DEVELOPMENT OF TRAUMA MANAGEMENT INTEGRATION SYSTEM FOR SAUDI ARABIAN HEALTH ORGANISATIONS

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Background:

According to King Abdullah International Medical Research Center in Saudi Arabia, Trauma sources tremendous suffering, not only leading to loss of life but also leaving people temporarily or permanently disabled. It also drains resources and leads to major economic loss. Due to the nature of trauma, the results of trauma can be modified by following certain systems, e.g., the internationally known Trauma System. The trauma registry shows that only 43% of admitted trauma patients were injured in motor vehicle accidents. The trauma mortality rate at Kingdom of Saudi Arabia is approximately 23,000 deaths per year. Trauma Patients 5000-6000 die annually from Recorded Trauma Accident (RTA). Police only calculated people who die at scene or on arrival to E.R. who up to a month death is related trauma. It has been calculated that immediately mortality from trauma is 48% make total mortality form car accidents 12,500 death/year. RTA is 43% then total trauma mortality will be 24,000-29,000. The Advanced Trauma Life Support (ATLS) program and the American College of Surgeons (ACS) showed that each trauma-induced mortality there are 3 permanently disabled and 20 temporarily disabled individuals, putting the annual number of permanently disabled individuals in Saudi Arabia at about 79,000. Much work is needed to develop accurate statistics for reference in planning and prevention programs. Furthermore, because we have one of the highest rates of trauma related mortality per 100,000 populations, we need to study the viability of applying the Trauma System in Saudi Arabia (KAIMRC, 2009). This research will focus on development trauma management to improve health care outcomes through engineering analysis.

Objectives: The purpose of this research is to bring together experts from the medical and engineering fields in which trauma acts as a fulcrum in understanding the engineering approach to medical cases. The emphasis of this research is on the retrospective study of medical scenarios as seen from the engineering perspective. An in-depth study is required to ensure the accuracy of both medical and engineering data. Where static, dynamic, temperature
and impact loads and velocities/accelerations are unknown; they are evaluated using the material properties and fracture geometry of case studies. From the analytical techniques, a prospective study would assist in predicting the outcome of post-trauma damage. Generally, the research covers a wide spectrum of trauma case studies and could be used in medico-legal test cases. The medical opinion can be translated into the engineering analysis there by validating or invalidating the total medical decisions. Hence the engineering profession in many simple and complicate medical test cases would assist the medical profession in providing results, thereby, cementing the bond between them on a common platform.
Abstract

There is rapid population growth in Saudi Arabia due to the improved economy of the country. This has resulted in many people owning cars; there is a high ratio of cars per family and hence many vehicles on the road. The road transport system is not very good coupled with high dependency on road transport are major causes of accidents in Saudi Arabia. Reckless driving is another reason for road accidents. The outcome of this is high numbers of car accidents in the country which result in injuries, disabilities and even death of the Saudi people. Research has shown that trauma results in economic loss since most of the trauma cases either die after or during the accident with the survivors becoming disabled.

There is need to develop a system that reduces the effects of the trauma cases in Saudi Arabia since the number of car accidents in the country are on the rise (Ansari, 2000, p. 37). The socio-economic burden is on the rise and there is depletion of the human resources in the country. The department of surgery in Al-Nour Specialist Hospital states that the families of the affected people by trauma also suffer from emotional and psychological stress. The trauma casualties also strain the healthcare services of the country. This research paper will focus on the development of a trauma management systems and its integration with the Arabian Health Organisation in trying to save lives of the individuals affected by trauma. The main focus will be the head injury patients being taken to the hospital and how they can be treated efficiently to full recovery.
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1.1 Introduction

In the developed world trauma is one of the most fatal kinds of health illness. There are numerous definitions of what trauma is but most define trauma as any incidence/occurrence that results in a serous head injury or damage. The number one cause of trauma in the developed world is road accidents. In an attempt to reduce trauma cases better roads, speed limits and safer cars are being developed.

There are different approaches towards the treatment and control of trauma that are defined by the extent of the injury. Major trauma is referred to as a state whereby the patient has multiple injuries at different points of the body. This type of trauma calls for immediate medical attention. Studies also show that 47.8% of all serious trauma incidences in the United States result in death. It is with this mind that special trauma management systems need to be devised for such a type of trauma (Beasley, 1996).

In recent years many hospitals and institutions in the UK have established trauma teams so as to cope with the increasing number of trauma cases. This is because trauma has been found to be a complex condition and thus needs the skill and care of more than one specialist. Many trauma management teams are often made up of nurses, orthopaedic surgeon and a medical surgeon coupled with specialised equipment and life support devices.

The mostly used term which is “head injury” is used to describe any trauma to the head and more specifically to the brain itself. The injury to the head can result in a skull fracture which is more common especially in children and can occur after seemingly minor head injuries caused by falls, blows such as being struck by a rock, stick or other objects (Riyad et al, 2006)
1.2 Trauma management

Trauma management is often a complex art and thus an intricate management procedure is needed. Many hospitals and institutions in the developed world often use a rigid structure/procedure that outlines what to be done and when it should be done in the event of an accident resulting in trauma. Critics however argue that a rigid trauma management system is ineffective in the treatment of trauma and that a flexible system that can adapt to each unique situation should be used instead. The disadvantages of a rigid management structure are that some procedures and guidelines might be used even when they are unsuitable for a particular incidence. Rigid trauma management systems also hinder perpetual improvement that is a basic requirement of any management system (Al-Naami and Arafah, 2010).

Advantages of a standard trauma management procedure include the fact that such a procedure is able to reduce the number of incidences that result in misdiagnosis and also ensure that similar treatment procedures are carried repeatedly on patients. Many trauma management systems in the developed world use the rigid structure of trauma management. This is facilitated by the use of linear programs and charts.
Management of trauma calls for a deep understanding of the three peaks of trauma and how they can be managed. These are namely the first peak, the second peak and the third peak. The first peak of trauma usually occurs a few minutes after the occurrence of an injury. This is the hardest type of trauma peak to handle and results in death unless immediate medical assistance is offered to the victim. The second type of trauma peak often occurs a few hours after injury and is easier to treat compared to the later. However second peak trauma is still a leading cause of death in the developing nations as they have poor access to health care and trauma treatment facilities. Third peak trauma deaths occur weeks after an individual has sustained an injury and are the easiest to treat in the presence of proper medical services (Dantzig and Thapa, 2003).

A trauma management integration system is a kind of a system that is well planned for the entire region which includes all the facilities and capabilities to take care of the injured according to the Saudi Trauma Society whose mission is “Enhancing community health through trauma prevention and its serious consequences”. This is coordinated by the country’s health organisation in ensuring that the trauma related injuries and incidences are well taken care of to enable full recovery of the patients. The trauma system should be mainly concerned in decreasing the incidences and the severity of trauma. This can be achieved by ensuring that any person sustaining trauma has access to the trauma care facilities and there are enough facilities and equipments to handle the number of patients from the trauma cases.

Saudi Arabia has a high number of persons sustaining trauma and there is no efficient mechanism to handle and manage the trauma cases. This results in the need to find a better mechanism for handling the patients from the trauma cases most of which are from road accidents (Ministry of Health, 2006)

1.3 Significance of research

This research will bring together experts from the medical and engineering fields in trying to understand the engineering mode of approach into finding a solution to the high number of accidents especially the head injury patients. Linear programming methods will be used in optimising emergency time to save the lives of the head injury patients who in most cases die from lack of proper treatment and care which should be delivered on time. There is a need to study the medical scenarios as seen from the engineering perspective to ensure the accuracy of not only the engineering data but also the medical data in improving the provision of facilities to the injured patients. The combination of information and data from the two fields might help in finding a better solution to the problem since trauma related deaths are the highest in Saudi Arabia and the solution to this could reduce the death toll rate in the country.
There is need to develop a system that reduces the effects of the trauma cases in Saudi Arabia since the number of car accidents in the country are on the rise (Ansari, 2000,p. 37). The socio-economic burden is on the rise and coupled with the depletion of human resources in the country. The department of surgery in Al-Nour Specialist Hospital states that the families of people affected by trauma also suffer from emotional and psychological stress. The trauma casualties also strain the healthcare services of the country. This research paper will focus on the development of a trauma management systems and their integration with the Arabian Health Organisation so as to create long term solutions to the high trauma related mortality in the country. The main focus will be on head injury patients in Asir and the mode of rescue and treatment so as to reduce the number of second and third peak deaths.

