LIST OF ABBREVIATIONS

APPA	Atmospheric Pollution Prevention Act, 1965 (Act 45 of 1965)
AQA	National Environmental Management: Air Quality Act, 2004 (Act 39 of 2004)
AQOs	Air quality officers
CM	Change management
DEA	Department of Environmental Affairs
DPSA	Department for Public Service and Administration
KM	Knowledge management
NGOs	Non-governmental organisations
NO_2	Nitrogen dioxide
NOx	Oxides of nitrogen
PM	Project management
PM_{10}	Particulates in the air with particle sizes less than 10 microns
SO_2	Sulphur dioxide
SPSS	Statistical package for the social sciences
SAAQIS	South African Air Quality Information System
TSP	Total suspended particles in the air
W	Weighted value of the outputs
X	Independent/input variable
Y	Dependent/output variable
ug/m^3	Micrograms per cubic meter

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CHAPTER 1: INTRODUCTION

'Believe those who are seeking the truth. Doubt those who find it'.

André Gide (Unknown)

The chapter provides an overview of the research into a resource allocation model to improve output efficiency. The focus of the study will be the South African public sector, with an emphasis on the management of air quality. The current state of play of the South African departments, and specifically the Air Quality Units, is presented to provide the context to the study.

The motivation for selecting the South African Air Quality Units is then discussed. This motivation is based on the challenges they face to complete their mandated outputs, which also provides the opportunity for fieldwork in the air quality management field.

The main purpose of this chapter is to highlight the context of the study, research design, high-level findings and conclusions as well as the contribution of the work to the South African Air Quality Units. The aim and objectives of the study also receive attention. Permission to conduct such a study, as well as the data capturing and statistical analysis of the data, is discussed. The value of the study and its limitations are also presented. The chapter ends with a discussion of the organisation of the rest of this thesis.

1.1 Introduction and Context

'The business rule of thumb in the last century – cheaper is better – is being supplemented by a new mantra for success: sustainable is better …'

Goleman (2009)

Goleman (2009: 11) stressed on the increasing focus of business to manage issues relating to environment and sustainability. Goleman (2009) indicated that sustainable decisions require an understanding of the environmental impacts of businesses to recognise long-term opportunities as well as mitigate potential short-term business risks.

Goleman (2009) added that environmental licences of businesses are now a key requirement and provides the licence to operate (Goleman, 2009). Public sector managers must be trained to respond through increased regulations and enforcement in the area of environmental management, specifically air quality management (Van Niekerk, 2008).

Mankins and Steele (2005) supported that there was a positive relationship between planning and the organisations' performance output, but argued that companies typically only realise 63% of the potential value of their strategy because of defects in planning and execution. Mankins and Steele (2005) provided a list of causes of performance loss, and identified inefficient resource allocation as the most important contributor to performance loss in organisations, as illustrated in Figure 1.1. Mankins and Steele (2005) added that any strategy could be realised, as long as planned and executed appropriately.

Aladin (2006) asserted that Government's performance loss can be attributed to the lack of implementation of legislation. Although Aladin (2006) praised the South African government departments for having the most innovative and progressive legislature, policies and programmes in the world, his work highlighted that there was a considerable gap between written regulation and reality (Aladin, 2006).

Models relating to efficient resource allocation can assist leaders in becoming efficient. Indeed, the Department for Public Service and Administration (DPSA) expressed the opinion that interventions that are informed by models that support efficient resource allocation can facilitate the required transformation of the South African government from their current state (poor output efficiency) to the required state (efficient output performance). According to the DPSA (2006), achieving the desired transformation depends on the ability of the public sector managers to convert policy mandates into patterns of action that produce efficient outputs. To be efficient, public managers must deliver on agreed objectives that are aligned to their resources. The percentage of completed outputs therefore serves as an indicator for output efficiency. In addition, there must be alignment of the departments' resources with the selected strategic objectives (DPSA, 2006).

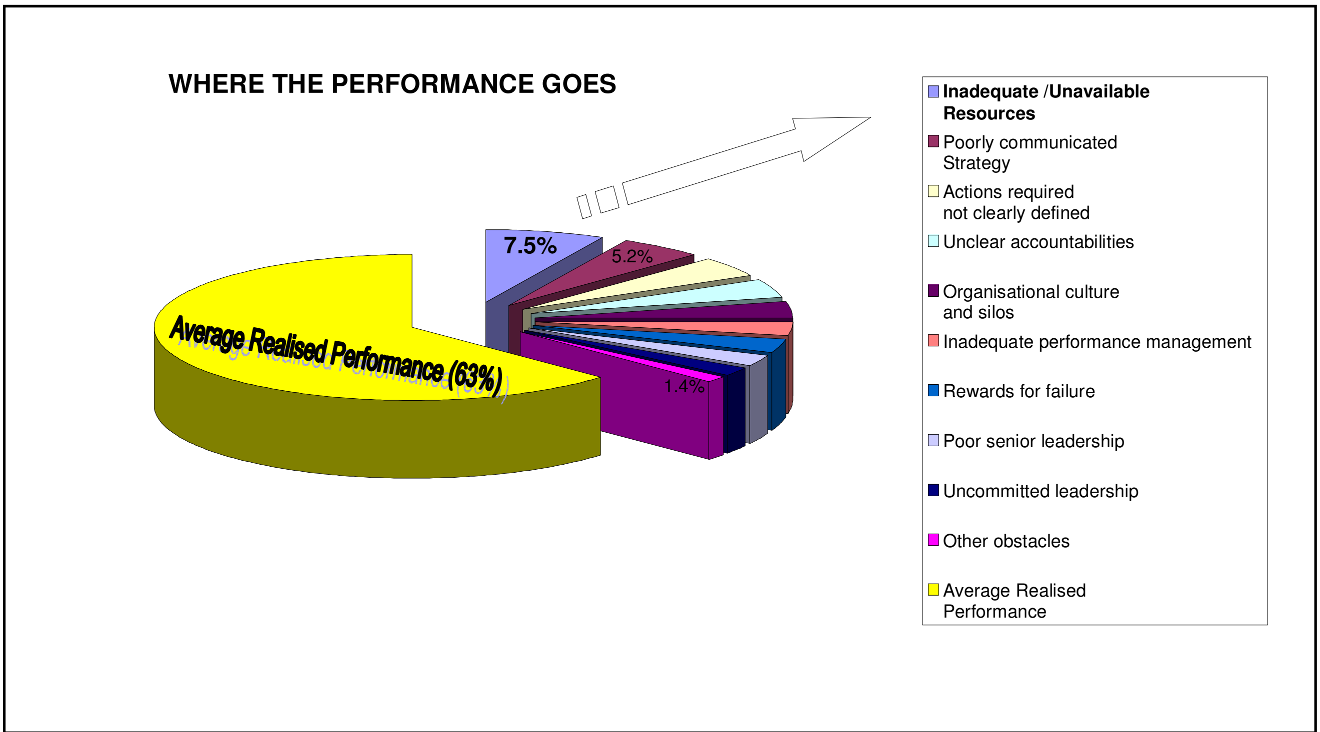


Figure 1.1: Contributing factors to performance loss (Mankins & Steele, 2005)

Public service departments have low output efficiency due to improper resource allocation to meet their mandated outputs (DPSA, 2006).

Organisations use models as tools for analysing and developing strategies to maximise their output efficiency (Recklies, 2004). The application of models in decision-making also allows for systematic and transparent outcomes (Gachet, 2004). Maltz (2001) defined a model as a simplified representation of reality – one that contains the salient features of the system or process under study. He added that a model describes how the variables of interest are related to each other. Typically, models can be manipulated to see how the system or process under study is affected by different inputs, or how changes in its form can affect system behaviour.

Maltz (2001) described the advantages of having the ability to manipulate the variables in a model as aiding in the development of theories to explain the behaviour of a process, and in gaining insight into its characteristics. A good model is one that incorporates the known characteristics of the process under study and that strikes the right balance between completeness and conciseness (Maltz, 2001). In developing such a model, not all variables are equally useful; therefore, a selection of the appropriate variables and establishing the relationship between the variables is critical to model building (Morris, 1967). Developing a model to a set of data is also guided by the principle that a simple parsimonious model is better than a complicated model, if both provide similar explanatory power (Maltz, 2001).

This study deals specifically with the South African Air Quality Units at the national, provincial and local government levels. Given the challenges of the South African Air Quality Units, this study focused on the development of a model to assist with the allocation of resources to improve the output efficiency of these Units.

1.2 Scope of the Study

When concepts are researched in the context of the public sector, it is impossible to study the whole population *i.e.* South African Government. A manageable scope for the study in the public sector was selected through a filtration process, as shown in Figure 1.2. The practical knowledge and professional experience of the researcher further guided the scope selection process.

Air quality management was highlighted as a critical environmental focus area due to the following factors:

- Increased stakeholder awareness (Goleman, 2009);
- Lack of compliance action (Van Niekerk, 2008); and
- Need for industries to rapidly change technology through environmental authorisation processes (Pape, 2001).

Lukey (2007) supported the scope of the study and added that the Air Quality Units were experiencing several challenges in terms of improving communication across the different spheres of government as well as accessing air quality data and using it to support efficient decision-making.

It was therefore, opportune to evaluate the potential for improving the output efficiency in the air quality management units.

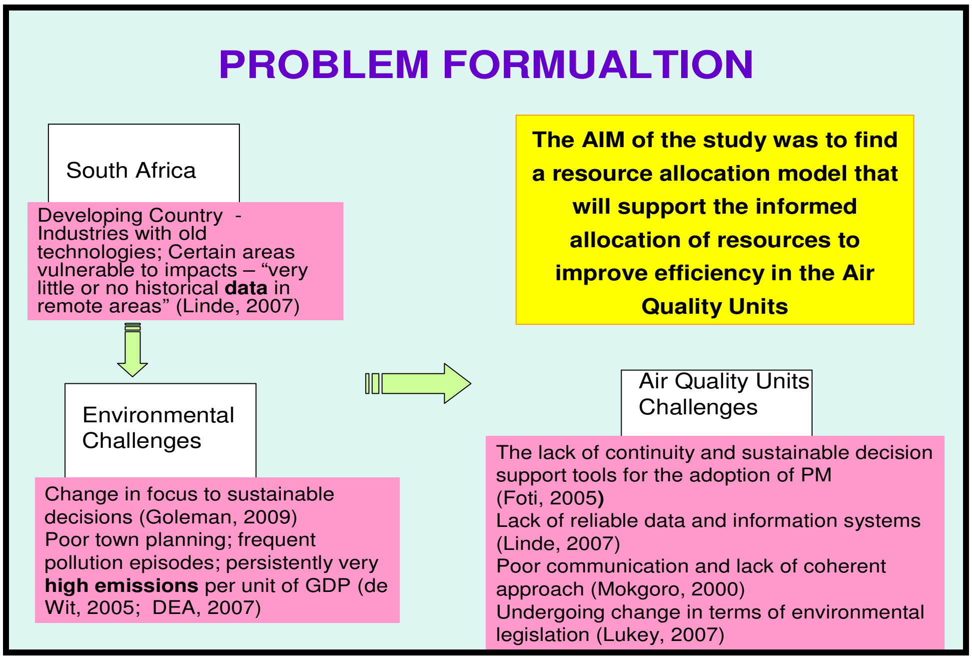


Figure 1.2: Problem formulation and scope of the study

1.3 Historical Development and Current State of Play

Markham (1994: 113) wrote: '*Air pollution has been a political issue in Britain for almost 800 years*'; however, before the nineteenth century, air quality impacts were managed as '*specific nuisances*' only.

By the early 1800s, the industrial revolution and particularly the burning of coal to produce steam had taken its toll on the quality of air over the major English industrial cities. The technology to enable steam engines to burn coal more efficiently, hence reduce the amount of smoke produced, was already in existence and one of the earliest patents for such a device was registered by James Watt in 1785 (Hadfield & Seaton, 1999). However, in the absence of any regulation or incentives, there was no interest on the part of industrialists for the adoption of smoke control. Michael Angelo Taylor first raised the issue in parliament in 1819 and he subsequently raised the profile of the issue of pollution over the years. One major objection that was highlighted related to concerns around the scientific uncertainty of the air quality data (Markham, 1994).

The lack of operational information management and knowledge systems to defend regulations on emissions was identified as an obstacle to efficient air quality management (Hadfield & Seaton, 1999).

Brimblecombe (1987) reported that the dense fog that enveloped London from 5 to 9 December 1952, and to which 4,000 deaths were eventually attributed, was credited as the trigger for the introduction of the Clean Air Act (1956). Through the provisions of this Act, local authorities were empowered to declare smoke control areas (Markham, 1994). Implementation, however, varied greatly between different areas. Nevertheless, the Clean Air Act (1956) was regarded as being successful in reducing smoke and smog. Some of the improvement in terms of air quality may however be attributable to technological changes, which were taking place in parallel, such as the discovery of natural gas in the North Sea, the development of nuclear power and the phasing out of steam locomotion (Hadfield & Seaton, 1999).

The involvement of the European Union in environmental legislation in the 1980s and 1990s, as well as increased recognition of the nature of air pollution problems, led to a change in emphasis in air quality management in the United Kingdom. There was a shift from control of point emissions to control of ambient levels (Hadfield & Seaton, 1999).

The first European Directive to define air quality standards for sulphur dioxide (SO_2) and particulates in the air with particle sizes less than 10 microns (PM_{10}) was adopted in July 1980. This was followed by directives for oxides of nitrogen (NOx) and lead and was implemented by the United Kingdom government in its air quality regulations of 1989. This introduced into the United Kingdom the first statutory air quality standards and was followed by a directive for ozone, adopted under the ozone monitoring and information regulations (Hadfield & Seaton, 1999).

The focus had shifted from the control of individual pollutants to the management of ambient levels of pollutants. However, ambient levels were the emergent outcomes of the interactions of the underlying effects that cannot be managed directly and are consequently more challenging (Hadfield & Seaton, 1999). Therefore, operational management systems were required to support decision-making by the authorities.

The imposition of limits and/or guidelines for ambient levels implied that the ability to monitor these levels was necessary to evaluate compliance. The focus of government interest had therefore increasingly been on this aspect of management. In 1992, the Enhanced Urban Network of monitoring sites became operational, in response to the need to monitor for compliance with the European Directives (Hadfield & Seaton, 1999).

The Enhanced Urban Network sites provided continuous monitoring of SO_2, NOx, carbon monoxide, ozone, PM_{10} and hydrocarbons using automatic instruments at a number of sites around the country. Trained local authority staff operated these sites and the information was coordinated centrally. The Rural Air Quality Network of 15 sites monitored ozone on the same basis (Hadfield & Seaton, 1999). However, monitoring of ambient pollution presented its own technological difficulties. At ground level, the main emphasis of air quality management was on the management and use of the data collected to make informed decisions.

Krupnick (2008) reported that air quality management ranked relatively low in terms of global priorities. Krupnick (2008) emphasised that air quality management interventions for developing countries were quite different from those of developed countries. This was due to conditions being different in these two sets of countries. With the rising marginal costs of pollution abatement in developing countries, the scope for reducing emissions cheaply was initially large.

The six major differences to managing air quality in developing countries relative to developed countries are as follows:

- Concerns about minimising costs overshadow concerns about reducing air pollution to a greater extent;
- Capital is more scarce than labour;
- Baseline emissions control is lower;
- Market distortions are more pervasive;
- The infrastructure for implementing an air pollution control system was minimal and transactions involved with that infrastructure are marred by corruption; and
- Revenue needs of governments were more pressing than reducing pollution.

Cannibal and Lemon (2000) reported on the strategic gap in air quality management. They concluded that the tight budgetary constraints applied to local air quality management have restricted local authorities to those procedures for which funding can be secured. This has inevitably hindered work towards efficiently managing air quality.

Krupnick (2008) also reported on a positive relationship between air quality management and strong regulatory institutions. These institutions were capable of allocating scarce resources, writing regulations, establishing an emissions baseline, tracking changes in emissions over time, enforcing regulations and monitoring air quality. The study reported that managing these factors was a major challenge in developing countries (Krupnick, 2008).

1.3.1 International Air Quality Management

Internationally, the history of pollution and pollution management dates back to early civilisation, with documented environmental regulations during Greek and Roman times. With the industrialisation of the late 18th and 19th centuries, the effects of pollution became more noticeable, affecting larger proportions of the population (Fedra, 2000).

The United Nations Environment Programme supported by the World Health Organisation recognised the severity of air pollution and initiated the Air Pollution in the Megacities of Asia project in collaboration with Korea Environment Institute and the Stockholm Environment Institute. Twelve cities were targeted: Bangkok, Beijing, Busan, Chongqing, Dhaka, Hong Kong, Jakarta, Kathmandu, Mumbai, Seoul, Singapore and Taipei (Haq, Han & Kim, 2002). The following themes were discussed for each city using available data (Haq, Han & Kim, 2002):

- situational analysis;
- urban air quality trends;
- air quality monitoring;
- impacts of air pollution; and
- enforcement and control strategies.

The air quality practices in the major cities were evaluated by Haq, Han and Kim (2002). Local and national government agencies in different countries were contacted and requested to respond to a questionnaire and to provide data and information. Krzyzanowski and Schwela (1999) reported that the annual mean concentration of SO_2 in residential areas was in the region of 50 micrograms per cubic meter (ug/m^3). Notable exceptions were several cities in China, India and Nepal, where SO_2 concentrations exceeded 100 ug/m^3 (Krzyzanowski & Schwela, 1999).

With respect to dust, the most commonly reported indicator was the mass of total suspended particles in the air (TSP). In many cities, the TSP annual mean concentration exceeds 100 ug/m^3, with the levels exceeding 300 ug/m^3 in several cities of China and India (World Health Organisation, 2001). In a limited number of cities, the mass concentration of PM_{10} was also measured. In Asian cities, an increase in PM_{10} concentration was experienced in the 1990s. This increase occurred even when a reduction in TSP was reported. An opposite trend and a reduction in PM_{10} level were seen in cities of Central and South America.

In most of the cities, the annual mean concentration of nitrogen dioxide (NO_2) remained moderate or low, not exceeding 40 ug/m^3 (World Health Organisation, 2001). Trends varied between the cities but a 5 to 10 per cent annual increase was more common than a decrease in concentration of this pollutant. The highest NO_2 levels and increasing trends were observed in the cities with high and increasing traffic. In South Asia and in Latin America, the high NO_2 concentration combined with the intense ultra-violet radiation resulted in photochemical smog with high ozone (O_3) concentrations.

The concentrations of air pollution in major and mega cities of developing countries often reached levels of concern for public health (World Health Organisation, 2001). The study highlighted the main reasons for the lack of implementation of emission control plans despite the adoption of such plans as follows (World Health Organisation, 2001):

- insufficient expertise and capabilities to formulate policies;
- low priority given to air pollution control compared to other social and environmental issues;
- insufficient allocation of resources to introducing pollution control policies; and

- inadequate political will and disjointed administrative framework in which the responsibility for air quality is divided among a number of government of ministries and local administrations, thus complicating policy-making.

Haq, Han and Kim (2002) concluded that air quality institutions required substantial strengthening in terms of human resources, organisational structure, facilities and financial resources based on partnerships among various parties, including private sectors and non-governmental organisations (NGOs). The aim of the partnership was to improve output efficiency and international cooperation. The lesson learnt was valuable in the identification of input activities, *i.e.*, resources must be allocated to partnering with other organisations to improve output efficiency.

The work done in the South Asian countries indicated similar issues of health concern (Mayerhofer, Chang, Atienza & Huizenga, 2003). The report indicated that air pollution affects a person's health directly and the productivity of the labour force, indirectly through ill health.

In Dhaka, air pollution-related illnesses claimed more than 15,000 lives each year. In Bhutan, acute respiratory tract diseases have affected from 10.1% of the total population in 1990, to over 14% of the total population in 2002. In Nepal, the cases of chronic obstructive pulmonary disease increased four times in the last 10 years and soared to more than 800 cases in 2002. In India, the air quality index in 20 cities was in the '*dangerous category*'; while in 14 cities the values were in the '*bad category*' (Mayerhofer *et al*., 2003:5).

Another impact of air pollution is increased health expenditure. A recent study on the economic costs associated with environmental degradation in India found that the total health costs due to air pollution averaged \$1.3 billion per annum. Other effects were reduced quality of life, premature deaths, corroded building materials, disturbed ecosystems and degrading conditions of livestock and vegetation (Mayerhofer *et al*., 2003). The major issues identified were (Mayerhofer *et al*., 2003):

- weak institutional capacity and lack of data
    - air quality monitoring was becoming an increasingly important issue;
    - there was a considerable shortfall in capacity in national and local Air Quality Units to implement a pollution control plan; and
    - the trends in terms of the reliability of data from public departments in developing countries were quoted as major obstacles to the studies done by Mrayyan and Hamdi (2006) and Foti (2005).
- lack of coordination
    - the responsibility for air quality management was divided among a number of ministries and local administrations, thus complicating policy-making, and systematic air quality monitoring; and
    - lack of coordination had impeded the development of a strategic framework for air quality management systems.
- poor information sharing
    - large amount of data on air quality and management initiatives at the national level, but the data was often not readily available to the other departments;
    - duplication in data collection and inconsistent decisions on similar air quality matters; and
    - poor information exchange on best practices and lack of harmonised air pollution policies.

The proposed solution by Mayerhofer *et al*. (2003), over a 12-month period, was based on the required inputs to achieve four critical air quality outputs as shown in Table 1.1. Mayerhofer *et al*. (2003) reported that ambient levels of dust, SO_2 and NOx must be monitored and managed. Further, resources must be allocated to knowledge management (KM) to set up and maintain air quality networks. The drawback of the work done by Mayerhofer *et al*. (2003) was that the resources of the departments in the form of man-hour requirements to efficiently undertake the recommended outputs were not quantified.

The Council for Sustainable Development in Hong Kong recommended a comprehensive and integrated approach to address the challenges related to air pollution management (CSD, 2008). The council urged the Hong Kong government to tackle the air pollution problem in a holistic and coordinated manner. The council also recommended than a comprehensive resource allocation study be undertaken to quantify the input activity requirements of the departments that were mandated to manage air pollution impacts (CSD, 2008).

Table 1.1: Inputs and outputs recommendations from Mayerhofer *et al*. (2003)

Inputs	**Outputs**
Budget: $400,000	Output 1: Local air quality networks established and developed
International consulting services: Three man-months	Output 2: Integrated air quality management system appropriate for the South Asian context, conceptualised and discussed.
Domestic consulting services: 68 man-months	Output 3: Capacity of key technical staff enhanced.
Technical assistance: Five man-months	Output 4: Action plans for selected cities formulated and agreed.
Equipment: 4 computers and printers.	
Four local workshops: Bangladesh, Bhutan, India and Nepal	
Two sub-regional workshops.	

The work of Mayerhofer *et al*. (2003) and CSD (2008) implied that, internationally, there was a lack of resource allocation tools to support air quality management units.

1.3.2 South African Air Quality Units

Government in South Africa refers to bodies responsible for governing the country and would refer primarily to the political executive, *viz*. the president and his cabinet at the national level; premiers and executive councils at the provincial level; and mayor and municipal managers at the local level (DPSA, 2006). In common usage, however, the term 'government' is often used to refer to the public administrative apparatus (Theunissen, 2000: 118). The Constitution (1996) binds the government of South Africa to abide by the principles of democracy and transparency and promote the rights and privileges of every citizen in the country (Theunissen, 2000; Allen, 2006; DPSA, 2006).

The government is further distinguished into three distinct spheres *viz*. national, provincial and local. Within the three spheres, there are departments that are responsible for delivering on the political mandates of the respective political executive. In South Africa, there is one national department, nine provincial departments and 284 local departments (DPSA, 2006). The heads of departments in the national and provincial spheres and the municipal managers in the local sphere are responsible for resourcing the departments with the required people, equipment, facilities, budget, utilities and materials to give effect to their mandates (Allen, 2006; DPSA, 2006).

The primary legislation governing air quality in South African is the Constitution (1996), specifically Section 24, which states that everyone has the right to an environment (including ambient air) that is not harmful to their health and well-being. Following South

Africa's first democratic elections in 1994, the Consultative National Environmental Policy Process was launched and the White Paper on National Environmental Management (1997) was published for public participation. The National Environmental Management Act (Act No. 107 of 1998) was subsequently published, followed by the White Paper on Integrated Pollution and Waste Management in 2000.

The National Environmental Management: Air Quality Act, 2004 (Act 39 of 2004); (AQA) was signed into law in September 2006 to address the poor air quality in South Africa and was planned for phased implementation due to the complexity of enforcement (Lukey, 2007; White & Van Tienhoven, 2009). The objectives of the AQA were as follows:

- To protect the environment by providing reasonable measures for:
  - the protection and enhancement of the quality of air in the Republic;
  - the prevention of air pollution and ecological degradation; and
  - securing ecologically sustainable development while promoting justifiable economic and social development.
- Generally, to give effect to Section 24(b) of the Constitution (1996) to enhance the quality of ambient air for the sake of securing an environment that is not harmful to the health and well-being of people.

The AQA replaced the outdated and inefficient 1965 air pollution legislation. The benefit of the new legislation was that it allowed for greater accountability from the Air Quality Units if air quality is not acceptable (White & Van Tienhoven, 2009). The Minister of Water and Environmental Affairs established the National Air Quality Framework Document (2007) in terms of the AQA, to provide the governance framework for air quality management. The National Air Quality Framework Document (2007) binds all organs of government in all spheres of government. The implementation of the air quality management plan in terms of the National Air Quality Framework Document (2007) is the responsibility of national, provincial and local government in terms of their various functions. This air quality management plan spans a period of five years (National Air Quality Framework Document, 2007).

The AQA called for the appointment of an AQO within each of the three spheres of government to manage and lead an Air Quality Unit (White & Van Tienhoven, 2009). The mandates of the AQOs were specifically defined in terms of Section 14 of the National Air Quality Framework Document (2007). The Minister must designate an officer in the department as the national AQO to be responsible for co-ordinating matters pertaining to air quality management in the Department of Environmental Affairs (DEA). The Provincial Member of the Executive Council must designate an officer in the provincial administration as the provincial AQO and be responsible for co-ordinating matters pertaining to air quality management in the province. Each municipality must designate an AQO from its administration to be responsible for coordinating matters pertaining to air quality management in the municipality.

An AQO must perform the duties or exercise the powers assigned or delegated to that officer. An AQO may delegate a power or assign a duty to an official in the service of that officer's administration, subject to such limitations or conditions as may be prescribed by the Minister. It was also recognised that some of the local departments did not have sufficient capacity to establish an Air Quality Unit, in which case these departments were supported by a larger local Air Quality Units (White & Van Tienhoven, 2009).

There were 228 Air Quality Units in South Africa (Lukey, 2007). The National AQO, Mr Peter Lukey, is charged with the responsibility of improving air quality management and communication across the three spheres of government (CSIR, 2007). A National Air Quality Management Forum was established to improve communication with all AQOs and other interested and affected government departments. The aim of the National Air Quality Management Forum (*cf.* Section 1.3.2) was to ensure efficient intergovernmental coordination and cooperation in the development and implementation of the required air quality management plans and programmes (Lukey 2007).

AQOs were also responsible for monitoring the ambient air quality limits, as per the standards in Table 1.2.

Table 1.2: South African ambient air quality standards (DEA, 2008)

Substance	10 minute maximum	1 hour maximum	8 hour maximum	24 hour maximum	Annual Average
Sulphur dioxide (SO_2) (ug/m^3)	500	350	-	125	50
Oxides of nitrogen (NOx) (ug/m^3)	-	200	-	-	40
Dust (ug/m^3)	-	-	-	75	40

The value-add of collaborating and partnering with other organisations leads to a significant increase in the number of air quality management alternatives generated and implemented. The number of alternatives implemented to manage air quality was therefore selected as one of the output variables.

The work undertaken by AQOs can be divided into daily routine and repetitive tasks and projects or non-repetitive activities. The routine tasks formed less than 30% of their activities, as the AQA demanded the development of decision support tools, establishing stakeholder dialogue and procuring and installing air quality monitoring stations (Lukey, 2007).

1.3.3 Challenges of the Air Quality Units

The major challenge of the National Department was that the administrative control of environmental management was fragmented (Lukey, 2007). The DEA was the lead environmental agency in South Africa (DEA, 2008). National and provincial government have concurrent jurisdiction with respect to environment and pollution control. Air pollution was a local government matter for which municipalities have executive authority. Historically, however, both provincial and local government mandates have been marginalised from the area of air quality management (Lukey, 2007).

There is currently no nationally integrated environmental permitting process in South Africa. There have been a few random attempts in certain local municipalities to integrate licensing into streamlined procedures (Lukey, 2007). This lack of integration is a source of frustration for many permit applicants (NAPCoF, 2008). However, constitutionally, administrative officials must ensure that cooperative governance (Section 2.4) is practised. This includes the requirement for all public departments to cooperate with each other by, *inter alia*, coordinating their actions and legislation (Lukey, 2007).

The AQO in the Western Cape reported on the following concerns at provincial level (Linde, 2007):

- poor town planning;
- frequent pollution episodes;

- very little or no historical data in the remote areas outside cities;
- inadequate national database on air quality permits;
- industries using old technologies;
- lack of coherent approach to air quality management between the different spheres of government;
- no or limited monitoring to validate emissions in the remote areas; and
- jurisdictional responsibilities not clearly defined.

Regarding efficient air quality management, Hadfield and Seaton (1999) identified gaps in information management and the development of knowledge systems to defend regulations on emissions for improved compliance action. In addition, Lukey (2007) asserted that the South African Air Quality Units are continually undergoing changes in the legislative framework and are unable to implement change management (CM).

These Air Quality Units are currently implementing the AQA. This Act presents a complete paradigm shift from the Atmospheric Pollution Prevention Act, 1964 (Act 45 of 1965); (APPA) approach. The APPA approach was based largely on point source emission control, which does not fully address the cumulative impacts of air pollution. As a result, certain areas of South Africa were exposed and vulnerable to exceptionally poor air quality by both local and international standards (CSIR, 2007). These changes create challenges such as the monitoring and reporting on air quality data and the use of knowledge to support decision-making processes (Lukey, 2007). The need to improve the efficiency of the Air Quality Units was also reported by De Wit (2005), who identified persistently high atmospheric emissions per unit of gross domestic product for South Africa relative to other countries.

The South African State of the Environment Report was prepared by the DEA and indicated that air quality management was an area of concern. The following trends were noted (DEA, 2007):

- air quality
  - : decreasing in general, with high SO_2 and PM_{10} levels.
- health problems due to air pollution
  - increasing by an estimated 20% over the next decade.
- vehicle exhaust emissions
  - Increasing, with various pollutants including oxides of nitrogen (NOx), predicted to increase by 27% by 2007 and up to 44% by 2011 (from 2002 levels) if emission controls or legislation were not in place.

Further reports on poor output efficiency within the South African Air Quality Units were evident from the review of previous researchers in the air quality management field as follows:

- Poor project management (PM), which was evident in the delayed authorisations for industry development applications and the inability to deliver on strategic projects (Pape, 2001; Madonsela, 2006).
- Schlemmer, Ahmed, Dagut, Hampton and Irvine (2004) reported on inefficient project outsourcing and collaboration with other organisations. This was mainly due to poor PM. Schlemmer *et al*. (2004) warned that a South African response was required to address the challenges.
- Wenzel (2007) criticised the government's unsustainable practice of downsizing to improve the efficiency within departments, due to the loss of institutional memory. Wenzel (2007) supported Schlemmer *et al.* (2004) and added that contracting out

government-mandated activities were also not sustainable, as it did not focus on capacitating the departments.

- Krupnick (2008) recognised the challenges to air quality management in developing countries like South Africa and agreed that skills to implement and enforce air quality legislation were limited in South Africa. The article highlighted the point that the implementation of appropriate air quality management improvement tools in the absence of a PM and KM environment would be challenging.
- The administrative control of environmental management was fragmented and there was no nationally integrated environmental permitting process in South Africa (Lukey, 2007). This lack of integration was a source of frustration for many permit applicants (NAPCoF, 2008).

A sustainable solution is required, in which the output efficiency of the Air Quality Units can be evaluated with the view to improving the number of mandated outputs completed. The contributing factors for developing a resource allocation model specifically for the Air Quality Units were as follows:

- There were planned changes due to the implementation of the AQA;
- The existing models could not be directly applied, as these required the use of vast amounts of data, which were not available within the Air Quality Units;
- The resource allocation model can be developed with data from the Air Quality Officers (AQOs) budget and performance reports; and
- The resource allocation model can provide a tool for the AQOs to allocate resources based on their mandated outputs.

Understanding the allocation of resources is important to organisations in both the planning and implementation phases (Mankins & Steele, 2005). The authors recommended that organisations discuss resource requirements early in the project to ensure project success.

The Chief AQO authorised the necessary permission to conduct this study. In addition, the researcher and the promoter were invited to all AQO meetings to provide feedback on the progress of the study and discuss any further information requirements. The Chief AQO offered the services of the officials in the national department to verify all data received from the provincial and local Air Quality Units (Lukey, 2007).

1.4 Input Activities and Output Efficiency of AQOs

The research undertaken investigates the inputs and outputs of the Air Quality Units in the three spheres of government. A discussion of the indicator variables relating to the input activities and output efficiency of the AQOs follows.

1.4.1 Indicator variables

An indicator variable quantifies and simplifies phenomena and helps in the understanding of complex realities (Harrell, Lee, Califf, Pryor & Rosati, 1984; Harrell, Lee & Mark, 1996). Indicator variables can measure the inputs and outputs of an organisation or system. Input indicators measure resources, both human and financial, devoted to a particular programme or intervention (e.g. number of hours spent on client services), while output indicators measure the quantity of goods and services produced and the efficiency of production (e.g. number of people served, number of reports completed). These indicators can be identified for activities or programmes. Several people must be involved in identifying indicator variables, including those people who collect and use the data and the people with the technical expertise to understand the strengths and limitations of specific measures.

Once selected, indicator variables provide the bridge between objectives and action. The input activities are considered the independent variable (x) and the output activities the dependent variable (Y). Specific indicator variables that were selected for the input and outputs for this study follow. The term '*indicator variable*' will be replaced by '*variable'* for the rest of this thesis.

X = input activities (number of man-hours spent)

- Independent variable (cause)

Y = output activities (number of activities completed)

- Dependent variable (effect)

1.4.2 Output Variables of AQOs

Webster and Omar (2003) believe that output efficiency can be gauged by a comparison between the inputs and outputs of an organisation: at a given input, the greater the output, the more efficient the organisation. The measurement of efficiency generally required: (a) an estimation of input variables; (b) an estimation of output variables and (c) a comparison between the two.

An efficient public service is one that completes its functions in the best possible and least wasteful manner (Webster & Omar 2003). If one were to apply Webster and Omar's (2003) explanation of the concept of output efficiency to the resource allocation activities of government, government performance could be deemed efficient when, with the given amount of resources available, its completed mandated tasks are maximised.

Hopkins (2009:2) indicated that it is hard to compare public and private sector performance efficiency because output in industry can be measured in financial terms, whereas '*the output of government departments is harder to quantity'*. Hopkins (2009:2) stated that the decline in public sector output performance '*reflects a culture of inefficiency*'. This implies that a public sector was efficient when its mandated activities were completed.

Kling (2006:2) asserted that '*the local understanding and meaning of efficiency improves actual efficiency*'. Krupnick (2008) supported the work of Kling (2006) and reported on a positive relationship between air quality management and a clear understanding of output efficiency. The specific variables that Krupnick (2008: 20) used to define '*strong regulatory institutions*' were departments that were capable of '*allocating scarce resources*' to complete outputs as follows:

- decision support tools,
- emissions baseline and inventories,
- air quality monitoring and tracking changes in emission levels over time, and
- enforcing regulations.

The outputs used in the model were based on the mandates of the Air Quality Units as detailed in the Air Quality Act of 2004 and related legislation, which included the variables discussed by Krupnick (2008).

AQOs are expected to authorise emission licences to industries that operate activities with the potential to emit noxious emissions. The AQOs must approve the industrial emission licences before the industries commence with the activities. There is a well-defined regulatory framework and extensive literature on impact assessment. There is also a broad range of environment impact assessment methodology to ensure completeness and consistency in the reporting of air impact assessments (Fedra, 2000). However, an environmental impact study is often voluminous and extremely technical, and the decisions on the emission licences were often delayed (NAPCoF, 2008).

The spread of industries that impact on air quality differ across the country. The DEA (2008) explained that Gauteng had the greatest number of industrial licences, as shown in Figure 1.3. The distribution of air emission licences within the different provinces was as follows:

- approximately 32 % in Gauteng;
- approximately 17% in KwaZulu-Natal;
- approximately 12% each for Mpumalanga and the Western Cape;
- approximately 6% in the Free State;
- approximately 5% each for North West, Limpopo, and the Eastern Cape; and
- less than 3% in the Northern Cape.

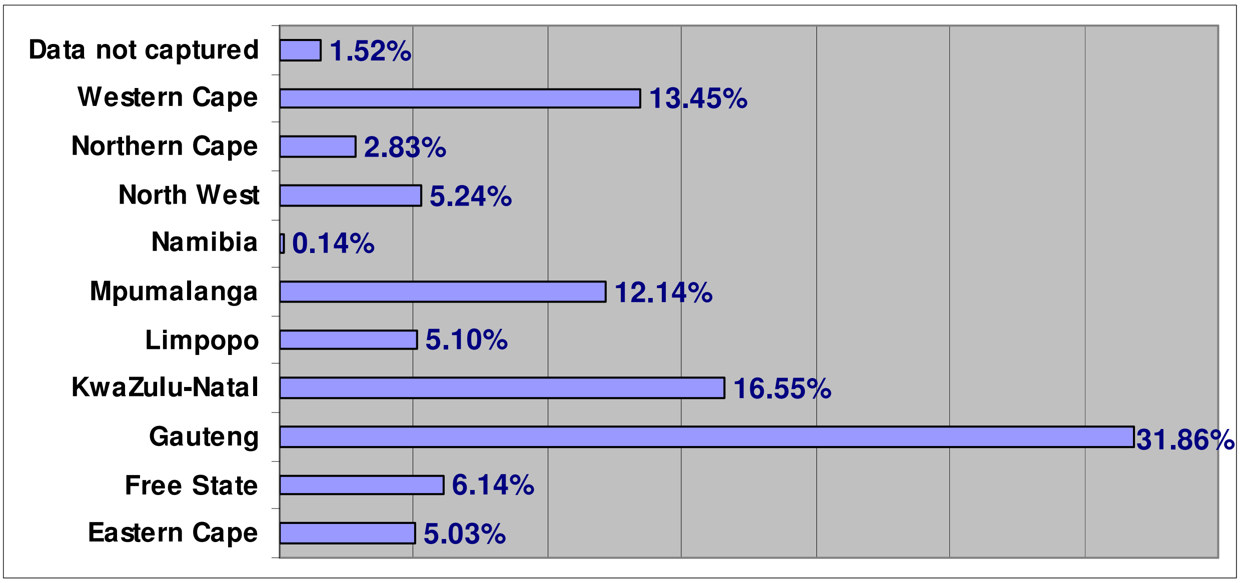


Figure 1.3: Industrial emission licences per province (DEA, 2007)

The AQOs are expected to collect and manage air quality data in their region of responsibility. South Africa has defined ambient air quality standards as a measure, which has components that may include some or all of the following (DEA, 2008):

- limit values;
- averaging periods;
- frequency of exceedances; and
- compliance dates.

AQOs need to monitor the ambient air quality within their designated areas as per the air quality standard requirements (DEA, 2008). There are many different types of air pollutants, and these have different effects on the environment and on people's health (Defra, 2007). Pollutant combinations also upset the natural balance of acidity and nitrogen levels in the environment, which affects the biodiversity in sensitive areas (Environmental Protection Agency, 2003).

A number of pollutants are potentially toxic to people and the environment. These include PM_{10}, heavy metals (lead), oxides of nitrogen (NO_X) and SO_2 (Environmental Protection Agency, 2003). The standards set for the identified pollutants are shown in Table 1.2.

PM_{10} concentrations have been shown to be elevated across the country with significant exceedances of human health limits. Increasing emphasis is being placed on PM_{10} due to the issuing of linear dose response curves for this pollutant by health organisations such as the World Health Organisation and the implementation of very strict limits for this pollutant by European and Australasian countries (DEA, 2007; World Health Organisation, 2001). Pollutants such as SO_2 and NOx have the potential to cause acidification (including acid rain), which can damage ecosystems and buildings (Environmental Protection Agency, 2003; Dore *et al*., 2007).

