Emergency Departments
A Systematic Mapping Review

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Abstract—Emergency services are essential and any person may require these services at some point in their lives. Emergency services are run by complex management and consist of many different parts. It is essential to establish effective procedures to ensure that patients are treated in a timely fashion. By obtaining real-time information, it is expected that intelligent decisions would be made. Hence, thorough analytics of problems concerning appropriate operational effective management would help prevent patient dissatisfaction in the future. Mapping studies are utilized to configure and explore a research theme, whereas systematic reviews are utilized to combine proofs. The use of improvement strategies and quality measurements of the health care industry, specifically in emergency departments, are essential to value patients’ level of satisfaction and the quality of the service provided based on patients’ experience. This paper explores and creates momentum with all the methodologies utilized by researchers from 2010 and beyond with the stress on patient fulfillment in the emergency services segment.

Keywords—Emergency; system; health care; emergency preparedness; systematic mapping

I. INTRODUCTION

Scoping studies [1], [5] through taxonomy and input involve searching existing literature to identify certain similarities between search methods and paper collection. Emergency services or Emergency Departments (EDs) manage various types of severe emergencies through acute out-of-hospital medical care. For the assessment of health technology, it is essential to include a decision-analytic model. This technological analysis needs to be updated at hospitals, as modeling methods are required to manage interactions between patients and EDs staff as well as patient care pathways. System analyses are also required due to the complex nature of EDs and the various issues experienced with them. Various studies exist on mathematical models in health care, but these do not include mathematical models in EDs even though such models are vital to reduce the long waiting periods experienced in EDs.

A. Study Motivation

Defining the motivation for research and its processes is essential. Responsive bounding in collaboration and inventive problem solving allows researchers to take competitive action and approaches. Saudi Vision 2030 focuses on economic diversification to achieve national goals by valuing performance and measuring sustainable action through Saudi Vision 2030’s governance model. One of Saudi Vision 2030’s main goals are to implement “efficient and high-quality health care” to improve the quality of health care services by increasing the effectiveness and output of care and boosting the accessibility of health care services to citizens. Improved ED systems allow for the amplification of resources utilization, assets, and economic stability, all of which have long-lasting effects.

B. Knowledge Gap

The topics studied were classified based on EDs mapping for 381860 articles from 1864-2017. Same research methodology used early this year in [32]. All EDs activity was well represented in results. The main problems and methods of EDs were classified looking for a theme. Gaps were found in the health care industry, emergency preparedness, quality of health care, performance measurement, and others, as shown in research questions answers: RQ2, RQ3 and RQ6.

II. BACKGROUND

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

Overcrowding can occur in EDs if waiting periods are long, and this may increase patient mortality risks. In addition, patients may leave without being checked, resulting in them readmitting to EDs again. Organizational, physical, and human factors must be considered in EDs patient and environments’. For instance, management systems, equipment, buildings, patient’s real time information, and their relatives must also be considered. Basic requirements include waiting areas and spaces avoiding overcapacity on hazardous time. The following order is used to deal with patients: registration, triage, examination, X-rays and Blood tests, evaluation, pharmacy, EDs bed location and EDs staff, handling, allocation, and discharging.
ED wait times may be long due to overcrowding. In addition, demand might not meet capacity, the number of beds might be insufficient, capacity management might be suboptimal, and patient acuity and service demand may vary [2]. From 2000–2009 [2], the discrete-event simulation method was the most common method used in EDs, especially in United Kingdom health care system. To a minor degree, system dynamics has also been used to improve wait times in EDs (see Fig. 1).

**Fig. 1.** Methods used to solve EDs problems from 2000–2009.

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

The Simulation software aims to address prevention-related issues, reduce wait times, and predict variables related to disaster situations in EDs. The simulation model identifies issue that occur in real situations, including those pertaining patient flow, arrival patterns, and the infrequent extraction of optimal resources in emergency response domains. The sources used for gathering data include direct sampling, historic data, hospital databases, and observation. Simulation method applied to enhance resources and reduce wait times by implementing a cost analysis and introducing strategic policies [7].

### III. METHODOLOGY

The information is taken from recent updates to suggest and guide. Mapping a system is only used as a starting point to evaluate existing studies by subject and classify them in order to conduct a thematic evaluation. This systematic study comprehensively details previous research. A systematic mapping study is used to summarize a research area and detect research gaps. Up-to-date sources are used for this study. Systematic mapping is a preliminary study that allows researchers to review papers related to a certain theme [3] and classify research, conduct a thematic evaluation. The systematic review process characterizes and summarizes existing research following a predefined protocol [4]. Therefore, offering an indication of a research field and distinguishing study gaps are the key targets of a mapping study.

