OPERATIONS RESEARCH IN HEALTH CARE: A SOUTH AFRICAN PERSPECTIVE

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ABSTRACT

The use of Operations Research (OR) for decision making and management of health care operations deals with the use of various models that enable decision makers in the health system to make more informed decisions and to plan and manage operations more effectively. Even though the use of OR in health care service delivery in developing countries has increased recently, there are still limited publications available in this field, despite the fact that these countries can significantly benefit from such applications. Considering that the dynamics of the health care system of developing countries differs significantly from those of more developed countries, it is important for customised solutions and decision support models to be generated for developing countries. This paper therefore summarises various OR related research studies and applications in the health sectors of developing countries. It also provides an overview of the South African health sector, its challenges and how OR techniques can be used to support decision making in the country’s health system.

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1 INTRODUCTION

After the establishment of the new government in 1994, extensive improvement and restructuring initiatives have been undertaken to improve health care service delivery to South Africans. Even though the restructuring and improvement of the South African public health care sector achieved various accomplishments in the last two decades, some obvious shortcomings are still evident [1].

South Africa’s health system performs poorly when its impact on the status of the nation’s health is compared with countries with a similar or smaller per capita Gross Domestic Product (GDP) [2]. In 2009, the South African government spent approximately 9.2% of GDP on health, an increase from the 8.5% of GDP spent in 2000. This is slightly less than Botswana’s, but more than any of the other upper middle-income African countries’ healthcare expenditure in 2009 [3]. Despite this expenditure on health, South Africa’s health outcomes are worse than those of many lower income countries [4].

One way in which some of South Africa’s health challenges can be addressed is through the use of Operations Research (OR). According to Winston and Venkataramanan [5], OR can be seen as a scientific decision making approach that seeks to find the best way to design and operate a system under conditions that require the allocation of scarce resources. The use OR for health care decision making and management deals with the development and use of various models that enable decision makers in the health care industry to make more informed decisions and to plan and manage day-to-day operations more effectively. Health care OR is not a new field and many researchers, consultants and practitioners have used OR techniques to solve many problems experienced during health care service delivery throughout the world.

Even though OR applications in health systems of developing countries have increased recently, there are still limited publications available in this field, despite the fact that these countries can significantly benefit from such applications. Considering that the dynamics of the health care system of developing countries differs significantly from those of developed countries, it is important for customised solutions and decision support models to be generated for developing countries. In addition, the inefficiencies present in many hospitals and clinics in South Africa also emphasise the importance of generating customised solutions and tools to address the operational and management problems experienced specifically in the South African health system.

1.1 Research aim

The purpose of this paper is to provide an overview of the current South African health care system, identify typical challenges experienced in the country’s health sector and highlight opportunities for improvement using OR techniques.

1.2 Research methodology

To obtain a broader understanding of the current health care system in South Africa and to identify potential ways in which OR can be used to address some of its inefficiencies, a comprehensive review of available resources and reports is presented. Specific emphasis is placed on the public health sector, since even small improvements in this sector could result in significant benefits to the majority of South Africans. Thereafter a comprehensive literature review on the use of OR in health care systems of developed and developing countries is provided, followed by suggestions to improve inefficiencies in the South African health care system with the use of OR.
2 HEALTH CARE SERVICES IN SOUTH AFRICA

2.1 Overview of the South African health system

Before 1994 South Africa had a fragmented health system that was designed along racial lines, with a highly resourced system for the white minority and a systematically under-resourced system for the black majority [6]. After the establishment of the new government in 1994, extensive improvement and restructuring initiatives have been undertaken to address the disempowerment, discrimination and underdevelopment of the health sector of South Africa by transforming it into an integrated and comprehensive national service that provided essential health care to all individuals [4].