The AQOs were also involved in impact studies that were not related to air quality management – for example, land change applications and housing development – and this increased delays in the authorisation process. The man-hours spent on non-air-quality-related activities were deemed as Other activities (*cf*. Section 1.4.3).

Using the mandated activities of the AQOs implies that the activities performed are known, defined and correct in terms of achieving output efficiency. As explained in Chapter 3 (Section 3.3.1), fifteen specific output variables were identified. The number of outputs completed per Air Quality Unit in each of the years 2005/6 and 2006/7 was expressed as a percentage of the total number (15) of identified outputs. The percentage of completed outputs served as a proxy for output efficiency.

1.4.3 Input Variables of AQOs

The man-hours allocated to undertake activities is the only factor considered to influence the output efficiency of the Air Quality Units, as resources such as equipment, facilities, utilities and materials were similar across the three spheres of government and the responsibility of the heads of departments (DPSA, 2006; Lukey, 2007). Further, De Geus (1997: 16) indicated that of the three sources of input variables for organisations: '*land or natural resources; capital; and labour'* the most critical factor was labour or people. De Geus's (1997) work supported the focus on man-hours as the input variable. De Geus (1997:19) added that for organisations to '*cope with the changing world*' and apply '*knowledge for competitive advantage'*, human capital must be efficiently managed.

The studies published by previous researchers in the field of PM, KM and CM were reviewed to identify the activities to monitor as input variables into the model (Rwelamila, 2007; Shenhar, 2004; Crawford, Costello, Pollack & Bentley, 2003). Twelve input variables were identified, and these were further grouped into five categories, *viz*. PM, KM, routine, other and CM, with the aim of simplifying the model. The inputs of the Air Quality Units were calculated as a percentage of the total man-hours spent on the 12 identified input activities. The inputs were grouped into five categories, *viz*., KM, PM, CM, routine activities and other activities. KM refers to information that is applied to describe, predict or adapt to a situation after it has been examined and compared to other information or data (Durant-Law, 2008). A '*know, how and why'* enrichment occurs with the addition of further context, experience and understanding, and this results in an understanding of principles (Durant-Law, 2008). KM is required for efficient policy development and implementation (Bridgman & Davis, 2004).

PM is a related set of disciplines that together enable managers to successfully accomplish their role and examine the variables of time, cost, resources and peoples' behaviour and their contribution to project success or failure (Moorcroft, 2006).

To improve PM and KM in an organisation demands changes to the status quo. Westland (2006) believed the lessons learned must be documented to enable efficient CM. Managers need to allocate resources to recognise the behavioural aspects of CM and deal with the problems that may arise (Meredith & Mantell, 2003). CM activities include the development of legislation and decision support tools as well as documenting the learning to facilitate growth and the required change.

Routine activities are necessary activities that should be conducted, as they relate directly to measurable outputs and include:

- performance management;

- preparation of monthly and annual progress reports;
- attendance of management meetings; and
- repetitive general administrative activities.

The AQOs also perform Other activities that do not directly support the management of air quality. The other activities include managing strategic projects that were not related to air quality management for example development of guidelines for solid waste disposal sites and land use planning and updating the Spatial Development Framework. Additional activities undertaken that were outside the AQOs mandated activities include:

- reviewing housing development impact studies and inputs into water licences;
- addressing public nuisance complaints relating to waste management;
- commenting on mining activities;
- supporting the development of by-laws that were not related to air quality management, *e.g.* by-laws relating to potable water supply systems, domestic waste-water systems, sewage disposal systems and municipal health services;
- preparing responses to legislature that were not relevant to air quality management; and

1.5 Research Aim and Objectives

The study aimed to develop a model that could predict the output efficiency of the air quality units, given the resources allocated to the inputs of that Department and the percentage of the total output activities completed.

The application of models to the air quality management field is complicated, as the information required to establish the relationship under investigation is not readily available (Krupnick, 2008). Further, Maltz (2001:23) warned that the relationships under investigation within an "*organisational context"* may emerge as complicated and would require complex analytical work to determine the structure of the model. For complex model building, it was recommended that exploratory analyses be undertaken using various functional forms to establish the best model to characterise the system (Maltz, 2001). Therefore, any practical approach (as applicable to this study) has to be iterative, adaptive and interactive, and the utilisation of statistical techniques is imperative.

The primary objective of this study was to identify the inputs that contribute significantly towards efficient Air Quality Units in terms of output efficiency. A secondary objective was to develop a model that would predict whether a department is efficient based on the percentage of man-hours allocated to its input activities relating to CM, PM, routine and other activities.

The research question investigated was:

> To what extent can the South African Air Quality Units' output efficiency be explained by the percentage of the resources allocated to variables relating to PM, KM and CM?

The term 'resource allocation' referred to the apportioning of the officials' man-hour costs into activities relating to PM, CM and KM. The '*efficiency*' of the Units referred to the percentage completion of the mandated outputs, activities and strategic projects (where 100 percent efficient implied that all required activities were completed).

With regard to the hypothesis of this study, the null hypothesis (Ho) that output efficiency cannot be explained by the percentage of the resources allocated to the input variables against the alternative hypothesis (Ha) that output efficiency can be explained was tested. Ha is the statement that will be accepted if the evidence enables Ho to be rejected at a 95% level probability.

H_1: There is no relationship between output efficiency and input variables of the Air Quality Units.

H_a: There is a relationship between output efficiency and input variables of the Air Quality Units.

If p <= 0.05, reject the null hypothesis and accept the alternative hypothesis. If p >= 0.05, fail to reject the null hypothesis (= 'accept' null hypothesis as being true).

Hypothesis testing to determine if there was, a statistically significant difference between the weighted value of the outputs (W) and unweighted outputs of the AQOs was also performed (Section 3.3.1.3). According to the analysis, a perfect fit would give a coefficient of 1.0 thus, the higher the correlation coefficient the better, and the unweighted y values would be used in the study instead of the weighted values.

H_o: Average of weighted output ≠ Average of unweighted outputs

H_a: Average of weighted output = Average of unweighted outputs

If p <= 0.05, reject the null hypothesis and accept the alternative hypothesis.

If p >= 0.05, fail to reject the null hypothesis (= 'accept' null hypothesis as being true).

The objectives of the study were to:

1. Identify the input activities that contribute significantly towards an efficient air quality unit; and

2. Develop a model for the prediction of an air quality unit's output efficiency based on the mandated input activities relating to PM, KM, CM, Routine and Other Activities.

1.6 Research Approach and Methodology

The research methodology focused on developing a regression model that could predict the efficiency of the Air Quality Units, based on the actual data collected for the period of two financial years (2005/06 and 2006/07). One important application of model development where the period of fit was different from the period of evaluation was the use of hold-out samples. With this technique of model evaluation, the period of model development ends at a time point before the end of the data series, and the remainder of the data is held out as a non-overlapping period of evaluation (Pallant, 2005). With respect to the period of development, the hold-out sample is a period in the future, used to compare the forecasting accuracy of model fit to past data (Pallant, 2005).

The 2005/06 financial year data was used to develop the model. The 2006/07 data was used as the hold-out sample to determine the predictive accuracy and the robustness of the model fitted in the study. The fact that the models for the 2005/6 and 2006/7 years corresponded was encouraging, in the sense that this confirmed the reliability of the model fitted. Further, using the holdout sample confirmed that the parameters selected in the model were correct.

The study followed a positivism research philosophy using quantitative data that was collected from a large group of participants.

1.6.1 Research Approach

Kling (2006) reported that a local understanding of the requirements for efficiency improved actual output efficiency of that organisation. To be efficient, Air Quality Units must understand what is considered efficient performance and the components of the inputs and outputs that are required to be efficient. The study used a quantitative approach to gather data relating to the Air Quality Units' input activities and mandated outputs. The main characteristic of the approach was that it related to hands-on systems-building, using data on agreed variables from a target population. The research design of the study is summarised in Figure 1.4.

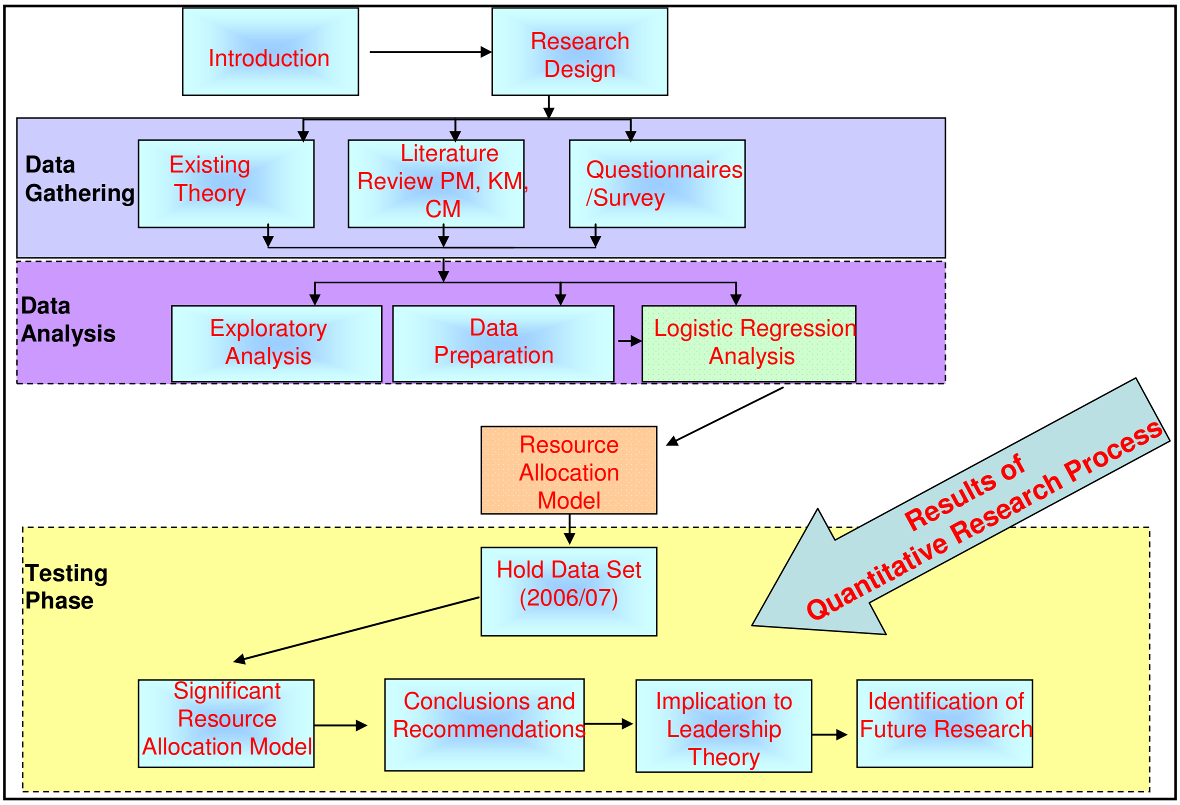


Figure 1.4: Research design summary

According to Bless, Higson-Smith and Kagee (2006), the primary purpose of hands-on systems-building research is to assist in solving a particular problem facing a particular community. This is referred to as applied research and is often achieved by applying basic research findings to a particular community's challenges. In this way, applied research may assist the community by offering solutions that will help to address its problems.

The resource allocation model was developed with the Air Quality Units as the research community, and, indeed, the findings of this study may inform departments in the public sector other than the Air Quality Units. Moreover, the research would enhance further research into how the model can be applied to other sections within these departments and other sectors of government. This study identified a tool to quantify resource allocation that is applicable to the South African context.

1.6.2 Research Method

A quantitative research design was adopted. A survey questionnaire approach was utilised, as large amount of standardised, numerical data was required from geographically diverse locations. The quantitative approach is useful, as it prevents bias in gathering and presenting research data and subjectivity of judgment is avoided. In addition, the findings, discussions and conclusions involved in the process are more objective.

1.6.3 Research Participants

The 228 ('N') AQOs in South Africa (CSIR, 2007), who were responsible for managing air quality in the three spheres of government, *viz*. national, provincial and local for each of the 2005/06 and 2006/07 financial years, were approached for data.

The number of samples (N) required must be 10 times greater than the number of input variables and the coefficients generated (Greenland, Schwartzbaum & Finkle, 2000;

Cox & Snell, 1989). The questionnaire developed for the research was mailed to all identified AQOs in South Africa (N = 228), which exceeded the minimum samples required for this study. In addition, data was sourced from the annual reports and quarterly reports of the Departments. The data published by the Department of Treasury provided the information to verify the accuracy of the data collected (DEA, 2008; Department of Treasury, 2008).

Gummesson (1991) referred to the aspect of reciprocity or mutuality, which means that application of the method should be equally valuable for both the researcher and the organisation. In this respect, Van Raaij (2001) refers to the importance of mutual commitment between the researcher and the research setting. The AQOs were committed to supporting the research, as the need for the model was recognised.

To achieve pertinent data, two inclusion criteria were imposed on the respondent, *viz*. the participants must be responsible for air quality management within the government department and attendees of the National Air Quality Management Forum (*cf*. Section 1.3.2) that is hosted by the DEA. In addition, Lukey (2007) and his national air quality management team validated all provincial and local Air Quality Units' data by comparing to data from published Annual Reports. A minimum of one and a maximum of ten employees, responsible for air quality management, provided the raw data to the AQOs.

1.6.4 Measurement Instrument

A questionnaire containing a detailed listing of all the inputs and outputs pertaining to air quality management (for each of the years 2005/6 and 2006/7) constituted the research instrument. In particular, the questionnaire requested each Air Quality Unit to provide data regarding the input activities and output performance.

The survey questionnaire was distributed to each of the 228 Air Quality Units in South Africa and completed by the AQO. Pre-testing of the questionnaire was considered essential because of the large number of respondents. In addition, the pre-testing served to test the validity of the survey instrument.

1.6.5 Statistical Analysis

Statistics refers to the science that deals with the organising, summarising, analysing and interpreting of numerical data (Johnson, Scholes & Whittington, 2007). The numbers may be quantitative (numerically scaled as ratio, ordinal, or interval) or qualitative (nominal). Organising the numbers into systematically arranged formats facilitates examination of the evidence. Summarising data describes numerical distributions, while analysing data implies that numbers will be arithmetically manipulated using various techniques for the purpose of extracting desired information from the numerical distributions. Finally, interpreting data includes arriving at results and probability-based conclusions drawn from results of data summaries and data analyses (Fowler, 2008).

Typically, statistics is subdivided into descriptive (summarising data that has been collected) and inferential (probabilistic conclusions about data not collected). Descriptive statistics serve to describe numbers representing measurements or variables (Johnson, Scholes & Whittington, 2007). Descriptive statistics are generally expressed visually as displays of graphs or tables and are expressed analytically with summary values for central tendency, dispersion, or relationships. Inferential statistics take on many forms depending on the hypothesis to be tested or research questions posed. Modelling as an inferential technique is often accompanied by visual diagrams showing relations among latent or measured variables (Fowler, 2008).

The Statistical Package for the Social Sciences (SPSS) version 15 was used to analyse the data. In addition to uni- and bi-variate descriptive measure and graphical displays, differences between Units in two categories of output efficiency in terms of the input variables were evaluated. Furthermore, the relationship between output efficiency and the input variables was explored and modelled. Stepwise binary logistic regression analysis was used for the model building. As recommended by Cox and Snell (1989), the validity and robustness of the model was tested using a hold-out validation subset (data from the 2006/07 financial year).

A discussion of logistic regression and the logistic regression curve follows to provide the background to the data analysis and model development in the study.

1.6.5.1 Logistic Regression

Logistic regression allows the researcher to test models to predict categorical outcomes (Pallant, 2005). In addition, it can be used to (Pallant, 2005):

- predict a dependent variable on the basis of continuous and/or categorical independents;
- determine the percentage variance in the dependent variable explained by the independents;
- rank the relative importance of independents;
- assess interaction effects; and
- understand the impact of covariate control variables.

The impact of predictor variables is usually explained in terms of odds ratios. Logistic regression applies maximum likelihood estimation after transforming the dependent into a logit variable. In this way, logistic regression estimates the odds of a certain event occurring (Garson, 2008).

Logistic regression has many analogies to linear regression:

- logit coefficients correspond to 'b' coefficients in the logistic regression equation;
- the standardised logit coefficients correspond to beta weights; and
- a pseudo R^2 statistic is available to summarise the strength of the relationship.

Logistic regression requires that observations be independent and the independent variables must be linearly related to the logit of the dependent. The predictive success of the logistic regression is assessed by looking at classification tables. A goodness-of-fit test such as the likelihood ratio test is available as indicators of model appropriateness, as is the Wald statistic to test the significance of individual independent variables (Garson, 2008).

Binary logistic regression, which is a form of regression, is used when the dependent is a dichotomy and the independents are of any type (Pallant, 2005). Significance tests for binary logistic regression include the omnibus tests of model coefficients. This table in SPSS reports significance levels by the traditional chi-square method. It tests if the model with the predictors is significantly different from the model with the intercept only. The omnibus test may be interpreted as a test of the ability of all predictors in the model jointly to predict the response (dependent) variable. A finding of significance corresponds to a research conclusion that there is adequate fit of the data to the model, meaning that at least one of the predictors is significantly related to the response variable (Garson, 2008).

Logistic regression is popular in part because it enables the researcher to overcome many of the restrictive assumptions of linear regression models (Garson, 2008):

- Logistic regression does not assume a linear relationship between the dependents and the independents.
- The dependent variable need not be normally distributed.
- The dependent variable need not be homoscedastic for each level of the independents; *i.e.*, there is no homogeneity of variance assumption: variances need not be the same within categories.
- Normally distributed error terms are not assumed.
- Logistic regression does not require that the independents be interval.
- Logistic regression does not require that the independents be unbounded.

1.6.5.2 The Logistic Curve

The logistic regression curve can be used to predict the outputs of the model (Pallant, 2005). The logistic curve relates the independent variable, X, to the rolling mean of the DV, P ($\bar{Y}$), through the formula shown in Equation 1.

Equation 1: Logistic Curve Equation (Pallant, 2005)

$$P = \frac{1}{1 + e^{-(a+bX)}}$$

Where,

- P is the probability of a 1 (the proportion of 1s, the mean of Y),
- *e* is the base of the natural logarithm (about 2.718) and
- *a* and *b* are the parameters of the model.

The value of *a* yields P when X is zero and *b* adjusts how quickly the probability changes with changing X a single unit. As the relationship between X and P is non-linear, *b* does not have a straightforward interpretation in this model as it does in ordinary linear regression.

1.7 High Level Findings and Recommendations

The resource allocation model developed in the study was able to predict with a high degree of accuracy the output efficiency of the Air Quality Units based on actual resources allocated to PM, CM and KM. This provides a firm guideline for Air Quality Units in South Africa to increase their output efficiency and ultimately improve air quality.

Only two variables, resources allocated to the other activities and KM, contributed to the prediction of the Air Quality Units' output efficiency. This implies that a parsimonious model was developed.

1.8 Significant Original Contribution and Reasons for Significance

The model developed, using the data for the years 2005/6 and 2006/7, is a valuable first step towards identifying the key drivers of output efficiency within the Air Quality Units. Given the extensive legislative reform undertaken in these Units, it was expedient to develop a model that allowed public sector managers to estimate the benefits of manipulating a number of inputs that are within their control, based on their mandates.

The study investigated the unexplored concept of output efficiency within the South African Air Quality Units, as opposed to the documented international studies. The research identified PM, KM and CM variables that are applicable to the public service and identified the enabling factors that were relevant for managing the Air Quality Units efficiently. This is the first study to quantify both the inputs and outputs of Air Quality Units and establish the relationship between these. The model developed highlights the importance of allocating sufficient man-hours to KM, CM, PM and routine activities to ensure a careful balance between the various activities the Air Quality Units.

A further contribution of the study is the development of a methodology that is applicable to measuring output efficiency *i.e.* the study informs other government departments and industry in general on a methodology to measure both inputs and outputs with the aim of determining the link between these. As such, the model can serve as a valuable tool for the authorities to motivate the type of inputs that are required to achieve mandated outputs. Indeed, the findings of this study may inform departments in the public sector other than the Air Quality Units.

To support the premise of the study, *i.e.*, that a resource allocation model can predict the efficiency of the Air Quality Units, the study has focused on the development of a parsimonious model, which identifies only the appropriate independent variables that significantly predict the output efficiency within the South African Air Quality Units. The new model is customised to the Air Quality Units' specific application of predicting output efficiency and managing the allocation of resources. The application of the model by public sector managers, specifically AQOs, will require them to quantify the resources that will be allocated to the input factors as well as understand the factors that will support improved output efficiency. The approach to quantify resource allocation can be used by other departments; the parameters, however, will need to be customised for the application.

1.8.1 The Potential Value of the Study

Improving the performance of the Air Quality Units remains a constant endeavour (DEA, 2007). Given the extensive legislative reform undertaken in the air quality regime, it is expedient to develop a model that allows public sector managers to estimate, based on their mandates, the benefits of managing the man-hours allocated to inputs that are within their control, with the aim of increasing their efficiency. The results of the study can guide public sector managers on how they should spend their time to become more efficient.

The study will also contribute to the understanding of inefficiencies in a public sector department, which will highlight poor resource allocation practices that must be avoided. The model developed should furthermore assist public sector managers to understand resource management better, which will ultimately improve the management of air quality in South Africa. Therefore, it serves as a model for clarifying the critical inputs that are required for AQOs to complete their mandated outputs successfully.

A key benefit of the resource allocation model will be the ability of the AQOs to evaluate the past performance patterns and their current mandates and respond to their resource allocation and managerial choices in a more informed manner.

The resource allocation model will provide a tool for the AQOs to link action to efficient output performance.

1.9 Limitations of the Research

The specific limitations of this investigation were:

- While some methods and processes discussed may be useful for other related industries; this study was limited to a South African government department mandated to manage air quality.
- The statistical analysis for this study is limited by the number of organisations in the South African Air Quality Units. The population consisted of 228 organisations.
- There were few literature sources in air quality management that used resource allocation models.
- The fact that the study referred to data of only a single country means that comparisons with other countries are not possible. Future studies should test the model with data from other nations so that a broad comparison of the allocation of resources to KM activities and its impact on output efficiency can be made.

1.10 Layout of Thesis

The thesis comprises of five chapters. In the current chapter (Chapter 1: Introduction and context), the thesis started with a motivation for the study, specifically the research question and the need for the study. The motivation for choosing the Air Quality Units in South Africa as the population for the study and the background to air quality management was presented. The chapter also touched briefly on the methodology followed for the study as well as the high-level findings. The significance as well as the limitations of the study was also discussed.

- Chapter 2: Literature review

The literature review focuses on the relevant areas that added value to the model developed in this study *viz*. the identification of variables of PM, KM and CM as inputs into the model to assess the efficiency of the South African Air Quality Units. The input variables selected for monitoring PM, KM, CM, Routine and Other Activities is summarised with specific references to previous research. The literature review also discusses the available models and management frameworks and details the motivation for the development of a resource allocation for the Air Quality Units, based on the limitations of the existing models.

- Chapter 3: Research Design and Methodology

The chapter details how the investigation will be conducted. The measurement for output efficiency in the Air Quality Units will be unpacked and the specific input variables for PM, KM and CM identified. The techniques for the research methodology, data collection, and data analyses form the central part of the chapter. The ethical considerations of the study are also presented.

- Chapter 4: Model Development

The data collected from the AQOs is statistically analysed. The logistic regression analysis, using the data collected, is discussed. The motivation for using the logistic binary regression technique to uncover the relationship between the variables under investigation is also discussed. The resource allocation model developed is finally presented, together with the variables that influence the output efficiency of the Air Quality Units. The chapter also seeks to address the study objectives identified in Chapter 1.

- Chapter 5: Summary and Conclusions

The last chapter summarises the aim and activities of the work undertaken through the chosen research methodology as a means of demonstrating relevance and completeness of the study. The findings are discussed in relation to the research question and objectives as well as the literature reviewed. The chapter sets out the conclusions of the study and the implications of the model for business leadership and policy interventions. Conclusions are also drawn about the implication and direction for future research.

1.11 Summary

The South African Air Quality Units were undergoing changes due to the implementation of the AQA (White & Van Tienhoven, 2009; Lukey 2007). The specific gaps indentified from the literature review were as follows:

- Air quality units were criticised for poor output efficiency (Aladin, 2006; Madonsela, 2006; Wenzel, 2007).
- The Air Quality Units needed to inculcate an active learning culture where sharing experiences was encouraged (DPSA, 2006).
- Capacity needs needed to be evaluated in terms of resource requirements to achieve mandated outputs (DPSA, 2006).
- Krupnick (2008) emphasised that air quality management requirements for developing countries were different from, and more challenging than, those in developed countries. One of the major differences was the inefficient KM systems in developing countries.

- Cannibal and Lemon (2000: 299) reported on the challenges at local authority level due to the focus on projects for which funding could be easily secured. As ‘securing funding’ was the main driver of the planning process, officials spent more man-hours on non-core activities (classified as ‘Other’ in this study).
- The CSIR (2007) explained that a tool was required to predict the output efficiency of the Air Quality Units.

This study evaluates the relationship between the Air Quality Units’ inputs and the mandated outputs. Insights into the AQOs mandates were also presented in this chapter. This chapter also provides an overview of the specific problem statement and the research methodology selected for this study. The research steps, processes and procedures that were followed were discussed. The statistical analysis of the data, the pilot study as well as gaining access to the required data was also discussed. In Chapter 2, the emphasis is on PM, KM and CM and its applicability to understanding output efficiency in the Air Quality Units.

CHAPTER 2: LITERATURE REVIEW

'Efficiency appears a somewhat elusive, omnipresent concept, which is not explicitly talked about, but is often implicitly alluded to. How can organisations become more efficient if they do not know what this means?'

Kling (2006)

The study aims to develop a model to help AQOs understand the requirements for output efficiency. Kling (2006) showed that an understanding of the factors that contribute to output efficiency actually improves the efficiency of the organisation; hence, it is important to identify and quantify the factors that contribute to the output efficiency of the AQOs.

In this chapter, the studies published by researchers on CM, KM and PM are reviewed to identify the previous activities that were monitored as variables (discussed in Section 1.4.1) that contribute to output efficiency. These variables are subsequently used to inform the selection of the input variables for this study as well as the grouping of the variables into categories relating to CM, KM, PM Routine, and Other activities.

The literature review focuses on the areas that added value to the model developed in this study, *viz*. the specific CM, KM and PM activities required for output efficient. In addition, the available models applicable to the study are discussed.

2.1 Introduction

Moorcroft (2006) described PM as a related set of disciplines that together enabled managers to accomplish their role successfully. The variables of man-hours, cost, quality and peoples' behaviour are examined in addition to the requirements for project success or failure.

Organisations that use PM focus on developing interdisciplinary project teams and open communication (Moorcroft, 2006).

KM refers to information after it has been examined and compared to other information or data, and that is then applied to describe, predict or adapt to a situation (Durant-Law, 2008). A '*know how and why'* enrichment occurs with the addition of further context, experience and understanding, to result in an understanding of principles (Durant-Law, 2008). Bridgman and Davis (2004) reported that KM was required for efficient policy development and implementation. The Bridgman and Davis (2004) study focused on allocating resources to knowledge transferred within government and prioritising and addressing system failures.

Brown and Eisenhardt (1998) stated that change was the striking feature of contemporary business and that the key strategic challenge was managing that change. Most successful organisations are those that are able to adjust themselves to new conditions quickly. Leaders must allocate resources and address problems that may arise from change (Meredith & Mantell, 2003). Efficient organisations monitor the resources allocated to planned learning processes (Recklies, 2004). Organisations also need to document the learnings (Nonaka & Takeuchi, 1995). Longman and Mullins (2004) recommended that for an organisation to manage change, it must capture the learnings in a projects lessons learned event and report.

Further details on PM, KM and CM, which provide insights into the selection of the variables used for data collection on the input activities, follow.

2.2 Project Management

The PM profession has grown in size and complexity largely because organisations understand that PM, particularly the management of portfolio of projects, is essential for an organisation to be efficient (Clark, 2004). PM first came to popular attention in the management literature in the late 1960s and early 1970s, although it has its origins in a number of distinct fields. PM is defined by the Project Management Institute's (2000 Edition) Project Management Body of Knowledge as the application of knowledge, skills, tools and techniques to project activities to meet stakeholders' needs and expectation from a project.

PM is defined as a unique effort, with a defined beginning, a defined end, a specific deliverable and assigned resources. Other definitions refer to planning, controlling, organising and tackling activities (Struckenbruck, 1981; Chapman, 2007). The PM process requires five different managerial activities (Project Management Institute, 2000):

i. define the project vision, goals and objectives;
ii. plan the performance specification, time schedule, budget, mix of people and physical resources to be used;
iii. lead by providing managerial guidance;
iv. monitor by measuring actual against planned activities and initiating corrective changes; and
v. complete and wrap up the required documentation.

Westland (2006) described the PM process in four phases using the *Method123 Project Management Methodology*, as shown in Figure 2.1. The four phases were as follows:

- Phase 1: Initiation involves starting up the project, by documenting a business case, the feasibility study, terms of reference, appointing the team and setting up a Project Office.
- Phase 2: Planning involves setting out the roadmap for the project by creating the following plans: project plan, resource plan, financial plan, quality plan, acceptance plan and communications plan.
- Phase 3: Execution involves building the deliverables and controlling the project delivery, scope, costs, quality, risks and issues.
- Phase 4: Closure involves winding down the project by releasing staff, handing over deliverables to the customer and completing a post-implementation review.

The critical success factors to improve output efficiency highlighted by Westland (2006) included the following:

- **efficient planning**, which requires an understanding of the system requirements; top management support and documented work processes and schedules.
- **communication** with all internal and external stakeholders, where stakeholders refer to any person or group who has a vested interest in the success of the project, *i.e*. either provides services to the project, or receives services from the project. A further recommendation was a communication plan that detailed the frequency and method of communication.

- **training and development of people:** Westland (2006) showed that when there were gaps in the skilled workforce – gaps caused by lack of training – then work became inefficient and money and time were lost. Westland (2006) recommended that for projects to be successful, an agreed schedule of training and development plans is required.

Westland (2006) believed that a post-implementation review must be undertaken to identify the level of project success. The lessons learned must be documented for future projects to enable efficient CM.

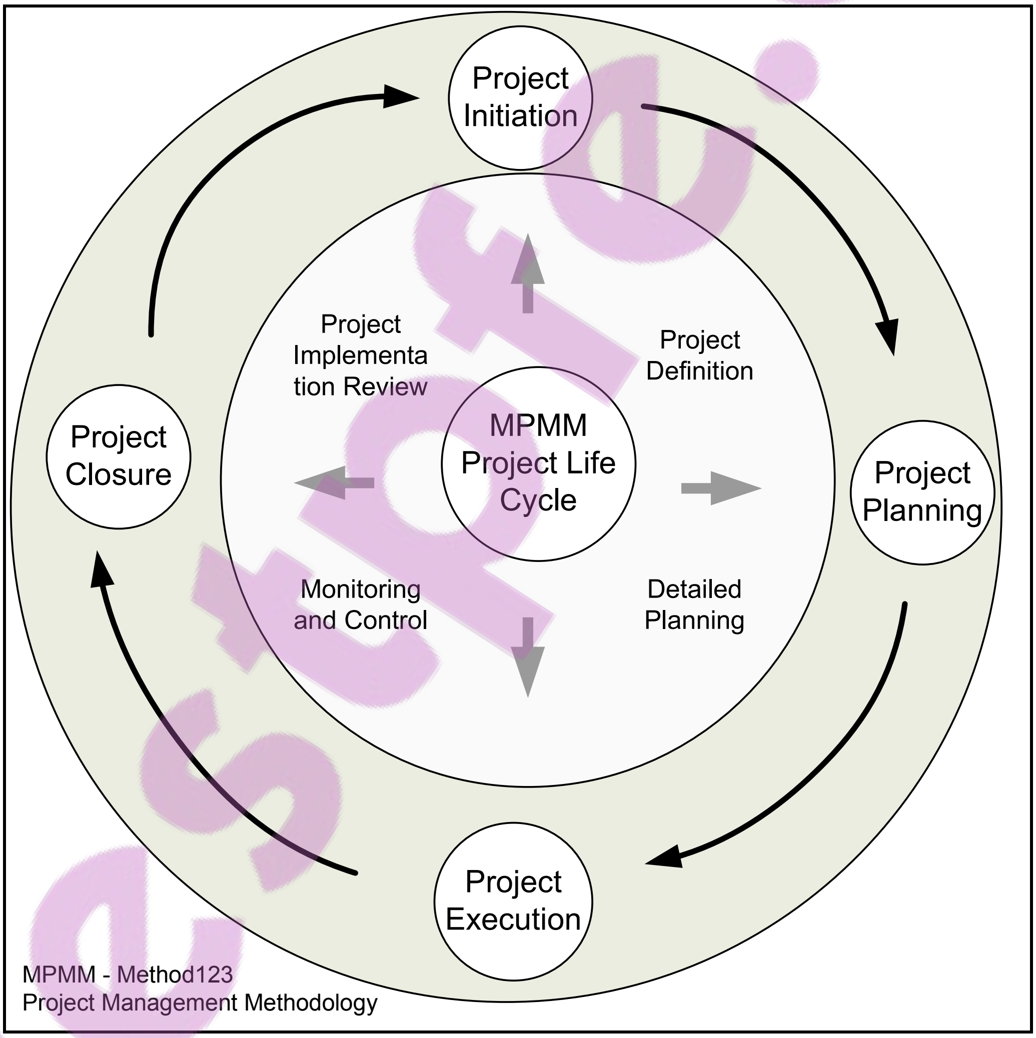


Figure 2.1: Four phases of project life cycle (Westland, 2006: 4)

Scott and Larry (2003) defined a project as a group of activities that needed to be performed in a logical sequence to meet preset objectives set by the client. The main components of a project were identified as follows:

- the project life cycle;
- definite start and finish date;
- a budget and cost estimate;
- activities that are unique and non-repetitive;
- consumed resources, can be from different parties and need coordination; and
- responsibilities are assigned and there was a single point of responsibility.

PM also addresses the issue of developing structure in a complex project. All the elements of the project are interrelated and must be balanced for project success. Planning, monitoring and making the necessary adjustments may be required during the project (Meredith & Mantell, 2003). The project goals and variables relating to time, cost, quality, people and utility can be managed using the pyramid shown in Figure 2.2 (Rwelamila, 2004).

Miller (2003) recommended that the scope of the project must be carefully managed for efficient project outputs. Further, any changes in the scope of the project must be matched with changes in the budget, time and resources. Gaither and Frazier (2002) added that efficient planning and control of projects require a panoramic view, logical thinking, a feel for detail and a commitment to meet the challenge to make it happen. Gaither and Frazier (2002) added that good communication was critical for completion of project outputs.

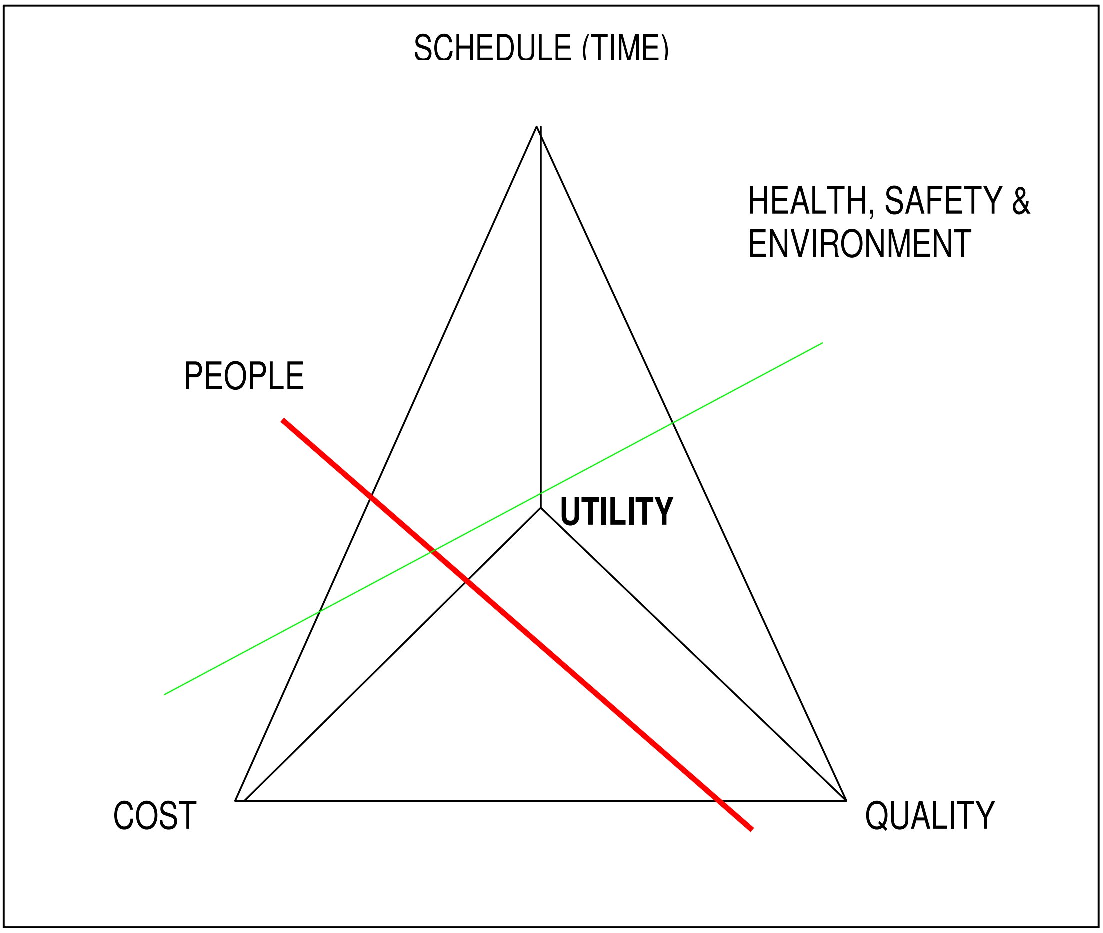


Figure 2.2: The pyramid for PM (Rwelamila, 2004)

The Project Management Institute defined the four major project phases: initiation, planning, execution and closure (Project Management Institute, 2000). Chapman (2007) indicated that almost every project goes through these four phases. Chapman (2007) added that cost and schedule estimates, plans, requirements and specifications should be updated and evaluated at the end of each phase, sometimes even before deciding whether to continue with the project. Large projects must be structured to have major programme reviews at the conclusion of significant project phases and these decision points are referred to as major milestones. Figure 2.3 illustrates the linking of major milestone review meetings with the completion of each phase (Chapman, 2007).

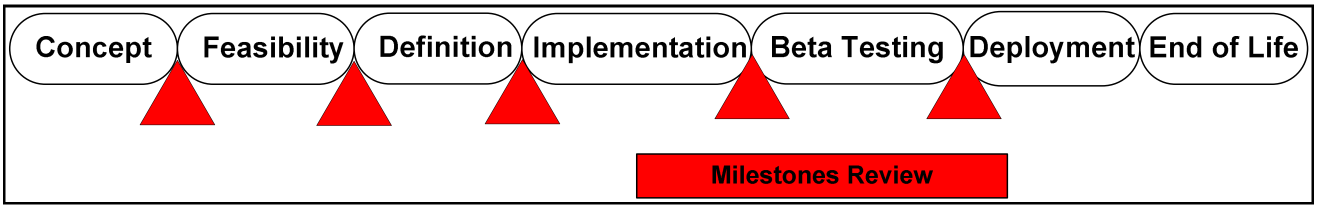


Figure 2.3: Linking of major milestone review meetings with the completion of each phase (Chapman, 2007)

Struckenbruck (1981) observed that government projects were segmented into five phases as follows:

- Phase 1: conceptual;
- Phase 2: definition;
- Phase 3: production or acquisition;
- Phase 4: operational; and
- Phase 5: divestment.

Figure 2.4 showed that, in comparison with traditional projects, government projects spending was relatively high in initiation and growth phases (Struckenbruck, 1981). The higher spending implied that government was committed to the resourcing of the project before production and operation phases (Struckenbruck, 1981).