**A. Research Questions**

The intelligence of this study, the monitoring strategies used in [1], [3]-[6], [8] and [32] were used to define the problems in EDs. The following research questions (RQs) were addressed:

- **RQ1:** Which techniques are used in EDs research?
- **RQ2:** Which topics are introduced in EDs research?
- **RQ3:** When and where were studies published?
- **RQ4:** How do studies visualize their results?
- **RQ5:** What problems were addressed in existing studies?
- **RQ6:** How are studies classified?

The management of our research area is performed through mapping studies. RQs in this research area are developed to meet aims systematically. Our aims for this systematic mapping study are a) to obtain a general idea of issues that require addressing in EDs, and b) to review the approaches used in existing research.

**B. Search for Primary Studies**

The search was conducted in the following databases resulting in: ABI/INFORM [9]-[10], Emerald [15]-[16], IEEE Xplore [17]-[21], and ProQuest Dissertations and Theses Global [22]-[27]. These were chosen because they are comprehensive databases containing millions of publications, especially on EDs, engineering and computer science. Moreover, these databases are user friendly and have advanced search features.

The identified keywords were as follows: *Emergency department, emergency medical care, emergency clinics*, and *methods*. These 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 the string (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 these sets. Each set was identified in the databases, and each search string can be found in (Table 1). This study was systematized based on the date it was conducted: early 2017, late 2016. (Table 2) shows the number of search results per database.

**TABLE I. DATABASE SEARCHES**

<table>
<thead>
<tr>
<th>Database</th>
<th>Command Search</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABI/INFORM</td>
<td>(&quot;emergency department&quot; or &quot;emergency medical care&quot; or &quot;emergency clinics&quot;) and (&quot;methods&quot;)</td>
</tr>
<tr>
<td>Emerald</td>
<td>(&quot;emergency department&quot; or &quot;emergency medical care&quot; or &quot;emergency clinics&quot;) and (&quot;methods&quot;)</td>
</tr>
<tr>
<td>IEEE Xplore</td>
<td>(&quot;emergency department&quot; or &quot;emergency medical care&quot; or &quot;emergency clinics&quot;) and (&quot;methods&quot;)</td>
</tr>
<tr>
<td>ProQuest Dissertations</td>
<td>(&quot;emergency department&quot; or &quot;emergency medical care&quot; or &quot;emergency clinics&quot;) and (&quot;methods&quot;)</td>
</tr>
</tbody>
</table>

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TABLE II. NUMBER OF STUDIES PER DATABASE

<table>
<thead>
<tr>
<th>Database</th>
<th>Search Results</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABI/INFORM</td>
<td>103,025</td>
<td>1864–2017</td>
</tr>
<tr>
<td>Emerald</td>
<td>12,313</td>
<td>1898–2017</td>
</tr>
<tr>
<td>IEEE Xplore</td>
<td>891</td>
<td>1924–2016</td>
</tr>
<tr>
<td>ProQuest Dissertations &amp; Theses Global</td>
<td>265,631</td>
<td>1897–2017</td>
</tr>
</tbody>
</table>

C. Study Selection

We ignored items based on several database features, as shown in Fig. 2. Quality assessment was based on an article’s citations at first place; articles without citations were excluded in some cases. The following inclusion criteria were considered: studies focused on the research methods for 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 not reviewed, studies duplicating other work, and non-English studies. The numbers of included and excluded articles in search process for database are given in Fig. 2 and final selected content in Table 4.

D. Data Extraction

The extracted data form used the modified template given in [32], which was updated to suit this study, as shown in Table 3. Each data area includes the item and value. Data extraction was completed by the first author and reviewed by second and third authors for validity and quality control.

TABLE III. ADAPTED DATA EXTRACTION TABLE

<table>
<thead>
<tr>
<th>Item</th>
<th>RQ Result</th>
<th>RQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study ID</td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td>Author Name</td>
<td>Name(s)</td>
<td></td>
</tr>
<tr>
<td>Year of Publication</td>
<td>Calendar year</td>
<td>RQ3</td>
</tr>
<tr>
<td>EDs Area</td>
<td>Knowledge area in EDs</td>
<td>RQ2, RQ6</td>
</tr>
<tr>
<td>Venue</td>
<td>Journal name</td>
<td>RQ3</td>
</tr>
<tr>
<td>Method</td>
<td>Method used</td>
<td>RQ1</td>
</tr>
<tr>
<td>Problem</td>
<td>Problem identified</td>
<td>RQ5</td>
</tr>
<tr>
<td>Visualization type</td>
<td>Style of presentation</td>
<td>RQ4</td>
</tr>
</tbody>
</table>

E. Validation and Verification

The data collected has strong degree of objectivity. This kind of validity is exposed to less risk than data obtained from quantitative analysis. To shrink this risk, data compilation table was adapted to back the documented data; the table used in Data mining [32] to allow for reexamination. Data collection table are used to document data and reduce risk. Further, data extraction can be rechecked, which also reduces risk. In this study, two different authors took these steps independently; when a common understanding is accomplished, risk to validity decreases [3]. In this study, the information gathered was accurate and objective thus, risk was limited [1]-[8].