Even though various successes were achieved many attempts to transform the South African health care sector and introduce financing reforms were unsuccessful, resulting in a two-tiered health system - i.e. public and private health sectors - that still maintains various inequalities in health care [6]. South Africa’s public health care sector covers approximately 65% of the country’s health care needs with an annual expenditure of 4.2% of GDP [7]. However, other estimates of the country’s public health sector coverage are significantly higher [1, 6]. Taking into account that South Africa’s spent 9.2% of GDP on health in 2009 [3], it can be deduced that less than 35% of South Africa’s health care needs are covered by 54% of the country’s health expenditure.

South Africa’s public health care sector follows a hierarchical structure divided into primary, secondary and tertiary health services [7, 8].

The primary health care system is mainly a nurse-driven service and focuses on preventative and health promotion services such as maternal and child care, immunisation, chronic illness and minor trauma. This serves as the point of entry to public health care services in the country [9]. Community Healthcare Workers (CHWs) also play an important role in the primary health care system as the provision of home and community based health services are crucial in achieving good health outcomes nationwide [15]. The primary health care system is divided into clinics, Community Health Centres (CHCs) and District Hospitals [7]. Clinics provide a range of primary health care services for eight hours a day, whereas CHCs provide the same services as well as 24 hour maternity, accident and emergency services. In addition, CHCs have a bed capacity of around 30 for overnight patient observations. Clinics and CHCs are mainly serviced by nurses with scheduled visits by doctors to assist with clinical diagnoses [9]. A district hospital is a primary health care hospital that provides out-and-in-patient healthcare services 24 hours a day 7 days a week, including maternal health services, Human Immunodeficiency Virus (HIV) and Tuberculosis (TB) treatment as well as minor and some major surgeries under general anaesthesia [10].

The secondary health care system deals with health conditions and needs that are too specialised or complex for District Hospitals and comprises General Regional and Specialised Regional Hospitals. General Regional Hospitals are hospitals that provide at least five of the following specialty health services; anaesthetics; diagnostic radiology; medicine; obstetrics and gynaecology; orthopaedics; paediatrics; psychiatrics; and surgery. A Specialised Regional Hospital provides a single specialty service such as psychiatric or TB facilities [9].

South Africa’s tertiary health care system comprises tertiary or academic hospitals that provide specialist services to the public including specialised medical procedures; complex curative interventions such as oncology; all types of surgeries; Intensive Care Unit services; radiology; pharmacy services; and laboratory services. A full range of medical and paramedical specialists are available 24 hours a day 7 days a week at these facilities [10].

The private health care sector in South Africa provides health services to around 35% of the country’s health care needs. The private health care sector is mainly utilized by South Africans with private medical scheme memberships, approximately 16% of the South African population. The rest of the private health care services are typically utilized by South
Africans without medical scheme memberships who pay for private primary health care services out of their own pockets and then use the public health sector for hospitalisations [7].

2.2 Challenges in the South African health system

The South African health system is currently experiencing many different challenges, some of them stemming from the fragmented and biased health system that was inherited by the new democratic government of 1994. In a comprehensive review on the status of the health system in South Africa, the Health Systems Trust classifies the country’s health sector challenges into service delivery; structural; resource, pharmaceutical, diagnostics and medical equipment; and information system challenges [10].

2.2.1 Service Delivery Challenges

Service delivery challenges deal with the access, coverage and quality of health care provided to patients. Three key service delivery challenges, as identified by the Health Systems Trust [10], are the large gap between good health policies and their implementation; inequity in health care service access, coverage and quality; and poor supervision of primary health care services.

Coovadia et al. [4] state that even though the public health system has transformed into an integrated and comprehensive national service, the inadequate implementation of good health policies in South Africa is still a major challenge. This is mainly due to inadequate human resource capacity and planning; poor leadership, stewardship and management; and increased stress on the public health sector as a result of the burden of disease, especially HIV/AIDS and TB, and restricted spending in that sector.

Despite the progress made towards improved access to quality health care for disadvantaged communities in South Africa, large health inequities still exist. Coovadia et al. [4] indicate that there are noticeable differences in the rates of mortality and disease between races, which reflect the differences in access to basic household living conditions and other determinants of health, such as access to health care services. Some barriers to the accessibility of quality health care in the country include unbalanced resource allocation; long travelling distances to health facilities and high travelling costs, especially in rural areas; high out-of-pocket payments for health care; long queues at health facilities; and disempowered patients [11].