Within each phase, there were a number of deliverables, milestones and hold points, which helped to focus the project team and impose controls. Lovegrove (2008) illustrated the project activities against time, as shown in Figure 2.5. Lovegrove (2008) added that project initiation should give a clear indication of the deliverables, outcomes and benefits of the project. In addition, at high level, the funding and resources required to deliver must be outlined, with the budget and key milestones agreed.

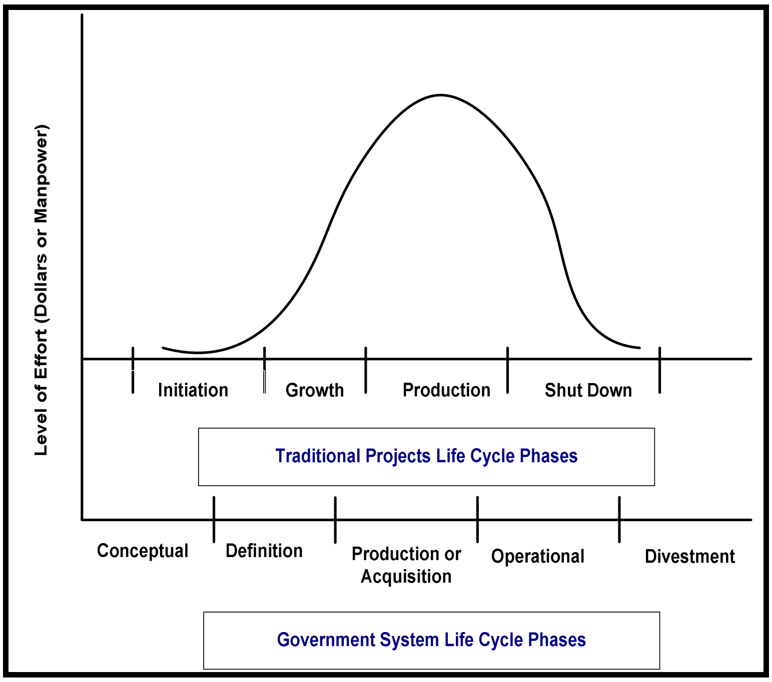


Figure 2.4: Phases in a project life cycle (Struckenbruck, 1981)

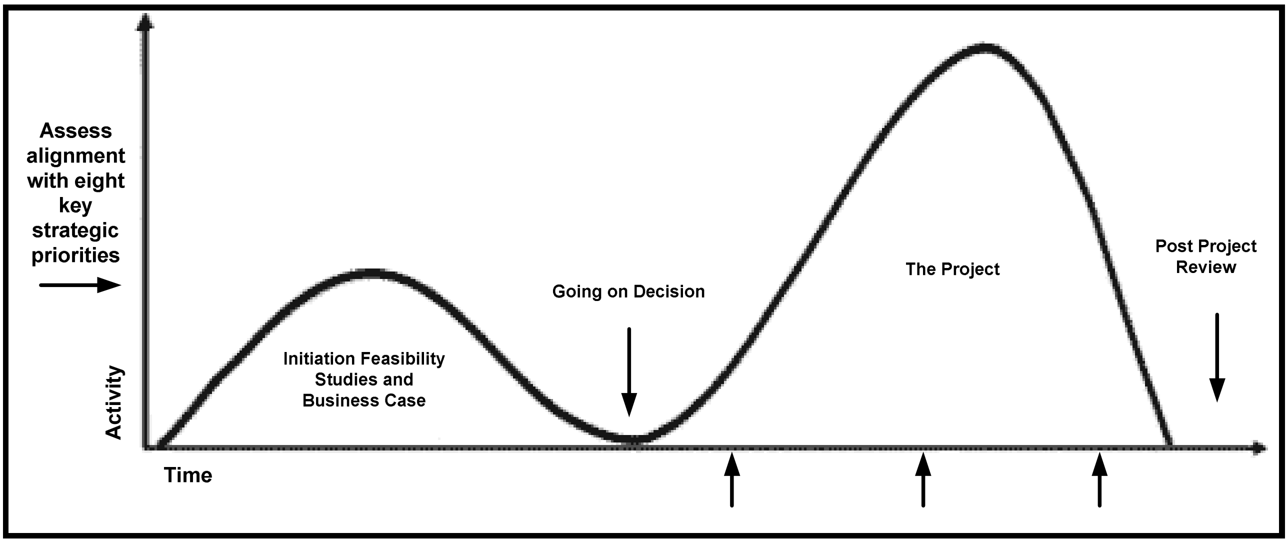


Figure 2.5: PM against time curve (Lovegrove, 2008)

At the end of the initiation phase, there must be agreement on the business case for the project. The purpose, problem statement, objectives, critical success factors, deliverables, outcomes, benefits and risks and the relationship among these elements should be established. Once the business case has been established, the project can be understood and scoped. It is then approved by the project board and ready to proceed into execution phase (Lovegrove, 2008).

Once a go decision is made, the project team would be reviewed to ensure the right resources are allocated and available and a steering group established, as required. This body would take over the day-to-day decision-making around the project. The project sponsor would chair the meetings and the project manager would focus on the day-to-day running of the project (Lovegrove, 2008).

The cost-benefit diagram in Figure 2.6 reveals that as projects proceed through the different phases, the cost of error increases as follows: concept: 5%, implementation 10% and finally errors at output phase could cost as high as 200% (Clark, 2004). The converse also applies: well-managed projects have huge potential to generate additional benefits for the organisation. Figure 2.6 also emphasised that it was cheaper to terminate a project in the early phases of the project than in the later phases (Clark, 2004). To avoid excessive PM error costs project managers must allocate resources efficiently for project success.

Ohlendorf (2001) described conflict as inevitable in PM. However, Ohlendorf (2001) added that conflict was not unfavourable, when properly managed. Several advantages were identified such as increasing personal growth and morale, enhancing communication and producing better project outcome. Conflict, however, must be well managed.

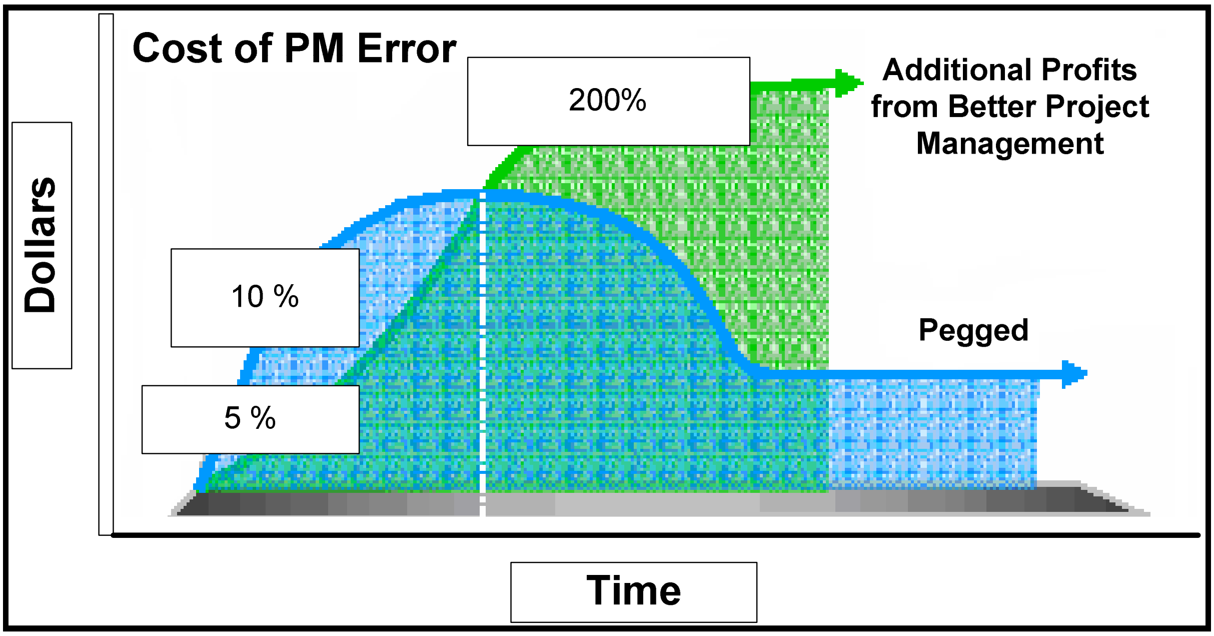


Figure 2.6: PM costs versus benefits (Clark, 2004)

2.2.1 PM in the Public Sector

PM in the public sector has attracted the interest of many scholars since the late 1980s, following the growing pressure on governments to abandon bureaucratic organisations in favour of leaner structures (Arnaboldi, Azzone & Savoldelli, 2003). The management literature contained a plethora of studies regarding project critical success factors, unfortunately the vast majority of the studies dealt with private sector organisations or at best a mix of public and private sector organisations (Rosacker, 2005). Although there were many similarities between private and public sector organisations, these were in many important and substantive ways quite different. For example, the primary objective of the private sector organisations was to generate a profit return to investors, while public sector organisations must deliver on their mandated outputs. Given the unique qualitative characteristics of these entities and organisations, it is important to understand PM in the public sector and not blindly apply private sector learnings without empirical validation (Rosacker, 2005).

Foti (2005) reported that whether a government department manages construction projects or environmental cleanup projects, PM can help optimise their output efficiency. Foti (2005) reported on several successful strategic projects, including the development of a regional cluster development programme in Brazil and the closure of a regional environmental landfill (Rocky Flats) to support the use of PM and KM in the public context.

The notable project variable (managing strategic projects) revealed that the project (Rocky Flats) was seven percent ahead of schedule and six percent under planned costs, at 86 percent completion of the project. Additional project success factors included improved taxpayer satisfaction levels as well as employee satisfaction. The paper reported that PM could make a difference in government; however, it was not a consolidated concept in government, unlike the financial, human resources and marketing areas. The paper concluded that the lack of continuity and decision support tools were the greatest weaknesses in the government's adoption of PM practices. Foti (2005) recommended that future research work must evaluate the output efficiency of public sector departments from other countries that are applying PM and KM, to further understand the variables that contribute to improved output performance.

Crawford *et al.* (2003) agreed that PM could improve government's partnering and outsourcing initiatives through diligent monitoring of contact conditions during project team meetings. They reported that even soft change projects, including risk management, training and learning, could be successfully managed in a public sector using the PM approach. Crawford *et al.* (2003) warned, however, that the process must be grounded by shared professional experience between the service provider and the government department. Learnings must be captured for efficient CM and the organisation must move towards a PM learning organisation where learnings are institutionalised (Crawford *et al.*, 2003). Crawford *et al*. (2003) assessed outsourcing and partnering activities relating to PM in the public sector. Crawford *et al*. (2003) agreed that PM could improve the efficiency of government services if resources were allocated to managing the outsourcing of projects.

The University of Cambridge (2007) indicated that government could improve implementation of the strategic projects through efficiently managing programmes as shown in Figure 2.7. In addition, successful government programmes showed the following attributes (University of Cambridge, 2007):

- aligned with strategies;
- had clear and consistent vision of the required change;
- focused on communication (internal and external);
- maintained operational knowledge systems and addressed problems with a sense of urgency;
- valued partnering and outsourcing engagements; and
- involved leadership and included a process to document learnings.

By understanding PM successes and failures, managers would be able to establish an environment in which communication was encouraged, collaboration with all partners valued, people developed and the project outputs completed (Ohlendorf, 2001).

Figure 2.7: Government implementing strategy through programmes (University of Cambridge, 2007)

2.2.2 Reasons for Project Successes and Failures

A selection of the reasons for project failures and successes is shown in Table 2.1 (Govender, 2004). Clear systems requirements definition topped the list, for reasons for success, followed by substantial user involvement. Poor planning was the major reason for project failures. Pinto and Slevin (1988) supported this finding and asserted that projects that do not allow sufficient time and resources would fail. Blair (2001) and Van der Merwe (2002) further stressed that the success of a project depended on the resources allocated to undertake the activities of the project.

Table 2.1: Major reasons for project failure and successes (Govender, 2004)

Reasons for Project **Success**	Reasons for Project **Failures**
1. Clear system requirements definitions	1. Not conducting feasibility studies
2. Substantial user involvement	2. Poor project planning
3. Support from upper management	3. Incomplete or changing requirements
4. Thorough and detailed project plans	4. Limited user involvement
5. Realistic work schedules and milestones	5. Lack of technical support
6. Strong leadership in the form of an experienced project manager	6. Lack of executive support
7. Strong communication	7. Unclear objectives
8. Suitable training and development;	8. Lack of required resources
9. Efficient CM	9. Ignoring the project environment

Black (1996) reported that in a survey of engineers, the number one rated reason for project failure was that the project was not adequately defined, and the required resources not clearly specified, at the beginning. Later, Gaither and Frazier (2002) claimed that the need for efficient control of time and cost performance was the number one motivator for world-class companies to develop PM techniques. Gaither and Frazier (2002) added that the more world class the organisation was, the more intense was the need to allocate resources during the planning phase of the project. The work of Black (1996) and Gaither and Frazier (2002) emphasised the importance the planning phase, which would include upper management commitment, strong PM leadership, efficient resource allocation to the project and having the correct role players at the steering committee actively engaging in the direction of the project.

Hargovan (2006) reported that the United Kingdom Office of Government Commerce identified the following causes of project failure:

- insufficient resources allocated to key strategic priorities including the agreed measures of success;
- lack of clear senior management ownership and leadership.
- lack of communication with stakeholders (project team, partners and service providers);
- lack of training and development plans;
- too little attention to breaking development and implementation into manageable steps;
- evaluation of proposals driven by initial price rather than long term value for money (especially securing delivery of business benefits);
- lack of understanding of and contact with the supply industry at senior levels in the organisation; and the
- lack of project team integration among clients, the supplier team and the supply chain.

Project failure was historically viewed as something to be avoided at all costs and to be hidden for a long as possible. However, the lessons captured from addressing project failures should be documented and applied to subsequent projects to support CM. The important lessons learnt reported by Hargovan (2006) were that PM should not be viewed as the flavour of the month issue and that there should be absolute commitment to resourcing the project.

2.2.3 Communication in PM

Several authors highlighted the PM variable – communication – as a success factor that improved output efficiency (Ohlendorf, 2001; Gaither & Frazier, 2002; Charva, 2002). Westland (2006: 7) described communication as the most important component within any project and the key to '*Getting the Right Things Done in the Right Way*'. Communication in projects was described as the transferring of knowledge between the project manager and other key people, who help streamline processes, and provide clarity and contingencies in case of risk (Patterson, 2010).

Charva (2002) indicated that the success of most projects, whether handled by a dedicated project team or a cross-departmental team, depended on a set of crucial communication skills and techniques that supported the project communication channels (*cf.* Figure 2.8). Communication was the prerequisite that enabled (Charva, 2002):

- setting and getting agreement on goals;
- coordinating people;
- discovering and solving problems; and
- managing expectations

Patterson (2010) reported that communication and people interaction makes or breaks a project. The '*lack of communication or a breakdown in communication*' was referred to as the most important documented reason for project failure, worldwide, at the Project Management Conference in Calgary (Patterson, 2010:1).

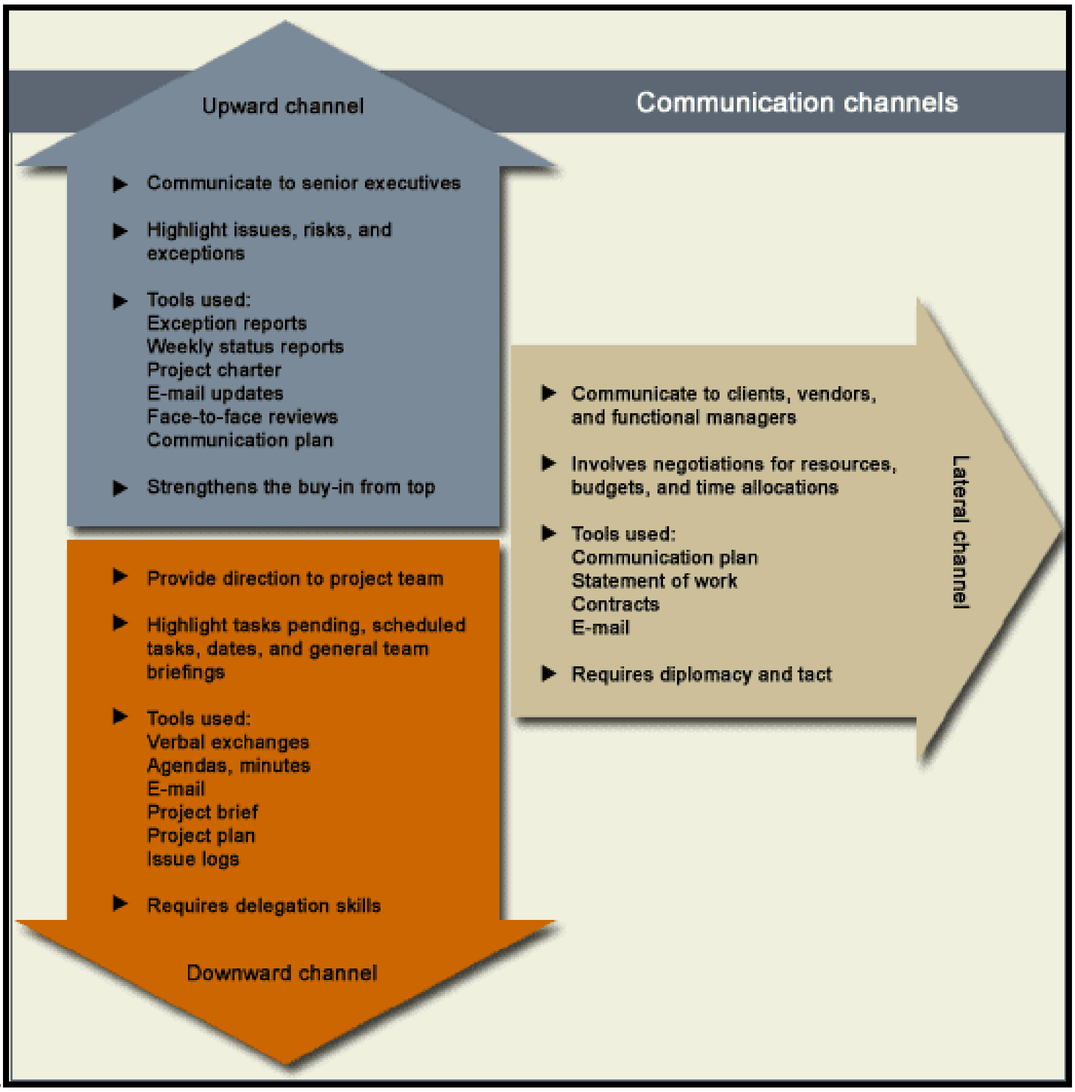


Figure 2.8: Project communication channels (Patterson, 2010)

2.2.4 Managing Outsourcing and Partnering with Other Organisations

Kakabadse and Kakabadse (2001) reported that for efficient performance outputs, work that was outsourced must be managed in a PM environment. Their work made specific reference to the quick response time required for changes to fix term contract clauses and organisations responding to opportunities for partnering with other organisations (Kakabadse and Kakabadse, 2001). Grimshaw, Vincent and Willmonts' (2002) work on partnering and outsourcing in the United Kingdom also concluded that the public sector benefited from working together in a partnership relationship with other industries and service providers when PM tools and techniques were applied.

Grimshaw *et al*. (2002) recommended that public sector managers be equipped with skills in outsourcing and partnering with other organisations to discover synergies and improve output efficiency. Sharon and Prefontaine (2003) performed several case studies to understand the different models of collaboration for delivering government services in the United States, Canada and Europe. The aim of Sharon and Prefontaines' (2003) study was to understand the fundamental elements of successful outsourcing and partnering that transcended cultural and national boundaries. Sharon and Prefontaines' (2003) work strongly recommended that the relationship only worked when there was a PM environment that was supported by a functional knowledge system. Manley, Shaw and Manley (2007) reported similar findings from their work on private and public sector collaboration.

Streit and Guzman (1995) undertook work on an international collaborative project to define air quality management options in Mexico City. Streit and Guzman (1995) concluded that a PM approach using shared resources from external partners had a positive impact on air quality in Mexico. A good understanding of resource allocation to manage the project was critical for the regulators to function efficiently, optimise on international collaboration initiatives and ultimately implement air quality management alternatives (Streit and Guzman, 1995).

2.2.5 PM Competence, Training and Development

PM competence and the required training and development must be in place for South African government projects to be well managed (Rwelamila, 2007). The Australian Institute of Project Management developed PM competencies based on the following factors (Australian Institute of Project Management, 2007):

- integration management;
- scope management;
- time management;
- cost management;
- quality management;
- human resources and conflict management;
- communications management;
- risk management; and
- procurement management.

Gareis and Heumann (2000) defined PM competence as the ability to perform the PM process efficiently, which required that the organisation have both PM knowledge and PM experience. Gareis and Heumann (2000) argued that for project success, PM competence must be described for the individual, team and organisation. To assess an organisation's project competence, the procedures documented by the organisation must be interrogated. The training and development plans of the individuals and teams must be informed by the gaps identified in PM competence. These competencies were also required to support with managing conflict and project implementation. Training and development interventions for efficient PM were the outflow of the PM competency assessment (Australian Institute of Project Management, 2007).

Rwelamila's (2007: 60) work on PM competence in public sector infrastructure organisations concluded that there was a lack of a '*collective brain*' in the public sector, which allows the public sector to gather knowledge and experience and store this in a '*collective mind*'. He argued that the public sector must formulate work processes, role descriptions, recipes, routines and databases of products or services and project knowledge to deliver on their routine activities. Rwelamila's (2007) recommended that for the public sector to improve output efficiency, a project-oriented organisation structure must be followed.

In a project-oriented organisation, at any given time a number of projects are started, performed, stopped, or even closed down. The more varied the projects and programmes of a project-oriented organisation are, the more complex the management of the organisation would be (Gareis & Heumann, 2000). Research showed that a project-oriented organisation had the following characteristics (Gareis, 2006):

- The organisational strategy was referred to as management by projects.
- Projects and programmes were used as temporary organisations.
- Networks of projects, chains of projects and project portfolios were objects of consideration for the management.
- PM, project portfolio management were the preferred processes.
- Know how assurance took place in expert pools.
- PM competence was assured by a PM Office and a Project Portfolio Group.
- A new management paradigm was applied, which was characterised by team work, partnering with other organisations, process orientation and empowerment.

The specific business processes of the project-oriented organisation can be visualised in a spider web graph (as shown in Figure 2.9), which could be used for the analysis of the maturity of a project-oriented organisation. For each of these processes, the project-oriented organisation requires individual and organisational competences (Gareis, 2006).

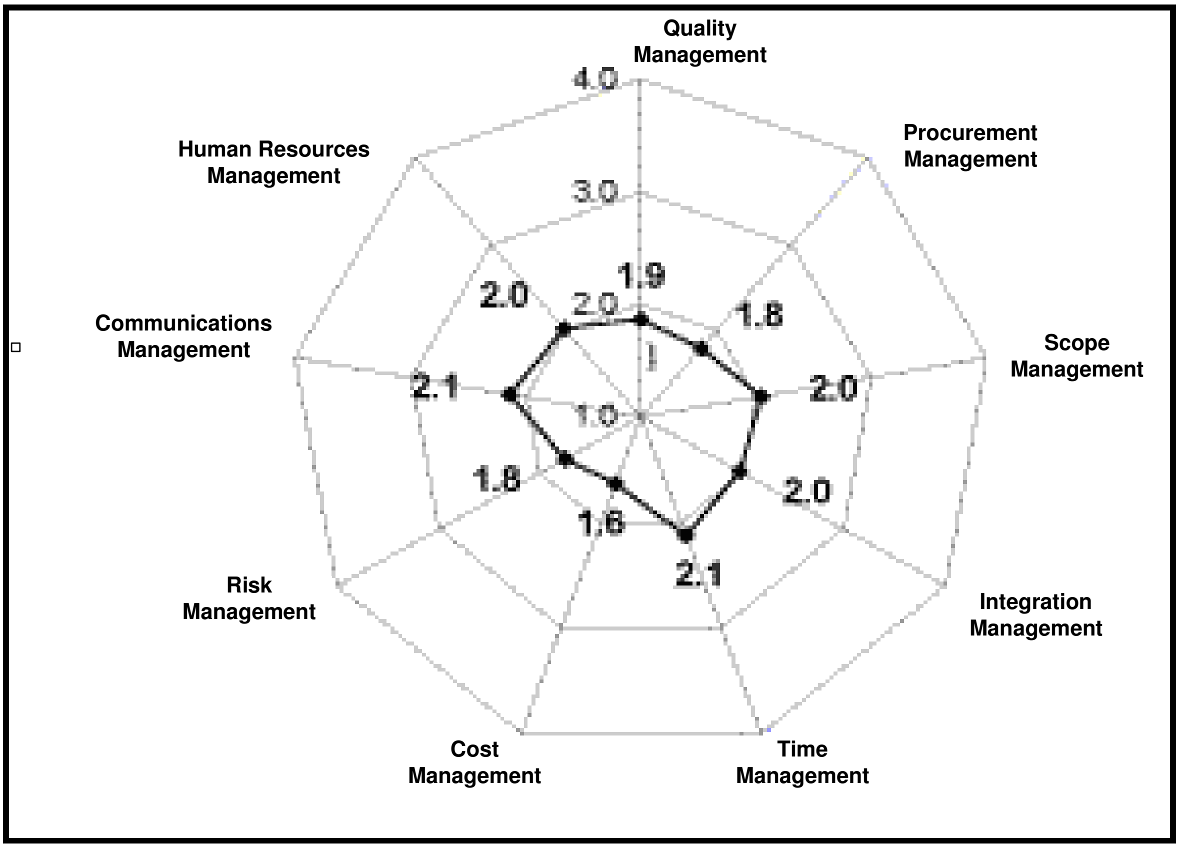


Figure 2.9: Spider web diagram to establish organisational competence (Gareis, 2006)

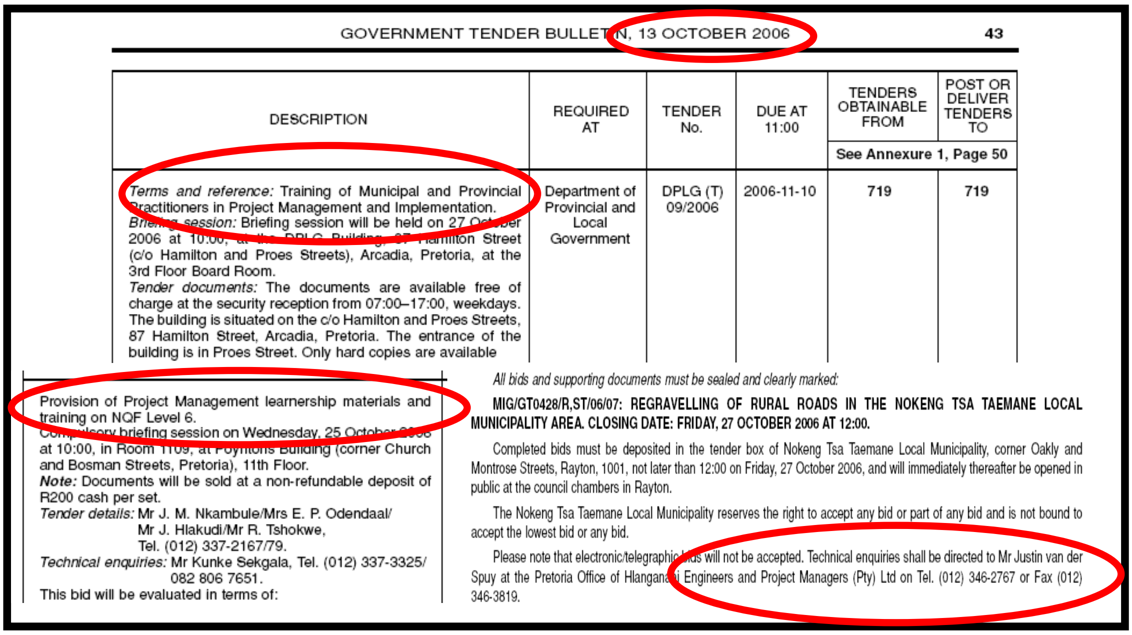
The Graham and Englund's (2004) seven-step process to build a PM centre of expertise was documented by Rwelamila (2007) as an important lesson learnt for public sector organisations to improve on their PM success. The seven-step process was as follows (Graham & Englund, 2004):

- Step 1: develop senior management support;
- Step 2: develop a structure for independent input;
- Step 3: develop a process for project selection;
- Step 4: develop upper manager's abilities in managing project managers;
- Step 5: establish a PM development programme;

- Step 6: making PM a career position; and
- Step 7: develop a learning organisation.

The work of Graham and Englund (2004) indicated that for the successful use of the seven-step process, PM competence, teamwork, cross-organisation cooperation and sustained leadership were prerequisites in the organisation. South Africa has identified the need to develop PM competence as a priority area in the public sector (Hargovan, 2006). Capacity building in the field of PM in the South African public sector was evident as follows (Hargovan, 2006):

- Qualifications, accreditation and unit standards were in place.
  - The South African Qualifications Authority gazetted a generic PM qualification requirements with accreditation processes;
  - Approved courses and unit standard compliant service providers that are registered and approved;
  - Tender advertisements for capacity building in PM as shown in Figure 2.10 for service providers;
  - Development Bank of Southern Africa initiative called Siyenza Manje focused on PM competence development;
  - Provincial programmes and projects address PM competence; and
  - Municipal Infrastructure Grant and Project Consolidate established Programme Management Units with direct transfer of funds to Municipalities.


GOVERNMENT TENDER BULLETIN, 13 OCTOBER 2006 43

DESCRIPTION	REQUIRED AT	TENDER No.	DUE AT 11:00	TENDERS OBTAINABLE FROM	POST OR DELIVER TENDERS TO
				See Annexure 1, Page 50	
Terms and reference: Training of Municipal and Provincial Practitioners in Project Management and Implementation. *Briefing session:* Briefing session will be held on 27 October 2006 at 10:00, at the DPLG Building, 87 Hamilton Street (c/o Hamilton and Proes Streets), Arcadia, Pretoria, at the 3rd Floor Board Room. *Tender documents:* The documents are available free of charge at the security reception from 07:00–17:00, weekdays. The building is situated on the c/o Hamilton and Proes Streets, 87 Hamilton Street, Arcadia, Pretoria. The entrance of the building is in Proes Street. Only hard copies are available	Department of Provincial and Local Government	DPLG (T) 09/2006	2006-11-10	719	719

Provision of Project Management learnership materials and training on NQF Level 6.
Compulsory briefing session on Wednesday, 25 October 2006 at 10:00, in Room 1109, at Poyntons Building (corner Church and Bosman Streets, Pretoria), 11th Floor.
Note: Documents will be sold at a non-refundable deposit of R200 cash per set.
Tender details: Mr J. M. Nkambule/Mrs E. P. Odendaal/ Mr J. Hlakudi/Mr R. Tshokwe, Tel. (012) 337-2167/79.
Technical enquiries: Mr Kunke Sekgala, Tel. (012) 337-3325/ 082 806 7651.
This bid will be evaluated in terms of:

All bids and supporting documents must be sealed and clearly marked:

MIG/GT0428/R,ST/06/07: REGRAVELLING OF RURAL ROADS IN THE NOKENG TSA TAEMANE LOCAL MUNICIPALITY AREA. CLOSING DATE: FRIDAY, 27 OCTOBER 2006 AT 12:00.

Completed bids must be deposited in the tender box of Nokeng Tsa Taemane Local Municipality, corner Oakly and Montrose Streets, Rayton, 1001, not later than 12:00 on Friday, 27 October 2006, and will immediately thereafter be opened in public at the council chambers in Rayton.

The Nokeng Tsa Taemane Local Municipality reserves the right to accept any bid or part of any bid and is not bound to accept the lowest bid or any bid.

Please note that electronic/telegraphic bids will not be accepted. Technical enquiries shall be directed to Mr Justin van der Spuy at the Pretoria Office of Hlanganani Engineers and Project Managers (Pty) Ltd on Tel. (012) 346-2767 or Fax (012) 346-3819.

Figure 2.10: South African Public Services commitment to building PM competencies

Hargovan (2006) added that the South African government and several business schools aimed to provide foundational PM training to 100 employees within local government. This was in support of the Accelerated and Shared Growth Initiative for South Africa and particularly the Joint Initiative on Priority Skills Acquisition. Geraldine Fraser-Moleketi in her November 2003 public address asserted that PM was one of the approaches that were extended to the public sector that have much to offer for efficient functioning. She added that PM had become a core skill in the make-up of all public sector managers and professionals (DPSA, 2006).

Ministerial Statements / 2006 Budget Vote Statements that supported the PM approach in the South African public sector included (Hargovan, 2006):

- Minister T Manuel: Budget speech 2006;
- Minister of Housing;
- Minister of Provincial and Local Government; and

- Minister for Agriculture and Land Affairs.

The provinces have also embraced the philosophy of a PM learning organisation and have initiated an interdepartmental forum in which all senior managers from the different provincial departments meet to discuss progress in terms of implementing PM in their departments. A general approach to PM in the province has been accepted and captured as Prince2 maturity model (Quassim, 2005). The provinces were still in the infant stage in terms of PM and delivery data was still not available in terms of project delivery time, quality and costs (Quassim, 2005). It has also been emphasised that there was a lack of coordination among national, provincial and local government. In addition, there was no reporting mechanism for the integration of data from the different spheres of government (Quassim, 2005).

The Gauteng Provincial Department of Agriculture Conservation and Environment was responsible for a budget of R228 million and managed projects ranging from the establishment of local food gardens to the development of strategies for sustainable development (McCourt, 2005). The department used a PM approach but on an informal basis. McCourt (2005) reported that PM was at an infant stage and that project outputs were not tracked using PM parameters. The monitoring of expenditure against outputs was, however, a key legal requirement and various systems existed to allow monitoring of expenditure at a programme and sub-programme level. However, this was not traced to individual projects or impacts on service levels.

PM can only be successful when the required top management support is visible (Handy, 2002). Top management is responsible for providing strategic direction and identifying strategic projects. An overview on strategic PM in an organisation follows.

2.2.6 Strategic PM

Strategy is something that must be crafted through an intimate connection between thought and action (guiding, responding and anticipating) and the creation of a shared perspective where individuals are united by common thinking and behaviour (Mintzberg, 1987a, 1987b, 1990, 2004). Brown and Eisenhardt (1998) stated that strategy was essentially about deciding where your business was going and then figuring out how to get there. They stated that firms often had a preoccupation with defining where to go, but that these strategies collapse in the face of rapidly changing industries. Before the strategy could be communicated and put into action, the destination had changed and companies had to start all over again.

Hill, Jones and Galvin (2004: 5) defined strategy in terms of its function as: '*an action a company takes to attain superior performance*'. Strategic projects are those projects that action the high-level objectives crafted by top management (Mintzberg, 2004; Grundy & King, 1992). Strategic project management is the management of those projects, which is of critical importance to enable the organisation as a whole to have competitive advantage. It specifically included the project that added value to the business, was not easily replicated and had the potential to open up new possibilities in the future (McDougall, 2008). Strategic projects must be aligned to the organisation's high-level objectives. In addition, strategic projects must support the organisation to establish project teams and function as PM learning organisations.

Brown and Eisenhardt's (1998) theory was based on complexity theory – that business and industry were complex adaptive systems. Brown and Eisenhardt (1998) proposed a competing on the edge strategy – the creation of a relentless flow of competitive advantages that, taken together, form a semi-coherent strategic direction (where to go).

They suggested that leaders create an adaptive and responsive organisation and to use this as the foundation for creating competitive advantage. Strategic direction would then emerge (Grundy & King, 1992).

The operating environment in which programme and PM exists has become increasingly complex. Leaders need to proactively manage the internal and external risks and master how to think and act strategically in today's uncertain world of political, economic and environmental change. Figure 2.11 shows the input factors that were required to enable efficient strategic decision-making as follows (McDougall, 2008):

i. opportunity leveraging through partnering and outsourcing;
ii. scenario planning and identification of strategic projects through training and development;
iii. empowering teams, people and partners; and
iv. timeline analysis.

Bower and Gilbert's (2006) research on strategic PM identified that for a company to be successful at strategy formulation and implementation, a resource allocation model must be defined. Bower and Gilbert (2006) concluded that the greater the number of strategic projects completed, the more efficient the organisation. Shenhar (2004) supported Bower and Gilbert's (2006) research on the need for allocating resources to managing strategic projects for improving output efficiency.

Brown and Eisenhardt (1998) highlighted the need to shift the focus from formulating strategy to execution (how to get there). A discussion of the requirements for implementing strategic projects follows.

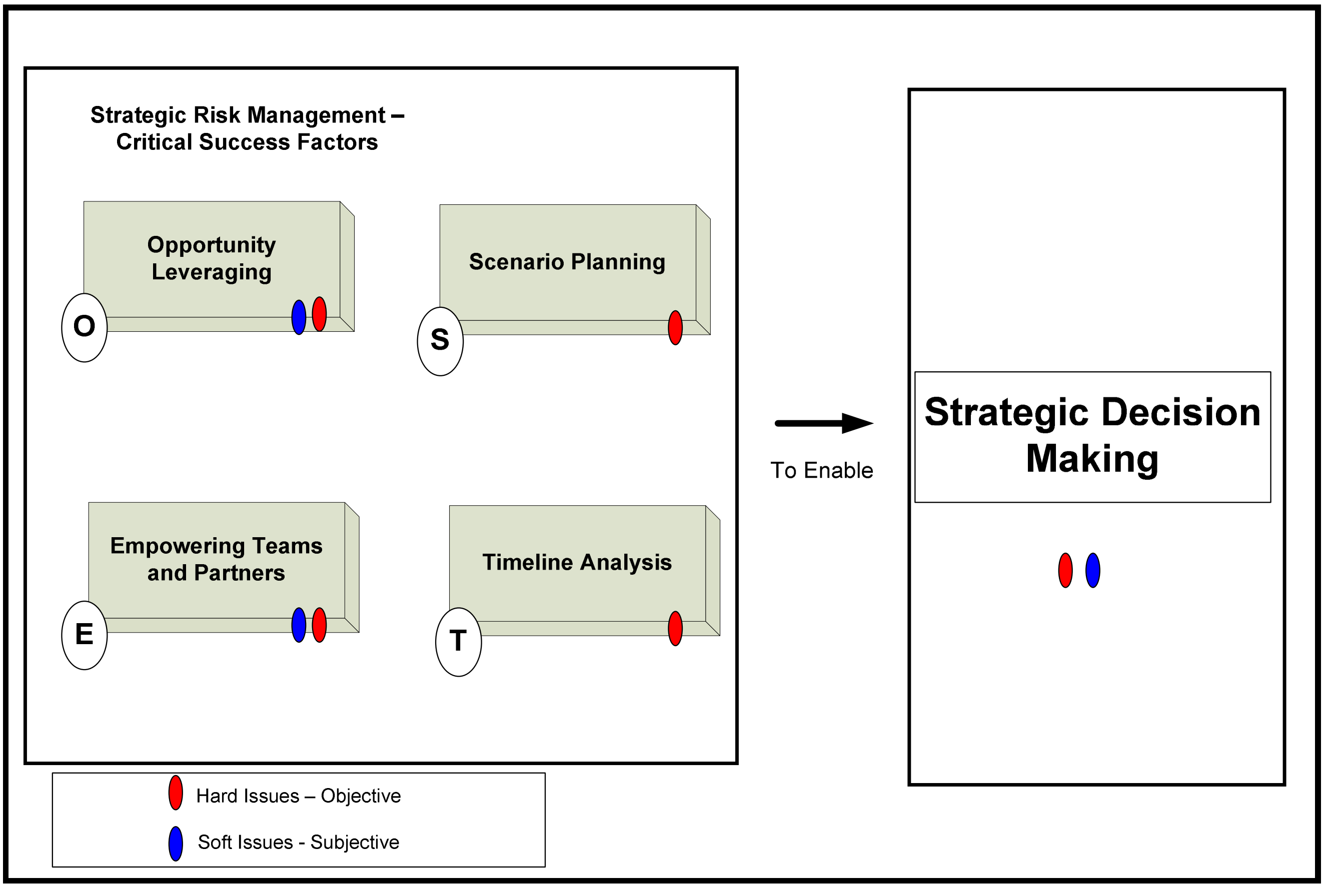


Figure 2.11: Critical project success factors for efficient strategic decision-making (McDougall, 2008)

2.2.6.1 Implementing Strategic Projects

Organisations that are efficient at implementing strategic projects successfully managed six factors, *viz.* action planning; organisational structure; human resources; annual business plan; monitoring and control and linkages, as shown in Figure 2.12 (Birnbaum, 2008).