1.6 Research question

The main focus of the study is how trauma can be handled and prevented since it is one of the biggest killers in Saudi Arabia. The integration of the linear programming models for optimising the emergency time to save the lives of head injury patients who die mostly because of delayed treatment and lack of proper facilities and equipment in the hospitals is to be analysed and appropriate solutions given to this problem.

The research question is on how trauma affects Saudi Arabia and how this problem could be alleviated using linear programming techniques.

1.7 Summary

The study has five main sections namely the introduction, literature review, methodology, data analysis and the conclusion. The literature review attempts to gain understanding on the topic of study based on the work of other researchers. The methodology and the analysis section will attempt to gain an understanding based on the data collected from hospitals in Asir.
Chapter 2

Literature Review

2.1 Introduction

This chapter has highlighted previous literature that focused on health care system in Saudi Arabia and case study Asir hospital describes the main problems of trauma which affects on trauma system there. Also, this chapter shows the linear programming roles to solve some difficulties facing health care system and tells us Saudi Arabia health system needs to apply it to reduce the increasing number of deaths result from weakness of trauma system there.

Health-care systems in general are facing extreme pressures to excel in an environment of rapidly changing expectations, exploding global resource needs, and increased financial demands. Achievement of effective resource allocation is both a consequence of and a solution for overcoming these challenges. It is imperative that such systems address the growing requirements for effective resource allocation. Moreover, today's health-care systems are complicated by multiple objectives, multiple evaluation criteria, and multiple decision-makers within the system, while resources and budget are extremely limited. As the health-care systems react to severe financial pressures, too much emphasis will be often placed on balancing the budget at the expense of the goals of the systems. The critical issue in the management of a health-care system is not just financial efficiency. The operational policy must be based on the compromised agreements of the diverse groups within the health-care system. Management of a health-care system prefers to assign personnel properly to each of alternative work schedules to meet both skill and work force requirements, and also to minimize its total payroll cost. Simplify the problem, three departments of the organization are selected because they are most complicated and complex in terms of the personnel assignment and scheduling. Management wishes to separate the personnel schedule for the emergency, radiology, and nuclear medicine departments. Each department has two types of employees: nurses and physicians in the emergency department, technicians and physicians in the radiology department, and technicians and physicians in the nuclear medicine department. Management must plan for the daily personnel levels. The health-care organization's policies split on-duty employees into six time periods. In each period, employees must remain on duty for 8 consecutive hr. There are costs involved with having too many personnel for a given shift as well as costs involved with not having enough employees to meet unexpected demands. The management objective is to assign human resources to a 1-week schedule that will meet the daily requirements with the minimal payroll costs. The personnel scheduling models have demonstrated that the use of flexibility in designing human resource schedules can result in a substantial improvement in manpower utilization. In determining human
resource assignment schedules the following assumptions are made: (1) the organization operates 24 hr a day, (2) all time periods are of equal length, (3) every employee performing the same type of work will receive exactly the same salary, and (4) extraordinary overlap does not exist. Subjective decisions that are based on past experience and intuition are very common in assigning personnel to several jobs. Mathematical programming can help verify the results arrived at by subjective decision-making and indicate errors involved in the selection of an optimal course of action (Kwak & Lee, 1997).

2.2 Health care in Saudi Arabia

The health care system in Saudi Arabia is still run and operated by the Saudi government. National health care systems are still common in many developing countries of the world. Scholars claim that this type of health care system has many advantages as it prohibits the commercialisation of crucial services that are critical to the lives of people in a country. Another advantage of such a system is that the government is able to regulate and control the prices for health care. This also facilitates the implementation of subsidies on health care and making it affordable to all people in an economy.

The national system of health care also has several disadvantages such as low quality of services in the event of poor governance and lack of vibrant and energetic service provision due to civil leadership (Ansari et al, 2000).

National hospitals in Saudi Arabia fall under the ministry of health. This ministry has the mandate of delivering health services to people from all corners and regions of the kingdom. Saudi Arabia has many health centres and clinics spread throughout the kingdom. These hospitals provide basic health care services to people and in cases where specialised treatment services are needed the patients are referred to referral hospitals which are often located in big towns and cities. Notable referral centres in the country include the King Faisal Specialist hospital, King Faisal Eye Specialist and research hospital to which major cases are referred (Ali and Mahmood, 1993).

Below is a chart that shows the outline of hospitals and health care facilities in Saudi Arabia.

Table. 1: Hospital capacity in Saudi Arabia

<table>
<thead>
<tr>
<th>Description</th>
<th>Number in country</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospitals</td>
<td>87</td>
<td>8500 beds</td>
</tr>
<tr>
<td>Dispensaries</td>
<td>622</td>
<td>50000 outpatients</td>
</tr>
<tr>
<td>Clinics</td>
<td>758</td>
<td>40, 763 outpatients</td>
</tr>
<tr>
<td>Laboratories</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Physiotherapy centre</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>
Saudi Arabia has one of the best health care systems in the Middle East. But in comparison to the health care system in the west, the countries system is still wanting and improvement is needed. There are minimal health facilities particularly in areas of low population and thus this makes the treatment of accident and injury victims in such areas difficult. Movement of such victims is often done to referral hospitals for specialised treatment.

2.3 Health in Saudi Arabia: Asir case study

Asir is a province in Saudi Arabia with its capital known as Abha. Asir is a highland region with relatively sufficient rainfall. It has a diverse combination of vegetation patterns such as palm forests, desert vegetation and juniper forests.

Initially the health system leadership in Asir was centralised with all control and supervision functions being undertaken from Abha. The management was divided into three sections namely: Hospitals department, dispensaries department and preventive medicine department.

However this system of management was not very effective. One reason was that there was lack of synchrony between the primary levels and the secondary levels of leadership and thus caused a breakdown in the system. The second reason was that there was little delegation of responsibilities and thus an excessive load was put on the top management; this caused a lack
of efficiency and proper execution of duties. Thirdly, there was lack of a proper method of appropriation of available resources. (Mauger, 1993)

In the early 90s reforms on the Asir hospital management system were carried out. These reforms resulted in the integration and delegation of duties between the health departments of Asir. The advantages of the reforms were better decision making, effective management, reduction in the amount of work load on the top management, better utilisation of resources and better services are offered to the population.

Fig. 3: Age ranges of car accident patients in Asir, (Khan et al., 2009)

2.4 Role of modern engineering in health care

Modern science is becoming diverse and as new knowledge is unearthed various fields of science are becoming more and more related to each other. The marriage of engineering and medicine has occurred gradually over the years but was spurred by the realisation that each field of science is able to add value and meaning to each other. The relationship between engineering and medicine was established in the 17th century by scientists such Galileo Galilei who was able to show the relationship and symmetry of various body parts from an engineering point of view. The Galileo model is still used in modern medicine (Dailey and Callaham, 1985).

In the beginning it was popular opinion that the merging of scientific fields would cause a decline in the kind of quality that science could provide. This opinion has been forced to change by virtue of time. In the modern world engineers employ medical principles in the design and manufacture of machines. At some point it was realised that for people to work
well including the engineers themselves then a proper understanding of the human body was vital. Common areas where medicine is employed in engineering include the design of machines and in the calculation/determination of forces and their effect on their human body.

Medicine is reliant on engineering as the quality of medical service has been improved due to the integration of these two sciences. Examples such as artificial hearts, pace making machines, blood purification machines, and ultrasound scanners are just a few of the machines that are now used in medicine. It is with the aid of such machines that doctors are able to diagnose and treat diseases more accurately.

![Fig. 4: Artificial heart fitted into a human body](image)

Engineering has not only been useful to medicine because of the machines and equipments that it has contributed to the field but also by fostering the use of analytical thinking and problem solving. By merging these two sciences doctors and medical personnel are able to implement linear models similar to those used in industries and by engineers (Dailey and Callaham, 1985).

