality, wait time and service time, ambulance time, emergency department layout and operations, emergency department environmental noise and pollution, and characteristics of the emergency department and patients. Structural equation modeling analysis revealed that characteristics of the emergency departments and patients could predict wait time and service time with general quality as a mediating variable. This result directed our attention to the importance of the emergency department and patient characteristics and the essential role of service quality in the emergency department systems.

Furthermore, using multiple regression analysis, result showed that the overall patient experience was predicted by wait time (how long a patient waited until he/she saw the doctor from the time he/she entered the emergency department). This result draws our attention to the importance of wait time as an operationalization of service quality in emergency room departments. In addition, significant sex differences were found in favor of females in some variables, such as the impact of traffic congestion, environmental factors related to the admission desk or registration areas (noisiness), service delays due to patient resistance, receiving full service in the emergency department, and time spent receiving the healthcare services. These results assured the importance of sex variables in simulating and modeling emergency department systems (ambulance transfer and emergency room processing).

Differences related to country were also present for some variables. US emergency departments provided better service according to the patients' responses to the survey, especially with regard to factors such as those related to the admission desk or registration

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areas (noisiness), service delays due to patient resistance, and time spent receiving the healthcare services. Again, these results reflect the importance of the country variable in the modeling and simulation processes. Patients reported that the following items happened most of the time in the emergency departments: traffic congestion; service delays caused by bystanders, patients, or family members; noisiness and unprofessional behavior at the admission desk or in the registration areas; negative impressions of patients and their family about the admission or registration process; and interference of legal issues and litigation proceedings with the efficiency of the admission process. However, patients reported that the following two factors happened rarely: friendly behavior of the staff at the admission or registration desk and patients left before being seen or receiving healthcare services.

Given that wait time was the main factor affecting the quality of services in the emergency departments, as revealed by patients' responses, a model was developed to help emergency department mangers understand the hidden causes of excessive wait times. This model served as a tool for assessing the impact of major output variables on key performance indicators and was also used as an effective method for testing different scenarios for possible system improvement based on real data collected from the emergency department sites. The quality of the ambulance transfer and emergency department processing simulated data were assured using probability density and bootstrap methods. The multiple regression analysis showed that four variables could predict ambulance operations per minute per week using the ambulance transfer simulated data. These variables were ambulance transfer time from the patient location to the emergency department (minutes), number of successful transfers, number of failed transfers or transfers stuck in traffic, and utilization percentage. No significant differences related to sex were found in the ambulance transfer data; however, there were differences

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in favor of the US with regard to ambulance response time to patient the location (minutes), average number of patients served (patients dropped off), and utilization percentage. On the other hand, the emergency department processing simulated data analysis revealed that it was possible to predict patient door-to-door service time with the average wait time of the patients at admission and time spent in the admission area. Sex differences were found; significant differences in the time spent in the admission area and the total number of patients served favored the males, and significant differences in ED processing time and utilization of the ED favored the females. Finally, there were significant differences in wait time from ED admission to the first contact with a doctor, ED processing time, average wait time of patients at admission, average door-to-door service time, and the total number of patients who remained in the system in favor of Malaysia.

5.6 Conclusion

Simulation models were used to examine the utilization of ED resources in various settings to analyze the average performance of ED systems. It is imperative to conduct additional simulation studies in developing countries in the future. This experiment involved the simulation of practical data with the help of a basic ED model (10%).

This study is the primary and principal ED simulation study in Kingdom of Saudi Arabia and Malaysia. The simulation models represented the exact real-world ED settings and thus offered convenient and clear analyses, which makes them an efficient mathematical model to improve decision-making in emergency departments. In the industrial sector, simulation modeling explains complex systems and offers solutions to significant issues.

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Simulation models are also used to design real-world systems that provide practical views. Hence, it becomes easy to predict the resources required by the actual ED and the performance of the actual ED prior to its deployment. The application of more simulation models has been recommended by ED experts. The results of the current study show a feasible 38.76% reduction in wait time for door-to-door service based on ED layout, available resources, daytime patient ambulance transfers and patient ED processing, and the overall capacity of the emergency departments mid-normal mode in Saudi Arabian healthcare systems.

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CHAPTER 6: CONCLUSION

In this thesis on EDs, the cost is the one factor that stands out. Cost reflects many areas not only in terms of money but also time. The high costs have a negative impact on the use of existing health care by patients, which means that more regulation is expected in this area. Emergency management has several complex factors, which should be used to test a health technology on its quality by way of an objective decision-making process. This analytical system should be frequently updated as simulation processes are critical for the management of physician, personnel, and patient pathways care in hospitals. The ED and the problems that occur are complicated and thus this research is very important. In contrast, some experiments have used mathematical models, although only a few studies have adapted ED structures to mathematical models.