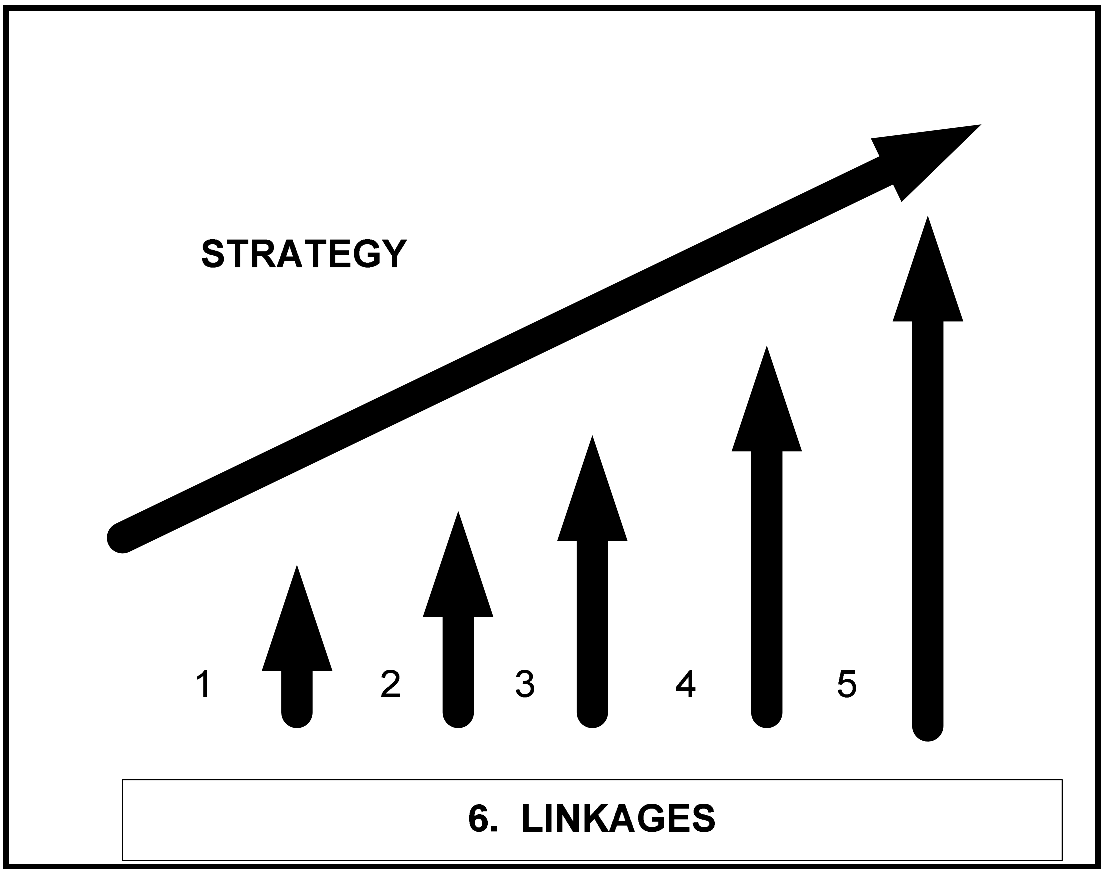


Figure 2.12: Strategy implementation: Six supporting factors (Birnbaum, 2008)

Organisations that are successful at implementation were aware of the need to allocate resource efficiently to the intended strategic outputs (Roseau, 1998; Eisenhardt, 2002). These organisations begin to think about that necessary budget and personnel commitment early in the planning process; the organisation ballparks the resource requirements during strategy development as well as during allocating budgets to the action plan. In that way, the organisation links the strategic plan to the annual business plan (and resources). The organisation eliminates the element of surprise that would otherwise be received at budgeting time (Birnbaum, 2008).

Birnbaum (2008:1) asserted that the reason for not implementing strategy was that there was a lack of 'linkage', which was 'simply the tying together of all the activities of the organisation'. The linkage was required to ensure that all of the organisational resources are rowing in the same direction. The variables of KM to support project success must also be investigated. The requirements for KM and KM systems in an organisation follow.

2.3 KM

Drucker (1993) defined knowledge as systematically creating and recreating knowledge to innovate. Durant-Law (2008) illustrated the knowledge conduit as shown in Figure 2.13 to support the understanding of the term knowledge.

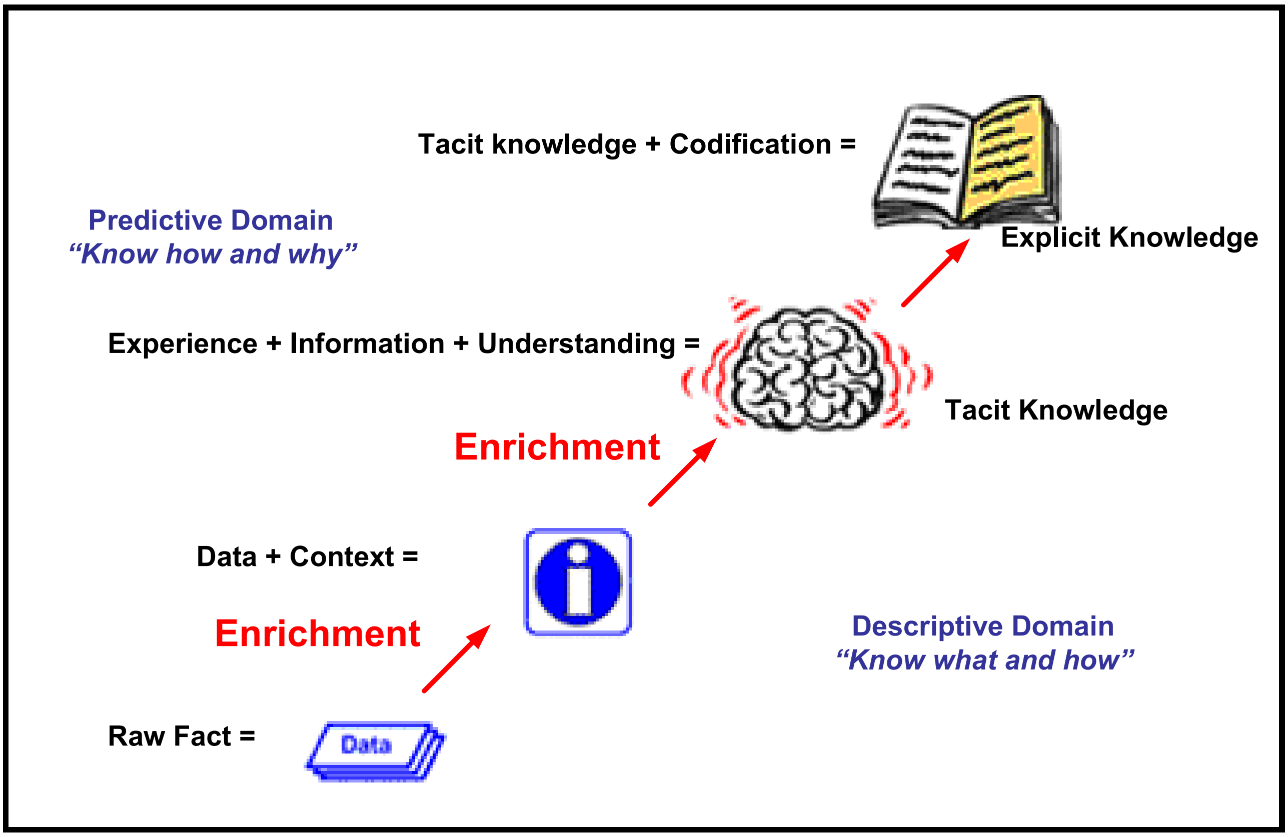


Figure 2.13: Knowledge conduit (Durant-Law, 2008)

Data is typically a set of discrete, objective facts existing in symbolic form that has not been interpreted (Davenport & Prusak, 1998). Data can be shaped and formed to create information (Laudon & Laudon, 1998). Information only becomes knowledge after it has been examined and compared to other information or data and is then applied to describe, predict or adapt to a situation (Durant-Law, 2008).

Enrichment occurs only with the addition of further context, experience and understanding, which results in an understanding of principles (Durant-Law, 2008). Knowledge is also referred to as the body of truths or facts accumulated by people in the course of time (Eurofield Information Systems, 2002).

Nonaka and Takeuchi (1995) referred to KM as the capability of an organisation to create new knowledge, disseminate it throughout the organisation and embody it in products, services and systems, as illustrated in Figure 2.14.

Organisations must nurture and leverage its intellectual capital by creating a collective and shared knowledge base (Ihua, 2008). KM has two essential tasks, *viz.* to facilitate the creation of knowledge and to manage the way people share and apply it (Davenport & Marchand, 2000). The authors argued that KM also included creating a culture where people share knowledge. KM therefore included the aspect not traditionally related to information technology, such as rewarding knowledge sharing.

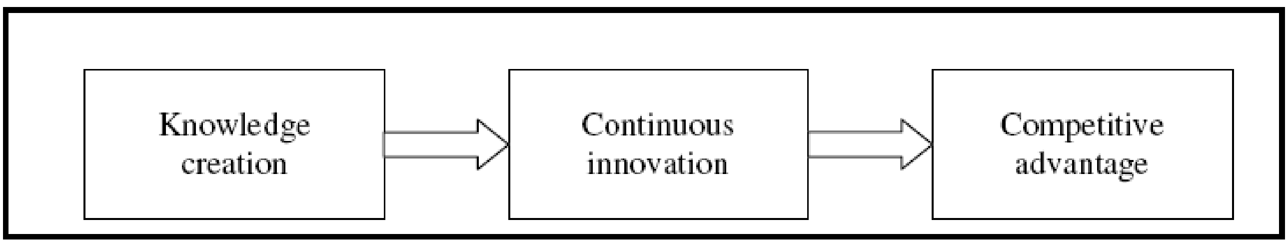


Figure 2.14: KM as a competitive advantage (Nonaka & Takeuchi, 1995)

KM as a management concept also involved some processes, which included managing the generation of new knowledge; capturing, storing and retrieving knowledge and experience; sharing, communication, collaborating and transferring; and using and building on what was known (Mayo, 1949). It also involved some enablers such as organisational culture; strategic and leadership support and infrastructural capabilities (Gold, Malhotra & Segars, 2001; Lee & Choi, 2003; Yu, Kim & Kim, 2007).

Several authors (Despres & Chauvel, 2000; Prusak 2000; Ihua, 2008) suggested that organisations define a map of KM to plot the KM activities. Some of these activities included senior management pronouncements and incentives schemes. The outcomes of KM (which includes patents, product launches and cycle time reduction) should be explicitly linked to the KM activities of the organisation (Despres & Chauvel, 2000; Westland, 2006). Murray (2000) added that knowledge managers started with the (desired) results and deduced what knowledge was required for achievement. Davenport and Marchand (2000) added that KM was more than managing people in that it also included managing information and processes. The emphasis, however, was on facilitating the transfer of information into knowledge and the sharing of knowledge to build organisational core competence and improve on its ability to manage change.

KM was also defined as the process through which organisations generate value from their intellectual and knowledge-based assets (Durant-Law, 2008). Most often generating value from knowledge involved codifying what employees, partners and customers knew, and sharing that information among stakeholders in an effort to devise best practices (Durant-Law, 2008). In addition, O'Dell and Grayson (1998:150) defined KM as a conscious strategy of 'getting the right knowledge to the right people at the right time'. O'Dell and Grayson (1998) added that it also helped people to share and put information into action in ways that improved organisational performance. There were several approaches to classifying the KM processes (Beckman, 1997; DiBella & Nevis, 1997; McAdam & Reid, 2000). McAdam and Reid (2000) described one KM process as four interrelated phases, each of which had an underlying scientific dimension as follows:

i. knowledge construction;

ii. knowledge embodiment;

iii. knowledge dissemination; and the

iv. application of knowledge.

There were many challenges relating to KM in organisations reported by Ruuska and Vartiainen (2005). Firstly, there were challenges associated with reinvention of the wheel and the sharing of knowledge accumulated in one project with others (Ruuska & Vartiainen, 2005). Project teams are temporary; therefore there was a risk that learning may be lost when teams disband. There were also challenges around how to enhance the communication of peers working in dispersed projects, as relationships in project organisations were maintained cross-functionally. This may increase knowledge sharing yet at the same time isolate people from peers (Ruuska & Vartiainen, 2005). To manage change efficiently, learnings must be documented and in-house KM systems developed and maintained (Ruuska & Vartiainen, 2005).

KM in organisations was generally based on two strategies *viz.*, codification and personalisation strategy (Hansen, Nohria & Tierney, 1999). The codification strategy relied on carefully codifying the knowledge and storing it in archives and databases, where it can be assessed and reused. In the personalisation strategy, knowledge is closely tied to the people who have discovered it and shared by personal face-to-face interaction. Social processes representing the personalisation strategy, as opposed to the use of technology or procedure aimed at the codification of knowledge, have also been recognised in project environments (Bresnen, Edelman, Newell, Scarbrough & Swan, 2003).

Skilled architects must think through the best approach to solving the business problem, the most beneficial way to partition functionality into services and the ideal coupling of these services into a working application. The increased focus on the design phase of the project implied that it would likely take more time and resources to deliver the first version of a service-oriented application. However, the rapid integration and reusability benefits gained by making the initial investment implied that future enhancements to the service-oriented architecture application could be delivered faster and with less risk and cost (Roque, 2006).

This knowledge then needs to be efficiently captured and embodied within the government (*e.g.* within its processes, practices, culture), disseminated and finally applied to create public policy. While knowledge had been recognised as a core strategic asset in increasingly dynamic public business environments and communities, more efficient governing and public policy development depends on a more systematic and efficient capture, dissemination, transfer and application of knowledge.

Gabriel, Kumar, Ordonez and Nasserian (2005) investigated potentials tools for improving the efficiency of the United States government agency. The authors proposed a multi-objective optimisation PM and KM model for project selection and information management. The model was applied to data collected from one of the United States government agencies that managed 84 separate projects. The results indicated improved budgetary efficiency for all the projects and the department's saving was used to fund an additional project. This improved the total number of outputs completed by the department. The authors added that even with uncertainties in costs and complexities in terms of objectives of the different projects, government efficiency was improved with PM and KM (Gabriel *et al.*, 2005).

The better the knowledge base on which public policies were built, the more likely the departments were to succeed in implementing the policies. In particular, good public policy emerged when knowledge was transferred efficiently within governments and when policy options were tested via ongoing knowledge transfer among government departments (Bridgman & Davis, 2004). In addition, KM processes support efficient stakeholder engagement that improved commitment to air quality management. The KM model developed by Bridgman and Davis (2004) is shown in Figure 2.15.

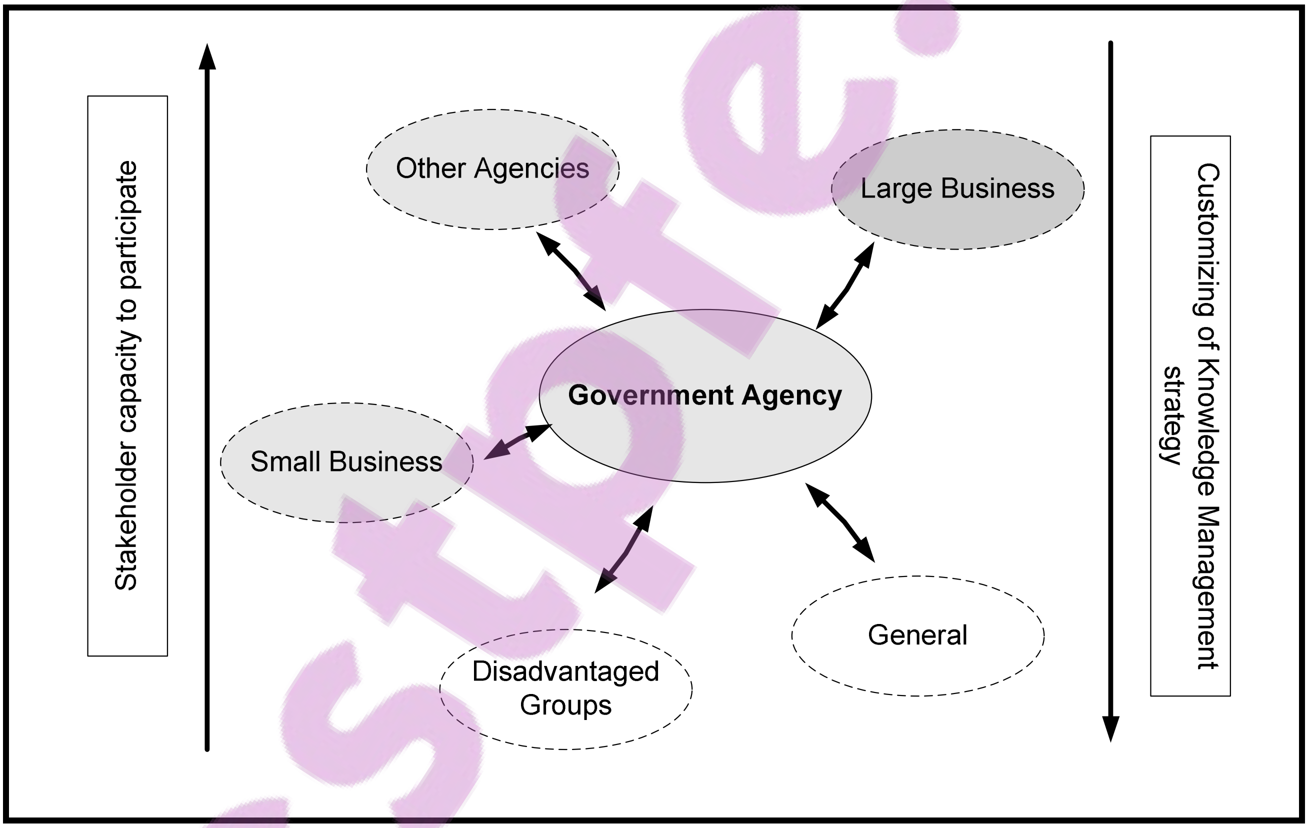


Figure 2.15: Creation of knowledge by interdepartmental collaboration and stakeholder engagement (Bridgman & Davis, 2004)

Bridgman and Davis (2004) suggested that future research on KM in the public sector must have a stronger focus on developing centralised reporting systems. Riege and Lindsay (2006) noted that the concept of KM was not new to the public sector. KM was integrated into government tasks and was inseparable from strategy, planning, consultation and implementation (Riege & Lindsay, 2006). Wiig (2002) indicated that developing and implementing public policy and central reporting systems required efficient KM processes. There was little research and few guidelines on how governments in practice could use KM to be efficient (Riege & Lindsay, 2006). To understand how the air quality data collected by the AQOs is managed, a discussion of the national air quality information reporting system follows.

2.3.1 Air Quality Information System and Centralised Reporting

Sterner (2003) reported that important factors for efficient air quality management included equity, politics, enforceability and the need to encourage cooperation and involvement. Krupnick (2008) supported these factors but added that decentralised air quality management had a greater impact due to local responsiveness. Krupnick (2008) added that governance monitoring and reporting structures must be clearly established to allow for the required flow of information.

Hadfield and Seaton (1999) indicated that efficient KM was required to defend regulations on emissions. Ehrlich, Wolff, Daily, Hughes, Daily, Dalton and Goulder (1999) asserted that increases in KM would alleviate or even eliminate future environmental problems and support high levels of environmental quality. Ehrlich *et al.* (1999) concluded that setting up knowledge institutions where people have access to information was a prime requirement for improving environmental performance. In addition, the public sector had the responsibility of ensuring that new knowledge was developed, maintained and shared to manage the environment efficiently.

In his PhD thesis on '*Managing information systems projects within government: factors critical for successful implementation*', Rosacker (2005) used a survey research methodology. He tested various factors to in order to come to an understanding of the requirements for implementing information system projects successfully. The following research question was studied: '*Do the critical success factors identified in previous research apply to government information system implementation projects?'* The findings at the overall project level supported centralised coordination of information and addressing systems failure as critical success factors. The dominant factor rankings for each stage were dissimilar when private sector entities were compared with public organisations. These outcomes provided insight into the differences between the private and public sectors. The recommendation from the study was that further empirical research into KM in the public sectors was required (Rosacker, 2005).

A centralised reporting system is required for efficient decision-making (Hadfield & Seaton, 1999). South Africa has recognised the need for central management of air quality data and initiated the South African Air Quality Information System (SAAQIS). The main objectives of SAAQIS were to provide a one-stop site for users on air and atmospheric quality information (DEA, 2008):

- centralised, verified data for practical implementation of the AQA to facilitate compliance with norms and standards by the different stakeholders; and
- vertical integration of the air quality information from the three spheres of government.

To deliver on the objectives, the centralised information system must have minimum downtime and must be based on a sound technology platform (Roque, 2006). Organisations need to develop a strategic approach to technology that would assist in business problems while keeping costs in line (Westland, 2006). Roque (2006) added that the alignment of KM architecture with business strategy was a critical success factor in any organisation.

Generating the verifiable air quality information would require a combination of establishing systems and maintaining these through prioritising and addressing systems failure. Posner (1987), Thamhain and Wilemon (1987) and Pinto and Slevin (1988) indicated that resources must be allocated for prioritising and addressing systems failure. Mankins and Steele (2005) added that failures in addressing priorities must be documented and the lessons shared. An understanding of managing systems failure was therefore important to maintain KM systems. A discussion of system failure and the variables for monitoring the management of systems failure follows.

2.3.2 Prioritising and Addressing System Failures

Weber (2007) undertook an extensive review on the factors for addressing systems failure. A summary, drawn from various sources, of the reasons for the failures follows:

- KM approaches not integrated in terms of people, processes and technology (Abecker, Decker & Maurer, 2000);
- KM approaches ignore impediments to knowledge transfer. Szulanski (1996) supported Weber (2007) and added that impediments to the transfer of best practices also suggest failure factors relating to the lack of understanding of the information;

- KM approaches may fail when these do not enforce managerial responsibilities (Weber, Breslow & Sandhu, 2001). Marshall, Prusak and Shpilberg (1996) list these responsibilities as follows: determine knowledge, enable knowledge collection, represent knowledge, embed knowledge in targeted processes, verify and validate knowledge, oversee knowledge reuse, monitor knowledge transfer and create infrastructure for the preceding responsibilities;
- KM approaches may fail when they do not properly oversee the quality of stored knowledge (Weber, 2007);
- KM approaches may fail when they do not promote collaboration. Collaboration is an important means for learning and sharing. Therefore, any KM approach that does not promote collaboration is likely to fail (Weber, 2007);
- KM approaches may fail when they are not able to show measurable benefits (Alavi & Leidner, 2001);
- KM approaches may fail because users do not perceive value in contributing. KM approaches do not typically offer any reciprocal value to compensate for the time allocated for knowledge sharing. Hence, contributors may not perceive any value in contributing, to themselves or others (Disterer, 2001).

Weber (2007) added that implementation guidelines to address these factors of KM system failures must be available to the people. For the KM approaches to integrate people, processes and technology, the people component must consist of knowledge facilitators and users who work together to understand the community processes and master the technology. The processes that are relevant to the target community should be identified and incorporated into the main steps of design and development of the KM approach. Actions to enforce managerial responsibilities should be incorporated into the design. There should be verification methods and maintenance methods so that stored knowledge remains relevant across time.

There should be continuous measurement of the systems efficiency (Ahn & Chang, 2002). Surveys asking users to comment on the documents relating to sharing of systems failures, frequency of review of systems failures and resources allocated to address systems failure have been recommended (Weber, 2007). The efficiency of the approach should reflect its ability to perform knowledge tasks such as sharing and leveraging knowledge. The variables used in the model to assess the resources allocated to address system failure were the man-hours spent on reviewing and sharing systems failures.

Kanter and Walsh's (2004) work on improving organisational efficiency in a large government department revealed that KM was critical for output efficiency. Kanter and Walsh (2004) added that government departments must establish knowledge systems that support reporting on project status as well as identify problems and assign accountability for problem resolution. In addition, the efficient implementation of KM would close the PM gaps identified, *viz*. lack of communication and ability to implement projects.

Change is often complex to manage and met with resistance. A discussion of CM and change strategies that allow for the capturing of lessons learnt during the change process to enable the growth organisations follows.

2.4 CM

The change from business as usual to more sustainable business practices was inevitable (Goleman, 2009). Change, however, creates stress in organisations (Goleman, 2009). According to Handy (1990), a business philosopher, organisations must maximise opportunities and minimise the risks relating to change. Handy (1990) indicated that leaders who understand the reasons for change spend less effort in protecting themselves from the change or resisting the inevitable. In a positive light, he argued that change was another word for growth and a synonym for learning.

According to Duck (1993), chief executives were radically restructuring their organisations, with little account taken of the resources needed to change skills or behaviour. Beer and Nohria (2000) added that about 70 percent of all change initiatives fail and stated that to improve the odds of success, executives must understand the nature and process of change better.

Recklies (2004) indicated that the change process occurs in seven phases. An understanding of the phases helps managers to assist employees through their natural resistance to change, without forcing the next stage. Forced progression results in unhealed wounds, which would surface later and possibly undermine the success of the change (Bridges, 1991; Bridges & Mitchell, 2005).

To transition employees through the process, Bridges (1991) suggested that managers must provide the people with four Ps: the purpose, a picture, the plan and a part to play. The purpose of the changes must be clearly explained in order to allow for a true understanding of the problem. Once people picture the problem, solutions can be identified jointly. Managers must develop a transition management plan that starts with where people were and then works forward. Lastly, managers must communicate on the role played by the people within the new business system. The success of the four Ps requires that managers be consistent, symbolise the new identity and celebrate success.

Schein (1980, 2002) described three types of change that occur in all teams and organisations: natural evolutionary change that occurs throughout the lifetime of the organisation; planned and managed change for managing future opportunities and threats;

and unplanned revolutionary change, where managers respond to the constant forces for change that impact on every organisation and that have profound effects on the organisation's ability to remain competitive and maintain productivity. Managers would use planned change to alter the organisation in advance of a problem with the aim of improving efficiency. Even in complex and dynamic environments, efficient managers strive toward planned change over reactive change.

Kotter and Schlesinger (1979) focused on the need for managers to develop skills for dealing with diagnosing resistance to change and choosing the appropriate methods for overcoming it. The authors suggested that people were resistant to organisational change for various reasons. First, people resist change because they have a desire not to lose something of value. Second, resistance is often an outcome of a misunderstanding of the change, and people perceiving that change might cost them more than they would gain. Unless managers openly discuss these misunderstandings and clarify them rapidly, resistance is often encountered. Organisations that run deep in mistrust are often plagued by this form of resistance. Third, people may contend that the proposed change does not make sense for the organisation. Resistance stems from the belief that the situation was different from what managers or those initiating the change effort see as the problem. These people typically see more costs than benefits resulting from the change. Lastly, people resist change due to a low tolerance for change. These categories of people fear not being able to develop the new skills and behaviour that would be required. Thus, they resist in order to maintain the status quo.

Kanter (1999) indicated that resistance to change also exists at organisational level. Organisations resist change to maintain stability or invest in long-term resources and the change impact on past contracts or agreements. Resistance to change must therefore be managed with the context in mind (Kotter & Cohen, 2003).

Management can use various approaches when attempting to introduce changes to individuals, groups or organisations (Kotter & Cohen, 2003). Kotter and Schlinger (1979) indicated that managers should consider three basic questions when dealing with organisational change: (i) What actually do we need to change? (ii) What options do we have? (iii) How should we carry out the change process? These questions would guide the change process and ensure that management adopt a clearly defined strategy for the initiation of change and that the *efficient* management of change is based on a clear understanding of behaviour and organisational needs.

With regard to change in the public sector, Batley (2005) in his article on the politics of service delivery reform indicated that there were leaders, supporters and resisters of public reform. Batley (2005) added that PM in the public context in developing countries presented greater difficulties than developed countries. Batley (2005) reported that in continents like Africa, there was a large gap between project design and outcomes, as there was no ownership of the project and systems failures were not prioritised and addressed. The author recommended decision support tools to sustain the change process.

2.4.1 Decision Support Tools

CM in government projects must be supported with standardised methods and procedures for efficient management of change (Hadfield & Seaton, 1999; Sullivan, 2002). These standardised methods are also referred to as decision support tools, which are interactive tools used by the decision-maker to answer questions, solve problems, and support or refute conclusions (DEA, 2007; Sullivan, 2002). All decisions related to air quality planning and management are characterised by multiple and usually conflicting objectives, and multiple criteria (Sullivan, 2002). The AQOs face the problem of uncertainty, hidden agendas and plural rationalities, which results from the wide public participation in the decision-making processes (DEA, 2007). The decision support tool can be incorporated into a structured decision-making process for air quality management to support CM (Environmental Protection Agency, 2003).

Regulations and guidelines for air quality management developed through a consultative PM process also support CM. Decision support tools foster trust and facilitate communication among stakeholders by making the process more collaborative and transparent, as they feature a process flow that could be approved by all parties during the planning phase (Environmental Protection Agency, 2003). Specific decision support tools in the South African Air Quality Units included decision matrices for the identification of high impact activities and industry-specific air quality impact manuals.

2.4.2 Learning Process

Knowledge must continuously be enriched to cope with changing circumstances, face new challenges and solve new problems. Kessels (2001:499) indicated that learning was '*the production process in which knowledge was created*'. This type of work has the characteristics of learning processes (Kessels, 2001). Knowledge is the main asset created through learning, and the main production tool is the individual or knowledge worker (Durant-Law, 2008). Distinguishing characteristics of knowledge workers are that they own and control valuable knowledge for the company, know how to make knowledge productive through learning, and are largely self-motivated. De Geus (1997) added that learning means being prepared to accept continuous change.

De Geus (1997:18) motivated that '*knowledge has replaced capital as the scarce production factor* and that organisations must focus on optimising the efficiency of people rather than 'optimising capital'. De Geus (1997:21) added that '*living, learning companies*' improve peoples' '*capability to learn*' as well as manage change. In the context of this study, the knowledge workers were the AQOs. In the context of this study, the knowledge workers are the AQOs.

Learning in the workplace can take place in different ways. Bolhuis and Simons (2001) proposed four different modes of learning, *viz.*:

- Learning through experience, which occurs because of acting, observing and experiencing what happens in a certain environment, how it was designed and how it works.
- Learning through social interaction driven by interaction between people and learning occurring from and through each other.
- Learning through theory that results from translating abstract, generalised and systemised information back into practice.
- Learning through critical reflection, which results from asking questions of oneself and others.

Durant-Law (2008) made an important distinction between the former two ways of learning and the latter two: the former take place automatically, the latter only take place because of a deliberate effort. Durant-Law (2008) used this distinction to demonstrate that organisations must create the required learning environment. He explained that the broader interpretation of learning was that learning is a continuous process (is more than formal education), and the quality of learning relates to the circumstances.

Graham and Englund's (1997) work focused on creating an environment for successful projects to manage change in organisations. They asserted that the future of an organisation rides on the success or failure of its PM process and organisations should aim to be PM learning organisations. The key factors reported for managing projects successfully included setting a project deadline and allowing time for planning and creativity; selecting a project manager and capturing learnings from previous projects (Graham & Englund, 2004).

The principles of a learning organisation were further stressed by Graham and Englund (2004). The concept of learnings was expanded to include adaptive learnings (coping and learning from the changes in the environment) and generative learnings (expanding one's capabilities and represents the impulse to learn). How organisations leverage learnings for competitive advantage was also evaluated. Graham and Englund (2004) boldly expressed the view that for organisations to survive the turbulent tide of change, organisations have to appoint senior managers to lead projects with multidisciplinary teams and all affected parties represented.

Moore (2003) indicated that documenting learnings and setting up in-house knowledge systems were important requirements for organisations to institutionalise knowledge and undertake CM efficiently. A discussion of CM, KM and PM in the public sector follows.

2.5 Summary of the Variables for Measuring Public Sector Efficiency

The complexity of investigating the components of public sector efficiency has been recognised by many researchers, and includes appropriate variables being defined to quantify output efficiency (Fedra, 2000; Struckenbruck, 1981). The Canadian Institute of Health Information Services (2000) defined efficiency as achieving desired results with the most cost-efficient use of resources.

The examples of existing variables used as input activities include (Canadian Institute of Health Information Services, 2000):

- man-hours spent on actual versus expected length of stay in hospital;
- man-hours spent on patients who may not have needed admission;
- comparative data on the man-hour cost of services;
- local/provincial man-hour costs of particular services;
- man-hour cost of treatment per outpatient, and
- ratios of day case surgery to all surgery.

The input variables for the health sector included capital, medical goods and labour. However, there are no available data for the measurement of either capital input or consumption of goods in the health service departments. Therefore, analysts often concentrate their effort on the measure of the apparent output of labour (Canadian Institute of Health Information Services, 2000).

To measure public sector input, the ideal variable recommended was the number of worked hours, weighted by the skills mix of qualifications (Canadian Institute of Health Information Services, 2000). Usually, the only available data on labour are the numbers of professionals of different categories. The Canadian Institute of Health Information Services (2000) proposed a synthetic variable taking into account the skills mix to obtain a total number of weighted hours worked.

The variables used in the model developed in this study considered the man-hours spent on activities relating to PM, CM and KM. As discussed in Section 1.4.3, De Geus's (1997) work on Living Companies supported the use of man-hours as an input variable. A discussion of the use of models as a management tool follows.

2.6 Models as Management Tools

Howard (1970) defined a model as a representation of reality in manipulable form. The model's manipulability permits one to see how the system or process under study was affected by different inputs, or how changes in its form could affect system behaviour. The advantages of having the ability to manipulate the variables in a model were as follows Howard (1970):

- permits experimentation;
- provides insight into processes on which experimentation was impossible or undesirable;
- aids in developing theories to explain the behaviour of a process and in gaining insight into its characteristics;
- permits one to extrapolate beyond available data and thus to reduce the length of time needed to study a phenomenon; and
- permits these experiments to be conducted at a lower cost than if one had to use the actual system.

There are physical models (*e.g.* an airplane for testing in a wind tunnel), semantic or verbal models (*e.g.* a description of a neurosis) and symbolic or mathematical models (*e.g.* the relationship between time and distance covered by athletes of varying fitness) (Maltz, 2001). This study focused on symbolic or mathematical models.

Maltz (2001) warned that the relationships under investigation could turn out to be complicated, and complex analytical work would be required to determine the structure of the model. In fact, it is often the case that a researcher knows (or suspects) that certain variables are useful in describing a process, but not how the variables interact, that is, whether the outcome was an additive or multiplicative (or some other) function of the variables. In such cases exploratory analyses are undertaken, using various functional forms, to see how best to characterise the system.

In developing a good model, a balance must be struck between completeness and conciseness (Maltz, 2001). Not all variables are equally useful; in fact, selection of the appropriate variables and establishing how these are related constitute the art of modelling (Morris, 1967).

The application of models in decision-making allows for systematic and transparent outcomes (Gachet, 2004). A discussion of the use of a model to drive decisions support in an organisation follows.

2.6.1 Model-Driven Decision Support Systems

Decision support systems are a loosely defined group of tools and include information systems, tools for scenario analysis and optimisation approaches (Power, 2003). A model-driven decision support tool emphasises access to and manipulation of a statistical, financial, optimisation or simulation model. This tool uses data and parameters provided by users to assist decision-makers in analysing a situation and are not necessarily data-intensive (Gachet, 2004).

Model-driven decision support systems have emerged over the last decades as important tools for planning and management (Gachet, 2004). Management problems that involve allocating public resources to address environmental challenges required a new approach to decision support (Fedra, 2000). The motivation for the new approach was that it was difficult to solve the inverse problem directly due to the complexities of the systems, and the changing nature of the decision-making process due to high staff turnover and the lengthy time for decision-making due to too much red tape (Fedra, 2000). Therefore, any practical approach proposed to drive decisions in the public sector has to be iterative, adaptive and interactive.

Broadbent (2010:14) reported on a model-driven decision support system in the United Kingdom *viz.*, '*Research Assessment Exercise'*, which involved evaluating performance measurement and resource allocation in the academic environment. The report focused on the extent to which the dual functions of performance measurement and resource allocation interacted at the university. Performance measurement referred to the quality of the papers submitted to the research committee and the resources looked at in the allocation of funding by this committee. The findings of Broadbent (2010) indicated that a central database to enable information management was a critical success factor for resource allocation. The drawback of the paper was that was not an '*in-depth academic review or a comprehensive description of the exercise'* but only provided a *'personal commentary and reflection based on practical engagement*' with the assessment exercise (Broadbent, 2010:20).

A generic decision support approach and framework must recognise the requirements and constraints of the decision-making process in the public context. Fedra (2000) added that efficient communication with a diverse audience was one of the basic requirements for a decision support system and the interactive approach. A review of existing models and management frameworks that are available to guide organisations to improve on their output efficiency and set up decision support systems follows. The aim of the review is to establish the suitability of the existing models and frameworks to guide AQOs on how to improve their efficiency.

2.6.2 Management Frameworks

Organisations use management models as important tools for analysing businesses and developing strategies (Recklies, 2004). These models are a simplified picture of reality and show those elements of reality in a business or an industry that are relevant for analysis of a certain problem. Those elements that are not relevant would be discarded.

Few models specifically evaluate organisational efficiency. However, numerous management methodologies for organisational improvement are presented in the form of frameworks in the literature, rather than models. Even though the literature referred to the management frameworks as models, it failed to meet the requirements of a model, *i.e.*, it was not a simplified representation of reality, could not be experimented with, and could not be used to predict behaviour. A brief discussion of the management frameworks follows; thereafter a discussion of the strengths and weakness of the frameworks will be undertaken.

- **Business Excellence Model**

The Business Excellence Model, as shown in Figure 2.16, is an over-arching, non-prescriptive framework based on nine criteria. Five of these are enablers and four are results (Sheddon, 2006):

- enablers: leadership; policy and strategy; people; partnerships and resources; processes; and
- results: customer results; people results; society results and key performance results.

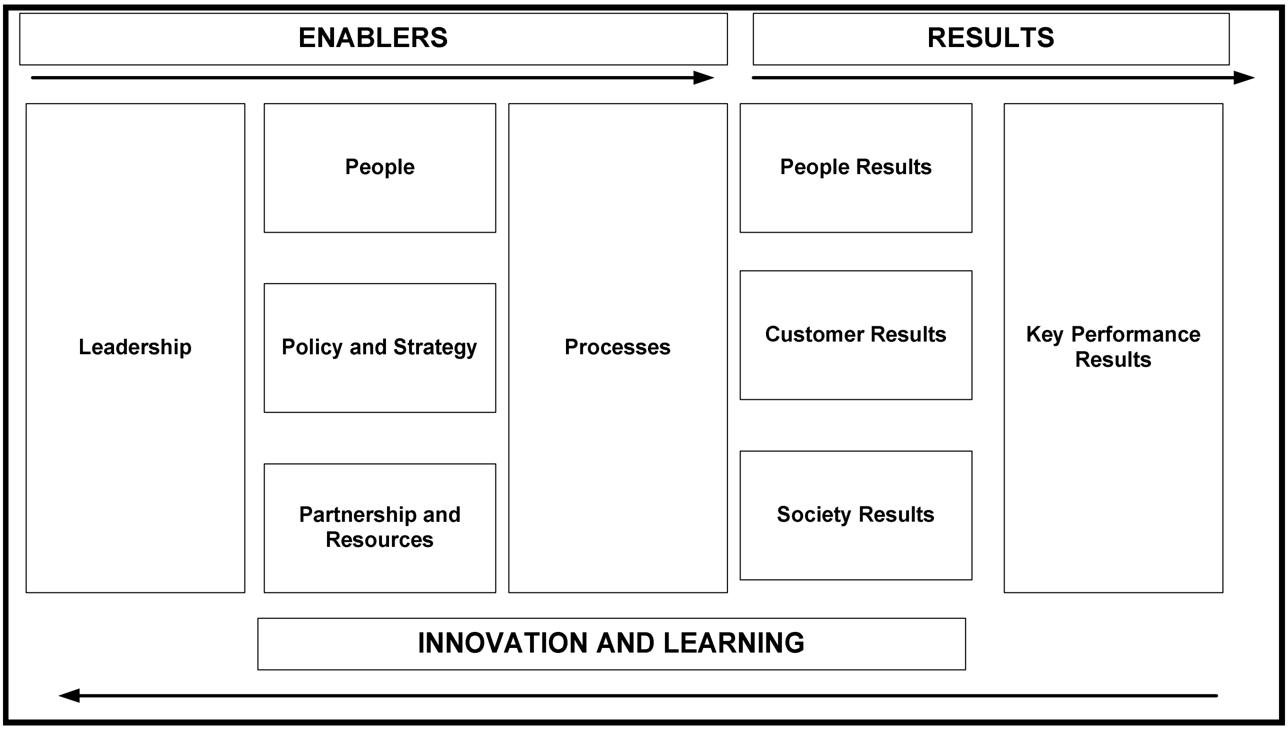


Figure 2.16: Business excellence model
(Sheddon, 2006)

The implementation of the Business Excellence Model was reported to enable the development of business excellence of a system on the basis of improvements to quality of its products and services. In addition, there were reinforcements of the fundamental forces of the system in terms of its flexibility and the speed to respond to customers (Sheddon, 2006). The Business Excellence Model is a tool that can be used for the following:

- self assessment;
- as a way to benchmark with other organisations;
- as a guide to identify areas for improvement;
- as the basis for a common vocabulary and a way of thinking; and
- as a structure for the organisation's management system.