The engineering form of thinking is objective and thus minimises the wastage of resources and time especially when treating trauma and other critical conditions. However, some sceptics claim that the engineering model when employed into medicine would erode the human and empathetic attitude that health workers should have. It is on this basis that some scholars do not recommend linear models and objective thinking in medicine.
2.5 Trauma in Saudi Arabia

Studies show that Saudi Arabia is the third in the world based on the number of traumatic head injuries per unit population. The United States has the highest number of head injuries that occur in a year. It has however been found that the survival rate of head injury victims in Saudi Arabia is much lower in comparison to that of the United States. Out of every 100,000 trauma victims in the United States, 8,000 die due to related complications in comparison to 30,000 that die in Saudi Arabia. The high mortality rates in Saudi Arabia can be owed to poor health care and trauma management practices in the country. This is backed by data that show that trauma incidences outside capital cities and urban centres result in 62% of the total trauma related death (Trauma cases in Saudi Arabia, 2010).

Trauma is the main cause of death in Saudi Arabia; mostly the young people. It is estimated that one person is killed and four are injured every hour. This shows that there should be an implementation of a system which should help in reducing the deaths in the country.

Saudi Arabia also has an abnormally high number of traumatic brain injuries. There have been numerous explanations as to what causes this phenomenon. The most credible phenomenon is that, Saudi Arabia has good roads and the population are able afford good cars. This is however coupled by poor speed and traffic regulations that result in over speeding and thus in fatal accidents. There is also poor education among the population on the need for safe driving and thus fault has been put on the country’s driving education system (Trauma cases in Saudi Arabia, 2010).
Since the 2008 Saudi Arabia has launched a campaign geared towards the improvement of its trauma management mechanisms. Notable changes include the training and employment of medical staff with the adequate skills for treating trauma. The country has sourced specialists particularly head trauma injury specialists from all over the world. These specialists are expected to bring in new knowledge and skill into the country’s medical industry. Some analysts however argue that this move will not be an effective solution in the long run and that privatisation is the only way that the government could solve the trauma problem. This is because government run institutions are known to be inefficient and therefore would not be useful in dealing with trauma; needs rapid and efficient response and handling.

The most common cause of the head injury in the world is caused by car accidents and with the rising demand of road transport in Saudi Arabia, this is the main cause of trauma related accidents. (Ann Saudi Med 2010; p50) there are various challenges faced in Saudi Arabia particularly in handling the trauma cases. Primary healthcare services in Saudi Arabia are provided by physicians who have no post-graduate training and hence the difficulty in handling trauma cases in the country. This is a big challenge in the implementation of a trauma system since the personnel required for the specialised care of the patients must first of all be trained before they can be trusted with provision of better services to the patients. As it can be seen from Asir region most of the staff in the hospitals are not experienced in handling major injuries attending to the emergency cases which contribute to highest number of trauma cases. The number of cases in the Asir region can be seen from the table below and it is evident that most of the patients have trauma related illness or situations.

Table. 2: Medical supplies of emergency hospitals in Asir province, (Siddiqui et al, 2002)
The health institutions in Saudi Arabia are faced with high numbers of trauma cases requiring the need for qualified personnel to take care of the injured. The road transport is also a contributing factor in ensuring that the patient is transported well to the required destination which is an appropriate medical institution. Saudi Arabia is a developing nation with the infrastructure being under development making the transportation of the injured to hospitals and to medical institutions a huge challenge which must be taken care of to ensure the head injury patients receive the specialised treatment within the appropriate time. Saudi Arabian hospitals have also been found to be ill equipped to deal with trauma cases (Ansari et al, 2000). Challenges faces by Saudi Arabian health care when it comes to treatment of trauma patients include:

- Shortage of related medical supplies
- Lack of advanced emergency response units
- Lack of well trained medical personnel
- Inefficient health care management systems
A high number of trauma related deaths tends to deplete the human resources available in the country since majority of the victims are males; who are traditionally the main gender providing manpower and provisions for their families. Trauma causes tremendous suffering, not only leading to loss of life but also leaving people temporarily or permanently disabled (King Abdullah International Medical Research Centre). It also drains resources and leads to major economic loss. Due to the nature of trauma, the results of trauma can be modified by following certain systems, e.g., the internationally known Trauma System. The trauma registry shows that only 43% of admitted trauma patients were injured in motor vehicle accidents. The trauma mortality rate at Kingdom of Saudi Arabia is approximately 23,000 deaths per year. Trauma Patients 5000-6000 die annually from Recorded Trauma Accident (RTA). Police only calculated people who die at scene or on arrival to E.R. who up to a month death is related trauma.

The loss of the family members who earn and provide for the family leads to a change in the household dynamics causing financial and economic losses. The victims who end up being disabled hence lose their ability to earn are burdened with their own healthcare and most of them opt to sell their assets and in most cases they end up being bankrupt (World Report on Road Traffic Injury Prevention Geneva, World Health Organization, 2004).

Trauma has had serious implications in the Saudi Arabian economy and measures are being taken so as to reduce the impact that it has to the country. Data collected show that the country has the highest trauma related fatality in the world. This calls for immediate action when it comes to the care of trauma patients and in the prevention of trauma.

Trauma is one of the leading causes of death in surgical patients making the management of trauma a difficult task. This requires great effort starting from the site of injury of the patient which includes pre-hospital treatment to the transfer of the patient to an appropriate centre or health institution. A study is conducted of the trauma cases that attended the emergency room, regardless of the cause or the severity of the injury. This study was conducted in a local hospital to gather some useful information to be used in the analysis and discussion of the trauma cases in Saudi Arabia. There will be development of a conceptual framework based on operation management, logistics management principles and operations research techniques (Al-Naami and Arafah, 2010).

It is seen that around one third of the patients who attended the hospital had been admitted. This showed that 82% of the trauma cases were admitted in the hospital and thus the need for a specialised trauma management system. The admitted cases required Orthopaedic or Neurological treatment making the two departments the most active departments in the hospital. This requires that these departments be supported by more staff and trained personnel than the rest of the departments which had less than 18% of the referred patients admitted in the hospital. Most of the injuries the patients sustained during accidents and most
of the cases required special attention of the patient during the transportation of the patient from the scene of accident.

The health services are among the important services which are mostly required in developing countries like Saudi Arabia and the provision of such services should be of vital importance in ensuring that the citizens of the country receive the appropriate treatment and care when needed. Lack of the appropriate equipment and professionals can lead to the loss of lives in hospitals.

Trauma in Saudi Arabia is a major public health problem with increasing rates of mortality and morbidity. The socioeconomic burden, depletion of human resources, the emotional and psychological stress on families, and the strain on healthcare facilities are also increasing. To minimize this impact, a national multidisciplinary trauma system has to be developed and implemented before it is too late to manage the further complexities of trauma in the future (Al-Naami, 2010).

2.6 What is a trauma system?

A trauma system is a planned, comprehensive, and coordinated region- or countrywide injury response network that includes all facilities and sectors with the capability to care for the injured, and is integrated with the local public health care system. This system involves components related to trauma prevention, prehospital care, hospital care, rehabilitation of the disabled, disaster medical planning, systems administration, trauma care education and training, trauma care evaluation and total quality improvement, and includes the participation of society. A country or a region should set their own goals according to the resources and facilities available. Ideally, a successful trauma system should involve the following goals:

- To decrease the incidence and severity of trauma
- To ensure optimal, equitable, and accessible care for all persons sustaining trauma
- To prevent unnecessary deaths and disabilities from trauma
- To contain costs while enhancing efficiency
- To implement quality and performance improvements in trauma care throughout the system
- To ensure that certain designated facilities have appropriate resources to meet the needs of the injured
These goals can be achieved collectively at once or gradually in steps depending on the local resources. The core functions and essential services of the trauma system are summarized in figure 6.

Figure 6: Core functions and essential services of the trauma system.
2.7 Linear programming in health care

Linear programming involves the techniques and the methods that are used to maximise/increase the return from a specific set of inputs. Linear programming gained popularity in industries and factories all over the world as it was able to help managers maximise outputs from their production facilities (Beasley, 1996).

Maximisation and minimisation of linear programming models is often carried out on a specific function that is subjected to a set of constraints. This type of mathematical analysis involves the optimisation of a certain function so as to acquire the most suitable parameters.

Linear programming is used in industries and engineering facilities so as to determine the optimum amounts of materials and resources that need to be invested into a certain activity so as to yield the maximum profits. There are five main activities that are often carried out with the aid of linear programming models and these include, planning, scheduling, routing and design work. This type of analysis is not only used in the calculation of optimum resources but is also used in the determination of optimum time and production routes. Through this technique researches are able to determine the optimum production plan that will ensure all critical activities are completed in time. It is due to the success of linear programming in engineering that its viability in health care was realised (Ali and Mahmoud, 1993).

