OPTIMAL DESIGN OF EMERGENCY DEPARTMENT UNDER MASS DISASTER

By

Eng. Ahmed Mohammed Ali Ibrahim Abou-Alam

Systems and Biomedical Engineering Department
Faculty of Engineering, Cairo University

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
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Under the Supervision of

Prof. Dr. Bassel Tawfiq
Thesis Advisor
Systems and Biomedical Engineering Department,
Faculty of Engineering, Cairo University, EGYPT

Dr. Bassem Ouda
Thesis Advisor
Systems and Biomedical Engineering Department,
Faculty of Engineering, Cairo University, EGYPT

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Approved by the Examining Committee:

Prof. Dr. Bassel Tawfiq, Thesis Advisor

Ass. Prof. Dr. Hossam El-Deen Abou-bakr, Member

Ass. Prof. Dr. Manal Abul-Wahed, Member

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ABSTRACT

Motivation: Disability of emergency department (ED) to provide high quality medical treatment to a huge number of victims in disaster situation leads to high mortality rate is the main motivation for this study. Such an increase in the number of patients creates overcrowding, forcing the patient to have to wait long times for treatment. Prolonged patient waiting times lead to death, permanent disability, or long treatment duration.

In recent years, there have been numerous publications proposing solutions for ED overcrowding published by recognized professional organizations. In 1995, the world health organization (WHO) issued a publication illustrates the guiding principles for triage in the disaster site. National Health Service (NHS) and Australasian College for Emergency Medicine (ACEM) provided guidelines in complete constituent spaces of the emergency department, in 2003 and 2007 in order. In 2008, Erik M. W. Kolb and others presented a new construction called “Patients Buffer” which is more efficiently organized waiting periods for patients in the ED during overcrowding. The main objective of this study is making an ED design reduces the overcrowding as possible.

This study has two targets; the first is to construct an ED design in a flexible manner commensurate with the possibilities of the hospital, reduces overcrowding and achieves the speed of movement within the ED during disaster. This is by using Computerized Relationship Layout Planning (CORELAP) Algorithm which maximizes closeness between ED spaces and each other to reach the design for the maximum optimality. The second is to improve the performance of an existing design. Using simulation software to help demonstrate, predict, and measure system strategies for efficient and optimized performance. Simulation software improves the ED performance by analyzing the impact of new ideas, rules, and strategies before implementation on live entities, without causing disruptions in ED service and without cost of experimentation.

The results are tow layouts; the first shows a new construction layout design for ED in a manner conducive to overcoming the overcrowding consequences as possible, and the second is improved layout decreases the patient’s waiting time to receive treatment by 82%. Finally, we are not claiming that this is the best design for ED, but we can consider it as a step on the road towards better ED design.
Chapter One

INTRODUCTION

1.1. Disasters

There is a range of impacts a community can experience that increase in severity along a continuous scale. As the seriousness increases these mishaps become emergencies that involve more people, as victims and as responders. Finding the threshold between emergencies and disasters depends on the ability of the community to deal with the event.

Every community has some coping resources to deal with accidents and emergencies. Coping resources are the individual and community skills, materials, equipment or services that can be used to meet the demands created by an incident.

The health care sector forms an important part of coping resources, from the self-administered treatments available at a pharmacy or a walk-in clinic, through the emergency medical services and hospital emergency departments, to the special care provided by other tertiary healthcare services [1].

Other coping resources can include municipal departments, emergency services, private companies, volunteers and other formal or informal sources. However, these resources may be very limited and not capable of meeting all the demands created by a larger scale hazard impact.

Disasters occur when an impact exceeds the community’s normal coping resources. Disasters require communities to take extraordinary measures to apply resources effectively and to gain access to additional resources to prevent or limit further damage.

The way of understanding disasters can also mean that the same event, for instance the same depth of snowfall, may be a disaster for one community but not for another, better prepared community [1].
For operational purposes, the World Health Organization defines a disaster as a sudden ecological phenomenon of sufficient magnitude to require external assistance. Another operational definition says that a disaster is any event that causes destruction and distress resulting in demands that exceed the response capacity of the affected community.

Depending on their nature, disasters are classified as: Natural disasters, or Man-made disasters [2].

**NATURAL DISASTERS**

These can be divided into
- a) Tectonic: Earthquakes, tsunamis, and volcanic eruptions.
- b) Meteorological: Hurricanes, droughts, and floods.
- c) Topological: Avalanches and landslides.