- **<u>The 7-S Model</u>**

The 7-S Model, as shown in Figure 2.17, begins with the premise that an organisation is not just a structure, but consists of a total of seven elements, viz. structure, systems, strategy, shared values, skills, style and staff.

These seven elements are distinguished in hard Ss and soft Ss. The hard elements (strategy, structure and systems) are tangible and easy to identify. The four soft Ss (skills; staff; style and shared values), however, are considered intangible. These are difficult to describe since capabilities, values and elements of corporate culture continuously develop and change. The 7-S Model has been deemed a valuable tool to initiate change processes and to provide strategic direction. A helpful application is to determine the current state of each element and to compare this with the ideal state. Based on this it is possible to develop action plans to achieve the intended state (Waterman, 1982).

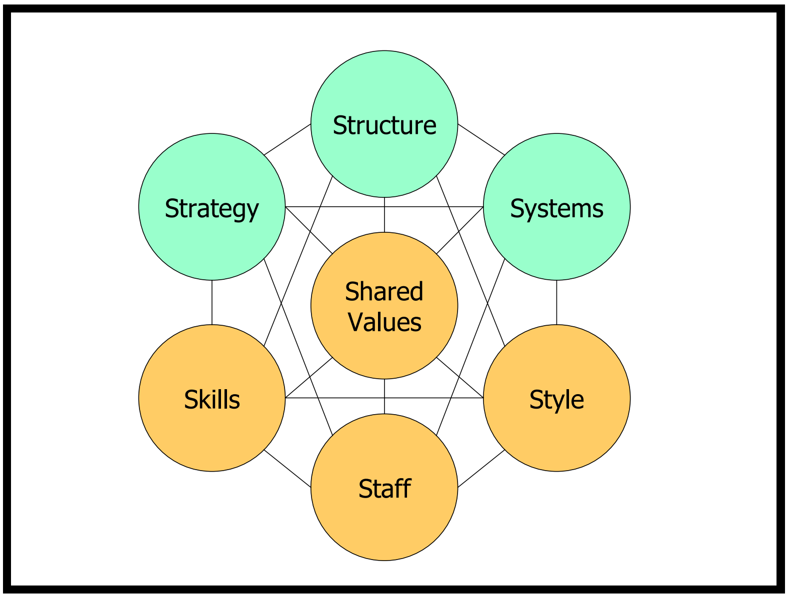


Figure 2.17: The 7-S Model (Waterman, 1982)

- **<u>The Value Chain</u>**

Porter (1985: 5) referred to the term 'Value Chain' in his book *Competitive advantage: Creating and sustaining superior performance* and proposed this as a framework to improve organisational efficiency. Value chain analysis describes the activities the organisation performs and links these to the organisation's competitive position. Therefore, it evaluates the value-add of each particular activity to the organisation's products or services. This idea explored the organisation as more than a random compilation of machinery, equipment, people and money (Porter, 1985). Systems and systematic activities facilitated a product or a service for which customers were willing to pay a price. Porter (1985) argued that the ability to perform particular activities and to manage the linkages between these activities was a source of competitive advantage. Figure 2.18 is the basic framework of Porter's Value Chain.

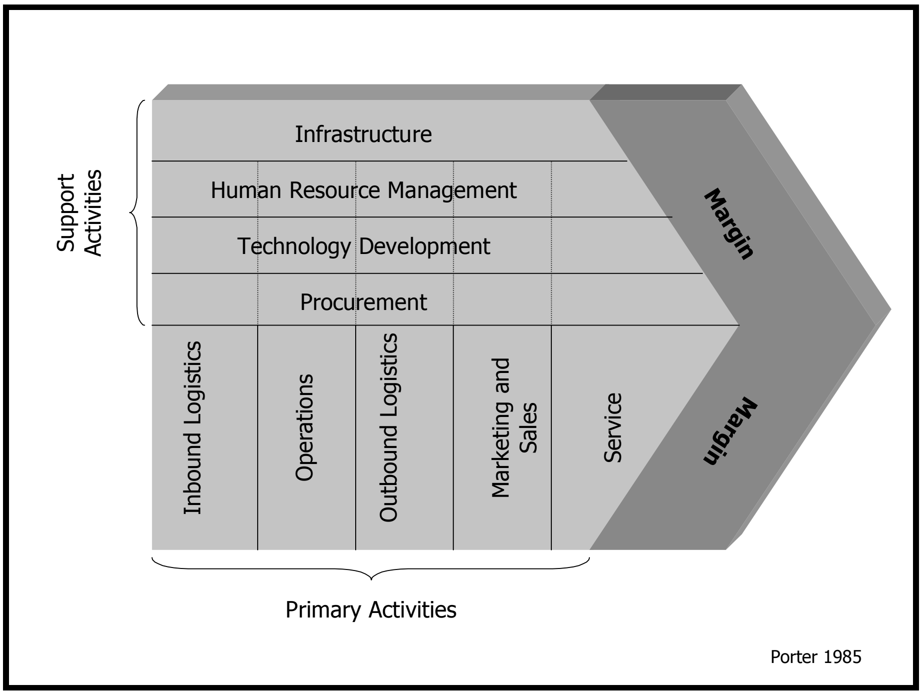


Figure 2.18: Basic framework for the Porter value chain (Porter, 1985)

In most industries, it is unusual for a single company to perform all activities from product design, production of components and final assembly to delivery to the final user by itself. Most often, organisations are elements of a value system or supply chain. Hence, value chain analysis should cover the whole value system in which the organisation operates.

One of the criticisms of Porter's theories is that they are dated, as they are based on the economic situation in the eighties. This period was characterised by strong competition, cyclical developments and relatively stable market structures. Porter's (1985) models focus on the analysis of the actual situation (customers, suppliers, competitors, value chain links etc) and on predictable developments (new entrants, substitutes etc). Competitive advantages develop from strengthening the organisation's position and addressing value-destroying activities. Hence, these models cannot explain or analyse today's dynamic changes, which have the power to transform whole industries. Shapiro and Varian (1998) added that the role of information technology was the foremost difference between strategy in what they called the '*Porter world*' and in the new world of new forces. The old economy used IT as a tool for implementing change. Today, technology and KM with efficient decision support systems has become the most important driver for change (Shapiro & Varian, 1998).

- **Model of Employee Communication**

The model devised by Moorcroft (2006) focused on representing the process of engaging employees in communication to improve organisational efficiency. It was specific to the methodology relating to the engagement process, as illustrated in Figure 2.19. The engagement was achieved by helping employees get a better idea of the impact of their actions on the organisation and promoting behaviour that supports the organisational objectives. Moorcroft (2006) indicated that applying the model of employee communication improved communications, employee alignment as well as the engagement scores.

- **<u>Learning Organisation Model</u>**

Zuber-Skerritt (2002) indicated that organisations needed to manage knowledge through action learning using the action research approach. The model proposed by Zuber-Skerritt (2002) is shown in Figure 2.20. Action research requires a learning organisation environment and the action learning needs to be a value-adding exercise for the organisation.

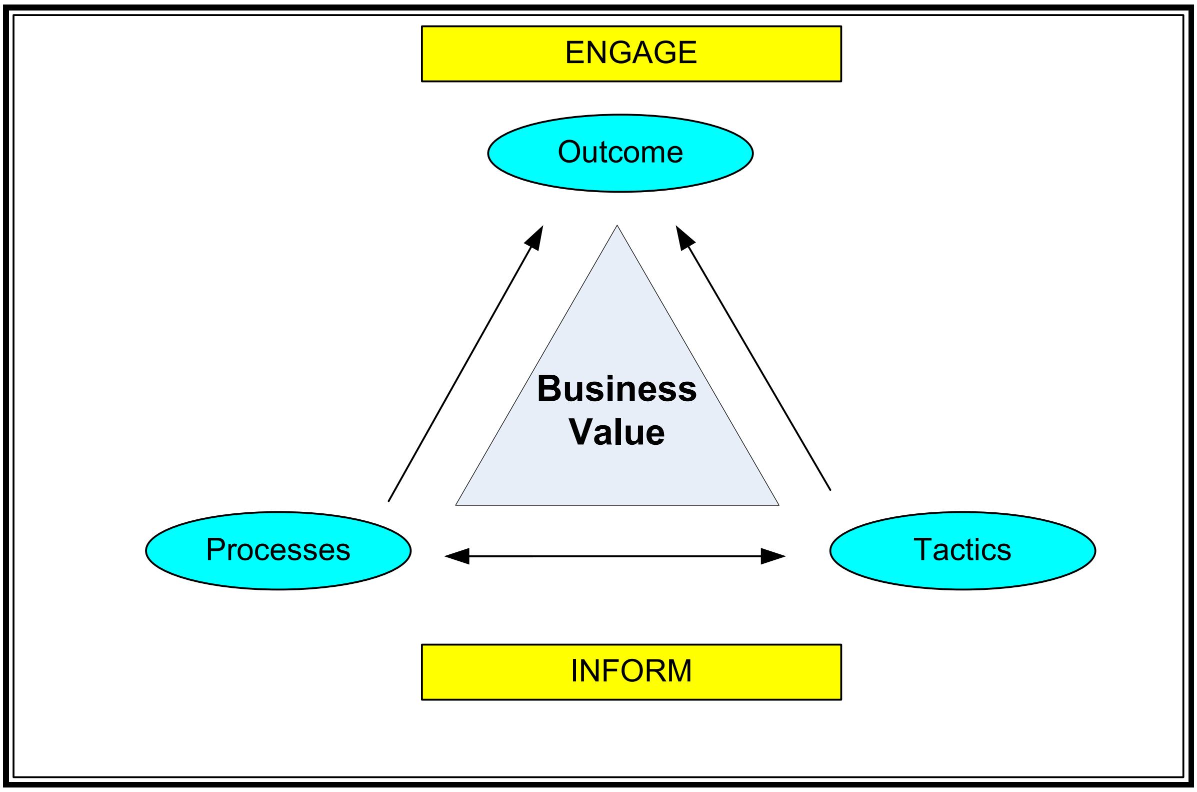


Figure 2.19: Moorcroft's (2006) model of employee communication

The model provided a framework that addressed nine core values that Zuber-Skerritt (2002) believed underpin action learning and action research. Zuber-Skerritt (2002) asserted that the model offered valuable support for organisations undergoing major transformation or planned changes and was also valuable in supporting innovation.

- **<u>The Drawback of the Existing Models and Management Frameworks</u>**

Overall, the management frameworks discussed provide a conceptual framework that can be used to outline possible courses of action or to present a preferred approach of an idea or thought. Moorcroft (2006), for example, offered a model for a specific scenario and limited application *i.e.* to support organisations to engage employees and improve business outcomes. The frameworks also attempted to simplify complex processes in diagrammatical terms.

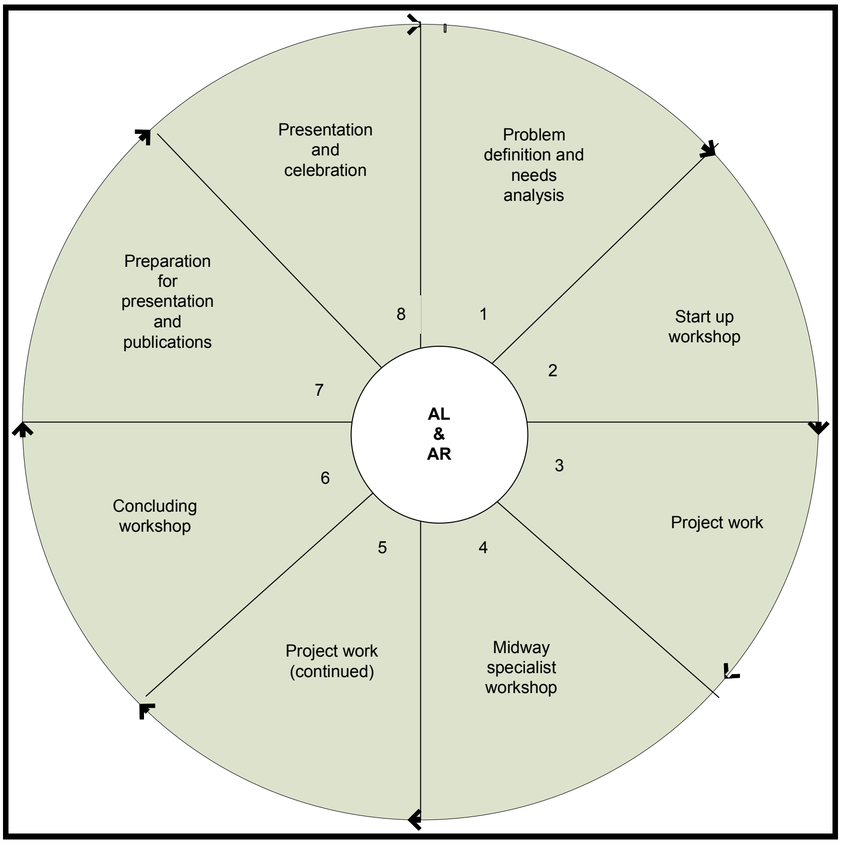


Figure 2.20: Action Learning (AL) and Action Research (AR) Model for the learning organisation (Zuber-Skerritt, 2002)

The Moorcroft (2006) model, being application-specific, cannot be generalised to other applications and does not cater for the inclusion of additional variables – for example, the impact of training and development and partnering with other organisations on output efficiency. The other frameworks discussed also displayed similar limitations. Porter's value chain model offered limited application, especially in the South African public service context, due to the difficulty in collecting information on customer needs.

The existing models and frameworks are data-intense. The 7S-model, for example, requires input data on all the 7-Ss to quantify the change in the performance of the organisation. The Public Financial Management Act (1999) drives the accounting philosophy in South Africa and is silent on the calculation methodology of the 7Ss (Public Finance Management Act, 1999).

In addition, extensive auditing is required to identify the areas to improve efficiency. The Business Excellence Model, for example, adopts a gap analysis approach, which fosters a reactive rather than a proactive approach to management: management focuses its energy on clearing the findings rather than on improving output efficiency. Furthermore, the Business Excellence Model requires resources and skills to develop the management system and undertake audits (self-assessment and benchmark), which were not available in the Air Quality Units.

The strength of the Learning Organisation Model is that it looks at the relationship between CM and the outputs of organisations that implemented action learning. The model, however, does not discuss the challenges of action research in the absence of the required support structures for action learning. Action research places the responsibility of seeking new knowledge that would add value to the organisation on the learners rather than on the facilitators. Zuber-Skerritt (2002) offers a limited teaching approach, *viz*. action research to support CM. He does not consider the use of case studies, business simulation models and the traditional capacity building workshops to supplement organisational learning and manage change. The action learning and action research approach proposed by Zuber-Skerritt (2002) was not an approved learning methodology in the South African Public Service Departments and has not been used in the Air Quality Units. There were also no designated mentors and tutors to guide the learning process within the Air Quality Unit. The model therefore has limited application in the air quality field.

The identified weaknesses in the existing management framework emerged mostly from the use of a single approach to improving identified variables, the fact that the departments' internal strategies, projects and mandates were not integrated, and the lack of a systematic and holistic approach to predicting output efficiency.

2.7 Management Models in the Public Sector and Academia

Ma (2010) focused on evaluating the assessment models available for the economic benefit of running a university in China. The efficient allocation of higher education resources was referred to as the distribution of education service to attain the maximisation of employment benefit of resources. Further, the term '*resources*' included human resources, financial resources and material resources (Ma, 2010:56). Ma (2010) reported that the depth of research in model development was insufficient. Scientific methods to assess and analyse the status quo and existing issues of allocation of higher education resources were required. Studies on how to optimise the allocation of higher education resources in China used the marginal cost-effect analysis method to set up an assessment index system of the economic benefit to the universities, and the comprehensive weighted score method was used to construct the assessment model. This approach is unsuitable for use in the air quality field as it focuses primarily on financial factors for decision-making *i.e.* how outputs would vary with changes in costs. The economic value-add to Air Quality Units, due to the marginal cost-effect of differing AQOs activities, was not perceived as a value driver (Lukey, 2007).

As far as models within the public sector are concerned, Jupp and Younger (2004) developed a model that expressed public sector cost-effectiveness as a function of citizen value-focused outcomes (*cf.* Figure 2.21). The objective of their model was to assist government to strike the right balance between the pressure to raise performance levels and the pressure to reduce costs. Jupp and Younger (2004) adapted the private sector principles of commercial shareholder value analysis to a public sector context from the perspective of the citizen and cautioned that assessing the cost-effectiveness of the public sector based on citizens' perceptions would only be valuable if the requirements of the citizens were similar.

South Africa has a dual economy: one part of the economy resembles that of developed countries, while the other part struggles with only the most basic infrastructure (Wenzel, 2007). The problem of a dual economy is that citizens have a wide range of expectations. The application of the Jupp and Younger (2004) model in the South African context is thus questionable, as it does not take into account the extreme nature of the differing citizen expectations. An additional drawback of the Jupp and Younger (2004) model is that it failed to evaluate the functioning of government in obtaining the required outcomes as well as operating efficiently. The outcome variable of the model only considers relative change over the years and was unable to predict whether the organisation was performing at an acceptable standard (Jupp & Younger, 2004). Important factors such as operating as teams, capturing learning across departments, and avoiding work redundancies were not included as inputs into their model. In addition, the model was not tested empirically. Jupp and Younger (2004) recommended further investigation into a more comprehensive tool that included the missing elements.

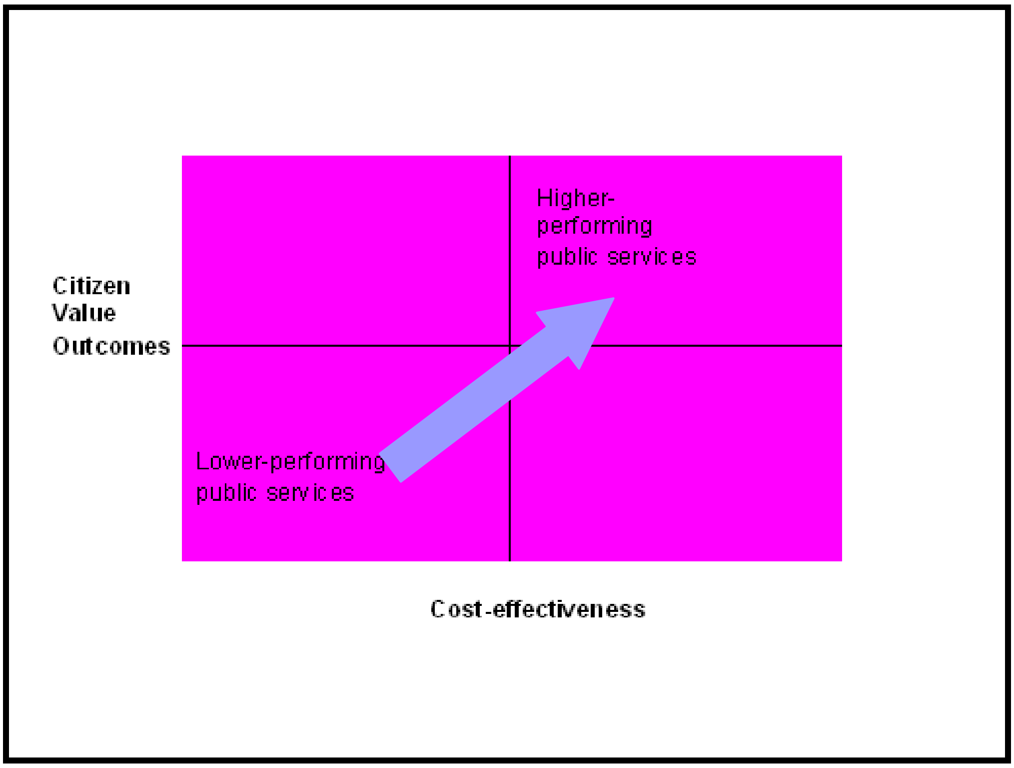


Figure 2.21: The Accenture Public Sector Value Model (Jupp & Younger, 2004)

Chafe, Neville and Rathwell (2010) undertook research to understand the effect of contextual differences on health resource allocation decision-making. Chafe *et al*. (2010) concluded that improving how health care resources were allocated would allow public coverage to meet all the existing and prospective demands. Better resource allocation decisions would lead to improved health outcomes, allow for a more efficient running of the health care system and make the system more responsive to the needs of the public. Chafe *et al*. (2010) concluded that by improving an understanding of the extent to which key contextual factors could impact on resource allocation, more viable reforms could be developed to achieve outputs.

Chafe *et al*. (2010) stressed that resource allocation was clearly affected by the institutional setting in which it was carried out and models that were developed for resource allocation must consider the data that was available at the institution. As the allocation of health care resources was firmly embedded within wider government budgeting processes, there was always political influence on how health care resources were allocated. One of the main implications for researchers is that proposals for reforming allocation processes must be attuned to the institutional and programme level environments in which the model will be used. A discussion of the resource allocation model that was available in the air quality field follows.

2.8 Management Models in Air Quality Management

Interest in the management of air quality had grown rapidly in recent years, as indicated by the growth of legislation (Lukey, 2007). According to Hadfield and Seaton (1999), air pollution and government's attempts at regulating it are not new phenomena. They asserted that air quality management had evolved over the last two decades in response to changes in knowledge about environmental management and perceptions of its importance.

Of interest to this study was the model developed by Hadfield and Seaton (1999), which has been referred to as the *soft complex systems model*. The researchers developed a co-evolutionary model of change in the context of air quality management (illustrated in Figure 2.22). The model included inputs relating to the physical changes in the environment, KM and CM within the public sector. The model demonstrated an important link between the physical change in the environment and the institutional change of an organisation due to the perceptual changes that are brought about by access to scientific information and the application of information. The authors argued that, while processes of physical and knowledge emergence were important, the driving force behind change was the emergence of dynamic processes of learning that lead to changes in policy, institutional arrangements and behaviour. The authors recommended that future work should be aimed at developing the model further to understand the impact of output efficiency from the emergent changes, strengthening the method through practical applications and investigating the implications for the development of policy. This model is useful, as it demonstrates a relationship between KM in Air Quality Units and the air quality outputs.

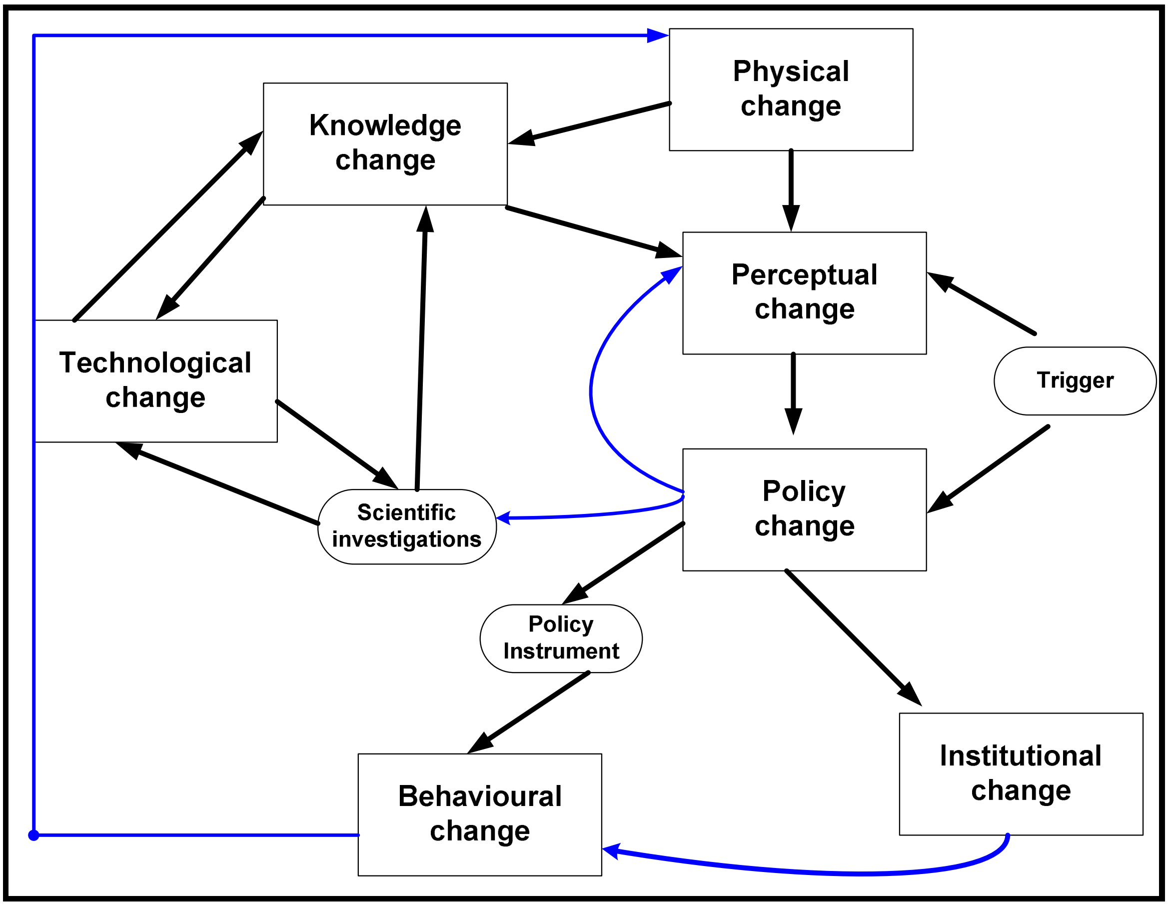


Figure 2.22: Top-down conceptual model of the linked processes of change (Hadfield & Seaton, 1999)

2.9 Summary

South African Air Quality Units have been under pressure to complete their mandated outputs. The literature search showed gaps in implementing PM, developing knowledge systems and capturing learnings that facilitate the required change in Air Quality Units (Madonsela, 2006). Further, given the extensive legislative reform undertaken in the Air Quality Units, it was beneficial to perform the field study in this area of government. Additional points that emerged from the review of PM, KM, CM and models were:

- Hadfield and Seaton (1999) reported that the lack of KM systems was a major obstacle to efficient air quality management and efficient CM in the public sector.
- Ehrlich *et al*. (1999) explained that the lack of PM and KM practices in government was the major reason for inefficient outputs.
- There was a lack of knowledge systems to empower Air Quality Units to make informed decisions and support the required change to facilitate improved output efficiency (McCourt, 2005).
- Riege and Lindsay (2006) indicated that little research and few guidelines were available to the Air Quality Units to ensure efficient KM practices.
- Streit and Guzman (1995) reported on the poor outputs from local Air Quality Units and that PM and a collaborative approach was required to address air quality challenges at this level.
- The management of strategic projects; training and development; managing project outsourcing and ensuring partnering with other organisations were identified as activities to monitor for PM areas for improvement in the Air Quality Units. Addressing communication was highlighted in particular as a key PM driver

(Westland, 2006). Resources must be allocated to these identified areas to improve output efficiency.

- Setting up KM and KM systems to manage air quality information and addressing systems failures was another important area for efficient air quality management. KM variables were identified for the Air Quality Units to improve output efficiency: the Air Quality Units must monitor air quality information from the monitoring stations; prioritise and address systems failure to maximise on the availability of the monitors and manage the knowledge process (Krupnick, 2008).
- CM in the form of developing tools and documenting learnings to support the required sustainable approach was critically required for efficient outputs (Goleman, 2009; Moore, 2003);
- Graham and Englund (2004) highlighted important elements of CM that required resources, specifically, documenting learnings and developing processes for change, for improved output efficiency

The aim of the review on models and management frameworks was to establish the suitability of the existing models and frameworks to guide AQOs on how to improve their efficiency. The review of the available models in the air quality field had fatal limitations (data-intense and immense resource requirements for auditing) and did not focus on the critical elements of PM, CM and KM – for example, capturing learnings and promoting a culture of teamwork. There are very few models in the air quality field that focus on the output efficiency of the public sector (Krupnick, 2008). The existing models and frameworks were therefore not applicable to support improved output efficiency in the Air Quality Units.

To be efficient the Air Quality Units must allocate resources in man-hours to the identified areas of PM, CM and KM. Further, the existing models served as an important building block to the model developed in the study. It was therefore deemed expedient to develop a new model for use in the air quality management field.

Krupnick (2008) indicated that the application of models to a field of study is often complicated and requires the involvement of the target population. Chapter 3 discusses the approach taken to involve the AQOs and the details of the methodology of the study.

CHAPTER 3: RESEARCH METHODOLOGY AND DESIGN

'I cannot experience myself as a scientific problem …. Science works with concepts of averages which are far too general to do justice to the subjective variety of an individual life'.

(Jung, 1973:3)

This chapter contains details regarding the research methodology and design, which unpacks the research philosophy, approach, strategy and time horizon of the study. The chapter also provides details on the data collection and analyses methods to address the objectives of the study and the research problem. Further, this chapter deals with the basic concepts regarding the theory of research methodology and describes the practical execution of the research as it was conducted in this study.

The research steps, procedures and processes undertaken are also outlined. The concept of efficiency is explored and a definition of output efficiency is formulated. The ethical considerations of the study are also presented. The variables required to measure output efficiency, CM, PM, KM, Routine and Other activities are explained with references to the literature search in Chapter 2. The systematic process used in the selection of logistic regression analyses is presented with a motivation of its suitability as a data analysis method for the data sets used in this study.

3.1 Study Aim and Objectives

The aim of a research study is '*exploratory, descriptive and explanatory*' (Fouché & Delport, 2002: 108). To this end, the research aimed to explore, describe and explain the relationship between the AQOs' input activities and output efficiency.

The study aimed to develop a model that could specifically predict the output efficiency of the air quality units, given the resources allocated to the inputs of that unit.

A research objective is a statement of precisely what a research exercise is intended to find out (Hussey & Hussey, 1997). '*Objectives*' are also referred to as '*the steps taken one by one*' within a certain time span to attain the aim (Fouché & Delport, 2002: 107, 109). As such, the study objectives are the crucial starting point from which follows the type of research to be done, the sample identification, the research instrument to be used, the approaches to be taken in analysing the data as well as reporting the findings.

The research question must address what the '*researcher is trying to determine and for what purpose the findings will be used*' (Grinnell, 1993: 25, 45). This study obtained an answer to the following question: To what extent can the South African Air Quality Units' output efficiency be explained by the percentage of the resources allocated to variables relating to PM, KM and CM?

The primary objective of this study is to identify the inputs that contribute significantly towards efficient air quality units in terms of output efficiency. A secondary objective is to develop a model for the prediction of whether an air quality unit is efficient based on the percentage of time allocated to the following input activities: CM, PM, KM, Routine and Other activities.

As this study aimed to develop a model that could predict the output efficiency of the Air Quality Units, based on the percentage of the mandated outputs completed, quantitative data was preferred over qualitative data.

A hypothesis is a statement that asserts a relationship between variables under investigation. The hypothesis can be formulated negatively where it is asserted that there is no relationship between the parameters being studied (null hypothesis - Ho). On the other hand, the alternative hypothesis (Ha) in quantitative analysis is the complement of the null hypothesis. The tests of statistical significance for this research were set at the 95 percent level (probability 0.05) and better. The level of significance is the chance willing to be taken to reject the null hypothesis given it is true (0.05 equals 1/20 chance).

The statement of the research hypothesis identifies the data necessary for the research effort. Data typically refers to a set of discrete, objective facts existing in symbolic form that has not been interpreted and can be either quantitative or qualitative (Davenport & Prusak 1998). Quantitative data collection methods are centred on the quantification of relationships between variables. Quantitative data allows for establishing relationships between measured variables and is primarily deductive reasoning. Measurement, numerical data and statistics are the main substance of the quantitative approach.

Fryer (1991) noted that qualitative researchers aim to decode, describe, analyse and interpret accurately the meaning of a certain observed phenomena. The focus of the researchers utilising the framework of the interpretative paradigm is on the investigation of authenticity, complexity and contextualisation. This study investigates the relationship between output efficiency and input activities of the AQOs in South African Air Quality Units. Creswell (1994: 37) stated that when the research was aimed at gathering data about the present existing condition and exploring the cause(s) of a particular phenomenon that occurred at the present situation within a target population, this method of research is referred to as the '*descriptive method of research*'.

The descriptive method of research is therefore applicable to this study. The advantage of the descriptive approach is that it allows for flexibility, as when important new issues and questions arise during the duration of the study, further investigation can be conducted. The drawback of descriptive research is that it is limited to the details of the present situation, as it exists at the time of the study.

The next step is to specify an appropriate research design to secure the necessary quantitative data for the descriptive research (Grinnell, 1993). Once collected, data is analysed appropriately to provide results. These are then generalised to form conclusions, which become part of the body of knowledge (Grinnell, 1993).

3.2 Research Methodology

Research methodology is a systematic way to solve a problem and provides the work plan of the research (Grinnell, 1993). It is essentially the procedures used to describe, explain and predict phenomena (Grinnell, 1993).

Lings and Lundell (2005) explain that the research process must be guided by the research methodology, which is informed by the research philosophy, as illustrated in Figure 3.1. The relationship between research philosophy and research methodology was also highlighted by Easterby-Smith, Thorpe and Lowe (2002) as important for good research, as it allows one to take a more informed decision about the research approach, decide which method(s) are appropriate for the piece of research, and think about constraints which may impinge on the research. The issues highlighted were used to inform the research design of this study.

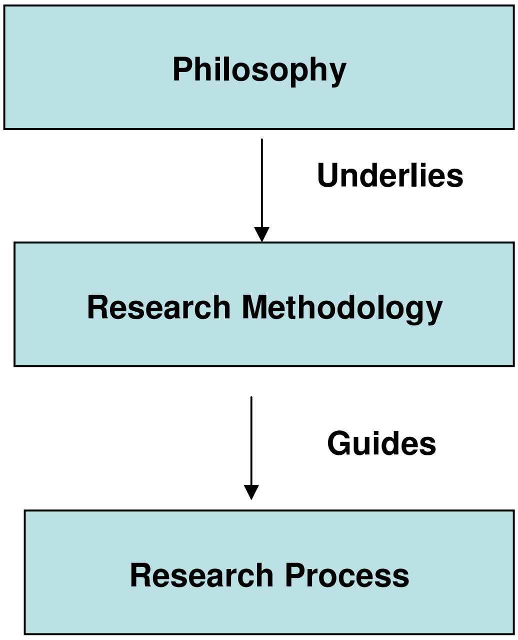


Figure 3.1: Research design flow from the research philosophy (Lings & Lundell, 2005)

3.2.1 Research Design

Grinnell (1993) stated that the research design is a plan or blueprint of how the research is to be conducted. The work of Saunders, Lewis and Thornhill (2003: 83) provided further details of the research design and defined the so-called research process '*onion*', consisting of five different layers, as follows:

Layer 1: research philosophy;

Layer 2: research approach(es);

Layer 3: research strategy(ies);

Layer 4: time horizon(s); and

Layer 5: data collection method(s).

For this study, selecting an overall research philosophy was the choice between two primary alternatives, *viz.* positivist and phenomenological philosophy. A number of authors have highlighted the main elements of the choice of research philosophy (Easterby-Smith *et al.*, 1991; Hussey & Hussey, 1997; Saunders, Lewis & Thornhill, 2003). In particular, Easterby-Smith *et al.* (1991) offered key features of the two philosophy paradigm alternatives as shown in Table 3.1.

Table 3.1: Research philosophy paradigms (Easterby-Smith et al., 1991:27)

Paradigm	Positivist	Phenomenological
Basic beliefs	The world is external and objective Observer is independent Science is value-free	The world is socially constructed and subjective Observer is part of what is observed Science is driven by human interests
Researcher should:	Focus on facts Look for causality and fundamental laws Reduce phenomenon to simplest elements Formulate hypotheses and then test these	Focus on meanings Try to understand what is happening Look at the totality of each situation Develop ideas through induction from data
Preferred methods include:	Operationalising concepts so that they can be measured Taking large samples	Using multiple methods to establish different views of the phenomena Small samples investigated in depth or over time

Given the study objectives as outlined in Section 3.1, the best fit was to follow the positivist philosophy. This was done recognising the following parameters identified by Easterby-Smith *et al*. (1991) for the positivist paradigm:

- The researcher was independent.
- The research was descriptive in nature (Section 3.1)
- An objective approach that related to actual and external phenomena as opposed to thoughts and feelings was applied.
- The study focused on data collection from a large group of participants.

The choice of using the positivist philosophy was aligned to the work done by Johnson, Scholes and Whittington (2007). The researcher indicated that quantitative research was consistent with the positivist philosophy in which numerical data was collected by the process of measurement, which was part of the design or plan for the investigation (Johnson, Scholes & Whittington, 2007)

Within the research process '*onion*', the second layer referred to the subject of research approach that flowed from the research philosophy (Saunders, Lewis & Thornhill, 2003: 83). The choice for the research approach was between deductive or inductive approaches (Saunders, Lewis & Thornhill, 2003). Johnson, Scholes and Whittington (2007) recommended the deductive approach when quantitative methods were used and the data was subjected to statistical analysis for the purpose of describing numerical distributions, testing models and forming inferential conclusions about the relationship among the variables under investigation. Given that the study was based on a quantitative approach and focused on model development using a large number of participants, the deductive approach was selected over the inductive approach.

Yin (1994) provided a decision matrix for the selection of a research strategy, which included the forms of research question appropriate per research strategy. Yin (1994: 35) recommended that studies that ask '*how much*' should use the survey research strategy. Saunders, Lewis and Thornhill (2003) supported the work of Yin (1994) and indicated that large-scale surveys were the recommended approach for research with large numbers of participants. Surveys also offered an opportunity to collect large quantities of data or evidence efficiently. Saunders, Lewis and Thornhill (2003: 84) warned that surveys were of less value when the researcher was asking about 'how' or 'why', *i.e.* questions with an open-ended character. In addition, surveys were less suitable when questions were more profound and complicated. The survey research strategy was therefore selected for this study.

The time horizon of a study refers to either cross-sectional or longitudinal approaches. Trochim (2006) differentiated between cross-sectional and longitudinal studies by characterising cross-sectional studies as those that represent a snapshot and take place at a single point in time. Longitudinal studies, on the other hand, involve at least two measurements taken over a period of time. For this study, data was required for more than one measurement period (to first test then subsequently verify the model developed). The longitudinal time horizon was therefore the preferred choice.

There are various data collection methods, including secondary data, observations, interviews and questionnaires. Gao (1993) supported the survey questionnaire approach when the following factors were prevalent in the population and data collected (Gao; 1993):

- collection of large amount of standardised data;
- the data collected varies in complexity;
- large number of respondents needed;

- different populations involved; and
- participants in widely separated locations.

The survey questionnaire data collection method was therefore selected as the data gathering instrument for this study. A survey questionnaire is an instrument that is specially designed to elicit information that is of use for the study (Saunders, Lewis & Thornhill, 2003). The survey questionnaire used to collect data from the AQOs is presented in Annexure 1. The survey questionnaire was divided into four main sections:

- Section 1: details of the air quality staff and budget;
- Section 2: the inputs into the model (X-variables);
- Section 3: outputs of the Air Quality Units (Y-variables); and
- Section 4: responses on the allocation of weightings to the outputs (Y-variables) and the need for the model.