Due to the wide capabilities of linear programming it is often referred to as operations research. Initial linear programming models only referred to numerical calculations that involved a set of functions coupled with a set of constraints. However with time as linear models gained popularity in solving complex problems this resulted in the use of network diagrams. Advantages of network diagrams in linear programming include the fact that a high number of problems can be simultaneously solved, as it is able to clearly show the relationship between several problems and the optimum results for each problem can be compared against each other so as to map out a proper path.
Linear programming has found numerous uses in health care particularly when determining the optimum response/ action path when treating serious illnesses.

There are various stages involved in the formulation of a linear model. The first stage is the formulation of an objective function. An objective function is what is maximised or minimised. In case of profits it is often maximised and it is common knowledge that people want to make more profits and in the case of time, it may be minimised. The objective function is then subjected to a set of constraining factors. Below is a sample equation of a simple linear programming model

Objective function = y + 4z = 320

Constraints  

\[ x \geq 312 \]
\[ y \leq 45 \]
\[ x + y < 86 \]

For the solution of such a linear program to be valid they constraining factors must hold true when substituted with the results.
The use of linear programming in medicine has gained worldwide recognition in the recent 15 years. Linear programming has improved the delivery of health care and has offered many solutions to medicine’s problems. Linear programming can be divided into sections such as definitions, preferences engines and constraints (Ferrin et al, n.d.). The definition involves the description and the statement of the problem, the preference states the objective that the user desires, a set of constraints that have to be achieved are stated and the problem is executed either graphically or by analytical solution. The linear programming approach enables the quantification of the health effects and therefore the desirability of the (re-)allocation of health-care resources. (Zon and Kommer, 1999) provide some simulation results in order to illustrate the working of the model.

A linear programming model can be adapted for providing for such services to the relevant patients during the emergencies which occur rarely but require special attention since it is during the emergencies that most people suffering from injuries succumb to death due to lack of specialised care and attention. This would help in ensuring that the goal of the Saudi medical services is achieved that is reducing the mortality and health deterioration caused by emergency incidents or illness in general. A trauma system which should be incorporated with the Saudi Arabian Health Organisation should use computational mechanisms to calculate and evaluate the condition of the patients who have had an accident and find the appropriate location or institution for further medical attention after the initial first aid has been administered. This is by use of the linear programming models that show the statistical information of such cases with the probabilities of full recovery available to the emergency personnel at the scene of the accident (Dailey and Callaham, 1985).

2.8 Linear programming as a tool in case-mix management

A mathematical model known as linear programming can be used by healthcare managers to derive an optimal case mix for diagnosis related groups (DRGs). Linear programming is a mathematical programming and optimization technique that has been widely used by business and industry for many years. It involves allocating scarce resources on the basis of a given criterion of optimality. Most often, this criterion is either maximum margin or minimum cost.

A classic application of linear programming in manufacturing is the "product mix" problem. In this problem, the objective is to determine the kinds and quantities of products to be produced that would maximize profits. The case-mix decision is similar to this manufacturing problem.

The linear programming model consists of an objective function and a set of constraints. The quantifiable goal that is to be maximized or minimized is the "objective function." This
function measures the effectiveness of a particular solution for a linear programming problem. The constraints are mathematical statements that specify elements of the problem such as the limitations of available resources or a demand level that must be met.

In a case-mix problem, the objective function may be to maximize margins. The amounts of resources available to service the various DRGs are the restrictions. Resource constraints may relate to such items as the limitations of available space, the number of qualified workers, or a demand requirement to service certain DRGs.

**Simplex method**

The more advanced linear programming technique known as the simplex method is used to solve complex linear programming problems. This model identifies an initial feasible solution and repeats the solution process, making successive improvements until the optimal solution is found. Such a process requires the use of a computer.

To illustrate the application of the simplex approach to case-mix management, assume that a hospital wants to maximize its margin while optimally using its resources. To meet this objective, management needs to know the exact number of cases it should service from each DRG classification. For the purpose of simplicity, only four DRGs are considered. The DRGs, along with the associated contribution margins, a form the following objective function: Maximize: $2,000 DRG 1 $1,500 DRG 2 $500 DRG 3 $300 DRG 4

The current resource requirements, weekly demand for each DRG, and the availability of resources are presented in Exhibit 1. For example, DRG 1 requires seven hours of diagnostic services, five bed days, 30 hours of nursing care, and $800 of pharmaceuticals. Note that the estimate of demand for each DRG has been stated as a constraint in the example. This ensures that the hospital will meet the community's minimum expected healthcare needs while maximizing the hospital's margins. From data presented in Exhibit 1, the constraints are stated in the following equations:

\[
\begin{align*}
7X_1 &- S_5 = 10 \\
5X_1 &- S_6 = 15 \\
30X_1 &- S_7 = 40 \\
X_4 &- S_8 = 160 \\
S_1 &= 480 \\
S_2 &= 170 \\
S_3 &= 1000 \\
S_4 &= 50000
\end{align*}
\]

Exhibit 2 shows the value of the objective function variables that result when the optimal solution is obtained. The values shown in the second column indicate that the hospital should service 10 DRG 1 cases, 28.3 DRG 2 cases, 40 DRG 3 cases, and 216.7 DRG 4 cases.
The third column shows the DRG margin coefficients. The objective function at the optimal case mix is: Max = DRG 1 (10 x $2,000) + DRG 2 (28.33 x $1,500) + DRG 3 (40 x $500) + DRG 4 (216.7 x $300). Thus, the margin is maximized at $147,500.

2. 9 Sensitivity analysis

Sensitivity analysis is the process of examining the extent the resources is being consumed and the effect on the objective function of model parameter changes. Linear programming provides management with the ability to make these assessments. (a) The contribution margin per DRG is the prospective rate per DRG minus the associated variable costs per DRG. The variable costs would include items such as direct patient care (routine, outpatient, diagnostic and therapeutic, ancillary service) and general services (CSS, dietary, laundry and linen, pharmacy). (b) The linear programming solution is obtained by using a computer package named Storm. This is a software package for a microcomputer that includes mathematical modeling techniques, such as linear programming, inventory management, and forecasting. Other excellent mathematical decision programs are also available.

Detailed information relating to the resource constraints that are provided from the computer solution is shown in Exhibit 3. The amounts reported as "slack values" are especially important to management because they provide a measure of resource use.

For example, the data for constraint 1 indicates that all hours of diagnostic services will be used, while the information for constraint 2 indicates that there will be 23.3 bed days unused. The slack value for constraint 4 indicates that $11,000 of pharmaceutical supplies will be unused. Management may want to consider cutting the inventory level in this area, because carrying unnecessary inventory is costly.

Constraints 5 to 8 relate to the demand for servicing patients in the various illustrated DRG categories. Slack values for these particular constraints, sometimes called "surplus" values, represent services that should be provided in excess of a minimum level. The slack values for constraints 5 and 7 indicate that only minimum requirements for DRG 1 and DRG 3 should be provided. In contrast, slack values for constraints 6 to 8 indicate that 13.3 and 56.7 patients, respectively, should be serviced in excess of the required minimum number of patients for DRG 2 and DRG 4.

Exhibit 3 also presents the "shadow price" for each constraint. Shadow price information indicates the dollar effect on margins of adding or deleting an additional unit of a given
resource. It is important for management to consider this type of information because in some instances resource changes will have little or no effect, while in other situations significant results will occur.

To illustrate the interpretation of shadow prices, consider constraint 1. The shadow price is $250. This means that the margin can be increased by $250 if one more hour of diagnostic services can be obtained. Similarly, for each additional hour of general nursing care that can be added, the margin will increase by $50. This information helps managers determine whether the benefits of adding resource units is less or greater than the associated costs. Shadow price information is also presented for the DRG minimum demand requirements (constraints 5 to 8). The shadow price for constraint 7 is positive and indicates that the margin will increase by $250 for each DRG 3 patient serviced above the required minimum. In contrast, the shadow price is a negative $1,250 for constraint 5. This indicates that the margin will decrease by $1,250 for each patient that is serviced above the minimum level required in the DRG 1 category.