**MAN-MADE DISASTERS**

There is no uniform classification for this category. Based on the nature and the effect, these disasters can be divided into:
- Chemical contamination.
- Mass intoxication.
- Fire.
- Mass accidents.
- Wars and Explosions.

Disasters results in death or injury to humans, and damage or loss of valuable good, such as buildings, communication systems, agricultural land, forest, natural environment, etc. Healthcare delivery system has to provide
medical facilities to a large number of patients [2]. Health Sector management plays an important role in reducing mortalities.

Whilst there is natural overlapping in the different types of health care, the distinctions between Primary, Secondary and Tertiary Health Care are very important to properly understand the role and necessity for health services provider. Where there are detectable breakdowns in health service delivery, failure to grasp the importance of each level of health care can usually be seen as the causative factor [3].

**Primary health care**, a basic level of health care that includes programs directed at the promotion of health, early diagnosis of disease or disability, and prevention of disease. Primary health care is provided in an ambulatory facility to limited numbers of people, often those living in a particular geographic area. It includes continuing health care, as provided by a family nurse practitioner [4].

**Secondary health care**, an intermediate level of health care that includes diagnosis and treatment, performed in a hospital having specialized equipment and laboratory facilities [5]. **Secondary care** is the service provided by medical specialists who generally do not have first contact with patients [6].

**Tertiary health care**, a specialized, highly technical level of health care that includes diagnosis and treatment of disease and disability, specialized intensive care units, advanced diagnostic support services and highly specialized personnel are usually characteristic of tertiary health care. It offers highly centralized care to the population of a large region [7]. It is usually on referral from primary or secondary medical care personnel [8]. Tertiary health care sector includes emergency departments.

A disaster situation for a healthcare facility occurs when the need for medical treatment overwhelms the actual treatment capacity. A disaster situation may also be defined as the point of using normal standard operating procedures is useless [9].

1.2. Overview on Emergency Department

Healthcare is a rapidly developing industry that faces many challenges. The main issue in the healthcare is characterized by patient waiting time in emergency department. An **Emergency Department (ED)**, also known as Accident & Emergency (A&E), Emergency Room (ER), Emergency Ward (EW), or Casualty Department is a medical treatment facility, specializing in acute care of patients who present without prior appointment, either by their own means or by ambulance. The ED is one of the few systems where seconds
can be critical to the patient’s life. The ED operates around the clock and receives different number of patients with various symptoms and degrees of severity.

ED is a vital element for any hospital, providing a wide variety of medical services around the clock. Typically, an ED is designed to provide high quality medical treatment, with the immediate availability of critical resources to the patients in need of urgent care. However, it has been observed that patients often rely on the ED for minor health problems [10].

Hospital Emergency Department (ED) offer a wide variety of medical care including prompt attention to critically ill patients, delivering rapid care for less urgent patients, and the treatment of injuries from trauma incidents. The primary role of the ED is the treatment of patients who are critically ill or injured. However, the ED provides care to a significant number of non-critical patients often due to the lack of capacity for their care in other parts of hospital. The ED also serves as the referral site for other providers to evaluate and stabilize patients and admit them, when necessary [10].

The ED is a core clinical unit of a hospital, its function is to receive, triage, stabilize and provide emergency management to patients who present with a wide variety of critical, urgent and semi urgent conditions whether self or otherwise referred. The ED also provides for the reception and management of disaster patients as part of its role within the disaster plan of each region.

In addition to clinical areas, emergency departments require facilities for the following essential functions:

- Teaching
- Research
- Administration
- Staff amenities

Hospital-based emergency departments (EDs) have evolved during the recent years to provide not only acute emergency care but also safety net care for indigent patients, public health surveillance, disaster preparedness, observation and procedural care, and in many cases, primary health care. Despite these expanding services, ED resources, including the overall number of ED facilities, beds within those facilities, and funding, have not increased commensurately. As a result, ED overcrowding is occurred.
ED overcrowding is a common medical care issue in the countries. One of major causes of ED overcrowding are holding patients waiting in the ED for inpatient unit admission where they block critical ED resources [12]. Acute illness and traumatic injuries happen at any time; often an ED is the only source of emergency medical care. Unfortunately, many EDs around the world are crowded on a daily basis. Sometimes an ED stay can last up to eight hours because of ED crowding. This problem has been recognized since the early 1990s.