Section 1 of the survey questionnaire contained questions on the characteristics of the respondents, *e.g.* name of the respondent and the number of years worked at the Air Quality Unit. Section 2 of the survey questionnaire required quantitative details on the resources allocated to the inputs, while Section 3 covered the requirements on the departments' mandated air quality outputs. Section 4 focused on the AQOs response to the weighting of the mandated outputs and the AQOs' views on the study, particularly on the usability and usefulness of the resource allocation model.

Figure 3.2 presents a summary of the research methodology for this study. The methodology was considered suitable for:

- the type of research question to be answered;
- securing data from a large portion of the population

- measuring all the important characteristics required in the study with reasonable accuracy;
- the quantitative analysis of the data collected; and
- model development using statistical techniques.

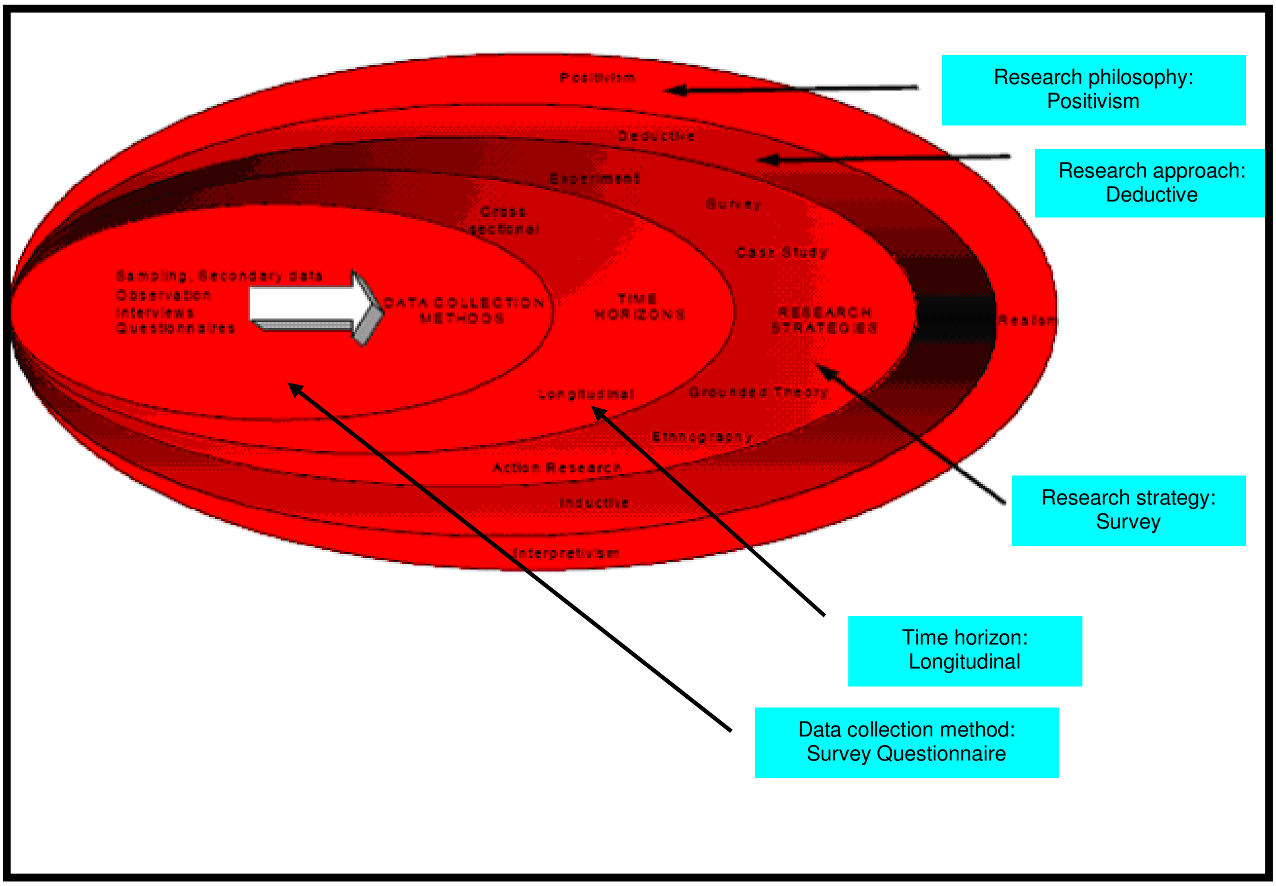


Figure 3.2: The research onion (Saunders, Lewis & Thornhill, 2003: 83)

3.2.1.1 Correlation Analysis

A correlation analysis is used as a measure of the relationship between two or more variables. The correlation coefficients can range from -1.00 to +1.00. The value of -1.00 represents a perfect negative correlation, while a value of +1.00 represents a perfect positive correlation. Pallant (2005) presented a table for selecting the appropriate statistical test based on the goal of the statistical analysis and the type of data (*cf.* Table 3.2).

Table 3.2: Selecting a statistical test (Pallant, 2005)

Goal	Type of Data			
	Measurement (from Gaussian Population)	**Rank, Score, or Measurement (from Non-Gaussian Population)**	**Binomial (Two Possible Outcomes)**	**Survival Time**
Describe one group	Mean, Standard deviation	Median, interquartile range	Proportion	Kaplan Meier survival curve
Compare one group to a hypothetical value	One-sample *t* test	Wilcoxon test	Chi-square or Binomial test	
Compare two unpaired groups	Unpaired *t* test	Mann-Whitney test	Fisher's test (chi-square for large samples)	Log-rank test or Mantel-Haenszel
Compare two paired groups	Paired *t* test	Wilcoxon test	McNemar's test	Conditional proportional hazards regression
Compare three or more unmatched groups	One-way ANOVA	Kruskal-Wallis test	Chi-square test	Cox proportional hazard regression
Compare three or more matched groups	Repeated-measures ANOVA	Friedman test	Cochrane Q	Conditional proportional hazards regression
Quantify association between two variables	Pearson correlation	Spearman correlation	Contingency coefficients	
Predict value from another measured variable	Simple linear regression or Nonlinear regression	Non-parametric regression	Simple logistic regression	Cox proportional hazard regression
Predict value from several measured or binomial variables	Multiple linear regression or Multiple non-linear regression		Multiple logistic regression	Cox proportional hazard regression

3.2.1.2 Pilot Survey

A survey questionnaire should be reliable and valid. Herbert (1990:160) referred to the reliability of '*good measurement in respect of the stability, dependability and predictability'* of the method used or '*its accuracy'*. The goal of reliability is to minimise the errors and biases in a study, which is achieved through accurately documenting the research methodology so that it is both repeatable and auditable (Herbert, 1990). A test is valid when the measuring instrument '*actually measures the things that it is supposed to measure*' (Bless & Higson-Smith, 2000:130).

The piloting or pre-testing of the questionnaire was considered essential because of the large number of respondents. Johnson, Scholes and Whittington (2007) indicated that there was no explicit justification of the sample size for a pilot study, but the pilot must cover the entire range of subjects in the full study. The piloting ensured that deficiencies in the measuring instrument were identified and addressed. The pilot study also played an important role in formulating the correct wording of questions in the measuring instrument.

The entire questionnaire was pre-tested as a pilot on five randomly selected AQOs from the target population (national, provincial and local). The pilot assisted in determining the maximum response time required to complete the questionnaire by the AQOs, which was 45 minutes. Understanding the time requirements enabled the appropriate time allocation for the total completion of the measuring instrument, which was communicated in advance to the AQOs.

After the questions were answered, the respondents were requested to provide suggestions or necessary corrections to the questionnaire to allow for further improvement and validity of the survey instrument. No revision of the questionnaire was required, as the respondents were able to complete the questionnaire with ease. These five responses were included as part of the research participants' responses.

To ensure optimal success when using the descriptive method (Section 3.1), Creswell (1994: 39) cautioned that a '*clear view*' of the investigated phenomena is required before the data collection procedure is carried out. A discussion of the specific data requirements for measuring the efficiency of the Air Quality Units follows.

3.3 Measuring Efficiency

Jupp and Younger (2004) defined output efficiency within government as departments that continually rethink the process of government to find ways to improve how public services were delivered and maintained. They added that to be efficient government required an awareness of the change in the environment and the ability to translate insight into action through the support of knowledge systems. Government must also focus on its core capabilities and must adopt outsourcing strategies to improve efficiency in its non-core activities.

Webster and Omar (2003) indicated that output efficiency relates to the comparison between the inputs and outputs of an organisation. The measurement of efficiency generally required: (a) an estimation of input variables; (b) an estimation of output variables; and (c) the comparison between the two, where, at a given input, the greater the output, the more efficient the activity or organisation (Webster & Omar, 2003). This implies that an efficient public service is one that completed its functions in the best possible and least wasteful manner (Webster & Omar, 2003). In the absence of market force incentives, the public service must optimally utilise its resources in doing its work (Webster & Omar, 2003).

This emphasised the need for the Air Quality Units to allocate resources to complete their mandated activities efficiently. Output efficiency in the context of this study refers to: the greater the number of mandated outputs completed, the greater the efficiency of the Air Quality Unit.

Organisations use models as tools to measure output efficiency and develop strategies to improve their output efficiency (Recklies, 2004). Chapter 2 highlighted that the existing models used for measuring the output efficiency of organisations have limitations in that the focus was primarily on improving product delivery time, and this required vast amounts of data that was not available in the public sector (Durant-Law, 2008). Developing a model using the quantitative approach involves the identification of observation units and variables that measure specific characteristics of the unit (Fowler, 2008). The selection of variables for measuring the inputs and outputs of the AQOs was guided by the questions recommended by Harrell, Lee and Mark (1996):

- Does the indicator enable one to know about the expected result or condition?
    - Indicators should, to the extent possible, provide the most direct evidence of the condition or result being measured.
- Is the indicator defined in the same way over time and is data for the indicator collected in the same way over time?
    - The definition of an indicator must remain consistent each time it is measured, and, where percentages are used, the denominator must be clearly identified and consistently applied.
    - Care must be taken to use the same measurement instrument or data collection protocol to ensure consistent data collection.
- Is data available for an indicator?

    - Data on indicators must be collected frequently enough to be useful to decision-makers.
- Is data currently being collected?
    - Resources for monitoring and evaluation data to inform the input variables must be defined within the organisation and collected for informing decision-making.
- Is this indicator important to most people?
    - Indicators, which are publicly reported, must have high credibility, be easily understood and be accepted by important stakeholders.
- Is the indicator quantitative?
    - Numeric indicators often provide the most useful and understandable information to decision-makers. Qualitative information may be necessary to understand the measured phenomenon.

> The questions recommended as a guideline for selecting the variables by Harrell, Lee and Mark (1996) were workshopped with the AQOs to identify suitable variables and data availability for the input activities and the output deliverables.

Although the matter of value in the private sector is by no means simple, there are generally accepted ways of measuring it, such as shareholder value analysis (Hopkins, 2009). Similar measures to guide public sector managers are not available (Jupp & Younger, 2004; Hopkins, 2009). The man-hours allocated to undertake an activity is the only factor considered to influence the output efficiency of the Air Quality Units. The heads of departments (Section 1.3.2) were responsible for the other resources in the departments, *viz*. equipment, facilities, utilities and materials, and these resources were similar across the three spheres (DPSA, 2006; Lukey, 2007).

The model developed in this study focused on data that was available in the Air Quality Units. The robustness of the model was tested using data from a second measurement period. The sections that follow detail the variables that were selected for measuring the output efficiency (dependent variable) and input activities (independent variables) of the AQOs.

3.3.1 Selecting the Output Variables (Dependent Variables)

The output of the Air Quality Units was based on the requirements of the legislation relating to air quality management in South Africa (AQA). This implies that the activities performed by the AQOs were known, defined and correct for achieving efficient output performance.

The new AQA approach required addressing output efficiency in the following areas (Lukey, 2007):

- communication through establishing industry-NGO-government forums;
- institutional frameworks, roles and responsibilities;
- air quality management planning and reviewing of industry impact assessment studies and identifying outsourcing opportunities;
- air quality monitoring and information management for ambient dust, SO_2, NO_x and heavy metals and the development of knowledge systems;
- air quality management measures and the identification of alternative tools for improving air quality; and

- general compliance and enforcement provisions through timeously identifying and managing non-compliances.

Fifteen specific output variables were selected through further unpacking the required deliverables of the AQOs as follows:

- decision support tools developed;
- dust, NOx, SO_2 and heavy metal levels in the atmosphere monitored;
- industrial applications reviewed;
- non-compliances identified and monitored;
- outsourced projects managed;
- industry-NGO-government forums established;
- cross-functional project teams established;
- air quality monitoring stations operational;
- knowledge systems operational;
- alternatives to manage air quality implemented; and
- other outputs.

3.3.1.1 Weighting the Output Variables

Weightings of the outputs of the Air Quality Units, as shown in Table 3.3, were established through workshops and discussions at AQO meetings before the administration of the survey questionnaires. The allocation of weightings to the outputs was based on the following criteria:

- timelines: minimum benefit (1) short term (2) medium term (3) long term (4);
- urgency: minimum urgency (1) can wait (2) urgent (3) very urgent (4);
- result of delays in action: reversible (1) reversible with minimum impact (2) reversible with major impact (3) permanent (4);
- number of people benefiting: very few (1) localised (2) regional (3) national (4).

Table 3.3: Outputs and the allocated weighted value (W) of the AQOs

Output (y)	Allocated weights (W)
Y_1: Decision support tools developed (0=No; 1=Yes)	7
Y_2: Were dust levels in the atmosphere (ug/m^3) within the required range? (0=No; 1 = Yes)	9
Y_3: Were NOx levels in the atmosphere (ug/m^3) reported? (0=No; 1 = Yes)	7
Y_4: Were SO_2 levels in the atmosphere (ug/m^3) reported? (0=No; 1=Yes)	6
Y_5: Were heavy metal levels in the atmosphere (ug/m^3) reported? 0=No; 1=Yes)	6
Y_6: Have industrial applications been reviewed? (0=No; 1 = Yes)	7
Y_7: Have cases of non-compliance been identified? (0=No; 1=Yes)	6
Y_8: Have cases of non-compliances been managed? (0=No; 1=Yes)	6
Y_9: Have outsourced projects been completed? (0=No; 1=Yes)	6
Y_{10}: Have industry-NGO-government forums been established? (0=No; 1=Yes)	7
Y_{11}: Have cross-functional project teams been established? (0=No; 1=Yes)	7
Y_{12}: Were air quality monitoring stations operational? (0=No; 1=Yes)	7
Y_{13}: Were knowledge systems operational? (0=No; 1=Yes)	9
Y_{14}: Have alternatives been implemented to manage air quality? (0=No; 12=Yes)	7
Y_{15}: Have there been other outputs? (0=No; 1=Yes)	3

Hypothesis testing was performed using the Mann-Whitney coefficient test (*cf*. Table 3.2; Pallant, 2005). The significance in the difference between the weighted and unweighted outputs was established by evaluating the p-value >0.05 for the hypothesis to be accepted. Once established, the analyses continued with the use of the relevant (weighted or unweighted) y variables.

3.3.2 **Selecting the Input Variables (Independent Variables)**

The input variables for this study relate to the activities undertaken by the AQOs to give effect to their mandates. Table 3.4 provides a list of the input activities undertaken by the AQOs, as discussed in Chapters 1 and 2.

Table 3.4: Input activities of the Air Quality Units

• Routine tasks (Sections 1.3.2 and 1.4.3)
• Manage strategic project (Section 2.2.6)
• Set up and maintain monitoring stations for managing air quality information (Section 2.3.1)
• Develop legislation and decision support tools (Section 2.4.1)
• Document learnings and set up in-house knowledge systems (Section 2.4.2)
• Communication with other departments (Section 2.2.3)
• Training and development (Section 2.2.5)
• Manage outsourcing as per business plans *i.e.* managing consultants and contracts (Section 2.2.4)
• Prioritise and address system failures (Section 2.3.2)
• Partner with other organisations – for example, industry associations and NGOs (Section 2.2.4)
• Manage knowledge – centralised reporting system, updating performance indicators (Section 2.3)
• Other activities: for example, addressing waste and nuisance-related complaints (Section 1.4.3)

3.3.2.1 Grouping Variables into PM, KM, CM, Routine and Other activities

The studies published by previous researchers in the field of PM, CM and KM were reviewed to identify the activities to monitor as input variables as detailed in Chapter 2.

Govender and Kruger (2009) detailed the identification of the work activities as unpacked in Table 3.5 and the rationale for the grouping of activities into specific categories, *viz*. KM, PM, CM, routine and other activities.

In summary, *Routine activities* (X_1) are necessary activities that should be conducted by an Air Quality Unit but that also relate directly to measurable output and include performance management: preparing monthly and annual progress reports; attending management meetings; and administrative activities. The AQOs are expected to spend less than 30% of their man-hours on routine actives (*cf.* Section 1.3.2). *Other Activities* (X_{12}) that AQOs perform do not directly support the management of air quality. These include reviewing housing development impact studies and inputs into water licences; addressing public nuisance complaints relating to waste management; supporting the development of by-laws that are not related to air quality management (for example, potable water supply systems, domestic waste-water systems, sewage disposal systems and municipal health services by-laws); and managing projects not related to air quality management (for example, solid waste disposal sites guidelines and updating the Spatial Development Framework).

KM (X_3; X_9; X_{11}) refers to information that is applied to describe, predict or adapt to a situation after it has been examined and compared to other information or data (Durant-Law, 2008). '*Know how and why'* enrichment occurs with the addition of further context, experience and understanding, and results in an understanding of principles (Durant-Law, 2008). KM is required for efficient policy development and implementation (Bridgman & Davis, 2004). The specific inputs are X_3: set up and maintain monitoring stations for managing air quality information; X_9: prioritise and address system failures and X_{11}: manage knowledge (centralised reporting system, updating performance variables).

PM (X_2; X_6; X_7; X_8; $X1_0$) is a related set of disciplines that together enable managers to successfully accomplish their role and examine the variables of time, cost, resources and behaviour and its contribution to project success or failure (Moorcroft, 2006). The man-hours spent on managing knowledge and knowledge processes, for example, was an important variable used by Rwelamila (2007) in his work on understanding PM competencies in public sector infrastructure organisations. The specific inputs are X_2: managing strategic project (as per business plans); X_6: communication with other departments; X_7: training and development; X_8: manage outsourcing as per business plans *i.e.* managing consultants and contracts; X_{12}: other inputs, for example addressing waste, nuisance and water complaints; and X_{10}: partner with other organisations, for example industry associations and NGOs.

Improving KM and PM in organisations demands changes to the status quo. Managers need to allocate resources to recognise the behavioural aspects of CM and deal with the problems that may arise (Meredith & Mantell, 2003). CM (X_4; X_5) activities include the development of legislation (X_4) and decision support tools as well as documenting the learning to facilitate growth and the required change (X_5). The inputs of the units were calculated as a percentage of the total man-hours spent on the 12 activities i.e. X_1 to X_{12}.

The identified input activities relating to PM, KM, CM, Routine and Other Activities as well as the definition for efficiency of the South African Air Quality Units were communicated in the annual conference for the AQOs (Govender & Kruger, 2009).

Table 3.5: Selection of variables for the independent variables

Independent Variable	Variable – Man-hours spent on:	Referenced from previous study to establish efficiency of organisation	Reference
Routine Work	X_1**: Routine Work** • Human resource functions, • Performance assessment, • Financial management • Reviewing industry applications	Public sector must formulate work processes, role descriptions, recipes, routines Standards for the main services referenced	Rwelamila (2007) Madonsela (2006) DPSA (2006)
PM	X_2: **Managing strategic projects (as per business plans)** • Identifying strategic projects in business plans • Establishing project teams • Internal communication • Developing project plans, • Monitoring and reporting progress	Group your projects based on their strategic impact and implement as per plan Teams perform better than individuals perform and transfer knowledge better Internal communication helps employees to have a better idea of how what they do impacts on the organisation The greater the focus on developing and managing interdisciplinary project teams, the greater the output efficiency	Shenhar (2004) Thompson and Strictland (1996) Project management body of knowledge (2000) Katzenbach and Smith (1993) Moorcroft (2006) Englund, Graham and Dinsmore (2003)

Table 3.5 (continued): Selection of variables for the independent variables

Independent Variable	Variable Man-hours spent on:	Referenced from previous study to establish efficiency of organisation	Reference
PM	X_6: **Communication with other departments** • Interdepartmental meetings • Communication to address synergies among departments • Share ideas on challenges and improvements etc	Intergovernmental relations key to efficient public sector Participation by members is encouraged Emphasis must be on the flow of communication Organisation fosters openness of communication and information Organisations must become boundary-less, with open communications Decentralised air quality management is more efficient; however, governance structures must be clearly established, with efficient flow of information The greater the allocation of time to communication and engaging people, the greater the output efficiency The greater the sharing and collaborating among different government department, the greater the output efficiency	Intergovernmental Relations Framework Act (2005) Ford and Randolph (1992) Cleland (1999) Gray and Larson (2000) Morrison, Brown and Smit (2006) Beer and Nohria (2000) Krupnick (2008) Wenzel (2007) Quassim (2005)

Table 3.5 (continued): Selection of variables for the independent variables

Independent Variable	Variable Man-hours spent on:	Referenced from previous study to establish efficiency of organisation	Reference
PM	X_7: Training and development • Develop project competence • Developing training plans • Attending training	PM competence part of AQOs' development plan There is a general culture of learning, personal development and professionalism Critical success factor in public sector is the empowerment and training to do the job	Australian Institute of Project Management (2007) Dver, Lipovetsky, Shenhar and Tishler (1998) Dinsmore (1999) Heintzman and Marsons (2006)
PM	X_8: Managing outsourcing as per business plans • Managing consultants as per contract conditions • Reviewing regular progress • Using close out reports	Outsourcing must be grounded in a PM approach, with risks and controls captured in contracts Outsourcing of government work must be project managed using PM tools (work breakdown structures, progress reports and close out reports)	Kakabadse and Kakabadse (2001) Manley, Shaw and Manley (2007) Crawford *et al.* (2003)

Table 3.5 (continued): Selection of variables for the independent variables

Independent Variable	Variable Man-hours spent on:	Referenced from previous study to establish efficiency of organisation	Reference
PM	X_{10}: Partnering with other organisations, for example industry associations and NGOs • Attending environmental stakeholder meetings • Collaborating on initiatives • Undertaking joint projects	Develop management community as a key resource Important factor for efficient air quality management was the need to encourage cooperation and involvement	APMBoK (2000) Sterner (2003)
KM	X_3: Managing air quality information from monitoring stations • Validating data • Inspecting monitoring stations • Generating air quality reports with trends	Data collection and reporting used as an variable for KM Air quality monitoring increasingly important issue in developing AQMPs The trends in terms of reliability of data from public departments in developing countries were quoted as major obstacles to efficient air quality management Air quality information required to make informed and efficient decisions on industrial applications	Mayerhofer *et al.* (2003) Mrayyan and Hamdi (2006) Foti (2005) DEA (2008)

Table 3.5 (continued): Selection of variables for the independent variables

Independent Variable	Variable Man-hours spent on:	Referenced from previous study to establish efficiency of organisation	Reference
KM	X_9: Prioritising and addressing system failures • Prioritising outputs based on planned goals • Documenting system and addressing failures with sustainable solutions • Establish monitoring and evaluation programmes to address systems failure • Reviewing of systems failures	Goals must be set with due consideration to the resources available Clearly identify priorities and each priority is translated into action items with clearly defined accountabilities, timetables and key performance variables. Failures in addressing priorities are documented and shared. Efficient public sector requires supporting monitoring and evaluation programmes to address systems failures Coordinate and monitor progress in order to achieve mandated objectives, which is critical in public sector Projects fail due to not addressing systems failure in planning and execution phases The greater the focus of resources in planning and tracking project changes, the greater the output efficiency	Posner (1987) Thamhain and Wilemon (1987) Pinto and Slevin (1988) Mankins and Steele (2005) International Monetary Fund (2006) Crawford *et al.* (2003) Gabriel *et al.* (2005) Blair (2001) Quassim (2005)

Table 3.5 (continued): Selection of variables for the independent variables

Independent Variable	Variable Man-hours spent on:	Referenced from previous study to establish efficiency of organisation	Reference
KM	X_{11}: Managing knowledge and knowledge processes • Setting up knowledge systems • Centralised reporting system • Performance Indicator Systems • Project tracking systems	The greater the application of KM by developing and implementing knowledge systems, the greater the output efficiency The more time spent on monitoring of targets and objectives of project and sub-projects against planned targets, the greater the output efficiency Knowledge systems empower departments to make informed decisions and support required change to facilitate improved output efficiency Sound information infrastructure Make systems and procedures user-friendly The organisation should establish firm, standardised PM systems Information systems must be purposeful to serve the requirements of users Public departments must gather knowledge and experience and store this in the collective mind	Ehrlich *et al.* (1999) Durant-Law (2008) Grimshaw *et al.* (2002) McCourt (2005) Sharon and Prefontaine (2003) Jupp and Younger (2004) Kanter and Walsh (2004) Laufer, Denker and Shenhar (1996) Longman and Mullins (2004) Tatikonda and Rosenthal (2000); Rwelamila (2007)

Table 3.5 (continued): Selection of variables for the independent variables

Independent Variable	Variable Man-hours spent on:	Referenced from previous study to establish efficiency of organisation	Reference
CM	X_4: Developing legislation and decision support tools • Drafting policies • Commenting on relevant legislation • Developing decision tools	Develop processes that lead to changes in policy, institutional arrangements and behaviour Increased focus on developing dynamic processes of learnings results in greater adoption of changes in policy, institutional arrangements and behaviour, and improvement in air quality Reported on the need for empowerment tools to support efficient decisions on industrial environment impact assessments	Hadfield and Seaton (1999) DEA (2007)
CM	X_5: Documenting learnings and evaluating knowledge systems • Establishing trends through: • Monthly report on performance, • Quarterly meeting feedbacks, • Interrogation of the knowledge systems	Evaluating change is key to relapse prevention There is a culture of learning in the organisation Lessons learnt are disseminated Every project should be a platform for learning and growth Summarise your project in a lessons learned event and report	Herzog (1991) Dvir, Lipovetsky, Shenhar, and Tishler (1998) Cleland (1999) Moore (2003) ; De Geus (1997) Dvir *et al.* (1998) Longman and Mullins (2004)

Table 3.5 (continued): Selection of variables for the independent variables

Independent Variable	Variable – Man-hours spent on:	Referenced from previous study to establish efficiency of organisation	Reference
CM	X_5 (continued)	Every monitoring and controlling activity must include lessons learned Organisations need to efficiently manage knowledge through action learning Organisations must focus on centralised expertise, problem solving and reflection (learning function) The more the focus on capturing learnings and moving towards a PM learning organisation, the greater the output efficiency	Shenhar (2004) Zuber-Skerritt (2002) Kessels (2001) Nonaka and Takeuchi (1995) Graham and Englund (2004) Wenzel (2007)
Other	X_{12}: Other Variables • Tasks undertaken that were excluded from mandated requirements	All tasks outside the mandates of the Air Quality Units	National Air Quality Framework Document (2007) AQA (2004)

The activities monitored in the different studies and detailed in Table 3.5 (*Column: referenced from previous study to establish efficiency of organisation*) were used to inform the selection of the 12 input variables (*Column: variable – man-hours spent on*) listed in Table 3.5. These 12 input variables were further grouped into five independent variables, *viz*. PM, CM, KM, Routine and Other activities, as shown in Column 1 of Table 3.5. The aim of categorising the input variables was to simplify the model.

3.4 Data Collection

The survey questionnaire requested each department to provide information regarding the 15 specific output variables that were identified. Each unit was requested to indicate a response (either yes: completed, or no: not completed) per output. An indicator variable (0 or 1) was allocated to each of the responses. The number of outputs completed per Air Quality Unit (*i.e*. the number of times a 1 appeared) in each of the years 2005/6 and 2006/7 was expressed as a percentage of the total number (a total of 15) of identified outputs. The percentage of completed outputs served as a proxy for output efficiency.

The inputs of the units were calculated by the AQOs as a percentage of the total man-hours spent on the 12 identified activities. The hours per activity was converted into man-hour costs using the hourly salary rates of the AQOs, based on their salary level and information in the Units' compensation records. An example of the assessment that was received from an AQO and the calculations to convert to man-hour costs is shown in Figure 3.3.

Activity	Hours per activity per year	% Hours per activity per year
Routine Work	850	59.70%
Strategic Project Management	374	16.35%
Managing Air Quality Information	128	5.59%
Systems development and documenting learnings	24	1.05%
Communication with other Departments	180	7.87%
Training and Development	188	8.26%
Managing Knowledge	20	0.87%
Other Tasks	4	0.31%
Total	**1768**	**100%**

Man Hour Costs

1. Number of working hours per staff:
   1 768 hours
2. Cost of staff:
   – From compensation records

Man hour cost:
= (1) x (2)

Man hour cost was expressed as % spend on each of the input variables per year.

Total hours in year (8 hours by 5 day by 52 weeks)	2080
Total sick leave hours (12 days)	-96
Total leave hours (22 days)	-176
Total family responsibility hours (5 days)	-40
Total working hours in the year	**1768**

Figure 3.3: Example of a completed assessment based on actual annual activities of an AQO and the calculations of the man-hour cost

There were various sources of input and output data for the Air Quality Units. The National Department of Treasury also publishes the selected departments' published annual reports and various internal reports – for example, quarterly reports, budget statements and time studies per position in the department (DEA, 2008; Department of Treasury, 2008).

Initial attempts to collect the data indicated that it was not stored in a central database. Sourcing data from published reports alone was therefore challenging. Electronic mailing followed by telephonic interviews using a survey questionnaire was preferred over face-to-face interviews due to the large number of Air Quality Units.

3.5 Research Participants

The South African government is divided into three distinct spheres (national, provincial and local) that are declared as distinctive, interdependent and interrelated in the Constitution (1996), where:

- distinctive: each sphere had its own unique area of operation;
- interdependent: the three spheres were required to co-operate and acknowledge each other's area of jurisdiction; and
- interrelated: there should be a system of co-operative governance and intergovernmental relations among the three spheres.

To establish the relationship between the inputs and output activities of the Air Quality Units in the three spheres of government, a total of 228 respondents were asked to participate (*cf.* Table 3.6).

To achieve pertinent data, certain inclusion criteria were imposed. The participants qualified to participate must be responsible for air quality management within the government department and attendees of the National Air Quality Management Forum (*cf.* Section 1.3.2).

This qualification ensured that the participants understood the mandates of an AQO and were responsible for undertaking the activities required by the AQA (2004). Lukey (2007) and his national air quality management team validated all the provincial and local Air Quality Units' data by comparing it with the departments' published annual reports.

The sample requirement, rule of thumb, was that there must be at least 10 cases per candidate independent variable and the coefficient (Harrell *et al.*, 1984; Harrell, Lee & Mark, 1996).

Data was collected for the 2005/06 and 2006/07 financial years. The respondents requested that their information be maintained as confidential; therefore, further breakdown of the sample is reported.

Table 3.6: Research participants

National (1)	Provincial (9)	Local (218 with designated AQOs)
National environment department situated in Gauteng (Pretoria)	Eastern Cape Free State Gauteng KwaZulu-Natal Limpopo Mpumalanga North-West Northern Cape Western Cape.	**Category A:** The metropolitan councils of which there are currently six: Tshwane, Durban, Johannesburg, Ekurhuleni, Nelson Mandela and Cape Town **Category B:** A municipality that shares municipal executive and legislative authority in its area with a Category C municipality within whose area it falls **Category C**: A municipality that has municipal executive and legislative authority in an area that includes more than one municipality

3.5.1 Permission to Conduct the Research

Lukey (2007) was consulted very early on in the study on the data requirements (Section 1.2.3). Fouché and Delport (2002) also highlighted the need to identify the gatekeepers or someone with the formal or informal authority who controls the access to and release of the data per expected response. The need for specific correspondence relating to the study objectives to these gatekeepers was also advised to improve the response rate (Fouché & Delport, 2002).

As far as this research undertaking is concerned, the gatekeepers referred to are the heads of departments and the municipal managers of the selected Air Quality Units (as Section 1.3.2 details). The following steps were taken:

- The national AQO discussed the study with the various heads of departments, municipal managers and AQOs.
- A letter requesting participation in the study was mailed to each of the gatekeepers in the Air Quality Units to secure the release of data by the AQOs.
- Electronic mail and telephonic contact was made with the gatekeepers and AQOs concerning the data requested.
- When the responses were not submitted within the agreed timelines, follow-up electronic mails and phone calls were made.

3.5.2 Ethical Considerations

This study required the participation of people, specifically public sector managers responsible for air quality management. Certain ethical issues were therefore addressed. The consideration of these ethical issues was necessary for ensuring the privacy of the participants. Significant ethical issues that were considered in the research process included consent and confidentiality. To secure the consent of the selected participants, all important details of the study were relayed, including its aim and objectives. By explaining these important details, the respondents were able to understand the importance of their role in the completion of the research. The respondents were also advised that they could withdraw from the study even during the process. This meant that the participants were not compelled to participate in the research. The confidentiality of the participants was also ensured by not disclosing their names or personal information in the research. Only relevant details that helped in answering the research questions were included.

The following code of ethics was adhered to during the research:

- Honesty: Data was honestly reported and the research population was not deceived in any way. All promises and agreements were maintained.
- Objectivity: Bias in experimental design, data analysis and data interpretation was avoided.

- Openness: Data, results, ideas, tools and resources were shared openly and new ideas in relation to the research were welcomed.
- Respect for intellectual property: All copyrights and other forms of intellectual property were respected. All material was appropriately referenced.
- Confidentiality: All confidential communications, such as personnel records, were kept confidential.

In addition, the following ethical considerations were applied when engaging with the AQOs: all data relating to salaries was kept confidential and any sensitive information relating to performance management was excluded from the research.

The AQOs were kept informed about the research study. The methodology and findings relating to the development of the resource allocation model for the South African Air Quality Units were communicated in the annual conference of AQOs (Govender & Eiselen, 2010).

The identities of the AQOs were maintained as confidential, as agreed during the data collection phase. In addition, the separation of the three spheres of government *viz*. local, provincial and national, was not pursued, as it could compromise the agreed code of ethics during data collection due to the limited number of national and provincial Units.

3.6 Data Analysis

This section looks at how the data collected from the AQOs was analysed to produce the findings and to draw the specific conclusions of the study. The quantitative data collected was analysed to inform the relationship between the AQOs inputs and outputs efficiency. The systematic approach to the selection of input variables that contribute the most towards the prediction of output efficiency of the AQOs forms the foundation on which the conclusions were drawn.

Mouton (2001:108) stated that data analysis involved '*breaking up*' the data into manageable patterns, trends and relationships. The aim of data analysis is thus to understand the various constitutive elements of the data through an inspection of the relationship between variables and to see whether there were any patterns or trends in the data. Analysis of research data did not in itself provide responses to the research objectives; analysis means categorising, ordering, manipulating and summarising data to obtain the required responses (Mouton, 2001:108). In this study, the data collected was organised, summarised and visually displayed in the form of statistics by means of frequency distribution tables and graphically in graphs.

The symbiotic nature of research and statistics results from the research design producing data that needs analysing and statistical techniques requiring data to perform their function. Statistical analyses can be performed using statistical packages (Johnson, Scholes & Whittington, 2007). The SPSS version 15 statistical package was utilised for the analyses of data in this study. Further background to statistics and the specific techniques used for the model development follows.

An important part of data analyses is checking the responses on survey questionnaires. The response is that part of the sample that generates the required information to the researcher; non-response is the part that does not provide information to the researcher ('t Hart, Van Dijk, De Goede, Jansen & Teunissen, 1998). Missing values or non-responses can be an indicator of an unrepresentative response (Durant-Law, 2008). Although AQOs were obliged to respond to all items and most of the inputs were completed either personally or telephonically, there was a possibility that cells could be left blank.

The data was checked for missing values to evaluate the completeness of the responses. The national department also verified the responses from the provincial and local AQOs as per the original agreement (Lukey, 2007)

3.7 Summary

The research was conducted to determine whether the outputs of the Air Quality Units can be predicted from the resources allocated to PM, KM and CM. The development of a resource allocation model using the data collected from a target population was also a study objective. The inputs of the AQOs were established through quantifying the man-hours spent on activities relating to CM, KM, PM, Routine and Other Activities.

The outputs of the AQOs were based on the AQOs mandated outputs. The following outputs were recommended for efficient air quality management in South Africa:

- Timeous development and adoption of regulations under the Act, *e.g.* ambient air quality standards, emission limits, guidelines for air quality monitoring, modelling and management;
- Capacity building of local, provincial and national government personnel in terms of provision of adequate training, support and resources;
- Development and implementation of coherent air quality management systems comprising current and comprehensive emissions inventories, cost-efficient and well-run monitoring networks, and suitable air dispersion models; and
- Standardisation of monitoring methods, emissions inventories, modelling approaches and source, emissions, air quality and meteorological data reporting.

Determining advantages, disadvantages and reliability of the research instrument was also an important part of the study objective. To complete these research objectives, the responses of AQOs were obtained in line with this topic. Data gathered were then computed for interpretation. The critical elements of the study are shown in Table 3.7.

Table 3.7: Design elements of the study

Elements of the Study	
Target Population	South African Air Quality Units within the Environmental Departments of the three spheres of government (N=228): • national, • provincial departments; and • local government departments.
Research methodology	Multi-criteria decision-making using logistic regression analysis
Inputs (X) elements of the model	Twelve variables based on activities undertaken by the AQOs that were further grouped into five categories *viz*. PM, KM, routine, other and CM with aim of simplifying the model
Outputs (Y) element of the study	Fifteen variables based on the mandates of the Air Quality Units
Data analysis	Binary logistic regression
Logistic Curve Equation for predicting outputs	$P = \frac{1}{1+e^{-(a+bX)}}$

There were sufficient Air Quality Units in South Africa to provide a statistically representative sample for the development of the resource allocation model with 12 input and 15 output variables. The development of a model using data collected from the South African Air Quality Units forms the focus of Chapter 4.

CHAPTER 4: MODEL DEVELOPMENT AND RESULTS

'A few observation and much reasoning lead to error; many observations and a little reasoning to truth.'

Albert Camus (unknown)

The aim of the study was to develop a model to predict the extent to which organisational efficiency can be explained by the percentage of man-hours allocated to a range of management activities. Chapter 3 detailed the research methodology selected for the study and the data management process, including the selection of the dependent (Section 3.3.1.3) and independent (Section 3.3.2.1) variables. Data was collected for two financial years (2005/6 and 2006/7) from the AQOs in the national, provincial and local spheres of government (N=228).

The current chapter covers the development of the resource allocation model using the data collected from the AQOs based on man-hours spent on the input variables and the number of completed output activities. The research methodology for the development of the resource allocation model focuses on developing a model that can predict the output efficiency of the Air Quality Units. Descriptive and inferential statistical analysis techniques are applied. The logistic regression technique is used to develop the model, using a subset of the data.

From the five input variables (CM, KM, PM, Routine and Other), the input variables that contribute the most towards the prediction of the Air Quality Units' output efficiency are identified. Finally, the application of the model in the air quality management context is presented.

4.1 Response Rate for the Study

The survey questionnaires were mailed to the 228 identified AQOs in South Africa, as detailed in Section 3.5.1. Several follow-up telephone calls were made to the respondents. All 228 participants met the minimum inclusion criteria *i.e.* they were the nominated AQOs and attended the National Air Quality Management Forums (*cf.* Section 1.6.3).

A response rate of 100% was obtained (subsequent to several follow-up requests). There were also no unusable or spoilt questionnaires. All questionnaires were completed within the allocated response time (45 minutes).

Section 4 of the research instrument required responses from the AQOs on their views on the need for a model to be developed to predict their output efficiency. All respondents indicated a positive response on the need for the model.

The data collection method, *i.e.* survey instrument, was successful at generating data from the participants to give effect to the quantitative approach required for the model development. The details on the statistical analyses for data interpretation follow.

4.2 Descriptive Statistics

The longitudinal time horizon for the study was the 2005/06 and the 2006/07 financial years. The 2005/06 and 2006/07 data sets were checked and corrected for missing cells and possible incorrect entries. The SPSS analysis reflected the missing values from the data sets as zero, which indicated that all questionnaires were 100% complete.