Note that DRG 1 has the largest margin coefficient ($2,000) among the DRGs (see Exhibit 2). If only the margin coefficient is considered, management might inadvertently attempt to service an unlimited number of DRG 1 cases. Management must be able to identify those DRGs that become unprofitable as a result of their resource consumption rates. Consequently, shadow price information provides a warning to management relative to unprofitable DRGs. Finally, the linear programming model allows management to perform "what if" type analysis. For example, to show what would happen if the margin coefficient of DRG 1 changed to $3,300, management can modify the problem by again running the model. The result is a new optimal mix of services (see Exhibit 4). It is now desirable to provide DRG 1 in excess of the 10 case minimum requirements (Robbins, 2011).

Nursing personnel costs make up a major portion of most hospital budgets. This report evaluates and optimizes the utility of the nurse personnel at the Internal Medicine Outpatient Clinic of Wake Forest University Baptist Medical Center. Linear programming (LP) was employed to determine the effective combination of nurses that would allow for all weekly clinic tasks to be covered while providing the lowest possible cost to the department. Linear programming is a standard application of standard spreadsheet software that allows the operator to establish the variables to be optimized and then requires the operator to enter a series of constraints that will each have an impact on the ultimate outcome. The application is therefore able to quantify and stratify the nurses necessary to execute the tasks. With the report, a specific sensitivity analysis can be performed to assess just how sensitive the outcome is to the stress of adding or deleting a nurse to or from the payroll. The nurse employee cost structure in this study consisted of five certified nurse assistants (CNA), three licensed practicing nurses (LPN), and five registered nurses (RN). The LP revealed that the outpatient clinic should staff four RNs, three LPNs, and four CNAs with 95 percent confidence of covering nurse demand on the floor. This combination of nurses would enable the clinic to:

1. Reduce annual staffing costs by 16 percent;
2. Force each level of nurse to be optimally productive by focusing on tasks specific to their expertise;
3. Assign accountability more efficiently as the nurses adhere to their specific duties; and
4. Ultimately provide a competitive advantage to the clinic as it relates to nurse employee and patient satisfaction.

Linear programming can be used to solve capacity problems for just about any staffing situation, provided the model is indeed linear (Matthews, 2005).

2.15 Chapter Summary

This chapter covered most of the previous studies which have done in the field of health care system especially in Saudi Arabia. Case study Asir hospital illustrated health care system and problems affect on it. Nevertheless, the literature review found that modern engineering systems support health care system. This provided an opportunity to review a number of linear programming system practices for enhance health care system. Moreover, the chapter presented needing of Saudi Arabia health care system linear programming model to support trauma management there.
Chapter 3

Research Methodology

3.1 Introduction

This chapter illustrates the research methodology and design used to develop a Trauma management integration system for Saudi Arabian’s health organisation using the linear programming model. The chapter presents the analytical research techniques for the developed research questionnaire. The study adapted quantitative and qualitative assessment methods in order to achieve the research objectives and the final framework. Moreover, this chapter presents in detail the targeted research sample, questionnaire distribution method and design, data collection, data analysis techniques that are based on the literature review and current construction company practices, as discussed in chapter 2. Figure 7 shows the study path that led to the final research goal.

![Diagram showing the research development strategy]

**Figure 7:** Research development strategy
Trauma is one of the leading causes of death in surgical patients making the management of trauma a difficult task. This requires great effort starting from the site of injury of the patient which includes pre-hospital treatment to the transfer of the patient to an appropriate centre or health institution. A study is conducted of the trauma cases that attended the emergency room, regardless of the cause or the severity of the injury. This study was conducted in a local hospital to gather some useful information to be used in the analysis and discussion of the trauma cases in Saudi Arabia. There will be development of a conceptual framework based on operation management, logistics management principles and operations research techniques.

It is seen that around one third of the patients who attended the hospital had been admitted. This showed that 82% of the trauma cases were admitted in the hospital and thus the need for a specialised trauma management system. The admitted cases required Orthopaedic or Neurological treatment making the two departments the most active departments in the hospital. This requires that these departments be supported by more staff and trained personnel than the rest of the departments which had less than 18% of the referred patients admitted in the hospital. Most of the injuries the patients sustained during accidents
The health services are among the important services which are mostly required in developing countries like Saudi Arabia and the provision of such services should be of vital importance in ensuring that the citizens of the country receive the appropriate treatment and care when needed. Lack of the appropriate equipment and professionals can lead to the loss of lives in hospitals. A linear programming model can be adapted for providing for such services to the relevant patients during the emergencies which occur rarely but require special attention since it is during the emergencies that most people suffering from injuries succumb to death due to lack of specialised care and attention. This would help in ensuring that the goal of the Saudi medical services is achieved that is reducing the mortality and health deterioration caused by emergency incidents or illness in general. A trauma system which should be incorporated with the Saudi Arabian Health Organisation should use computational mechanisms to calculate and evaluate the condition of the patients who have had an accident and find the appropriate location or institution for further medical attention after the initial first aid has been administered. This is by use of the linear programming models that show the statistical information of such cases with the probabilities of full recovery available to the emergency personnel at the scene of the accident. A sample questionnaire that is to be distributed to the respondent has been attached below. The main objectives of the questionnaire are:

- To collect first hand data from the Asir area
- Identify the optimum time for the treatment of trauma patients
- Identify the prevalence of trauma related illnesses in Asir
- Identify systems that need to be put in place so as to implement a trauma management system in Asir

3.2 Questionnaires

Questionnaires will be used to collect data from respondents in the Saudi Arabian health care system. An advantage of this type of data collection is that it is able to provide raw data at reasonable costs that at relative ease. This is because questionnaires eliminate the need for the researcher to be actually present in all situations and this facilitates the collection of data from multiple sources while the researcher is located in one central location.

The questionnaires were distributed to various health centres and hospitals in Saudi Arabia. Specific emphasis was paid to hospitals in Asir province as they were found to be most affected by trauma management problems.
The mode of distribution of the questionnaires was through postal mail and delivery services. Some respondents claimed that postal mail was a slow way of sending them the questionnaires and thus door to door delivery companies were used. These were found to be indeed effective means of distributing the questionnaires as they were three times faster compared to postal mail (Dantzig and Thapa, 2003).

Responsible and ethical data collection principles were also employed in the questionnaire campaign. The respondents were informed of the anonymity and this was aimed at facilitating honest and open responses from the respondents. Adequate measures were also taken so that the physical addresses of the respondents were not revealed at the time of tallying and compiling of the data so as to protect their privacy.

The main objectives of the questionnaire was to collected data on the number of trauma patients, the major causes of trauma, number of trauma incidences that result in fatalities, number of trauma incidences that result in survival, the level of equipment in Saudi hospitals, common trauma peaks and respective responses and the overall amount of time taken to evacuate trauma victims.

The questionnaires were then collected and the data tallied. This was done with care so as to avoid the compilation of incorrect data and information. Data that was found to have outlier values and data that incomplete was removed from the tally. This was done so as to ensure that the questionnaire process remained accurate and that only accurate results were passed on to the analysis phase. This was done according to a preferred work plan so as to facilitate uniform collection and analysis of all the questionnaires.

3.3 Interviews

Face to face interviews were also conducted during the study. Interviews were however limited to a few individuals who had a vast amount of knowledge on trauma in Saudi Arabia. Among those interviewed were traumatic brain injury researchers, orthopaedic doctors, surgeons, ambulance drivers, paramedics and nurses. The interviews were an invaluable tool in the collection of first hand data and several advantages over the questionnaires. This is because the questionnaire was rigid and fixed and thus the researcher could not be able to acquire information that out of the questionnaire. The interviews on the other hand were very
flexible and thus facilitated for questions outside the planned to be asked and answers to be acquired (Beasley, 1996).

Informal interviews were carried out in the study. There was no fixed set of questions and the respondents were made to feel comfortable and free during the interview. The interview took the form of a conversation and thus the respondents were free to air their personal opinions which were not necessarily verified facts. This type of data collection enabled the researcher to discuss important issue with the respondents and thus from these discussions carry out studies so as to establish the validity of these opinions.

The method of data recording used in the interview was note taking. The researcher took short notes of important aspects that were brought up in the interview. Planning of the interviews was done before hand and constant communication was maintained with the respondents so that the process remained as scheduled. The location of the interviews was dependent on the preferences of the respondents and varied from hospitals, restaurants, hotels and playgrounds.