The reasons for the poor supervision of primary health care services are similar to those resulting in the inadequate implementation of policies. Coovadia et al. [4] assert that a central challenge to the health system is the reluctance to strengthen the management of human resources. This is partly due to limited managerial capacity. However, they also identify limited training support and supervision activities, ill-discipline, absenteeism, and moonlighting as other factors exacerbating the problem.

2.2.2 Structural Challenges

The structural challenges of the South African health sector are a direct result of the challenges experienced in its governance and management. Poor stewardship at policy level, weak management, and weak supportive supervision at the implementation levels are major obstacles to improving South Africa’s health system [4]. In the same vein, the Health Systems Trust [10] identifies some of the key structural challenges of the sector as inefficiencies; inconsistent delegation of human and capital resources; an institutional environment that often precludes the implementation of new learning and innovation; and inadequate organisational structures with a lack of lower level management.

The inadequate management and governance at lower levels in the health system, i.e. district and sub-district levels, resulted in a lack of responsiveness to community needs; a
general lethargy in the district health system; no prioritising or actions around pressing primary health care needs; a fragmented delivery system implementing multiple uncoordinated interventions and campaigns; as well as the separation of community, home and facility based functions [10].

Mayosi et al. [12] also identify the integration of the public and private health sectors, vertical programmes and community outreach programmes as a key challenge in the health sector. They comment that despite many achievements, the coordination of implementation at many levels in the health system remains a challenge.

2.2.3 Resource Challenges

The resource challenges in the South African health sector all result from the shortage of adequate financial, infrastructure and human resources. There are currently major deficiencies in the physical structure and security of facilities, the infrastructure of many existing facilities are inadequately designed, and insufficient maintenance of facilities and equipment impacts negatively on staff retention and morale in the South African health sector [10].

An appropriate, sustainable and trained workforce is a key priority for the health sector in South Africa. Workforce planning is an important process in the management of human resources and massive investments in a country's health sector are focussed toward employing and training health workers. It is therefore important that this “massive investment in training and employment of the health workforce is well planned, appropriately targeted and properly managed” [13].

However, various human resources challenges still exist in this sector in South Africa. Some of the human resources challenges in the sector are identified by the Health Systems Trust [10] and include insufficient workforce planning; the maldistribution of human resources; and high attrition rates. In addition, training opportunities provided to staff in the health sector are inadequate, resulting in health personnel that are not sufficiently trained or orientated to understand their responsibilities and the role of social determinants on health outcomes.

This is confirmed by the National Department of Health [13] who states that even though ensuring the appropriate supply and distribution of health care workers in the country is critical, the supply of health professionals in South Africa is not currently actively being managed.

Another key resource challenge in the South African health sector is the availability and efficiency of health facilities. Two international indicators commonly used to assess the efficiency of hospitals are the Average Length of Stay (ALOS) and the Bed Utilisation Rate (BUR) - also known as the Bed Occupancy Rate or Usable Bed Utilisation Rate. According to the Health Systems Trust [14] the ALOS is a measure that determines how much time patients on average spend in district hospitals. This provides an indication of the efficiency of the hospital and the quality of care provided. An extremely long ALOS indicates that patients are kept in the hospital too long. This is typically caused by a shortage of medical personnel and by operational inefficiencies. Conversely, a very low ALOS is also a problem as it may indicate that the quality of care to patients is compromised. The BUR measures the occupancy of usable and available beds in district hospitals [14]. The BUR therefore determines how efficiently a hospital is using its available capacity. A low ALOS and relatively high BUR indicate that a hospital is functioning well.