Table 4.1 shows the descriptive statistics, which includes the mean response, minimum, maximum, standard deviation, skewness and kurtosis values for the output efficiency (weighted and unweighted) versus PM, KM, CM, Routine and Other input variables for the 228 AQOs in South Africa.

The correlation coefficient between the weighted and the unweighted output efficiency was 0.998 ($p<0.01$). Since p was <= 0.05, the null hypothesis was rejected and the alternative hypothesis accepted (Section 3.3.1.3). The correlation coefficient was very high and indicated a strong correlation between the calculated weighted values and the unweighted values. The implication was that the output variables were generally of equal importance. The responses from the AQOs to Section 4 of the survey questionnaire supported the view that the outputs should not be weighted, as all outputs were considered equally important for efficient air quality management. All further analyses were done on the unweighted efficiency values.

The kurtosis values reflected in Table 4.1 indicated signs of leptokurtic distribution, and most of the cases were outside the normality range. KM and other variables displayed negative kurtosis, which indicated that too many cases were in the tails of the distribution. The other variables displayed positive kurtosis, which indicated too few cases in the tails.

The skewness results obtained indicated that all variables except Other activities were outside the range required for normal distribution. The positive value for skewness implied that there was more count in the tail than expected from a normal distribution and most cases were to the left *i.e.* poor output efficiency. In addition, there was evidence of the presence of a number of outliers.

4.2.1 Investigation of causes of outliers

The causes for the outliers were investigated systematically in terms of errors of data entry, missing values in the questionnaires, unintended sampling from non-population members and true abnormal distribution. The initial three sources were eliminated through visual inspection of the data. The only possible reasoning for the outliers was that the underlying population distribution was indeed abnormal, which indicated that the outliers were due to true abnormal distribution.

The data in Table 4.1 indicated that Air Quality Units had high output efficiency (>50%), despite allocating high percentages of man-hours to routine and other inputs. This was due to strong individuals in the local authority Air Quality Units who worked very long hours to perform in the different areas of air quality management. The other officials in the Department were involved in health impact assessments, for example the exposure of workers to unsafe conditions, which do not contribute to the management of the air quality. This was not a sustainable situation, as the efficiency may decrease as soon as the individual moves out of the department.

The data in Table 4.1 also indicated that Air Quality Units had low output efficiency (<10%), despite allocating high percentages of man-hours to routine and other inputs. The majority of the local authority Air Quality Units have not addressed their mandates in terms of air quality management. The AQOs attended the AQO meetings, managed the ambient air quality data and assisted with compliance management at industry visits, which were arranged by the national Air Quality Unit. However, the overall proportion of time spent by AQOs on managing air quality in their region of responsibility was low. The remainder of the individual's man-hours was spent on municipal activities, which included addressing nuisance issues around illegal waste dumping and noise or public disturbances. As these phenomena were not sustainable, it was justifiable to exclude model inputs from responses from Air Quality Units that display these trends.

> In both years, there was a tendency towards poor performance, with output mean values being relatively low (25.87 and 25.78 respectively).

Table 4.1: Descriptive analysis of data collected for two financial years (N=228)

Descriptive Statistics

Year		N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
		Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
2005-6	weighted	228	0%	100%	24.41%	26.096%	1.511	0.161	1.046	0.321
	y	228	0%	100%	23.48%	25.873%	1.551	0.161	1.173	0.321
	routine	228	0.91%	88.24%	15.9736%	18.31199%	1.122	0.161	0.265	0.321
	PM	228	0.00%	54.30%	10.0746%	12.21817%	1.564	0.161	1.747	0.321
	KM	228	0.00%	31.00%	6.5058%	9.10559%	1.187	0.161	-0.179	0.321
	CM	228	0.00%	18.10%	1.4693%	3.17194%	3.326	0.161	11.840	0.321
	Other	228	0.61%	98.24%	65.7592%	30.78321%	-0.644	0.161	-0.773	0.321
	Valid N (listwise)	228								
2006_7	weighted	0	0%	100%	23.88%	25.950%	1.511	0.161	1.158	0.321
	y	228	0%	100%	23.71%	25.783%	1.545	0.161	1.158	0.321
	routine	228	1.00%	88.00%	16.0789%	18.29886%	1.120	0.161	0.242	0.321
	PM	228	0.00%	56.00%	10.3509%	12.60829%	1.553	0.161	1.781	0.321
	KM	228	0.00%	31.00%	6.4518%	9.19454%	1.178	0.161	-0.206	0.321
	CM	228	0.00%	18.00%	1.4298%	3.21743%	3.305	0.161	11.693	0.321
	Other	228	0.00%	96.00%	65.3202%	30.85790%	-0.634	0.161	-0.789	0.321
	Valid N (listwise)	228								

The frequency values of the efficiency data (Table 4.2) showed that more than 50% of the responses indicated that the output efficiency was less than 10%. The graphic representation of the spread of the responses on output efficiency (Figure 4.1) indicated that most of the respondents were performing below 50% output efficiency. Further, Figure 4.1 confirmed that the spread was not reflective of a normal distribution as prescribed by McCullagh and Nelder (1989).

The violations in assumptions of normal distribution in the data sets, specifically that variables be normally distributed and the relationship between the two variables be linear, as shown in Table 4.3, implied that linear regression analysis could not be utilised.

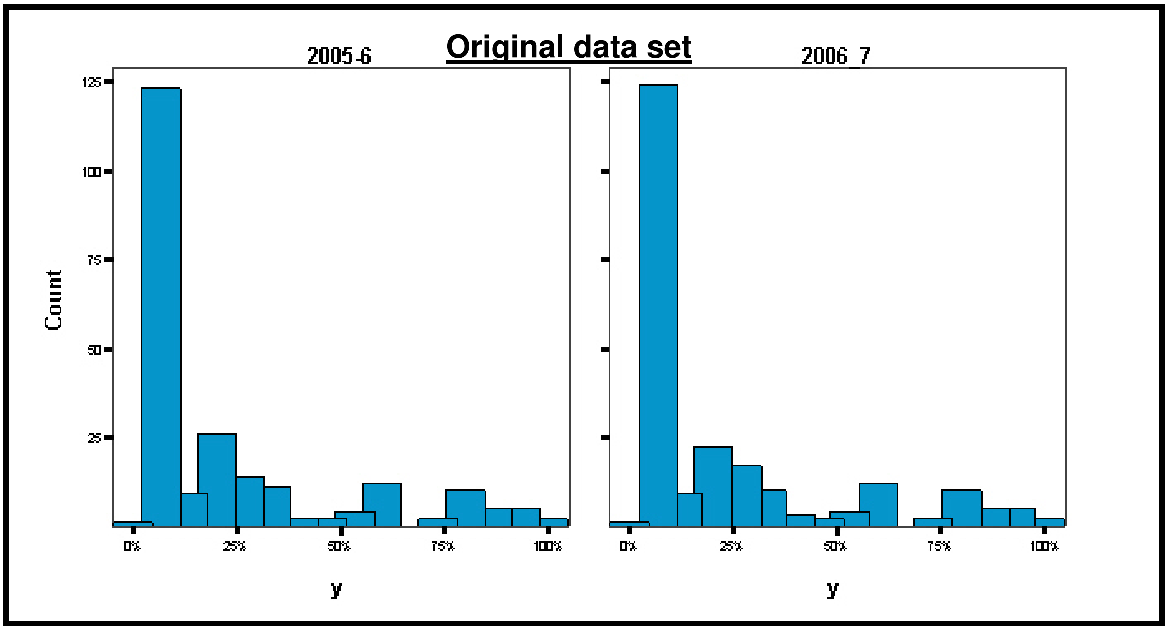


Figure 4.1: Display of the output efficiency responses from the Air Quality Units (N=228)

Table 4.2: Frequency values of the output efficiency data (N=228)

Year			Frequency	Percent	Valid Percent	Cumulative Percent
2005-6	Valid	0%	1	0.4	0.4	0.4
		7%	123	53.9	53.9	54.4
		13%	9	3.9	3.9	58.3
		20%	26	11.4	11.4	69.7
		27%	14	6.1	6.1	75.9
		33%	11	4.8	4.8	80.7
		40%	2	0.9	0.9	81.6
		47%	2	0.9	0.9	82.5
		53%	4	1.8	1.8	84.2
		60%	12	5.3	5.3	89.5
		73%	2	0.9	0.9	90.4
		80%	10	4.4	4.4	94.7
		87%	5	2.2	2.2	96.9
		93%	5	2.2	2.2	99.1
		100%	2	0.9	0.9	100.0
		Total	228	100.0	100.0	
2006_7	Valid	0%	1	0.4	0.4	0.4
		7%	124	54.4	54.4	54.8
		13%	9	3.9	3.9	58.8
		20%	22	9.6	9.6	68.4
		27%	17	7.5	7.5	75.9
		33%	10	4.4	4.4	80.3
		40%	3	1.3	1.3	81.6
		47%	2	0.9	0.9	82.5
		53%	4	1.8	1.8	84.2
		60%	12	5.3	5.3	89.5
		73%	2	0.9	0.9	90.4
		80%	10	4.4	4.4	94.7
		87%	5	2.2	2.2	96.9
		93%	5	2.2	2.2	99.1
		100%	2	0.9	0.9	100.0
		Total	228	100.0	100.0	

Table 4.3: Deviation from normality in the data collected (N=228)

Assumptions for normality		Motivation
Independent observations	√	Data sets collected per Air Quality Unit must be independent of each other. This is also an assumption that holds for non-parametric techniques.
Continuous variables	√	Variables expressed as percentage
Variables normally distributed	X	Deviation from normal distribution noted. For the normal distribution assumption to be justified, approximately 68% of the values must be within one standard deviation of the mean, about 95% of the values must be within two standard deviations and about 99.7% lie within three standard deviations. This is known as the 68-95-99.7 rule, or the empirical rule (McCullagh & Nelder, 1989).
Relationship between two variables are linear	X	The scatter plots revealed that the data was systematically different.

√ - assumption for normality met; X – violation in the assumption for normality

4.3 Data Preparation: Clustering of Data into Categories

The data analysis clearly indicated that most of the local authorities were *not* delivering on their mandates in terms of air quality management and that the Air

Quality Units spend most of their man-hours on Other activities or in some cases Other and Routine activities only. As this phenomenon (*i.e.* very low output performance from a large proportion of the sample) influences the research correlation values, the identification of a subset of data to improve statistical analysis was investigated.

4.3.1 Overview of Descriptive Statistics

The frequency distributions of the dependent variable (output efficiency) revealed that more than 50% of responding Air Quality Units (54.4% in 2005/6 and 54.7% in 2006/7) had an output efficiency of less than 10%, *i.e.* satisfied either none or only one of the required output mandates. The descriptive statistics for each of the input variables, *i.e.*, CM, KM, PM Routine and Other activities of the Air Quality Units, with output efficiency of less than 10% and of Air Quality Units with an output efficiency of at least 10% or greater are shown in Table 4.4.

In addition to uni- and bi-variate descriptive measure and graphical displays, differences between departments in two categories of output efficiency, *viz.* those departments that attained none or only one of its target outputs and those that attained more than one of its target outputs, were evaluated. In this regard the null hypothesis that the means of the two groups were equal was tested against the alternative hypothesis that the group means differ.

Table 4.4: Descriptive statistics

(Of the percentage of man-hours spent on input activities for Air Quality Units with an output efficiency of less than 10% and for Air Quality Units with an output efficiency of 10% or more)

Output efficiency	Year	Independent variable	M	SD	Skewness	Kurtosis
Less than 10%	2005/6 (n=124)	Routine activities	10.858	15.934	1.570	0.490
		Project management	3.001	3.784	4.207	17.457
		Knowledge management	1.323	4.122	5.104	25.083
		Change management	0.126	0.254	2.906	8.961
		Other activities	84.692	18.181	-1.278	-0.337
	2006/7 (n=125)	Routine activities	11.272	16.213	1.520	0.335
		Project management	3.272	5.590	5.482	35.913
		Knowledge management	1.224	4.050	5.105	25.268
		Change management	0.072	0.340	6.214	46.180
		Other activities	83.864	18.714	-1.194	-0.538
10% or more	2005/6 (n=104)	Routine activities	22.073	19.151	0.792	0.253
		Project management	18.508	13.411	0.675	-0.207
		Knowledge management	12.685	9.568	0.100	-1.448
		Change management	3.071	4.163	2.085	3.999
		Other activities	43.186	27.344	-0.017	-0.948
	2006/7 (n=103)	Routine activities	21.913	19.052	0.823	0.317
		Project management	18.942	13.411	0.713	0.017
		Knowledge management	12.796	9.699	0.060	-1.454
		Change management	3.078	4.230	2.064	3.891
		Other activities	42.816	27.578	-0.018	-1.014

M = Mean; SD = Standard deviation

The relationship between output efficiency and the input variables was also explored and modelled for those departments that reached more than one of their outputs: a distinction was made between Air Quality Units reaching more than half of their outputs and those that reached less than half.

Table 4.4 shows that Air Quality Units with an output efficiency of less than 10% spent on average more than 80% of their man-hours on Other activities (mean = 84.6% in 2005/6 and 83.9% in 2006/7). As a result, a small percentage of their man-hours was spent on average on Routine activities, CM, KM, and PM activities. As far as the distribution of the independent variables was concerned, the input variable, Other activities, was negatively skew, further indicating that the majority of the responding Air Quality Units spent very large percentages of their man-hours on these activities. Each of the variables Routine activities, CM, KM, and PM was positively skew and leptokurtic, indicating that the majority of responding Air Quality Units spent very small percentages of their man-hours on each of these activities. For Air Quality Units with 10% or less output efficiency, the distribution of the independent variables therefore deviated from the assumption of normality.

Of the responding Air Quality Units who had an output efficiency of 10% or more, *i.e.*, two or more mandated activities completed, the descriptive statistics (Table 4.4) showed that the Air Quality Units on average spent less than half of their man-hours on Other activities (M = 43.19% and 42.82% in 2005/6 and 2006/7 respectively). In addition, nearly a quarter of their man-hours were spent on Routine activities (mean = 22.1% and 21.9% in 2005/6 and 2006/7 respectively). The remainder of man-hours were predominantly devoted to PM and KM activities, while very few man-hours were on average spent on CM activities. Except for CM activities, the distribution of the independent variables showed small deviations from normality. Only CM is positively skew (with skewness values exceeding 2 for both 2005/6 and 2006/7) and leptokurtic (kurtosis values exceeding 3 in both 2005/6 and 2006/7).

From the above discussion, it is evident that Air Quality Units with an output efficiency of 10% or more spend on average more man-hours on routine, CM, KM, and PM activities than those Air Quality Units with an output efficiency of less than 10%. In contrast, those with an output efficiency of less than 10% on average spend more man-hours on Other activities and less man-hours on Routine activities, CM, KM, and PM activities.

The observed differences in the allocation of resources to Routine, CM, KM, and PM activities between the two groups of Air Quality Units were supported by the independent samples t-tests (Table 4.5). The sample t-tests revealed that there was a statistically significant difference between the means of the two groups of Air Quality Units in terms of each of the input variables (p-value < 0.0005 in each case).

A heuristic approach was applied for the resource allocation model development, where exploration of possibilities rather than following set rules was followed (Goldratt, 1992).

Table 4.5: Results of t-test

(For statistical significant differences between means of Air Quality Units with an output efficiency of less than 10% and Air Quality Units with an output efficiency of 10% or more)

Year	Independent variable	t-statistic	df	p-value	Mean Difference	SE Difference
2005/6	Routine activities	-4.75	200.67	<0.0005	-0.112	0.024
	Project management	-11.42	116.78	<0.0005	-0.155	0.014
	Knowledge management	-11.27	134.83	<0.0005	-0.114	0.010
	Change management	-7.20	103.65	<0.0005	-0.029	0.004
	Other activities	13.22	173.56	<0.0005	0.415	0.031
2006/7	Routine activities	-4.49	201.14	<0.0005	-0.106	0.024
	Project management	-11.09	131.08	<0.0005	-0.157	0.014
	Knowledge management	-11.32	131.19	<0.0005	-0.116	0.010
	Change management	-7.19	103.09	<0.0005	-0.030	0.004
	Other activities	12.86	173.53	<0.0005	0.410	0.032

df: degrees of freedom; P: probability; S.E. – standard error

4.4 Model Development and Interpretation

To develop a heuristic model for the prediction of output efficiency, the focus was henceforth devoted only to those Air Quality Units with an output efficiency of 10% or more. The data sets with output efficiency greater than 10% are shown in Annexure 2. The rationale for the decision was that Air Quality Units with less than a 10% output efficiency predominantly devote their man-hours to O*ther activities* (as described in Section 4.3.1) and were not delivering on their mandated outputs. As the influence of this phenomenon (*i.e.* very low output performance from a large proportion of the sample) impacts on the research correlation values, the identification of a subset of data to improve statistical analysis was investigated. The number of Air Quality Units that met this criterion (more than 10% output efficiency) in 2005/06 was 104, while 103 did so in 2006/07.

The utilisation of a multiple linear regression model was investigated first. The underlying assumptions related to using linear regression models were, however, not met due to the distribution of the dependent variable (output efficiency) for each of the years 2005/6 and 2006/7 being positively skew (*cf*. Figure 4.2). Hence, the assumption of normality was not justifiable.

The independent variables, CM, KM, PM, Routine and Other activities also deviated from the assumption of being normally distributed. Although the strength of the linear relationship between the dependent and each of the independent variables (as evaluated using both the Pearson product moment correlation coefficient as well as the Spearman's Rho coefficient) ranged from a low of approximately 0.3 (between *output efficiency* and *KM*) to a high of approximately

0.4 (between *output efficiency* and *PM*) and -0.5 (between *output efficiency* and *other activities*), the graphical displays revealed the presence of outlier values. The applicable statistical tests were selected from Table 3.2, with the goal of quantifying the association between two variables. The causes for the outlier values were then investigated for possible errors in data entry or data capturing errors. No data entry or capturing errors were evident, as discussed in Section 4.3.1.

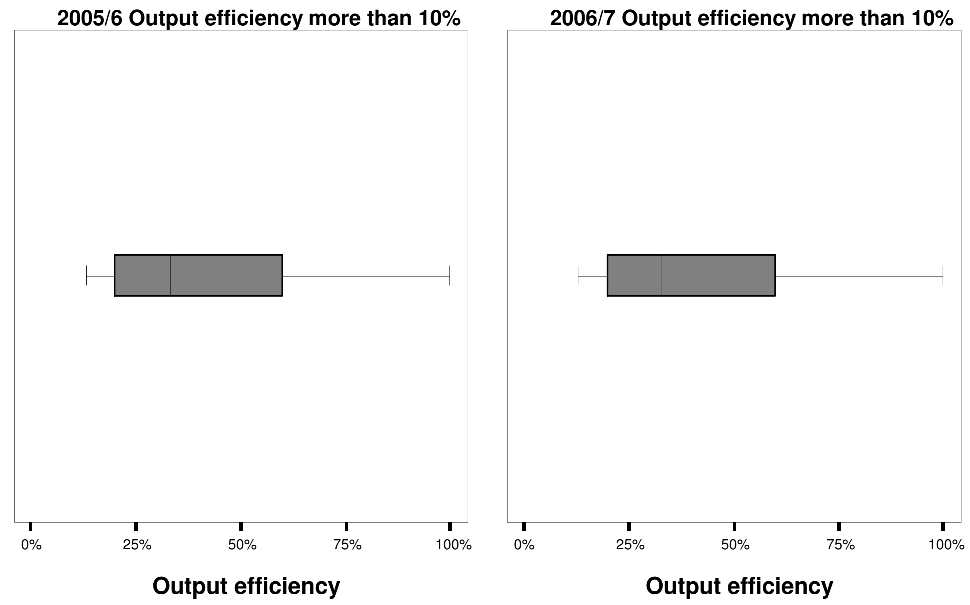


Figure 4.2: Distribution of output efficiency for Air Quality Units with an output efficiency of 10% or more

The possibility of data transformation (for example a logarithmic transformation of the dependent variable) was subsequently investigated. The data transformation methods reflected in Table 4.6 was applied to the data to check if the linearity of the relationship increased rather than decreased. Testing the effect of a transformation method involved looking at residual plots and correlation coefficients. When the residual plots showed non-random patterns, the transformation was repeated with a different approach. Despite these efforts, the problem of non-normality and outlier values persisted.

Table 4.6: Data transformation methods investigated (Pallant, 2005)

Method	**Transformation(s)**	**Regression equation**
Exponential	Dependent variable = log(y)	$\log(y) = b_0 + b_1x$
Quadratic	Dependent variable = square root (y)	Square root (y) $= b_0 + b_1x$
Reciprocal	Dependent variable = 1/y	$1/y = b_0 + b_1x$
Logarithmic	Independent variable = log(x)	$y = b_0 + b_1\log(x)$
Power model	Dependent variable = log(y) Independent variable = log(x)	$\log(y) = b_0 + b_1\log(x)$

The possibility of using a logistic regression model was then considered. Logistic regression is recommended when the assumptions underlying linear regression are not met (Garson, 2008). As the dependent variable was separated into two categories, binary logistic regression technique was used for the model development. The factors that contributed towards the prediction of whether the Air Quality Units would be efficient were systematically evaluated.

4.4.1 Output Efficiency

The output responses of the Air Quality Units that were more than 10% efficient are displayed graphically in Figure 4.3. The data sets with output efficiency greater than 10% indicated an improved spread, moving towards a normal distribution compared to the original data set (Figure 4.1). In addition, the former data set displayed a binodal response – *i.e.* approximately 50% of the respondents were less than 50% efficient, while the other 50% were greater than 50% efficient. The trend was repeated in the 2006/07 financial year. The dependent variable, output efficiency, was divided into two segments, *viz.* Air Quality Units reaching less than half of their output efficiency (*i.e.* at least 10% but less than 50%) and those reaching at least half of their output efficiency.

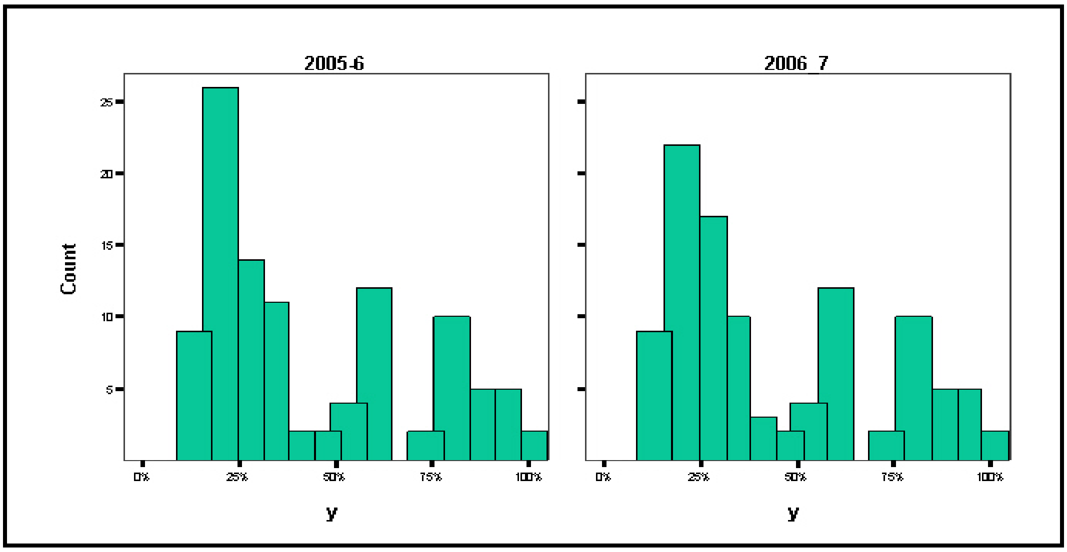


Figure 4.3: Display of the responses from the Air Quality Units with greater than 10% output efficiency

The Air Quality Units with output efficiency of 50% or more were defined as being efficient, while those with an output efficiency of at least 10 but less than 50%

were defined as less efficient. This categorisation was done on logical grounds rather than on the observed distribution of the dependent variable.

The dependent variable encoding table used in the SPSS assessment (Table 4.7) showed that the dependent variable category greater than or equal to 50% was coded with the reference category 1; and the less than 50% category was coded 0 for the 2005/06 and 2006/07 data sets.

Table 4.7: Coding used for the output efficiency

Dependent Variable Encoding

Year	Original Value	Internal Value
2005-6	Less than 50%	0
	50% or higher	1
2006_7	Less than 50%	0
	50% or higher	1

The case processing table used in the SPSS assessment (Table 4.8) indicated that 104 and 103 samples were included in the analysis for each of the two years and there were no missing values from the data sets. The sample numbers were greater than those recommended by Greenland, Schwartzbaum and Finkle (2000); Cox and Snell (1989), Harrell *et al*. (1984) and Harrell, Lee and Mark (1996) for statistical representivity (10 samples for each independent variable and 10 for each coefficient generated *i.e*. >60 samples).

Table 4.8: Case processing summary for data used in binary logistic regression

Year	Unweighted Cases(a)		N	Percent
2005-6	Selected Cases	Included in	104	100.0
		Missing Cases	0	0.0
		Total	104	100.0
	Unselected Cases		0	0.0
	Total		104	100.0
2006_7	Selected Cases	Included in	103	100.0
		Missing Cases	0	0.0
		Total	103	100.0
	Unselected Cases		0	0.0
	Total		103	100.0

The resultant split in the sample for 2005/06 and 2006/07 used in the model development was (i) 0: 10 - < 50%; and (ii) 1: ≥ 50%.

4.4.2 Input Activities (Independent Variables)

The independent variable, *CM*, was re-coded into two categories using the mean value (for the year 2005/6) as the cut-off point: less than 1.50%, and 1.5% or more. The resultant split in the sample for 2005/06 and 2006/07 is shown in Table 4.9. The mean value (1.5%) was used, as it had validity in terms of separating one type of performance from another (Cox & Snell, 1989).

Based on the observed clustering in the relationship between KM and output efficiency, as shown in Figure 4.4, three distinct categories of the independent variable, KM, were formed, with Air Quality Units spending (i) less than 10%; (ii) between 10 and 20%; and (iii) more than 20% of their man-hours on KM activities. The three distinct categories were repeated for the 2006/07 data set.

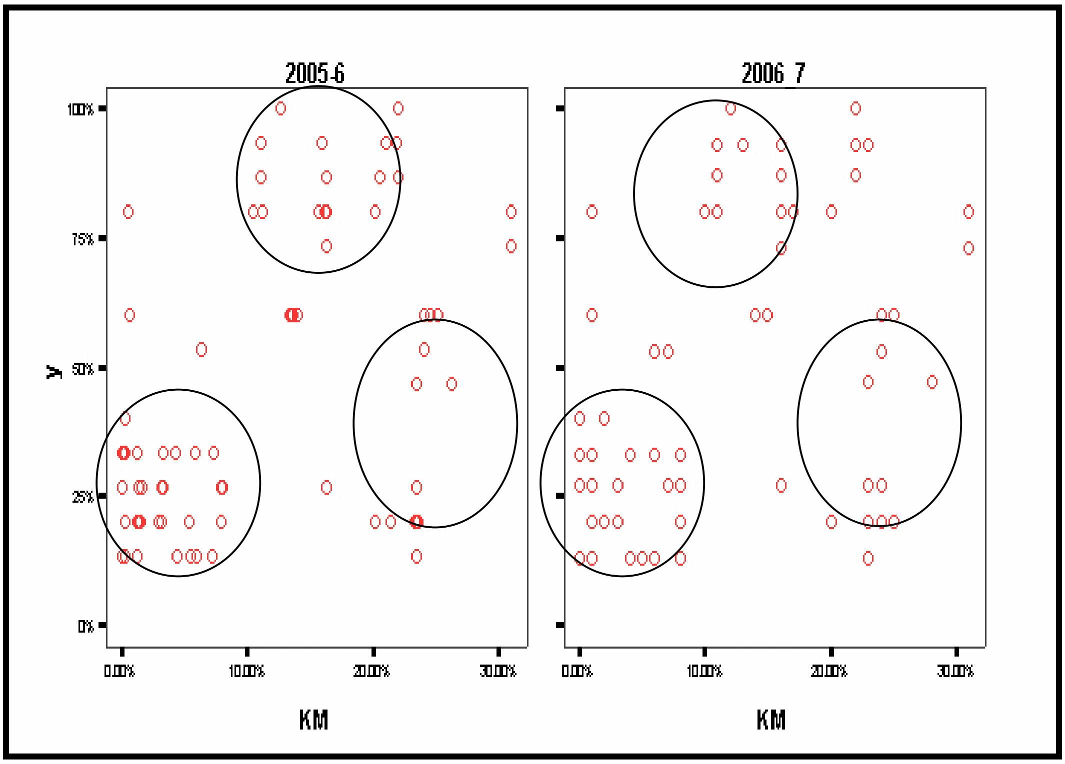


Figure 4.4: Scatter-plot of relationship between KM and output efficiency

Table 4.9: Recoding of CM input variable

Recoded change management

Year			Frequency	Percent	Valid Percent	Cumulative Percent
2005-6	Valid	Less than or equal to 1.5%	56	53.8	53.8	53.8
		More than 1.5%	48	46.2	46.2	100.0
		Total	104	100.0	100.0	
2006_7	Valid	Less than or equal to 1.5%	52	50.5	50.5	50.5
		More than 1.5%	51	49.5	49.5	100.0
		Total	103	100.0	100.0	

Independent Samples Test

Year			Variances		t-test for Equality of Means						
										the Difference	
			F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Upper	Lower
2005-6	y	Equal variances assumed	29.091	0.000	-6.959	102	0.000	-30.476%	4.380%	-39.163%	-21.789%
		Equal variances not assumed			-6.680	71.095	0.000	-30.476%	4.562%	-39.573%	-21.380%
2006_7	y	Equal variances assumed	27.752	0.000	-7.890	101	0.000	-32.897%	4.169%	-41.168%	-24.627%
		Equal variances not assumed			-7.845	74.077	0.000	-32.897%	4.193%	-41.253%	-24.542%

The number of Air Quality Units in each of the categorised dependent and independent variables are shown in Table 4.10.

Table 4.10: Number and percentage of Air Quality Units within categorised variables

Year	Output efficiency categories	Number of units	% of total
2005/6	Less efficient (at least 10% but less than 50% output efficiency)	64	61.5%
	Efficient (50% or more output efficiency)	40	38.5%
	Total	104	100
2006/7	Less efficient (at least 10% but less than 50% output efficiency)	63	61.2%
	Efficient (50% or more output efficiency)	40	38.8%
	Total	103	100.0
Year	**Change management categories**	**Number of units**	**% of total**
2005/6	Less than or equal to 1.5%	56	53.8
	More than 1.5%	48	46.2
	Total	104	100
2006/7	Less than or equal to 1.5%	52	50.5
	More than 1.5%	51	49.5
	Total	103	100.0
Year	**Knowledge management categories**	**Number of units**	**% of total**
2005/6	Less than 10%	45	43.3
	Between 10 and 20%	22	21.2
	More than 20%	37	35.6
	Total	104	100.0
2006/7	Less than 10%	44	42.7
	Between 10 and 20%	22	21.4
	More than 20%	37	35.9
	Total	103	100.0

4.5 Developing the logistic regression model

A binary stepwise logistic regression model was fitted to the data, where the dependent variable was the categorised output efficiency, efficient / less efficient. The independent variables were the categorised independent variables, *viz*. *CM* (two categories) and *KM* (3 categories), as well as the scale variables, *PM* and *other activities*. The independent variable, *routine activities,* was not included due to the functional relationship between the independent variables *i.e.*, together these add up to 100%. The variables used in the development of the resource allocation model are summarised in Table 4.11.

Table 4.11: Summary of variables used in logistic regression

Variable	Type	Value
CM	Recoded/categorical data/ Independent	2 categories 0: <1.5%; and 1: ≥1.5%
KM	Recoded/categorical data/ Independent	3 categories: KM_rec : <10%; KM-1: 10–20%; KM_2: >20%
PM	Continuous/ Independent	0 – 100 %
Y (output efficiency)	Recoded/categorical data/Dependent	2 categories; 0: 10 - <50%; 1: ≥50%
Other	Continuous Independent	0–100 %

The ‘best’ regression model was developed in stages. From the list of five potential explanatory variables, SPSS repeatedly searched for variables that had to be included in the model. The best explanatory variable was used first, then the second best and so on. One of the benefits of using stepwise logistic regression is that it provides a parsimonious model.

The classification table (Table 4.12) contains the results of the analysis without the independent variables used in the model. It served as a baseline for comparing with the model that included the independent variables. The overall percent correctly predicted was 61.2%, which is relatively good at significance levels of 0.02.

Table 4.12: Classification table for the recoded output efficiency

Classification Table(a,b)

Year		Observed		Predicted: Output recoded: Less than 50%	Predicted: Output recoded: 50% or higher	Predicted: Percentage Correct
2005-6	Step 0	Output recoded	Less than 50%	64	0	100.0
			50% or higher	40	0	0.0
		Overall Percentage				61.5
2006_7	Step 0	Output recoded	Less than 50%	63	0	100.0
			50% or higher	40	0	0.0
		Overall Percentage				61.2

a. Constant is included in the model.

b. The cut value is .500

Variables in the Equation

Year			B	S.E.	Wald	df	Sig.	Exp(B)
2005-6	Step 0(a)	Constant	-0.470	0.202	5.438	1	0.020	0.625
2006_7	Step 0(a)	Constant	-0.454	0.202	5.049	1	0.025	0.635

a. Variable(s) entered on step 2: Other.

B – coefficient for the constant; S.E. - the standard error around the coefficient for the constant; df - the degrees of freedom for the Wald chi-square test; Exp(B) - the exponentiation of the B coefficient

The model, including the independent variables, correctly predicted 89% of the cases overall and had a good fit, as shown in Table 4.13. There was an improvement of 28% from the base model.

Table 4.13: Variables included in the model

Classification Table(a)						
				Predicted		
				Output recoded		
Year		Observed		Less than 50%	50% or higher	Percentage Correct
2005-6	Step 1	Output recoded	Less than 50%	63	1	98.4
			50% or higher	19	21	52.5
		Overall Percentage				80.8
	Step 2	Output recoded	Less than 50%	59	5	92.2
			50% or higher	6	34	85.0
		Overall Percentage				89.4
2006_7	Step 1	Output recoded	Less than 50%	62	1	98.4
			50% or higher	19	21	52.5
		Overall Percentage				80.6
	Step 2	Output recoded	Less than 50%	58	5	92.1
			50% or higher	6	34	85.0
		Overall Percentage				89.3

a. The cut value is .500

4.5.1 Variables of Interest

Binary logistic regression using logit as the link function was performed using PM, KM, CM, Other and Routine variables. For both the 2005/6 and 2006/7 years, the logistic regression models fitted to the data indicated that two independent variables significantly contribute towards the prediction of an Air Quality Unit being efficient (more than 50% output efficiency) *viz*. the categorised variable KM and the scale variable *other activities*.

For both years, KM (categorised) entered the model first, indicating that it was the best predictor of whether a department was efficient or less efficient. In particular, for each of the years 2005/6 and 2006/7, the logistic regression model fitted to the data showed that the odds of being efficient increased if an Air Quality Unit spent between 10% and 20% of its total man-hours on KM activities (rather than less than 10% of its man-hours on these activities). Similarly, but to a lesser extent, the odds of being efficient increased if an Air Quality Unit spent more than 20% of its man-hours on KM activities (rather than less than 10% of its man-hours on these activities).

Table 4.14 provided an indication of the contribution or importance of each of the predictor variables. The Weld test indicated that Other, KM_rec (KM = >20%) and KM (i); (KM = 10–20%) contributed significantly to the model (significant value <0.05). KM 2) was not significant *i.e.* KM <10% category. The same variables to be included in the model were repeated when the 2006/07 data set was used.

Table 4.14: Variables included in the binary regression model

Variables in the Equation								
Year			B	S.E.	Wald	df	Sig.	Exp(B)
2005-6	Step 1(a)	km_rec			22.158	2	0.000	
		km_rec(1)	5.124	1.128	20.631	1	0.000	168.000
		km_rec(2)	1.583	0.583	7.372	1	0.007	4.870
		Constant	0.156	0.393	0.158	1	0.691	1.169
	Step 2(b)	Other	-0.063	0.015	17.435	1	0.000	0.939
		km_rec			13.651	2	0.001	
		km_rec(1)	4.372	1.189	13.514	1	0.000	79.225
		km_rec(2)	0.631	0.693	0.829	1	0.363	1.879
		Constant	2.556	0.698	13.388	1	0.000	12.881
2006_7	Step 1(a)	km_rec			21.841	2	0.000	
		km_rec(1)	5.099	1.128	20.417	1	0.000	163.800
		km_rec(2)	1.558	0.584	7.125	1	0.008	4.748
		Constant	0.165	0.393	0.176	1	0.675	1.179
	Step 2(b)	Other	-0.062	0.015	17.044	1	0.000	0.940
		km_rec			13.640	2	0.001	
		km_rec(1)	4.372	1.190	13.501	1	0.000	79.199
		km_rec(2)	0.640	0.692	0.856	1	0.355	1.897
		Constant	2.473	0.685	13.043	1	0.000	11.858

a. Variable(s) entered on step 1: km_rec.
b. Variable(s) entered on step 2: Other.

B – coefficient for the constant; S.E. the standard error around the coefficient for the constant; df - the degrees of freedom for the Wald chi-square test; Exp(B) - the exponentiation of the B coefficient

After the effect of KM on the dependent variable had been accounted for, the variable *other activities* contributed further to the prediction of whether a department was efficient or less efficient. In contrast to the man-hours spent on KM activities, the odds of being efficient decreased the more man-hours were spent on activities other than CM, KM, PM and Routine activities. This statement held true for the models fitted for both 2005/6 and 2006/7.

The parameter estimates based on the data of 2005/6 and 2006/7 were very similar: parameter estimates differed only in the second or third decimal places. Based on the model summary, it became evident that if an Air Quality Unit spent less than 10% of its man-hours on KM activities, the probability of being efficient decreased rapidly when more man-hours were spent on Other activities. In fact, if more than 40% of its man-hours were spent on Other activities, there was a very low probability (below 40%) of being efficient. Further, if an Air Quality Unit spent more than 20% of its man-hours on KM activities, the probability of being efficient also decreased the more man-hours were spent on other activities. If it spent more than 50% of its man-hours on other activities, the probability of being efficient was less than 40%. Finally, if a department spent between 10 and 20% of its man-hours on KM, it was very likely to be efficient, *viz*. more than a 50% probability of being efficient, irrespective of the man-hours spent on Other activities.

The criterion for the inclusion of a variable in the model was that the p-value (where 'p' referred to the estimated probability) for the likelihood ratio test was $p < 0.05$. This implied that there was adequate fit of the data to the model, meaning that at least one of the predictors was significantly related to the response variable.

Cross-validation of the logistic model was done to overcome the problems relating to over-fitting the model to noise in the data, generally experienced when stepwise methods are used, by fitting the model to the data collected for the 2006/07 financial years. The 2006/07 data was also used to test the robustness of the model.

The selection of contributing variables from all the predictor variables yielded a parsimonious model containing only the input variables that contributed to the prediction of output efficiency. For the model developed, only two variables (KM and Other) out of five variables (Routine, PM, KM, CM and Other) contributed to the prediction of the Air Quality Units' output efficiency.

The 'B' values (Table 4.14) indicated the direction where allocating resources to Other resulted in a decrease in output efficiency and allocations to KM (10–20%) resulted in increase in efficiency. The "Exp (b)" column, which predicted change in odds for an Air Quality Unit increase in the corresponding independent variable, indicated increased odds that KM (10–20%) affects output efficiency. This phenomenon was also common to the 2006/07 data set.

The best-fitting binary regression model was therefore deemed to include the variables Other and KM (10 – 20%). **This implied that air quality units that allocated between 10 and 20% of their resources had increased odds of having output efficiency greater than 50%.**

4.6 Information from the Logistic Curve

The model developed using logistic regression, is shown in Figure 4.5, where "P" refers to the estimated probability for the Air Quality Unit. The model allows for predicting the classification of the Air Quality Units as either less than 50% or greater than and equal to 50% efficient.