3.4 Weaknesses and strength

Challenges faced during data collection were mainly due to the high cost of transport and accommodation that the researcher incurred especially in the live interviews. The face to face interviews were found to be expensive and cumbersome as the respondents were spread too far apart. Another challenge that was faced was in the distribution of questionnaires. Some questionnaires that were distributed via post took too long to reach the respondents and thus door to door delivery had to be used in some cases. Such occurrences resulted in expenses in the study going above the budgeted figures.

In some instances language was a barrier as some respondents were not able to fully understand English. This brought about communication problems as the respondents were not able to fully understand the questions that had been put into the questionnaires. This was noted during the tallying of the data as some open questions were found to have irrelevant answers. Such questionnaires were removed from the total tally as they had the ability to create outlier and wring values.
Strength of the research methodology was noted as the research team was able to adjust and cope with unexpected circumstances. This was also done in a timely manner so as to avoid the occurrence of serious delays and failure to meet the intended schedule. Support from government agencies and ministries particularly the Saudi Arabian Ministry of health were invaluable in the data collection process. It is through the cooperation between the researcher and the ministry that suitable respondents and hospitals form study were chosen.

3.5 Linear programming

Data collected was then analysed and used in linear programs so as to establish the optimum parameters that would improve the overall service delivery for trauma injury patients. This was through the use of use of mathematical equations to solve real life problems. Linear programming as a method of data interpretation proved effective in solving problems caused by trauma injuries in the study. This was through a series of steps that lead to the solution. The first step was to formulate the problem. This was done by the use of charts where the information was listed so as to enable the programmer to understand the problem. The second step is to assign constraints to the available data. Such constrains define the characteristics of the variables and will aid in solving the model. The decision variables were then selected as they define the needed outcome. Equations were then developed from the set constraints and include all the variables. The equation is then written into a linear programming model which includes the subject statement and the signs for the variables. From the model a solution of the problem is then achieved and interpreted (Beasley, 1996).

3.6 Chapter Summary

This chapter presented the research methodology that was used to do this research. In deed, the chapter shows the used method and data analysis techniques to attain the study’s objectives. The study’s targeted sample and the questionnaire design are presented in detail. The adapted data analysis technique is the IPA method, which is supported by the two additional techniques of Exploratory Factor Analysis (EFA) and Gap Analysis. Chapter 4 will present the application of the research methodology in more detail.
Chapter 4
Data Analysis

4.1 Introduction

This chapter presents the data analysis for the data collected from the questionnaire. The questionnaire was sent to almost hospitals experts’ employee. The sample profile is presented in this chapter. Also, the study adapted the Importance Performance Analysis (IPA) method to analyse the questionnaire data. This method was supported by Exploratory Factor Analysis (EFA) to create the dimensions of the TQCWM strategy. Furthermore, Gap Analysis was conducted to examine the respondents’ tendency towards improvement and their concern for the dimension’s associated variables. The above data analysis methods will attempt to support the creation of the TQCWM strategy for the Australian construction industry.

The primary aim of the study was to assess the treatment of head injury patients in Saudi Arabia. The Asir hospital was taken as the case study from which most data was collected. The data collected from questionnaires and interviews was tallied and then used in the preparation of linear programming models.

The linear programming models will be used to determine the optimum procedures to be used in the treatment and control of trauma in patients. Various decisions will be considered by the linear programming models so as to find the most optimum route from the scene of injury all the to the operation room. Due to the complexity and the high number of linear programming models involved in the treatment process a flow network made up of individual programs will be used. This chart will form a decision making structure from which aspects such as the optimum route, optimum line of action for involved medical personnel, optimum delivery route, criteria for operation of head injuries etc

4.2 Assumptions

Several assumptions have been made in the study and these include:

- The cost at the time of study will remain constant
- Shorter ambulance routes will result in shorter delivery time for injured patients if the ambulances travelled at the same speed
The speed and accuracy of service delivery by the medical personnel will only be dependent on factors such as availability of equipment, and type of traumatic injury but not on personal abilities.

4.3 Process involved in formulation of a linear program for Asir

An objective should be set at the beginning of the study i.e. find the optimum time to treat head injury patients to avoid trauma. All the variables that affect the time of treatment should be listed down. The important variables should be selected from the list based on how they affect the time. Standard units of quantifying these variables should be prepared. These will be done with the aid of qualified staff and personnel. For example, how is the programmer going to quantify trauma? In such a case the programmer will consult with doctors and surgeons so as to find an appropriate scale for trauma. The scale could be out of 10 or even out of 100 depending on the other variables. The scale should be proportional to the other variables so as to allow for easy computing.

These variables are then translated into a set of constraints that are based on the hospital’s resources; financial, labour and equipment. A solution of these constrains is then carried out analytically. The results are interpreted and applied to the case of study.

4.4 Liner program for injure scene

At the scene of the injury the rescue workers will be faced with two major options. The first option would be to initiate rapid evacuation of the patient using a shorter but more expensive route while the second will be to evacuate the patient using a longer route that is also cheaper. The second option will be used for minor injuries that do not need immediate medical attention. This part of the linear program is qualitative in nature and thus depends on the judgement of the medical personnel. It is however a very critical phase as it determined the outcome of the whole linear programming chart.

Accident scene

Route 1 (Air):
Trauma symptoms such as depressed skull, fractured skull, nasal and ear bleeding

Route 2 (Road):
Minor injuries such as broken bones, shallow cuts, no signs of heavy internal or external bleeding
4.5 Linear programming for optimum rescue route

4.4.1 Rescue routes

Table. 3: Rescue routes

<table>
<thead>
<tr>
<th>Properties</th>
<th>Route 1 (Road)</th>
<th>Route 2 (Air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated cost of single rescue</td>
<td>400 riyal</td>
<td>1000 riyal</td>
</tr>
<tr>
<td>Time required to arrive at hospital</td>
<td>40 minutes</td>
<td>20 minutes</td>
</tr>
<tr>
<td>Time taken by medical personnel to administer treatment</td>
<td>70 minutes</td>
<td>50 minutes</td>
</tr>
</tbody>
</table>

4.4.2 Constraints

Amount of available funds at the hospital < or = 500,000 Riyals per month

Time to accident scene < 50 minutes

Personnel hours available < 1000

Waiting time at hospital <= 20 minutes

Number of ambulances <= 40

Available fuel <= 2000 litres
Time to death of patient = 300 minutes

Number of accidents is unlimited

Demand for medical care is unlimited

4.4.3 Decision variables

The objective to reduce the time required to give medical assistance to the patient.

Number of cases at option 1 is $x$ and the number of cases at option 2 is $y$.

Therefore:

$$Z = 400x + 1000y$$

$$500000 = 400x + 1000y$$

4.4.4 Equations

$$70x + 50y < 1000$$

$$8x + 7y \leq 2000$$

$$3x + 5y \leq 40$$

Solution

Route 1 was found to have the longest rescue time but also cost the least. This calls for adequate planning by the hospital management so as to facilitate the use of Route 2 in critical injuries. This is because the hospital will have to overlook the cost in such situations as life has more value than money.

4.6 Linear programming for cost of rescue operation

To reduce the time required to get a trauma patient attended to as well as find the optimum cost of rescue operation.
500000 = 400x + 1000y
70x + 50y < 1000
8x + 7y <= 2000
3x + 5y <= 40

Solution

From the linear programming model the hospital can be able to know that

Route one can handle 77 cases a day while route 2 can handle 182 cases. These numbers are found from the solution of x and y in the linear programming model. The values are substituted so as to get the optimum x and the optimum y.

Example y = (2000 – 8x) / 7
500000 = 400x + 1000((2000 – 8x) / 7)
500000 = 400x + (2000000 – 8000x) / 7
X = 77

Therefore substituting:

Y = 182

These are the optimum numbers that would fit the hospital’s staff and budget resources. But to meet this, the hospital must improve on personnel hours available and increase the number of ambulances as they are limiting constraints in this situation. This is a sample program that demonstrates how linear programming would work in this situation.