IV. RESULTS

Several publications were identified and reviewed between 2010 and 2017 in each database. For more details see Table 4. Other related data are given below to answer the RQs after Table 4 in Sections A,B,C,D,E and F.

A. RQ1: Which Techniques are used in ED Research?

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

B. RQ2: Which Topics are Introduced in EDs?

The topics screened were categorized based on EDs research topics. All EDs activities are well presented. The main problems in EDs and the methods used to study them are covered by mapping [9]-[27], and they are not influenced by a specific topic. Thus, research gaps were found in emergency preparedness, health care quality, patient satisfaction, performance measurement, and health care industry, as shown in Fig. 3 and 4.

C. RQ3: When and where were studies published?

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

In this study, only peer-reviewed journals, conferences, and materials were included to answer this question. Fig. 4 to 6 provides an overview of articles included targeted venues. Engineering, simulation, and process management only account for 2% of the total studies on EDs between 2010 and 2016.

Fig. 2. Study selection process.
<table>
<thead>
<tr>
<th>ID</th>
<th>Author Name</th>
<th>Year</th>
<th>Area in EDs</th>
<th>Venue</th>
<th>Method</th>
<th>Problem</th>
<th>Visualization Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Allnutt et al</td>
<td>2010</td>
<td>Skills and Competencies</td>
<td>Australian Health Review</td>
<td>Survey conducted as part of quantitative research using an information sheet and consent forms sent through email</td>
<td>Assessment of nurse practitioner’s role as observed by a client along with their satisfaction with their nurse practitioner’s education, care, skill, and knowledge.</td>
<td>Tables</td>
</tr>
<tr>
<td>2</td>
<td>Fulop</td>
<td>2012</td>
<td>Skills and Competencies</td>
<td>Journal of Health Organization and Management</td>
<td>Qualitative research with interactive interviews to present accounts of how health care professionals describe leadership</td>
<td>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</td>
<td>Tables</td>
</tr>
<tr>
<td>3</td>
<td>Hanson</td>
<td>2011</td>
<td>Quality</td>
<td>Australian Health Review</td>
<td>Qualitative research using a literature review</td>
<td>Demonstrated that health care centers need a structured strategy to enhance data quality and create a robust information culture that harnesses health information</td>
<td>Process map</td>
</tr>
<tr>
<td>4</td>
<td>Morgans and Burgess</td>
<td>2012</td>
<td>Emergency Department or Ambulance Utilization</td>
<td>Australian Health Review</td>
<td>Qualitative research using a comprehensive literature review</td>
<td>Defined and measured inappropriate emergency health service use in Australia</td>
<td>Text: Percentages and classification</td>
</tr>
<tr>
<td>5</td>
<td>Rosenberg and Hickie</td>
<td>2013</td>
<td>Skills and Competencies</td>
<td>Australian Health Review</td>
<td>Qualitative research using a review</td>
<td>Provided an ideal approach to community and home mental care</td>
<td>Text: Percentages and classification</td>
</tr>
<tr>
<td>6</td>
<td>Scott</td>
<td>2010</td>
<td>Management</td>
<td>Australian Health Review</td>
<td>Qualitative research on planning, hospital discharge, patient discharge, and discharge processes to conduct a systematic meta-review of controlled trials</td>
<td>Determined the relative efficacy of pre-discharge interventions to reduce post-discharge problems in adults</td>
<td>Tables and Text: Percentages and classification</td>
</tr>
<tr>
<td>7</td>
<td>Lantz and Rosén</td>
<td>2014</td>
<td>Management</td>
<td>Health Organization and Management</td>
<td>Queueing theory to study the time of arrival, exact time of triage, and total number of patients and arrival rates and system capacity measures and derive average queuing times and the theoretical relation between them.</td>
<td>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</td>
<td>Mathematical equations and figures (graph), tables</td>
</tr>
<tr>
<td>8</td>
<td>Buttigieg et al.</td>
<td>2016</td>
<td>Quality: Process reengineering</td>
<td>Journal of Health Organization and Management</td>
<td>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</td>
<td>Determined the root causes of quality issues specific to the three settings; objective trees were formed to suggest solutions to these quality issues</td>
<td>Tables, figures, charts</td>
</tr>
<tr>
<td>9</td>
<td>Esfahani et al. 1</td>
<td>2016</td>
<td>Quality: Engineering</td>
<td>38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society</td>
<td>Segmentation methods, neural network/deep learning, and convolutional neural networks classified into three groups as tracking-, model-, and filter-based</td>