In 2011 the ALOS in South African district hospitals was 5.6 days and the BUR was 73% [15]. While the BUR is relatively close to the target of 75%, the ALOS is still significantly longer than the target of 3.4 days [16].
2.2.4 Pharmaceutical, Diagnostics and Medical Equipment Challenges

Even though pharmaceuticals, diagnostics and medical equipment are essential for delivering quality health services in South Africa, the management and regulation of these resources are not adequate. These are various guidelines related to pharmaceuticals, diagnostics and medical equipment, such as the Essential Drugs List, but methods to ensure adherence to these guidelines are lacking. To make matters worse, the South African health sector is frequently haunted by pharmaceutical shortages and stock-outs mainly due to weak management systems for forecasting, procurement, warehousing and distribution [10].

This issue is again highlighted in the 2012/13 South African Health Review where the authors caution that the state of many public health systems in South Africa, in particular pharmaceutical supply and delivery systems, threatens the expansion of successful treatment programmes in the country [15].

2.2.5 Information System Challenges

South Africa is often seen as data rich but information poor as the data systems in the country are not adequate to provide good quality, nationally representative information in a timely manner [12]. One of the key challenges acting as a barrier to the establishment and utilisation of an adequate health information system in South Africa is the absence of a culture of information use [10].

This lack of an information culture in the health sector of South Africa is due to, amongst others, the shortage of clear and comprehensive policies and guidelines to support the implementation of health information system legislation; poor alignment in the information system between the measurements and objectives; limited availability of hardware; inadequate technical support; a shortage of human resources; a complex work environment; a distrust of technical solutions; inadequate training opportunities; the lack of governance and standardisation related to health information systems; as well limited buy-in and involvement of managers in data management activities [9, 10].

Further exacerbating the problem is the inadequate investment in health management information systems [10]. However, strategic investments in the South African health information system are essential in developing the ability to prepare, manage and use data for decision making in the health sector [12].

3 USING OPERATIONS RESEARCH FOR HEALTH CARE DECISION SUPPORT

The use of OR in health care is not a new field and many researchers, consultants and practitioners have used OR techniques to solve many problems experienced during health care service delivery throughout the world. A summary of papers presented over 35 years at the European Working Group “Operational Research Applied to Health Services” (ORAHS) is provided by Brailsford and Vissers [17]. They identify various functional areas where OR have been applied, i.e. Finance, policy, governance and regulation; Public health and community service planning; Patient behaviour; Planning system or resource utilisation; Quality management and performance monitoring; Risk management and forecasting; Workforce management; Research; and Other. For the purposes of this paper, these OR application areas in health care service delivery are combined into the five categories discussed in this section.

3.1 Governance, Policy and Strategic Planning

OR is often used at government and institutional levels to assist with the planning and development of legislation, health policies, strategies and management guidelines. Examples of such applications are presented by Hutton et al. [18] who integrate various OR techniques to analyse the cost effectiveness of interventions to combat Hepatitis B in the United States and China. The results of their analysis helped to change the US public health policy on
Hepatitis B screening. In addition, it also encouraged policymakers in China to enact legislation that provide access to free Hepatitis B vaccinations for hundreds of millions of children.

Bennet et al. [19] provide an overview of similar projects where the Department of Health in England used OR techniques to analyse health policies and guide policy decisions. They comment that even though OR modelling fits into the overall process of policy decision making, the key lies in the ability to understand policy issues in ways that allow for the insightful application of relatively simple models. To this end, they believe that finding a requisite model is a key skill for OR practitioners in government. Such a requisite model could be a dramatic simplification is some respects, but should still capture enough of the full picture to provide practical and insightful guidance for policy decision makers.

OR can also be an invaluable tool in the management of government health programs. To this end, Tao et al. [20] present a resource allocation model that can enable improved local sexually transmitted disease control and prevention programs in the United States. Seeing that publicly funded programs usually have insufficient funds available to screen and treat all patients, their model focuses on providing an optimal strategy for screening and treating women with Chlamydia trachomatis and Neisseria gonorrhoea. They conclude that resource allocation models can successfully be used to guide decisions about the effective use of limited resources available for sexually transmitted disease control and prevention.