4.7 Linear program for trauma treatment time

4.7.1 Rescue time for trauma patients

Table 4: Rescue time for trauma patients

<table>
<thead>
<tr>
<th>Time between the accident</th>
<th>Time taken for treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>How to order?</td>
<td>Why us?</td>
</tr>
<tr>
<td>1. Fill in order sheet</td>
<td>* Plagiarism FREE</td>
</tr>
<tr>
<td>2. Make payment</td>
<td>* Affordable prices</td>
</tr>
<tr>
<td>3. Writer starts</td>
<td>* Unlimited revisions</td>
</tr>
<tr>
<td>4. Order completed</td>
<td>* Confidential service</td>
</tr>
<tr>
<td></td>
<td>and arrival at the hospital</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Blood loss per minute</td>
<td>60 units</td>
</tr>
<tr>
<td>Degree of physical head injury</td>
<td>20</td>
</tr>
<tr>
<td>Degree of trauma</td>
<td>10</td>
</tr>
<tr>
<td>Cost of sustaining patient’s life</td>
<td>2 riyals per minute</td>
</tr>
</tbody>
</table>

Fig. 8: Linear programming chart

4.7.2 Constraints
In this scenario, measurable and quantifiable units for trauma and injury must be defined by the hospital. A unit of trauma that the victim suffers per minute and the degree of head loss per minute should be agreed upon, and used as standard hospital units.

Time to death of the patient without rescue $\leq 150$ minutes

Time do death without surgery at hospital $\leq 80$ minutes

Maximum allowable degree of head injury $\leq 4000$ units of injury

4.7.3 Equations

$20x + 20y \leq 4000$ units of injury

$10x + 50y \leq 5000$ units of trauma

$x \leq 150$ minutes

$y \leq 80$ minutes

4.8 Linear programming model for optimum rescue time

To find the optimum rescue time and treatment for head injury victims.

$20x + 20y \leq 4000$ units of injury

$10x + 50y \leq 5000$ units of trauma

$x$ is less than 150 minutes

$y$ is less than 80 minutes

Solution

A graph is used to find the optimum time for treatment of the injury patients. This is done by representing the equations and the constraints in the graph. A data set is acquired so as to be able to plot the graph. This is acquired from solving the above equations simultaneously.
Table 5: Optimum treatment time for trauma patients

<table>
<thead>
<tr>
<th>Line being plotted</th>
<th>Value of x (time from accident to hospital)</th>
<th>Value of Y (time to administration of treatment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line 1 point 1</td>
<td>3600</td>
<td>0</td>
</tr>
<tr>
<td>Line 1 point 2</td>
<td>0</td>
<td>3600</td>
</tr>
<tr>
<td>Line 2 point 1</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>Line 2 point 2</td>
<td>266</td>
<td>0</td>
</tr>
<tr>
<td>Line 3 point 1</td>
<td>0</td>
<td>2000</td>
</tr>
<tr>
<td>Line 3 point 2</td>
<td>857</td>
<td>0</td>
</tr>
<tr>
<td>Line 4 point 1</td>
<td>0</td>
<td>1625</td>
</tr>
<tr>
<td>Line 4 point 2</td>
<td>3250</td>
<td>0</td>
</tr>
</tbody>
</table>

The maximum allowable time for a patient to be delivered to hospital before death is 150 minutes. The maximum allowable time for administration of treatment to a patient is 80 minutes before death occurs. This means that:

x should be less than 150 minutes (x <= 150)
y should be less than 80 minutes \((y \leq 80)\)

From these values a graph is then plotted. A graph of time from accident against time taken for treatment to be administered.

**Fig. 9: Linear programming chart**

**Interpretation.**

The red line represents \(20x + 20y \leq 4000\) units of injury.

The blue line represents \(10x + 50y \leq 5000\) units of trauma.

The green line represents \(x \leq 150\) minutes.
The purple line represents $y \leq 80$ minutes.

The optimum value lies below the red, brown, green, and purple lines. Therefore, the result achieved is; the optimum time for $x = 122$ minutes and the optimum time for $y = 78$ minutes. This means that the optimum time for a patient rescue is 122 minutes and the allowable time for head injury operation is 78 minutes. Below is a network flow diagram that represents the linear programs that will be involved in the treatment of trauma in Asir hospital. The flow diagram puts into consideration factors such as the different roles of various medical staff and outlines the different paths that could be followed in the treatment of trauma. The chart covers issues such as who does what and when and the most appropriate rescue and treatment procedure.
4.9.1 Discussion

A similar model has been developed and applied to the EMS of Riyadh. The model seeks to allocate stations and allocate a number of ambulances to respond to emergency situations and this is in line with the goals of the Saudi government and the Saudi Health Organisation. This model should be advanced and integrated with all the regions emergency services in responding to the accidents in the areas as it maximises the time needed to arrive at the scene of accident and in return the casualties have a better chance of surviving since they receive the required treatment and attention in time (Al-Naami, 2010).

The linear programming models can be used in finding the shortest routes that an emergency vehicle or ambulance can use in transporting the casualties to a better facility. This is one of the key areas in ensuring that the time for saving the casualty is maximised. Research has shown that the time taken by an ambulance to transport the victim to a health institution or hospital for specialised treatment can determine the survival success of the patient since the more time taken to reach the hospital, the less chance of survival for the patient. Head injuries especially the ones involving internal bleedings can be fatal within a short period of time and the need for immediate special attention is of vital importance since any wastage of time increases the chances of the patient not making it. In the Saudi Arabia the transport network is being developed and most people rely on it for transportation making the prevalence of traffic jams being unavoidable. This creates a need to find a solution to the transportation of the injured patients in fast and reliable manner to ensure that the chances of survival of the patient are maximised. This can be achieved by using linear programming models in the estimation of the time taken to transport a patient to a nearby health institution in order for the patient to receive the required treatment. The variables at the point in question are not only the shortest amount of time required for the patient to receive the specialised treatment but also the shortest amount of time required for the patient to be transported to a medical or health institution which has the required professionals for handling the specific case or injury of the patient.

The nurses working in the hospitals need a systematic organisation and this can be achieved by using the linear programming models. This is where a particular nurse is assigned a certain shift depending on the historical data that has been analysed. A nurse might be given a shift during a particular month which has been mostly characterised by the injured patients having the same type of injuries. If the nurse is a profession in that field, the integrated trauma system may assign the nurse to the particular shift associated with the high number of the
particular type of injury. This is to enable the patient to receive the specialised care immediately and improve his chances of recovering fully from the injury.

4.9 Findings

The linear programming models can be used to provide efficient methods of maximising the time for a patient with head injuries in receiving treatment within a reasonable amount of time and in the appropriate medical institution. The trauma cases in Saudi Arabia are high and result in the death of many people in the country resulting in the need of a mechanism or system to reduce the number of deaths related to trauma in the country.

(Ansari et al, 2000) There is need for assessment of the regions in Saudi Arabia which might include the population demographies, topography with the locations and access to the hospitals and pre-hospital resources being put into consideration. This should help in the evaluation of the transport channels or avenues for the head injury patients for faster delivery to the hospital. Identification of the populations of the regions is also important in helping in the provision of the necessary specialised treatment facilities for a certain group of people that constitute the highest population in the region. For example, if a region has many elderly people the hospitals and medical institutions may provide more facilities to cater for the elderly people since most of the population has many elderly people and this would help in increasing the time taken to provide the specialised services to the elderly people in the region who might have suffered from injuries. This is necessary since even during calamities there will be enough resources to take care of the population due to the uneven distribution of the population patterns in the region. This can be shown by the figure showing the trauma cases in Saudi Arabia (Siddiqui et al, 2002)

![Trauma cases in Saudi Arabia](image)
Thorough assessment and analysis of the gathered data is important as it helps in evaluating and defining the high-risk geographical and demographical characteristics of injuries within a response area. There is a high possibility that a certain region has an affinity towards a certain type of injury or accident which prevails mostly in that area. This can be analysed using the linear programming models to come up with response criteria and approaches to be used in such events after they have occurred. This can be seen from the table below which is an evaluation of the optimal locations and the optimal values for transferring a patient to the required hospital in time.

4.9.2 Results from questionnaire

It is expected that the chances of recovery of head injury patients in Asir will be dependent on the time of arrival of the patients in hospital. Patients who use longer routes will have a less chance of survival as they will arrive in hospital when they are already suffering from serious trauma.

From the data collected it is established that the chances of recovery from head injury among patients in Asir is dependent on the time of arrival of the patients in hospital. Patients who use longer routes will have a less chance of survival as they often arrive at the hospital when they are already suffering from serious trauma.