Overcrowding has dramatic consequences, although an ambulance with a patient is indeed near a particular hospital, it may have to be diverted to a hospital far away, because the initial ED was full. This is called “diversion status” of the overcrowded hospital. Frequently, hospitals in an area go on diversion status simultaneously. This leads to higher mortality rates for those diverted patients [12].

1.3. Emergency Department Patients Classification

There are many emergency patients classification according to countries variation. The most urgent clinical feature identified determines the ATS category (Australasian Triage Scale). Once a high-risk feature is identified, a response commensurate with the urgency of that feature should be initiated [13].

<table>
<thead>
<tr>
<th>AUSTRALIAN TRIAGE SCALE CATEGORY</th>
<th>(Maximum waiting time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATS 1 Patients in need of immediate treatment for preservation of life.</td>
<td>Immediate</td>
</tr>
<tr>
<td>ATS 2 Seriously ill or injured patients whose lives are not immediate danger.</td>
<td>10 minutes</td>
</tr>
<tr>
<td>ATS 3 Patients with serious problems, but apparently stable condition.</td>
<td>30 minutes</td>
</tr>
<tr>
<td>ATS 4 Standard cases without immediate danger or distress.</td>
<td>60 minutes</td>
</tr>
<tr>
<td>ATS 5 Patients whose conditions are not true accidents or emergencies.</td>
<td>120 minutes</td>
</tr>
</tbody>
</table>

1.4. The Patients’ Journey

In designing new ED facility it is essential to understand the journey the patient makes through the department. This will vary depending on the means of arrival, the clinical condition, and whether the patient is an adult or a child [14].
The patients arrive at the ED through a variety of modes. Figure 1.2 shows the distribution of patients arriving via these modes. Historical data shows that approximately 70% of the patients arrive to the ED as walk-in patients, 25% of patient arrivals arrive via ambulance, and the remaining patients arrive by wheel chair, carried, escorted by police, or by helicopter [10].

![Figure 1.2 Modes of arrival of patients [10]](image)

Patients arriving by ambulance are immediately admitted to a bed upon their arrival. However, ambulatory patients can go through the triage process, if their medical condition is not critical. When patients arrive on foot or by public or private transport Figure 1.3:

- A patient will arrive at the main entrance to the emergency department.

- From there they will go to the reception/triage area where they will be greeted. Assessment and first aid are provided in the reception/triage area [11], and either directed to an assessment room/fast track, or asked to wait a short time before being called to the next available assessment room. In most cases, a small number of patients will need to be transferred immediately to the treatment or resuscitation room, and the others are discharged [14].

- Registration, assessment, examination, and minor treatment if appropriate, will take place in the assessment room. Tests will not take place here. The majority of patients are fit to be discharged at this stage.

- Other patients will be taken to a treatment room for tests, more extensive clinical examination and treatment.
• some patients may be moved to the clinical decision unit/observation unit (for a number of hours depending on local decision). In some instances they may be admitted directly to an acute ward [14].

When patients arrive by ambulance Figure 1.4:
• Patients arriving by ambulance who require a stretcher will normally be taken to the treatment room or if necessary to the resuscitation room directly.

1.5. Problem Definition

Disability of ED to provide high quality medical treatment to a huge number of victims in disaster situation leads to high mortality rate is the main motivation for this study. Such an increase in the number of patients creates overcrowding, forcing the patient to have to wait long times for treatment. Prolonged patient waiting times lead to death, permanent disability, or long treatment duration.

Overcrowding in ED is one of the most important issues facing hospitals nationwide. The ED is primarily affected because it is a public service that is free and always available for everyone, independently of the social and economic status of the patient [25]. Health professionals staffing ED of public hospitals complain of deteriorating working conditions due to overcrowding, it appears to be an unavoidable national problem with a regular occurrence, sometimes daily [26].

ED overcrowding affects the quality of healthcare and patient satisfaction, the major cause of ED overcrowding are holding patients waiting in the emergency department where they block critical ED resources, under mass disaster when inpatient is much more than normal conditions [15].

Overcrowding takes place if both of the following conditions apply when 100% of ED beds are utilized and, if the number of patient waiting for treatment is more than 50% of ED beds [12]. Three general themes existed among the causes of ED crowding: input factors, throughput factors, and output factors, figure 1.6. These themes correspond to a conceptual framework for studying ED crowding. Input factors reflected sources and aspects of patient inflow. Throughput factors reflected bottlenecks within the ED. Output factors
reflected bottlenecks in other parts of the health care system that might affect the ED.

Figure 1.3 Ambulatory patient journey [14]