Reassessment of the research objective and answering the research questions was developed in this research regarding the EDs current EDs problem and methods were used, an abstraction one of the data mining processes was used to create momentum on answering these questions. From 2000 to 2019 a table of data extraction was created in Appendix A and furthermore discussion from Ch.3 and Ch.4. answering the research question regarding the optimal way to harness our knowledge and improve EDs was covered in Ch.6. All research objective was achieved. Each chapter cover the objective that was planned to achieve. Current knowledge on the area was fulfilled and satisfied.

Feasibility and focus and effect on focused and definitive results such as professional skills and professional practice [22], lessened the acute in-patient care, was the greater health system savings factor [23]. ED advises the management and preparation of emergency services and provides an insight of the publics' health, the growing

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importance of EDs in the delivery of medical care in complex cases, along with the evolving nature of the disease in the population in need of immediate medical attention [24]. The initiative of $167 million was intended to provide leadership in the implementation of evidence-based clinical practices to the Front-Line Registered Nurses (RN) at the bedside [18]. The cost model and the metrics of this model for EDs are the cost optimization of the process; Value, organizational performance, time, cost assessment, hospital stay and preparation for discharge [19]. A sustainable connection essential to the transformation of the healthcare system [20]. A new health care administration educational environment to help emerging new staff [21] requires more research to verify the researchers ' results. Increased use of care management processes analyzed to influence patient experience and healthcare quality positively [27]. There has been some progress in clinical outcomes and process indicators [28]. Extreme importance of patient satisfaction to guarantee a better care quality [29]. Reducing the variability in the Emergency Department hospital admissions results in savings. For different emergency departments the uniform thresholds of admission to risk are very significant [30]. The goal of generating savings for patients joining services should be to ensure that qualified patients who are involved can be enrolled promptly [31], with both increased service quality and reduced costs. Profile innovation is new tool to provide hospitalist reviews to improve collaboration and patient development. Teamwork is an important competency in the health sector [32]. Patients with short-stay can save $3.1 billion a year [33]. A shift in the process would encourage employees to take up more of their time in direct patient care to achieve optimum performance, thereby reducing the overall cost and the patient's total time in the hospital. Management may have to redistribute resources to improve the quality of operations [34]. The health information exchange (HIE) is thought to increase performance, reduce the cost of healthcare and improve patient satisfaction

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by exchanging electronic information such as laboratory reports, clinical summaries and prescription lists [25]. Public health, hospital system and service management need to consider high-reliability systems of patients requiring zero result defects [26].

The options in this analysis are as follows. Continuous preparation and exercises with detailed data analysis is needed for emergency preparedness programs. The main factors are the people involved, the officials and equipment to be used in emergency situations. The emphasis should be on patient experience, degree of patient satisfaction, productive processes, patient safety and fast response systems. Health care systems are rather weak in developing countries, so it is important to address problems and the demands for emergency health care in hospitals. The implementation uncertainties for activity-based funding also need to be handled.

To maintain informed decision-making and an efficacious handling of emergencies in regular or emergency circumstances with reduced and managed crowding, it is important to manage EDs and give personnel information of the ED policy, structure, power, network, etc. Analyses and use of the correct technique to execute emergency procedures is successful. Researchers need to analyze the current scenario and the work holes for ED simulation modelling [35]. Case studies for multi-label health care personnel should be undertaken to recognize skills and abilities in the workforce [36]. In order to ensure command in EDs [39] EDs need leadership inside management [37].

Quality standards in hospitals must be revised with Ch.4 and Ch.5, characteristics and observations into the research subject to be undertaken in the emergency and risk management field in the future [40]. Based on the findings of this report the following approaches are recommended: Emergency preparedness programs and comprehensive information analyses require ongoing training and simulations. It continues to be a challenge to Evidence based Practice in EDs and their effective and efficient participation

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in medical and administrative leadership. It is necessary to use a scientific classification-based structure, framework, process and results to identify existing barriers to DES. The operation of EDs and the processes involved should be overseen by an experienced management team with knowledge, skill and experience in improving quality, modelling, simulation and process reengineering. Instead of handling tasks and procedures in the healthcare system, especially for EDs, a greater number of doctors should thus remain just doctors. For this reason, it is important that technicians with a history in six-sigma and quality assurance be included in the leadership team in order to oversee health care workers and their facilities. The terms are listed in this report as components of EDs, ED organizational leadership, staff competencies and expertise, emergency preparedness, technology performance and use and simulation of education, even though ED is the whole term and describes the ranking tree by each definition. Health systems are severely deprived of medical services in developing countries; hence it is important to address the remaining issues and to meet the essential healthcare requirements for the hospital. There must also be control of the risk of introduction of activity-based financing.