Patients who will be operated by experienced surgeons will have a higher chance of survival as the surgeons in this case are expected to be experienced and skilled. Patients who spend a lot of time in the waiting room also have higher chances of death compared to those who receive immediate treatment.

The walking speed of the nurses and medical personnel also affects the chances of survival of the patients (Marmour and Sinreich, n.d.). Hospitals that have clear and unobstructed walkways, proper construction plans, lifts and hoists to facilitate faster movement are likely to have more survivors.

Below are linear programming models based on the questionnaire (On a scale of one to 10)

Below are charts that show the different opinions of respondents of different routes in Asir and on the time that it takes for a head injury to turn fatal. The respondents’ answers were categories on a scale of one to ten.
Route model

<table>
<thead>
<tr>
<th></th>
<th>Route 1</th>
<th>Route 2</th>
<th>Route 3</th>
<th>Route 4</th>
<th>Route 5</th>
<th>Route 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic</td>
<td>9</td>
<td>3</td>
<td>9</td>
<td>4</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Distance</td>
<td>4</td>
<td>8</td>
<td>3</td>
<td>9</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Obstructions</td>
<td>6</td>
<td>2</td>
<td>7</td>
<td>6</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

Fatal head injury model

<table>
<thead>
<tr>
<th></th>
<th>&lt;30 minutes</th>
<th>&lt;50 minutes</th>
<th>&lt;70 minutes</th>
<th>&lt;100 minutes</th>
<th>&gt;100 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>First aid administered</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>8.5</td>
</tr>
<tr>
<td>No first aid administered</td>
<td>1.1</td>
<td>3.7</td>
<td>5.4</td>
<td>5.9</td>
<td>7</td>
</tr>
</tbody>
</table>

Head operation

<table>
<thead>
<tr>
<th></th>
<th>Hospital 1</th>
<th>Hospital 2</th>
<th>Hospital 3</th>
<th>Hospital 4</th>
<th>Hospital 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doctor and experience</td>
<td>7</td>
<td>4</td>
<td>9</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Patients waiting time/waiting line</td>
<td>3</td>
<td>6</td>
<td>8</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Hospital organisation and ease of movement</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Medical personnel walking time</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>
As a result we can classify which hospital able to apply linear programming model depend on its facilities and capabilities.

**Chapter Summary**

Linear programs have been found to improve the overall efficiency of hospitals with regard to trauma management and treatment. Data collected in the study shows that there exists a problem in determining the appropriate actions among the medical staff especially during critical moments. This in some instances has resulted in fatalities and is the major cause for death among trauma patients in Asir.
Chapter 5
Conclusion and Recommendations

5.1 Introduction

There is need for the government to come up with policies and rules that govern the way the emergency injuries and situations are handled and setting standards for the personnel working in the hospitals and the medical institutions. The Saudi Arabian government should ensure that the people working in the hospitals are well trained in order for the public to receive specialised attention and care.

The hospitals should obtain the necessary equipments for handling the emergency cases and this should be governed by the government. There should be the establishment of good communication channels in the hospitals to ensure that the emergency cases are well handled in trying to save lives.

Extensive research and analysis should be done by statisticians and engineers so as to come up with parameters that define head injuries and trauma. This will allow these conditions to be represented as variables and thus be integrated into the linear programming model. An in-depth and inclusive method of linear programming should be devised so as to include all the parameters that affect head injury patients into a linear programming model. The model should analyse traffic condition, ambulance equipment available, staff skill, number of doctors, time of day, month of year, age of patient, type of accident, type of injuries sustained, level of first aid done and time of arrival at the hospital, so as to be able to come up with an effective linear program.

Linear programming could also be implemented in Riyadh. The benefits of the system can be seen from the Asir model. This technique optimises on the delivery time of the patients to the hospital as it considers factors such as traffic, ambulance condition and accident scene. It also optimises on the use of resources by the hospital in treating trauma and other related cases.

However a Riyadh model would be more complex since it is a large city. The determining environments for delivery time will be much more than there are in Riyadh. This
system if implemented in Riyadh would save many lives and also improve the quality of service delivery in this city.

5.2 Limitations and future prospects

The use of linear programming in the trauma system in Saudi Arabia is one of the milestones in the provision of better health services to ensure that the lives of people are saved. This should be one of the steps in the long run to ensure that the injured people receive treatment and care within the shortest period of time and hence reducing the mortality rate of the Saudi citizens who die mostly from trauma. Other mechanisms should also be put in place and incorporated together with the trauma system in helping to save the lives of the injured by minimising the time taken by an injured person to get access to medical services during an accident.

Scientific and mathematical theories are increasingly being integrated into many professions in today’s world. Linear programming when integrated with medicine can be able to offer objective and accurate analysis of the daily occurrences.

The long term benefits of linear programming to the health sector would be reduced number of deaths and critically ill patients, reduction in annual expenditure incurred by the health ministry, improved organisational systems and proper utilisation of staff and equipment.

For the implementation of this system to be possible; a proper plan should be developed. The plan should consider the targeted regions, targeted illness and diseases (trauma), the number of hospitals to implement the system, the phases of implementation and the type of linear programs to be used. The preliminary phase will involve the assessment and choosing of variables to be used in the program. These variables must be able to give the most optimum results.

The implementation of a linear programming system in Saudi Arabia will have to be done in systematic phases. These phases include the education and training of the medical staff, the placement of supporting structures and the systematic integration of the model into the hospital system. Training and education of staff is of vital importance in the
implementation of a programming system as the have to understand the system and how it works so as to function in it.

5.3 Summary

A major challenge that will be faced in the implementation of a linear program will be the choice and assessment of variables. This is mainly because the best variables that represent the desired qualities will have to be chosen. Another problem is that some variables do not have units of measurement. The programmers will therefore be forced to quantify various conditions such as trauma, shock and head injury.

If such a system is implemented in Asir it will be of great benefit to the Asir people and especially to head injury patients. The Asir health agencies should embrace this technology and move their level of health care a notch higher.

REFERENCE


Ministry of Health, 2006., Health Indicators. Department of statistics. [Online] [Accessed


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APPENDIX A

Research Questionnaire
SAMPLE QUESTIONNAIRE

Name of Hospital: _____________________

Location of hospital: _________________

Occupation

(Please tick where appropriate)

[___] Doctor

[___] Nurse

[___] First Aid personnel

[___] Surgeon

[___] Rescue personnel

How many head injury patients have you attended to this year? ________________

What is the major cause of these trauma incidences? ________________________

How many deaths due to trauma have you witnessed this year?________________

How many head injury survivors have there been this year? ___________________

From which region do you receive most head injury patients?__________________

Do you think the Saudi government has done enough to reduce road accidents?

[___] Yes

[___] No
How long does it take for a head injury to turn fatal?

[____] less than 30 minutes

[____] less than 50 minutes

[____] less than 70 minutes

[____] less than 100 minutes

[____] more than 100 minutes

How long does it take to move a patient from the ambulance to operation room

[____] 1 minute

[____] 2 minutes

[____] 3 minutes

[____] 4 minutes

[____] 5 minutes

What are the major signals that a patient needs a head operation? Please tick where appropriate

[____] Swelling

[____] Facial fracture

[____] Stiff neck

[____] Depressed skull

What type of shoes do the nurses and health practitioners wear
Rubber shoes with flat base
Rubber shoes with high heels
Any type of shoes depending on current fashion

Do you think the type of shoes and clothing affect the speeds at which the health care personnel in your hospital/centre respond to emergency especially trauma?
Yes
No

How long does a head operation take?
less than 20 minutes
less than 40 minutes
less than 60 minutes
less than 80 minutes

How many ambulance rescue routes exist in Asir area?

What is the approximate rescue time for each route?
Route 1
Route 2
Route 3
If a scale of 100% represents death, what percentage of head injury would be inflicted on a patient for every 10 minutes the patient stays without treatment? ____________________

What is the average walking time in minutes that a medical personnel takes so as to administer treatment to the patient? ____________________

How many head injury surgeons are there in your hospital? ____________________

Please list the experience of each of these surgeons in years ____________________

How long does it take to prepare your hospital’s operation theatre? ____________________

Do you think that your hospital is well equipped to deal with head injuries?

[ ] Yes

[ ] No

[ ] May be
What recommendations would you give, so as to improve the treatment services of head injury patients?