<td>Described vessel segmentation to ensure that the images obtained are of high quality by reducing their noise and enhancing their contrast</td>
<td>Figures, tables, mathematical equations</td>
</tr>
<tr>
<td>10</td>
<td>Esfahani et al. 2</td>
<td>2016</td>
<td>Quality: Engineering</td>
<td>38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society</td>
<td>Neural network, deep learning methods</td>
<td>Proposed a method to enhance the detection of melanoma through an analysis of enhanced images</td>
<td>Figures, tables, mathematical equations</td>
</tr>
<tr>
<td>11</td>
<td>Jafari et al</td>
<td>2016</td>
<td>Quality: Engineering</td>
<td>38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society</td>
<td>Algorithms for digital image magnification of details and extraction features to detect surfaces</td>
<td>Proposed an efficient pre-screening mechanism for pigmented skin lesions</td>
<td>Graphs, figures, mathematical equations</td>
</tr>
<tr>
<td>12</td>
<td>Jamali et al</td>
<td>2016</td>
<td>Utilization</td>
<td>38th Annual</td>
<td>Experimental use of the robust</td>
<td>Proposed a robust watermarking</td>
<td>Graphs, figures,</td>
</tr>
<tr>
<td>ID</td>
<td>Author(s)</td>
<td>Year</td>
<td>Area of Knowledge in EDs</td>
<td>Venue of Publication</td>
<td>Method</td>
<td>Problem</td>
<td>Visualization Type</td>
</tr>
<tr>
<td>----</td>
<td>-------------------</td>
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<td>-------------------------------------------</td>
<td>------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>15</td>
<td>Donnelly</td>
<td>2013</td>
<td>Management</td>
<td>Queen’s University Ph.D. Thesis</td>
<td>Multiple-method case study of systematic, scientific, systematic, and empirical knowledge</td>
<td>Co-produced knowledge about a complex problem</td>
<td>Tables, graphs</td>
</tr>
<tr>
<td>16</td>
<td>Gautam</td>
<td>2000</td>
<td>Management</td>
<td>Southern Illinois University Ph.D. Thesis</td>
<td>Quantitative, cross-sectional, descriptive, correlational survey</td>
<td>Determined health beliefs and knowledge to determine the factors that predict demographic variables</td>
<td>Tables</td>
</tr>
<tr>
<td>17</td>
<td>Nikolai</td>
<td>2014</td>
<td>Emergency Preparedness: Disaster Response</td>
<td>University of Notre Dame Ph.D. Thesis</td>
<td>Mixed-method study using quantitative research to observe, collect, and analyze key documents including past situation reports, after action reports, and exercise documents and qualitative research to classify informal and formal interviews with emergency managers</td>
<td>Coordinated new forms of collective action to solve critical problems in crises at a specific time for a specific purpose to prioritize recommendations</td>
<td>Tables, charts</td>
</tr>
<tr>
<td>18</td>
<td>Cheung</td>
<td>2011</td>
<td>Utilization Geometric Optimization</td>
<td>The University of Texas at Dallas</td>
<td>Algorithm to simulate the process</td>
<td>Proposed a method to simplify problems and allow for their observation at different angles to find the shortest path to the solution with the fewest amount of obstacles</td>
<td>Figures, mathematical equations</td>
</tr>
<tr>
<td>19</td>
<td>Pandit</td>
<td>2013</td>
<td>Utilization: Resource Allocation</td>
<td>The University of California</td>
<td>Experimental use of Webster’s algorithm, real-time optimization methods, multi-user resource allocation (content-aware networking), adaptive Webster’s method, and simulation methodology</td>
<td>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</td>
<td>Graphs, figures, mathematical equations</td>
</tr>
</tbody>
</table>

Fig. 3. Subjects with a research gap in performance measurement.

Fig. 4. Overview of topics with research gaps in emergency preparedness and health care quality.
D. RQ4: How do Studies Visualize their Results?

In this study, the visualization approaches of previous studies were identified (see Table 4). Most commonly, figures or graphs and tables are used to visualize data.

E. RQ5: What Problems were Addressed in Existing Studies?

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 4 and Fig. 3, 4 and 8.

F. RQ6: How are Studies Classified?

Classification of content in Fig. 7 as scanned but Fig. 8 is systematic cluster we built through taxonomy of our content extracted from Table 4. That is, Skills and Competencies, Management, Quality, Emergency Preparedness, and Utilization of EDs. Furthermore, classification of scanned content showed that the review type papers were rare. Thus, systematic mapping and systematic review papers are appropriate to be conducted.

V. Conclusion

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.

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.

VI. FUTURE WORK

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

REFERENCES