Primary and secondary evidence must be collected by interviews, polls, literature reviews and analysis at both medical and national level by the managers. Data should be interpreted and processed by the EDs operational managers by meta-analysis or EDS plus PLS and should be able to highlight similarities, disparities and deficiencies of waiting time, registration process, costs, visits to patients, and other aspects. Ultimately, the problems faced by ED can be overcome when service risks are adequately tracked and handled, and patient information is properly recorded. In particular, ED administrators are required to prevent overpopulation and prolonged waits by monitoring patient stays and using their staff's skills and expertise.

If the administrator prevents conclusions, provisional inference, data collecting with a single phase and selection of the meta-analysis for the primary data-analysis, data collection from a specific data source or costing method and information tracking mistakes, such as in the case of self-reporting patients, the quality of the health services can also be assured. In order to analyze factors such as waiting time, patient registration, costs, number of visits and others, the director is required to conduct interviews, assessments, research reviews and meta-analysis, and to identify the comparisons, various types of analysis and the median discrepancies. The ED manager must be mindful of the standard of health services, treatment costs, service times, patient satisfaction, and duration of stay, quality of ED performance, healthcare access, patient admission, and demographics.

6.1 Future Research Directions

The successful application of real-time analysis of information in EDs and quality evaluation in emergency systems should be focused in future research. The implications of this work can be used to improve healthcare standards. The work on crises and risk management that should be carried out in future is addressed in chapters 4 and 5.

In comparison, emergency response, patient satisfaction, waiting time and hospital-based overcrowding; issues, challenges and strategies will be identified in upcoming regional organizational research studies along with national healthcare skills and competencies. The findings must be treated as true and confirmed. The feasibility of real time data collection, quality assessment of emergency systems, organizational control, process reengineering and the use of modelling in EDs should also be the subject of future research.

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Research on the performance of emergency systems and ensuring that practices are continued to collect patient data in EDs in real time are required for the hour. Studies are needed to assess the quality of emergency departments with respect to the demographic characteristics of patients, patient movement through an ambulance and ED time in order to carry out clinical criteria as well as ED time simulator management tests. When undertaking multi-label research, the skills and talents of the personnel involved in health care can be found out [2]. To order to facilitate smooth operations within EDs, emergency departments require management [3] which gives leadership [2] to the followers. ED management must ensure better and revised quality of care and services over time [3].

6.2 Research Recommendations

This thesis has its general research recommendations and specifics as shown in the following:

- Effective E-Systems, ERP systems or standard governmental databases (i.e. healthcare databases) possess great capability may provide for the more effective decision-making process (Almozayen et.al, 2017, etc.).
- Services should concentrate on ensuring that qualified patients are timely registered (Kelley et al, 2013).
- Additional research to verify the findings of the researchers is needed. Facility and priority and the influence of the associated interventions on desired and established performance like professional competence and professional practice (Skinner et.al 2015).
- Quality standards for health care, regulations, architecture, efficiency, network, etc., must be revised (Alharethi et.al, 2019).

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- The main factors are people, agencies and emergency management equipment and the focus should be on the experience of patients, rates of engagement, effective procedures, patient safety and quick response programs. The activity of EDs and the associated systems should be managed by a professional project management team with expertise, skills and know how to improve quality, design, simulate and reengineer (Zayed et.al, 2018).
- System for training advancement of the emerging new health services administration workforce (Harding et.al, 2017)
- Reducing variance in the Emergency Department's hospital admissions (Sabbatini et.al, 2014).
- Analyzed procedures to have a positive impact on patient experience and healthcare quality (Wiley et.al 2015).
- Leadership has to reallocate resources and increase the efficiency of operations (Merkle et.al, 2002).
- Extreme flexibility in achieving better quality of care for patients (Stock et.al, 2014).
- New tool for providing feedback on better inter-professional collaboration and patient care to hospitalists. Health care role in communities is critical (Chesluk et.al, 2012).

Other specific recommendations that EDs surroundings within the healthcare is quite complex and the amount of data generated is complex too therefore, a data mining technique is essential to analyze and draw conclusions. Furthermore, considerations to Quality Care; Management (Patient Record) along with continues quality Improvement tools: “Lean Six Sigma” and eHealth: “Admission-Discharged Process” are highly

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important to improve quality care and beneficiary to healthcare systems in short- and long-term strategy planning.

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