On a more institutional level, Cabrera et al. [21] present a decision support system for the operation of emergency health care departments. This system is developed using agent-based simulation and optimised to find the best staff configuration for the emergency department to minimise patient waiting time and maximise patient throughput. The system can assist managers with the development of strategies and management guidelines for the improvement of emergency health care departments.

Agnetis et al. [22] use OR to provide guidance to decision makers on long-term operating room planning policies. They evaluate various approaches to define operating room elective surgical schedules that provide the best balance between stability and flexibility. Their results indicate that introducing a limited amount of flexibility into the structure of surgical schedules can yield significant benefits in terms of the waiting time and due date performance of operating rooms. They conclude that simulation and optimisation models can be profitably used for planning and scheduling on an institutional level, potentially resulting in various benefits, such as better clinical results, higher patient and staff satisfaction, improved patient safety and improved institutional performance.

### 3.2 Resource Planning

The planning and allocation of resources at health facilities is another area where OR can be invaluable. These types of institutional decisions typically require the planning and allocation of limited resources in a way that will enable the efficient, timely and effective treatment of patients at health facilities. OR techniques can be used to provide decision makers with an indication of the best possible resource allocations that can be achieved under a given set of limitations.

This is illustrated by Stinnet and Paltiel [23] who present a mathematical framework for allocating scarce resources efficiently within budgetary, practical and ethical constraints. They comment that the model is a powerful tool that eliminates the need for restrictive assumptions. However, they caution that the usefulness of their model, and all other models of this type, is limited by the need for accurate information of the costs and impacts of decisions. However, as a counterargument they highlight that the use of informed rough estimates is preferable to making uninformed decisions or relying on invalid assumptions.

An application of OR for resource planning at the Department of Veterans Affairs in the United States is provided by Syam and Côté [24]. They present a location-allocation model
for specialised health care services, such as the treatment and rehabilitation of strokes or traumatic brain injuries. The primary objective of their model is to provide a mathematical framework, for the assignment of admission districts to treatment units, that incorporates the cost of providing services as well as the service level at which these services are provided. The model is then applied to one of the Department of Veterans Affairs specialised health care services to evaluate the impact of several factors on the objectives of the model. They conclude that most of the major factors considered in the analysis have a significant effect on the assignment of admission districts to treatment units.

Although the use of OR during resource planning, usually focuses on planning resources at an institutional level it also proved to be a useful planning technique on a national level. To this end, Bowers et al. [25] present a resource allocation model that can inform strategic resource allocation decisions for a national patient transport service in Scotland. They highlight that their model enabled management to identify a more rational and strategic allocation of resources and examine the trade-offs between service levels and resource requirements. They conclude that their work also illustrates how both simple and sophisticated models offer complementary qualities and that it is possible to achieve a balance with the simpler models built on the foundations of the more complex approaches.

### 3.3 Patient Planning

Not only can OR be used to efficiently plan the resources of health systems, but also to plan and schedule patients in the health system. This is illustrated by Day et al. [26] who present a model of a decision process to improve patient flow in United States hospitals by allocating cardiac diagnostic testing time slots to patients. They ascertain that their model provides a flexible, robust and dynamic network scheduling tool that can be used for patient scheduling in any cardiac diagnostic testing centre. Their model is then applied to a local hospital and the resulting solutions are evaluated using simulation. They conclude that significant improvement in the quality of in-patient service and hospital revenue can be realised with only a minor decrease in out-patient service levels.

### 3.4 Supply Chain and Inventory Management

Kelle et al. [27] state that the field of health care supply chain and inventory management has been given relatively little attention in the past, despite its size and importance around the world. However, various studies dealing with the use of OR to support supply chain and inventory management decisions exist. Most of these studies rightly focus on the development of appropriate inventory management models for various health care facilities as inventory investments in health care is estimated to be between 10% and 18% of revenue, and any measures to control expenditures in this area can have substantial impacts [27].

This is illustrated by Nicholson et al. [28] who present two mathematical models for the management of non-critical medical supplies inventories in the United States. The first model determines inventory costs and service levels of an in-house three-echelon distribution network, whereas the second model determines the inventory costs and service levels of an outsourced two-echelon distribution network. These models are compared and results indicate that the two-echelon network results in inventory cost savings without compromising the quality of care. These two models also provide a way for decision makers to investigate strategic inventory decisions within two distribution networks.

In another study, Katsaliaki and Brailsford [29] present a simulation model of the blood supply chain of a typical hospital in the United Kingdom. They ascertain that, in contrast to other inventory models in the literature, their model considers an entire vertical section of the supply chain; include mismatching; incorporate products with different shelf lives; and include the time spent in the assigned inventory stage during the calculation of remaining shelf life. Their simulation model is then used to evaluate various inventory management
policies and identify the most suitable one to implement in order to reduce shortages, wastage and costs whilst increasing service levels and safety.

In a more recent study, Baboli et al. [30] investigate supply chain and inventory management challenges in a downstream pharmaceutical supply chain and state that traditional inventory models are not ideal for pharmaceutical inventory management as they cannot optimise the total cost of the system. They consequently present centralised and decentralised models for multi-product replenishment policies that focus on the joint optimisation of both inventory and transportation cost for pharmaceutical products. They state that their models can be applied to determine the reorder quantity and replenishment period of a family of products that has a stable demand, low prices and high turnover rates. They also assume a constant deterministic demand rate and order lead time. However, their models don’t make provision for any shortages as it is assumed that no shortages are allowed.

While some of these studies include the application of these models to case study hospitals, consideration to the actual implementation of the improved inventory management systems at health care facilities are inadequate. The process of using OR to provide effective supply chain and inventory management decision support is not limited to the quantitative component of inventory modelling and supply chain simulation. Various other factors need to be taken into account.

To this end De Vries [31] investigates the process of reshaping a medicine inventory management system through an explorative qualitative case study in a hospital. He determines that various outcomes in the implementation of a new inventory management system in a hospital are heavily influenced by the dynamics of the relationships and interactions between stakeholders. His study highlights that the process of successfully developing and implementing a new inventory management system at a healthcare facility requires a thorough understanding of the relationships and interactions between different stakeholders at the facility.

In an attempt to improve the current pharmaceutical inventory management policy at the local storage unit of an individual care unit of a case study hospital, Kelle et al. [27] present a decision support tool to facilitate improvements of the current inventory management practices. They ascertain that the use of their tool as a decision support system for pharmaceutical inventory management at the case study hospital can reduce its inventory related pharmaceutical expenditures by up to 80%.

3.5 Quality Management

In the context of this paper, health care quality management refers to both the quality of care and the safety of patients in the health system. The availability of OR related publications in the field of health care service delivery quality and safety is limited.

In one study Kanagarajah et al. [32] use agent-based simulation to evaluate the complications of health care improvements and its impact of patient safety, economics and workloads. They argue that agent-based simulation has the potential to be a useful tool for studying the quality of health care and analysing the complex adaptive behaviour of health care systems.

A study where OR is used to improve the quality of care to patients in a hospital environment is presented by Van Essen et al. [33]. Their study focuses on developing an operating theatre scheduling model that will reduce emergency surgery waiting time and allow hospitals to maintain a high quality of care by scheduling elective surgeries using break-in-moments to compensate for emergencies. The model is then tested by means of simulation and compared to historical data of the operating room for inpatients at the Erasmus Medical Centre in the Netherlands. The results indicate that the use of their model
for the scheduling of elective surgeries can reduce the waiting time for emergency surgery by approximately 10%.

4 USING OR FOR HEALTH CARE SERVICE DELIVERY IN DEVELOPING COUNTRIES

Even though the use of OR to improve health care services and operations in developing countries has increased recently, there are still limited publications available in this field. Most of these publications focus on hospital management as health care resources in developing countries are often located at secondary levels [34].

Hani et al. [35] present a case study on medical consumables inventory management at a public hospital in Indonesia. They performed a qualitative analysis of problems experienced during medical consumables inventory management by conducting several in-depth interviews with relevant stakeholders as well as various field observations. Key problems identified through this study include a lack of human resources; inadequate information systems; storage space constraints; as well as late supplier payments.

In another study in Indonesia, Rachmania and Basri [36] examine the inventory management practices in a public hospital and identify excessive stock levels, poor demand forecasting and a lack of information technology support as the three major challenges experienced. They investigate the suitability of the basic (r,Q) and periodic review (R,S) inventory models for the management of oncology medicine at the hospital and ascertain that the (r,Q) inventory is the better of the two as it carries less stock while still satisfying demand. They also compare various demand forecasting techniques and determine that trend-corrected exponential smoothing is the most appropriate forecasting technique for oncology medicine.

Hauman [37] presents a South African case study for the Western Province Blood Transfusion Service. She uses simulation to model the blood inventory management policies at the organisation, and examine their effects on blood bank service levels and the associated delivery system. Multi-objective optimisation is then used to identify various improvement alternatives for the current inventory management systems at blood banks.

An application in policy planning in South Africa is presented by Lagarde et al. [38]. They perform cost-effectiveness analyses of various human resource policy interventions to address the shortage of nurses in the rural areas of the country. They conclude that increasing the salaries of nurses is not the most effective intervention and other downstream interventions, such as study leave, can result in better outcomes at a lower cost. However, their results indicate that the best and most cost effective approach to address this problem is to rather focus on upstream measures, such as recruiting more nursing students from rural areas.

In a resource allocation study, Ahmed and Alkhamis [39] integrate optimisation and simulation to develop a decision support tool for decision makers at an emergency department at a hospital in Kuwait. The decision support tool determines the number of staff members required to optimise patient throughput and reduce patient’s time in the system subject to budget constraints. The tool is applied to an actual hospital emergency department and results indicate that a 28% increase in patient throughput and a 40% decrease in patient waiting time can be realised with existing resources. The value of this tool lies in its ability to enable decision makers to evaluate various alternatives for the planning of operations in the emergency department.

An interesting application to the area of patient safety is presented by Brent et al. [40] who use the analytical hierarchy process in health care waste management systems in the rural areas of developing countries. Their approach is applied to South Africa and Lesotho to illustrate how the analytical hierarchy process can be used to provide decision support to the health systems of developing countries.
4.1 Opportunities for OR in Health Care Service Delivery in Developing Countries

Despite some studies on the use of OR to improve health care services and hospital operations in developing countries, available research in this area is still lacking. Low-income and developing countries can significantly benefit from the application of OR in health care service delivery [41]. Specific areas where OR can have the biggest impact are as follows:

- **Improved access to medical products and services.**
  
  Access to medical products can be improved by means of OR applications focusing on improving and informing decisions during inventory and supply chain management. In addition, the use of OR to assist with the planning and development of legislation, health policies, strategies and management guidelines can also enable improved access to medical products and services.

- **Increased hospital or clinic efficiency and quality of service.**
  
  Every hospital and clinic in developing countries must do more with less. OR can therefore help health facilities to improve their efficiency and quality of service by means of improving quality of operations through quality management applications; designing effective health information systems; planning and scheduling limited resources; modelling resource availability and utilisation; and diagnosing diseases more efficiently [41].

- **Improved emergency medical service efficiency.**
  
  Emergency medical services, such as ambulances, can rely on OR applications to determine adequate fleet sizes and enable faster response times through better resource planning and management [41].

- **Improved effectiveness of clinical interventions.**
  
  Ghosh et al. [41] indicate that the MDGs for health and nutrition can be accelerated through the application of OR techniques. This can be achieved through the use of OR to assist with the planning and development of legislation, health policies, strategies and management guidelines, as well as through improved resource planning, supply chain and inventory management in health systems.

- **Prevention, control and elimination of communicable diseases.**
  
  The prevention, control and elimination of communicable diseases can be accelerated through the application of OR techniques [41]. This is possible through OR applications focusing on the planning and development of regulations, policies, strategies and guidelines; supply chain and inventory management; resource planning; patient planning; and quality management.

- **Building equitable and efficient health care systems.**
  
  Ghosh et al. [41] indicate that OR can help with the development of a global health research culture and facilitate the development of effective and equitable health systems through evidence-based policy making, practice and knowledge translation.

Mistry et al. [42] identify various OR applications as part of the fight against multi- and totally drug-resistant tuberculosis (TB) in India. They suggest the following OR application areas to tackle the challenge of drug-resistant TB in Mumbai:

- **Better diagnosis, drug susceptibility testing, classification and definition of cure.**
  
  OR can be invaluable to this particular application area through modelling the effects of new technologies; network mapping and modelling; improving resource allocation; and modelling of the effects of changes in timing of activities.
Better prescribing practices across care providers.
The particular usefulness of OR to improve prescribing practices stems in its ability to enable the modelling of the effects of legislation and drug control; modelling of the effects of changing the balance of ambulatory and inpatient management; and modelling of the effects of adverse drug reactions.

Better integration of TB diagnosis and treatment with Anti-Retro Viral medicine for patients with HIV.
This can be achieved through the modelling of diagnosis and transmissibility; and the modelling of the effects of preventative therapy.

Better infection control.
The value of OR in achieving better infection control is through the modelling of the effects of changes in infrastructure and routines.

Even though the recommendations made by Mistry et al. [42] focus on drug resistant TB in India, most of these OR applications can be be invaluable tools for all developing countries in fighting the global TB pandemic.

4.2 Opportunities in South Africa
The key opportunities for OR to enable improved health care operations and service delivery in South Africa, in addition to those discussed above, are summarised in Figure 1.

Figure 1: Opportunities for OR in health care service delivery in South Africa
Some of the service delivery challenges in the South African health sector can be improved by means of OR applications focusing on patient planning; resource planning, scheduling and management; and quality management. Improved patient management, resources planning, and quality management will result in improved access, coverage and quality of health services provided to patients. In addition, the use of OR to assist with the planning and development of legislation, health policies, strategies and management guidelines can also enable improved access to health care.
The South African health sector’s resource challenges can partly be addressed through the use of OR to manage patients in the system more efficiently; to plan and manage scarce resources more efficiently; and to assist with the planning and development of evidence-based health policies and management guidelines.

Great progress in addressing the structural challenges in the South African health sector can be achieved through the use and application of OR to assist with the planning and development of legislation, health policies, strategies and management guidelines.

Major improvements in the pharmaceutical, diagnostics and medical equipment challenges of the South African health sector can be achieved through OR applications focussing on planning policies, guidelines, and strategies as well as through more effective supply chain and inventory management in the health system.

Finally, many of the information system challenges can be addressed though OR applications focussing on more effective resource planning and management. The use of OR to assist with the planning and development of legislation, policies, strategies and management guidelines related to health information systems can also be invaluable in addressing information system challenges in the South African health sector.

Despite the many opportunities for OR in the South African health sector, merely developing and applying various OR solutions will not be enough to address the challenges in the sector. In order to achieve the best results with these opportunities, it is important for the relevant OR principles to be prioritised, designed, implemented and replicated within national health programmes as well as institutionalised as a critical part of monitoring and evaluation of the health system of the country [41].

5 CONCLUSION

Despite the strides made towards a “long and healthy life for all South Africans”, many challenges still exist within the South African health sector, some of them stemming from the fragmented and biased health system that was inherited by the new democratic government of 1994. Failure to address these challenges in the South African health system will result in the country not attaining the health goals it has set for itself.

One way in which these challenges can be addressed is through the use of OR. The use of OR in health care is not a new field, but there is a general lack of OR applications to the health systems of developing countries. Considering that the dynamics of the health systems of developing countries differ significantly from those of more developed countries, it is important for customised solutions and decision support models to be generated for these countries.

This paper therefore focused on providing an overview of the South African health sector, its challenges and how OR techniques can be used and applied to support decision making and management in developing countries’, and in particular South Africa’s, health systems.

6 REFERENCES


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