2005/06

$$P\text{ (output 50\% or higher)} = \frac{1}{1 + e^{-z}}$$

where,

$$z = 2.556 - 0.063\text{other} + 0.631\,\text{KM (if > 20\% man-hours)} + 4.372\,\text{KM (if 10 - 20\% man-- hours)}$$

2006/07

$$P\text{ (output 50\% or higher)} = \frac{1}{1 + e^{-z}}$$

where,

$$z = 2.0473 - 0.062\text{other} + 0.64\,\text{KM (if > 20\% man-hours)} + 4.372\,\text{KM (if 10 - 20\% man-hours)}$$

Figure 4.5: The logistic representation models for the 2005/06 and 2006/07 data sets

This implied that air quality units must decrease resources allocated to other tasks and allocate 10–20% of their resources to KM.

In terms of model fit, the pseudo-coefficients of determination, *viz.* the Cox and Snell R^2 of 0.506 and 0.503 and the Nagelkerke R^2 of 0.688 and 0.683 for the years 2005/6 and

2006/7, respectively indicated a good model fit. In addition, the model that includes the two independent variables, *viz*. the categorised variable KM and the scale variable Other activities, correctly predicted 89.4% and 89.3% of the units as either efficient or less efficient for the 2005/6 and 2006/7 data sets respectively (*cf*. Table 4.15).

The chi-square goodness-of-fit test, as shown in Table 4.16, indicated that the inclusion of the variables was justified, as the significance of the steps was less than 0.05. There were similar findings when the 2006/07 dataset was used. This implied that there was adequate fit of the data to the model, meaning that at least one of the predictors was significantly related to the response variable.

The Cox and Snell R^2 and Nagelkerke R^2 provide pseudo R^2 values, as shown in Table 4.17. The values indicated that 50–68% of the variance could be explained by the model; which demonstrates a strong association or a good model fit (Cox & Snell, 1989).

Table 4.15: Classification table based on logistic regression models

Year		Observed categories	Predicted categories		
			Output efficiency categories		Percentage of units correctly classified
			Less efficient (at least 10% but less than 50%)	Efficient (50% or more)	
2005/6	Step 1	Less efficient (at least 10% but less than 50%)	63	1	98.4
		Efficient (50% or more)	19	21	52.5
		Overall%			80.8
	Step 2	Less efficient (at least 10% but less than 50%)	59	5	92.2
		Efficient (50% or more)	6	34	85.0
		Overall%			89.4
2006/7	Step 1	Less efficient (at least 10% but less than 50%)	62	1	98.4
		Efficient (50% or more)	19	21	52.5
		Overall%			80.6
	Step 2	Less efficient (at least 10% but less than 50%)	58	5	92.1
		Efficient (50% or more)	6	34	85.0
		Overall%			89.3

Table 4.16: Omnibus tests of model coefficients

(Showing chi-square goodness-of-fit test for the resource allocation model)

Year			Chi-square	Degrees freedom	Significance
2005-6	Step 1	Step	49.974	2	0.000
		Block	49.974	2	0.000
		Model	49.974	2	0.000
	Step 2	Step	23.411	1	0.000
		Block	73.384	3	0.000
		Model	**73.384**	**3**	**0.000**
2006_7	Step 1	Step	49.235	2	0.000
		Block	49.235	2	0.000
		Model	49.235	2	0.000
	Step 2	Step	22.854	1	0.000
		Block	72.089	3	0.000
		Model	**72.089**	**3**	**0.000**

Table 4.17: Test for goodness of model fit

(Using Cox and Snell and Nagelkerke R-square)

Model Summary

Year	Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
2005-6	1	88.612(a)	0.382	0.518
	2	65.202(a)	0.506	0.688
2006_7	1	88.374(b)	0.380	0.516
	2	65.520(b)	0.503	0.683

by less than .001 for split file Year = 2005-6.
by less than .001 for split file Year = 2006_7.

4.7 Summary

An exploratory analysis of the data was undertaken, and this was followed by data preparation and classification prior to applying logistic regression analysis. Preliminary assessment of the data was undertaken to test the assumptions of linear regression. Violations in assumptions of normal distribution in the data set were identified, which implied that linear regression analysis could not be utilised.

The variables were subjected to recoding of the original scores to ensure suitability of analysis as recommended by Pallant (2005). As the dependent variable showed two distinct categories, binary logistic regression using logit as the link function was performed using PM, KM, CM, Other and Routine variables. The logistic regression model was informed through investigating the following parameters:

- An overall evaluation of the model and examination by the likelihood ratio tests, where p-values smaller than 0.05 indicated that the independent variables most likely influence the dependent variables;
- Statistical significance of individual predictors (independent variables) using the Wald chi-square statistic. The predictors with p-values smaller than 0.05 were deemed insignificant;
- Goodness-of-fit test statistics to indicate the appropriateness of the model and its fits with the actual outcomes. This was estimated with the Cox and Snell and Nagelkerke R-square tests, where the significance of the chi-squared value is an indicator of goodness-of-fit ($p>0.05$ indicates that the model fits the data well);

- An assessment of the predicted probabilities of the model presented in a classification table, where the predicted outcome was compared to the actual outcome.

These parameters were aligned to the reporting requirements recommended for logistic regression analysis by Peng, Lee and Ingersoll (2002). A model including all the variables was produced, using binary logistic regression.

Binary logistic regression was used, as the distribution of the output efficiency of the two sets of data (2005/06 and 2006/07 years) indicated two distinct categories. The forward stepwise method using the Wald criterion provided an elegant solution to the modelling of the data with significance value $p < 0.05$. The model was able to predict with a high degree of accuracy (86%) whether output efficiency would be <50% or ≥ 50%. This prediction held for the 2006/07 data set.

The implication of the model was that the Air Quality Units' predicated output efficiency could be classified as either <50% or ≥50% based on the following variables:

- Amount of resources allocated to other activities; and
- Amount of resources allocated as a % category to KM.

The model explained that the probability of the Air Quality Units' output efficiency being ≥50% increased if 10–20% of man-hours were spent on KM, but decreased if greater than 10% of man-hours were spent on Other activities.

The study was able to claim that the methodology was appropriate to the objectives of the research and was a warrantable addition to knowledge.

CHAPTER 5: SUMMARY AND CONCLUSIONS

'The beginning and the end reach out their hands to each other.'

Chinese Proverb (Unknown)

Kling (2006) indicated that when the contributors to output efficiency within the organisational context are understood, the output efficiency of that organisation actually improves. While no model fully represents the complexity of reality, it attempts to describe, the resource allocation model developed in this study functions to better define the enquiry domain of output efficiency in the Air Quality Units. Therefore, it serves as a model for clarifying the critical inputs that are required for AQOs to complete their mandated outputs successfully and to actually perform efficiently.

In this chapter, the research findings are summarised and the conclusions are evaluated in relation to the objectives set for the study. The contribution of the study to the air quality field is discussed, and, finally, suggestions are made for future research.

5.1 Introduction

Managing air quality in South Africa is an important issue (Pape, 2001; Lukey, 2007). The complexity of managing air quality in a post-apartheid country, where many citizens are being denied the right to an environment that is not harmful to their well-being, was a further motivation for the study (Mokgoro, 2000; Foti, 2005). Mokgoro (2000) asserted that the scale and size of change introduced in South Africa since the early 1990s have no parallel anywhere in the world. Implementing solutions required extraordinary means that could not be obtained from off-the-shelf offerings, and a South African specific study was therefore required.

The research question (Section 1.5) was to what extent the South African Air Quality Units' output efficiency could be explained by the percentage of the resources allocated to variables relating to PM, KM and CM. The question was answered through the development of a resource allocation model based on the data collected from South African AQOs. The application of models in decision-making allowed for systematic and transparent outcomes (Gachet, 2004). In addition, it supports future planning and budgeting within the Air Quality Units.

Lings and Lundell (2005) described a good doctorate-level research project as one that tackled a significant issue of interest to the chosen research community and offered scope for originality, but that could be focused to allow for planning and management. Lings and Lundell (2005) added that a good research project should result in a significant contribution, and, whatever the outcome of the research, it should be able to be investigated within the time and resources available. The applicability of these requirements to the model developed in this study is detailed in Table 5.1. In addition, the research community supported the project and worked expediently during the data collection and analysis phase, which was demonstrated through the 100% response rate of the study (Section 4.2).

Table 5.1: Criteria for a good research project (Lings & Lundell, 2005)

Criteria	Applicability to Model Developed in this Study
Contribution is an issue of interest to the chosen community	The South African Air Quality Units were undergoing a paradigm shift from point source emission management to ambient air quality management (Section 1.3.3). The study provided a model to understand the requirements to perform efficiently. Further, the 100% response rate demonstrated the high level of interest in the chosen community.
Originality	This study is the first to quantify both the inputs and outputs of Air Quality Units and establish the relationship between these. The model developed is a valuable first step towards identifying the key drivers of output efficiency within the Air Quality Units. The logistic regression model is the only tool available to the South African Air Quality Units to quantify the amount of man-hours to be allocated to KM and other tasks.
Significant contribution	This study makes a significant contribution to the body of literature on the subject, which lacks empirical studies that have a South African context, as detailed in Section 5.6.
Can be investigated within timelines and resources available	The need for the study was recognised by the research community. The data was provided within acceptable timelines by all 228 AQOs.

5.2 Gaps Identified in the Literature Review

The historical development of air quality management was presented in Chapter 1 as follows: the discussions relating to the dense fog in 1952 that claimed 4,000 lives in London; the introduction of the Clean Air Act (1956) and the regulatory changes in the United

Kingdom Government towards ambient air quality management. The DEA (2007) indicated that air quality in South Africa was decreasing, with high SO_2 and PM_{10} levels. Further, health problems due to air pollution were projected to increase at an estimated 20% over the next decade if air quality management was not prioritised. The international changes and the potential impact on human health in South Africa highlighted the importance of the South African government allocating resources to manage air quality in country.

As this study had a South African context, it was appropriate to discuss the South African air quality management challenges at the start of the research i.e. Chapter 1. Chapter 1 covered the basic theory and concepts required for understanding and interpreting literature on PM, KM and CM as well as specific and measurable variables for PM, KM, CM used by previous researchers. Chapter 1 also highlighted the previous researchers' findings on the lack of efficiency of the Air Quality Units.

Krupnick (2008) reported a positive relationship between air quality management and strong regulatory institutions. The converse was also true: poor air quality was a consequence of weak regulatory institutions in the country. The Air Quality Units' need for a model to predict output efficiency prompted the undertaking of the field research. The study itself then focused on developing a model to predict the output efficiency of the Air Quality Units in South Africa, with the view to understanding which inputs were critical to improving their output efficiency.

Throughout the study, the AQOs were assisted in understanding the specific requirements of an efficient regulatory institution to achieve their mandated outputs.

The existing models and frameworks (nationally and internationally) were not suitable for use in this study due to the gaps identified in Chapter 2. The gaps included the complex nature of the models and data not being available in the Air Quality Units. The application of the existing models, which considered stakeholder perceptions, would not be valid in the South African context, as South Africa has a dual economy and citizens have a wide range of expectations (discussed in Section 2.7).

The current models have not been tested empirically (Jupp & Younger, 2004); i.e. models were published without any explicitly known relationships between the parameters under investigation. The value-add of empirically testing the resource allocation model developed in this study was that the AQO understand *how* the critical input factors affect their output performance. This study also provided guidance on *which* actions would have the greatest impact on output performance and shed new light on *why* limited resources must be allocated to activities outside their mandates.

5.3 Evaluation of the Methodology Selected

The research design, unit of measurement, identification of participants for the study, data collection and the evaluation of the survey questionnaire were discussed in Chapter 3. As the aim of the research, formulated in Section 1.5, was to develop a model that could predict the output efficiency of Air Quality Units given the resources allocated to the inputs of that department, a quantitative design approach was selected. The approach was aligned to the recommendations of Webster (2003) and Keshav (2007).

The main characteristic of the approach was that it related to hands-on systems-building using data on agreed variables from a target population. The heuristic approach (Section

4.4.1) selected for the model development was based on experience with working with the AQOs as well as model development statistical packages.

To measure the efficiency of the Air Quality Units, a definition for output efficiency was formulated (*cf*. Section 3.3). The definition was guided by the contributions of previous researchers in the field of efficiency, as shown in Figure 5.1. For example, when the requirements for the output performance were used to define the input activities, there was a greater understanding of the outputs, and the organisational efficiency improved (Murray, 2000 and Kling, 2006). Drucker (2002) indicated that the greater the outputs, with the given inputs, the more efficient the organisation.

INPUTS(I)	OUTPUTS (O)	IMPACT ON EFFICIENCY	REFERENCES
Given the I	The greater the O	The greater the efficiency	Drucker (2002)
	The greater the actual O versus planned O	The greater the efficiency	Webster (2003)
When O are used to define I	There is a greater understanding of desired O	And the efficiency improves	Murray (2000) Kling (2006)
Given I	Greater the benefits to public i.e. improved air quality	The greater the efficiency	Webster (2003)

Figure 5.1: References used for defining efficiency based on inputs and outputs

For this study the definition of output efficiency was:

- The greater the number of mandated outputs completed, the greater the efficiency of the air quality unit.
- The outputs of the air quality units were based on their legal mandates (AQA; National Air Quality Framework Document, 2007), as discussed in Section 3.3.1
- The outputs were therefore known, defined and correct, as discussed in Section 1.4.2.

Each Air Quality Unit was requested to indicate the number of outputs completed out of a total of 15. The number of outputs completed per Air Quality Unit was expressed as a percentage of the total outputs, which served as a proxy for *output efficiency*. As indicated in Section 3.6.1, the national department verified the responses from the provincial and local AQOs as per the original agreement with Lukey (2007).

Chapter 2 detailed the studies published by previous researchers in the field of PM, KM and CM (Rwelamila, 2007; Shenhar, 2004; Crawford *et al.*, 2003). The man-hours allocated to undertake activities was the only factor considered to influence the output efficiency of the Air Quality Units, as discussed in Section 1.4.3. The selection of the 12 input variables was based on the Routine, CM, KM, PM and Other activities, as summarised in Table 3.5. The inputs of the Air Quality Unit were calculated as a percentage of the total man-hours spent on the 12 identified input activities. The inputs were grouped into five categories, *viz.*, KM, PM, CM, routine activities and other activities. Figure 5.2 indicates the final variables that were used to develop the model.

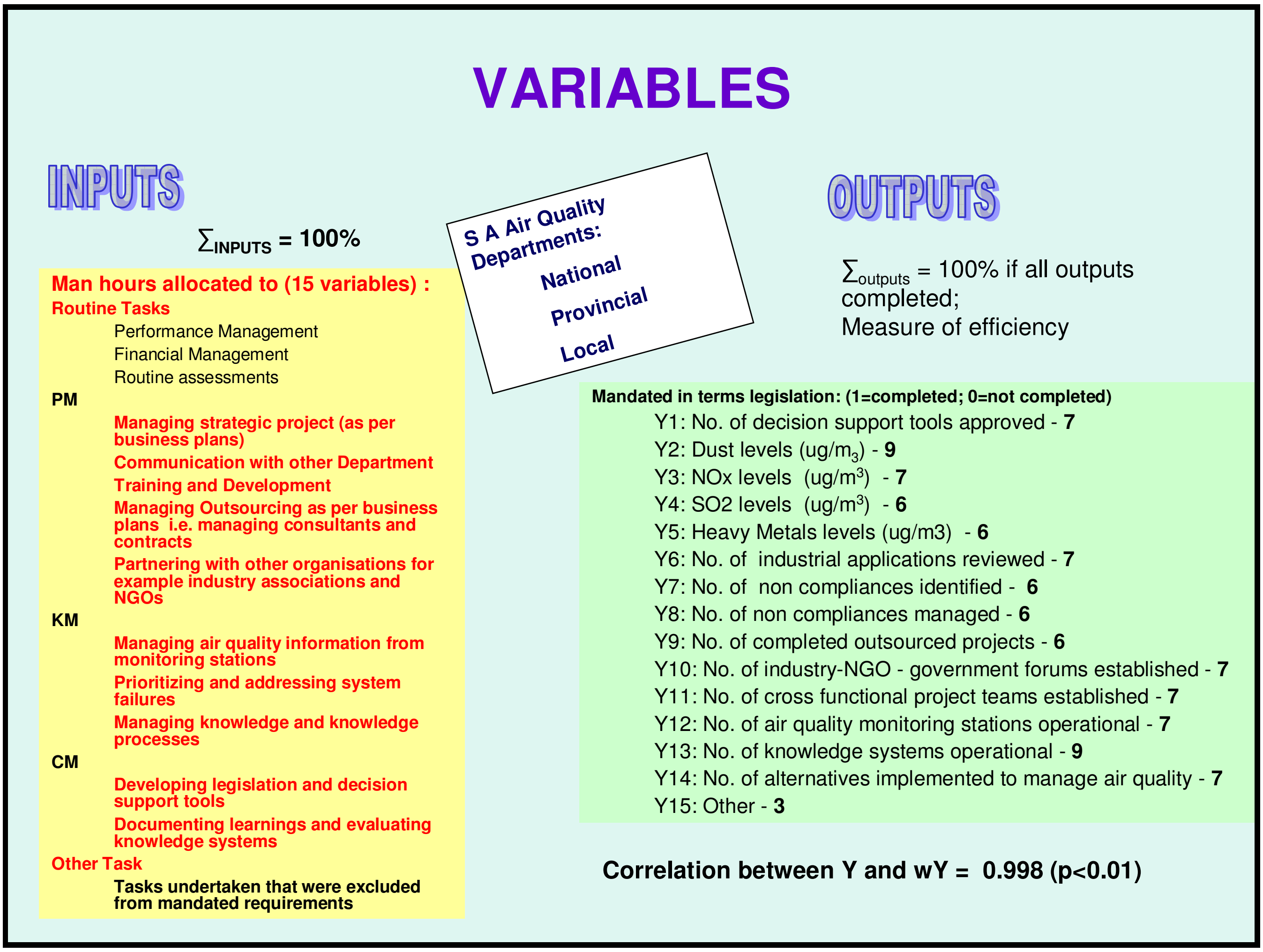


Figure 5.2: Summary of variables used for the model development

5.4 Evaluation of the Research Results

The results obtained from the analyses of the survey questionnaires were presented in Chapter 4. The validity of the survey instrument was confirmed in the pilot survey, and no adjustments to the questionnaire were required.

A 100% response rate was received for the survey questionnaire. The response rate is defined as the percentage of survey invitations that result in a response (Pallant, 2005). A high response rate is the key to legitimising a survey's results. When a survey elicits responses from a large percentage of its target population, the findings are seen as more accurate (Pallant, 2005). This study can therefore claim to be an accurate reflection of input activities and output performance of the air quality units in South Africa.

The excellent response rate of the survey can be attributed to the high level of interest in the study among the respondents, and the nature of the questions and instructions. The AQOs were also familiar with the allocation of resources to activities as well as the status or progress on their outputs, as this was required as part of their monthly progress report. The experience and insights of the AQOs (as part of the qualifier requirements – Section 3.5) enabled them to answer the survey questionnaire with ease.

The researcher also established legitimacy with the target population through following formal channels with the support of the DEA. The formal approach helped convince the respondents to participate in the survey. Further, the procedure for conducting the survey and providing feedback was clearly explained. The head of departments of the provincial and municipal departments allowed the AQOs time to fill out the questionnaire, which sent a positive message that their opinions were valued and led to honest, timeous and useful responses.

The reliability of the research was demonstrated by the complete responses received from the AQOs. The complete responses were primarily due to the methodology being well documented and the data requirements being customised to the participants' area of expertise. In addition, since the interviewees had an in-depth knowledge of the research field, there is a good chance that the same results will occur in repeat studies.

The results from the analyses of the responses from the 228 AQOs were clear: not all Air Quality Units were performing efficiently, and there were violations to the normal distribution in the data sets. Table 4.1 indicated that for both the 2005/06 and 2006/07 financial years, less than 50% of the target population (N=228) had output efficiencies that were greater than 10%. The poor output efficiency of these AQOs fully justified the establishment of a resource allocation model in the South African air quality context.

A subset of the data was selected for the model development, which excluded the responses from the Air Quality Units that were performing below 10%, as discussed in Section 4.5. The Air Quality Units with output efficiency of 50% or more were defined as being efficient, while those with an output efficiency of at least 10 but less than 50% were defined as less efficient (*cf.* Section 4.5.1).

The objectives of the study were to (i) identify the inputs that contribute significantly towards efficient Air Quality Units in terms of output efficiency; and (ii) develop a model for the prediction of whether an Air Quality Unit is efficient based on the percentage of time allocated to the following input activities: CM, PM, KM, Routine and Other activities. **The logistic regression analyses approach (Chapter 4) provided an elegant solution to the research objectives.**

5.4.1 Developing a Model: Objective 2

The '*best*' regression model was developed in stages, as detailed in Section 4.6. The sample sizes (n=103 for 2005/6 and n=104 for 2006/7) were deemed sufficient due to being larger than those recommended by Greenland, Schwartzbaum and Finkle (2000) and Cox and Snell (1989) for statistical representivity (10 samples for each independent variable and ten for each coefficient generated).

> The model, including the independent variables, correctly predicted 89% of the cases overall, which was a good fit.
>
> The result was repeated for the 2006/07 data set, which indicated that the model developed was a robust model.

One of the benefits of using this technique was that it produced a parsimonious model. A parsimonious model is a model with as few parameters as possible for a given quality of a model and that leads to unambiguous and unequivocal predictions (Goldratt, 1992). This satisfied the requirements of Objective 2.

> For both the 2005/6 and 2006/7 years, the logistic regression models fitted to the data indicated that the categorised variable KM and the scale variable Other activities contributed significantly towards the prediction of an air quality unit being efficient.

5.4.2 Inputs that contribute significantly toward efficient Air Quality Units: Objective 1

The model fit (based on both the 2005/6 and 2006/7 data) was graphically illustrated in Chapter 4 (Table 4.17). The relationship between the parameters of interest was established as follows:

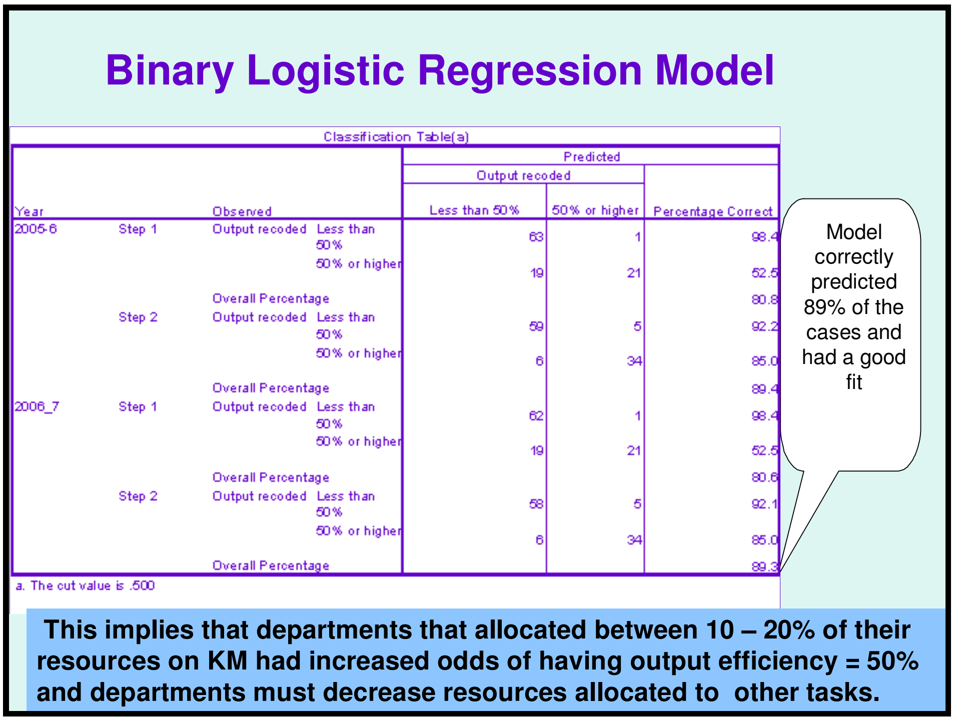
- **a direct** relationship between output efficiency and the amount of man-hours spent on KM (10–20%); and
- an **indirect relationship** between output efficiency and Other activities (<10%).

KM activities included activities that related to managing air quality information from monitoring stations prioritizing and addressing system failures; and managing knowledge and knowledge processes. Other tasks were activities that were outside the mandates of the AQOs and included **r**eviewing housing development impact studies and addressing public nuisance complaints. This satisfied the requirements of Objective 1.

The major drawback of the existing models and management frameworks is that they have not been tested empirically (Jupp & Younger, 2004). The resource allocation model developed in this study was able to define the relationships between the parameters under investigation and was therefore able to overcome this limitation. The study can indeed be deemed a valuable addition to the current body of literature on models.

5.5 Implications of the Findings

We can conclude that we know more about the application domain and the functioning of the binary logistic model in the South Africa Air Quality context. Another result of the model was that we now know more about the concept of output efficiency and the relationship between KM and efficiency. Thus, the research design of this study worked. In addition, statistically significant and complete responses were provided for study Objectives 1 and 2 as summarised in Figure 5.3.



Classification Table(a)

Year		Observed		Predicted: Output recoded: Less than 50%	Predicted: Output recoded: 50% or higher	Predicted: Percentage Correct
2005-6	Step 1	Output recoded	Less than 50%	63	1	98.4
			50% or higher	19	21	52.5
		Overall Percentage				80.8
	Step 2	Output recoded	Less than 50%	59	5	92.2
			50% or higher	6	34	85.0
		Overall Percentage				89.4
2006_7	Step 1	Output recoded	Less than 50%	62	1	98.4
			50% or higher	19	21	52.5
		Overall Percentage				80.6
	Step 2	Output recoded	Less than 50%	58	5	92.1
			50% or higher	6	34	85.0
		Overall Percentage				89.3

a. The cut value is .500

Figure 5.3: Research findings for the logistic regression analyses

This study was the first to quantify both the inputs and outputs of Air Quality Units and establish the relationship between these. The model fitted to the data for the years 2005/6 and 2006/7, albeit heuristic, was a valuable first step towards identifying the key drivers of output efficiency within the Air Quality Units. The model highlights the importance of allocating sufficient man-hours to KM activities: the likelihood of completing at least 50% of targeted outputs decreased if either too few man-hours (less than 10%) or too many man-hours (more than 20%) were spent on KM activities. Furthermore, the more man-hours spent on activities not directly related to KM, CM, PM or routine activities, the lower the likelihood of reaching at least 50% of targeted outputs. Hence, in order for a department to reach at least 50% of its targets, there should be a careful balance between the various activities the department undertakes.

A further output of the study was the development of a methodology that was applicable to measuring output efficiency. Indeed, the findings may inform other government departments and industry in general on a methodology to measure both inputs and outputs.

The parsimonious model developed in this study allows leaders the ability to increase the probability of output efficiency of their Air Quality Units by:

- understanding their mandated outputs;
- allocating 10–20% of the total man-hours to KM;
- allocating less than 10% of resources to other activities outside the objectives of the Air Quality Unit;
- applying the principles of PM and CM; and
- empowering and capacitating their staff.

Proper management of air quality in terms of the Air Quality Units' mandates must be encouraged through the following activities:

- Greater understanding of the definition of performance efficiency in terms of using the desired outputs (Murray, 2000) to define the allocation of resources to inputs and working towards planned targets (Webster, 2003; McCourt, 2005);
- Securing commitment from top management to operate as a PM learning organisation (Englund, Graham and Dinsmore, 2003), and developing and sustaining interdisciplinary project teams both within the Air Quality Unit and across the different spheres (Quassim, 2005);
- Coordinating efforts and exchanging technical information among different Air Quality Units, industry sectors and NGOs to establish a comprehensive air quality knowledge system;
- Emphasising the need within Air Quality Units to prioritise and address systems failures and share lessons learnt;
- Increase focus on developing a '*collective brain*' within government (Rwelamila, 2007: 60) through an improved learning network system that would support the planned change in policies, institutional arrangement and behaviours within the Air Quality Units;
- Clearly defining the other tasks that must be undertaken and minimising these tasks to less that 10% of the Air Quality Units allocated resources.

The outcomes from the process included:

- An improved understanding of the variation in public sector performance in the different spheres over man-hours; and
- A sound and connected basis for planning and budgeting for the public service. De Geus (1997:55) asserted that '*planning was the catalyst*' for efficient decision-making and enabled '*acting*' on systems failure.

The authorities must address potential systems failure through defining responsibilities as follows:

- determine KM requirements;
- enable air quality data collection through the purchase and maintenance of monitoring stations;
- embed knowledge in targeted processes;
- verify and validate knowledge;
- oversee knowledge reuse;
- monitor knowledge transfer; and
- create infrastructure for the preceding responsibilities.

An additional limitation of the study was that the resource allocation model was fitted with data from Air Quality Units that were performing at above 10% efficiency *i.e.* more than two of the 15 mandated outputs were completed. The model therefore cannot be used for Air Quality Units that have an output efficiency of less than 10%.

5.6 Contribution of the Study to Leadership

This study developed a much quicker method for AQOs to allocate resources. Through using the data generated from the AQOs, this study demonstrated the first use of logistic regression analyses for the calculation of output efficiency based on the mandates of the Air Quality Units.

This study presents a new model for determining optimal output efficiency of Air Quality Units in South Africa. The model was also validated with data from a different financial year. The model developed in this study provides an elegant approach to the allocation of resources compared to the current process where AQOs are only provided with mandated outputs through legislation, and there are no guidelines to improve output efficiency. Consequently, this work will be helpful for AQOs as part of their planning and budgeting processes.

The study by Ehrlich *et al.* (1999) on knowledge and the environment concluded that future increases in knowledge would, more or less automatically, alleviate or even eliminate future environmental problems. They highlighted the point that the major obstacle that prevented knowledge from alleviating environmental impacts was not having the necessary tools to put general theoretical solutions into practice. Riege and Lindsay (2006) indicated that there was little research and few guidelines on how governments in practice could use KM to be efficient. The model developed can assist in closing the gaps identified.

Kanter and Walsh's (2004) work on improving organisational efficiency within government revealed that KM was critical for output efficiency. This study supported the work of Kanter and Walsh (2004), but added that there is a positive relationship between KM and output efficiency. The amount of resources to be allocated to KM can be quantified using the methodology developed in this study.

Chafe *et al*. (2010) asserted that by improving the understanding of the extent to which key contextual factors could impact on resource allocation, more viable reforms could be developed to achieve outputs. Chafe *et al*. (2010) stated that there was no single correct way to allocate resources and no perfect model. What was required for the public sector was a model that was comprehensible to non-specialists and acceptable to practitioners, politicians and the general public. The model proposed in this study has the capacity to meet these requirements.

Further, this study facilitates the change required to develop and capacitate the AQOs as part of government's priority skills programme (DPSA, 2006):

- All spheres of government must secure the well-being of their people and must function optimally; and
- Government needs to inculcate an active learning culture where learning champions are recognised and sharing experiences encouraged.

The organisational strategy for the project-oriented air quality units must be management by projects. PM must be the preferred process, and the organisational structure must take the form of project teams. Partnering with other organisations must also be encouraged.

5.6.1 Decision-Making Implications for Air Quality Units

The data collected from the AQOs, as shown in Annexure 2, confirmed that less than 30% of their time was spent on routine activities. Table 4.4 revealed that for Air Quality Units with 10% or more output efficiency, an average of 22.05% for 2005/06 and 21.9% for 2006/07 of man-hours was spent on routine activities. This implied that more than 70% of their time was spent on project-type activities. This confirmed the need for a project-oriented organisational approach (Gareis, 2006) to be adopted by the Air Quality Units (*cf.* Section 2.2.5).

Mankins and Steele (2005) highlighted the point that understanding the allocation of resources was important to organisations in both the planning and implementation phases. Further allocation of resources within the Air Quality Units was a challenging task due to the lack of decision support tools (Lukey, 2007). The study assisted the AQOs in systematically identifying the contributors to output efficiency, quantifying the number of man-hours to be allocated to their input activities and ultimately calculating their output efficiency. The output efficiency calculations were simplified as follows:

- The process of weighting the outputs was not required as the unweighted outputs had a good fit to the weighted outputs; and
- KM resource allocation requirements were clearly defined.

The parsimonious and robust model developed in this study can therefore be used to assist AQOs to become efficient.

The model allows policy- and decision-makers to allocate resources to the two critical areas for improved output efficiency, *i.e*. KM and other activities. At present, such an explicit classification for the allocation of resources to KM and other inputs is not practised. The implication of these contributions is that by using the model developed in this study, Air Quality Units can be more efficient, and they will achieve this by limiting the man-hours spent on non-core matters.

Further, the application of the model by public sector managers demands that resources allocated to the input factors are quantified and the factors that support improved output efficiency understood.

The model developed supports the crossing of boundaries between different fields of study by integrating literature from various theoretical disciplines, *viz*. PM, KM and CM, to enable academics and practitioners to work in interdisciplinary groups.

5.7 Application of the Model

The model allows for predicting the classification of Air Quality Units as either <50% or ≥50% efficient. In 2005/06 and 2006/07, 89% of the cases were correctly predicted based on the following variables:

- Number of man-hours spent on other activities; and
- The category allocation for KM, i.e. 10–20% of resources allocated to KM.

The model showed that the probability of output efficiency increasing to greater than 50% was significant if 10–20% of man-hours were allocated to KM. The probability decreases if Air Quality Units spend more man-hours on other tasks.

Riege and Lindsay (2006) expressed concerns that there was little research and few guidelines on how governments in practice could use KM to be efficient (Section 2.3). The specific guideline that this study offers the Air Quality Units is: in order to increase output efficiency, allocate 10–20% of the units' man-hours to KM. The specific activities involved in KM in the air quality context were as follows:

- Setting up and maintaining monitoring stations for managing air quality information;
- Prioritising and addressing system failures; and
- Managing knowledge (centralised reporting system, updating performance indicators).

To establish the impact of allocating resources to other activities, the logistic curve equation from the binary regression model was used. The plot of the resources allocated to other tasks versus the probability of performing above 50% output efficiency is shown in Figure 5.4. The trends indicate that as resources are allocated to other tasks, the probability of output efficiency greater than or equal to 50% decreases. Further, as the man-hours allocated to other inputs exceed 10%, the decrease is more pronounced. This implies that Units must aim to spend less than 10% of their man-hours on other outputs.

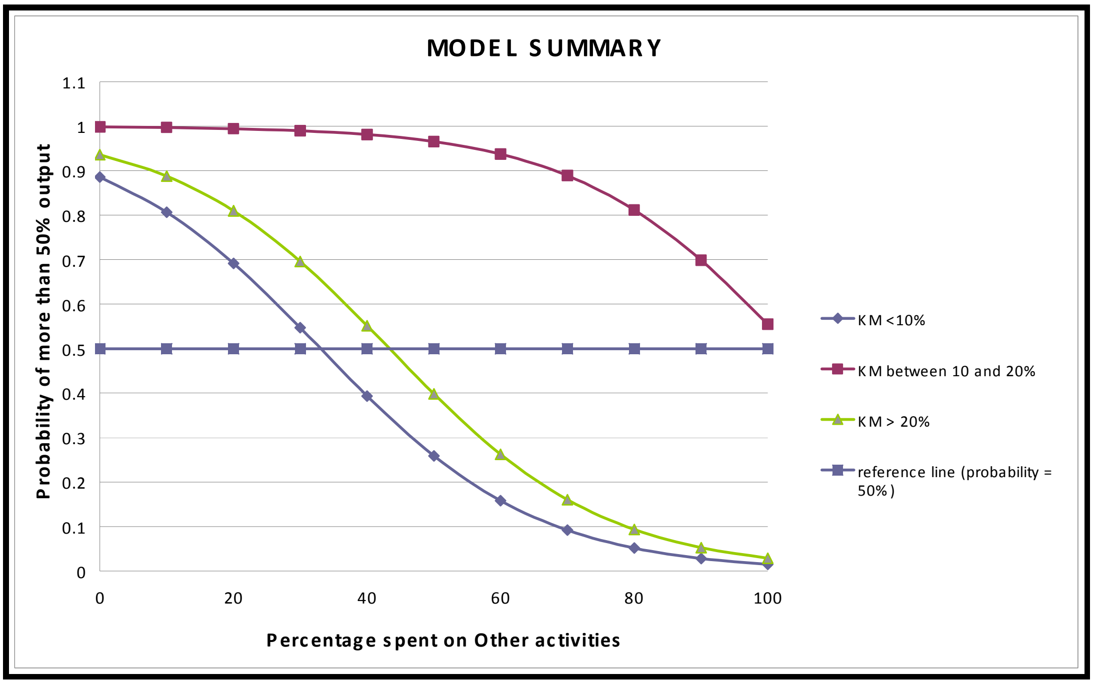


Figure 5.4: Plot of resources allocated to other activities

The managerial implications of parsimonious elements of the model include the managers being able to increase the probability of output efficiency of their Units by:

- Understanding only the mandated outputs that are required and working with unweighted values;
- Allocating 10–20% of the total man-hours of the resources for managing air quality to KM;
- Allocating less than 20% of resources to other activities outside the objectives of the Air Quality Units;
- Appling the principles of PM and CM;
- Empowering and capacitating their staff.

For the purpose of applying the model within the Air Quality Units, the relationship between the resources allocation model and the output efficiency was displayed in a non-statistical representation (*cf.* Figure 5.5).

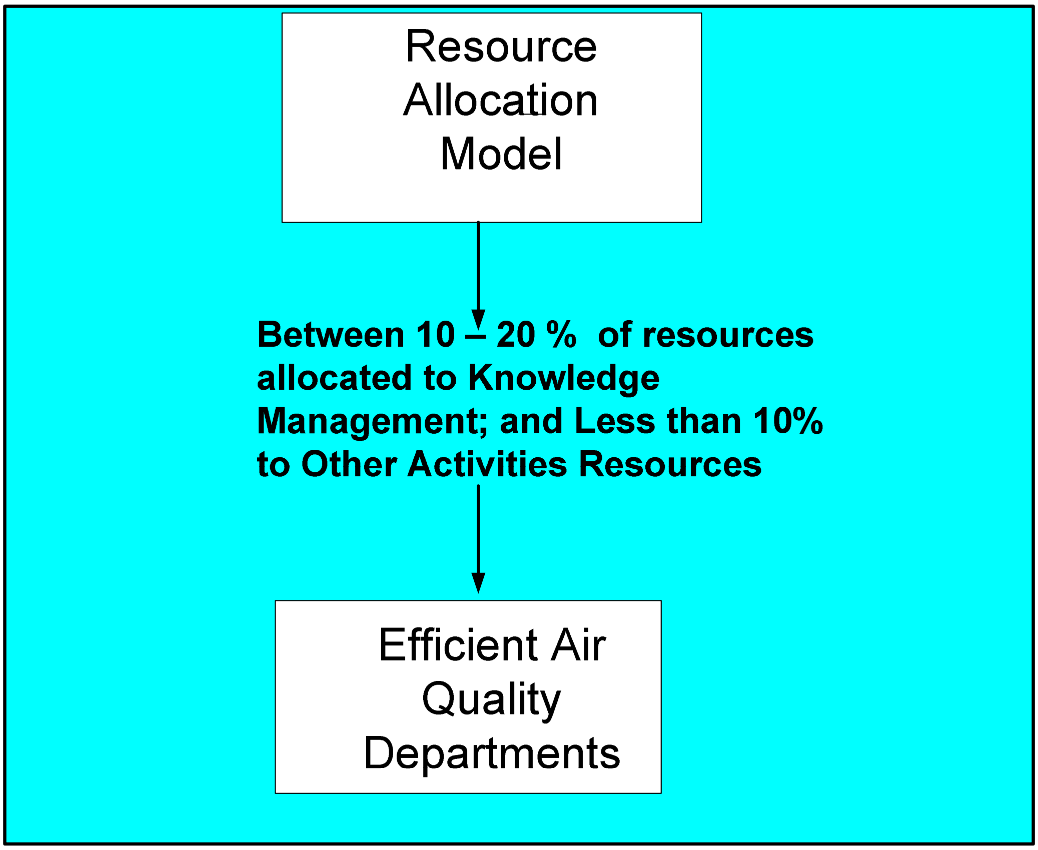


Figure 5.5: Non-statistical representation of the model developed

As regards the use of the model developed as an institutional driver to contribute towards improved efficiency within Air Quality Units, the following potential improvement exists:

- improving the setting of objectives by the Air Quality Units: the model provides a mechanism that enables AQOs to clarify objectives. It proves a useful tool for setting priorities over the short and medium term and can clarify what results are expected from the Air Quality Units.

- improving the monitoring of performance: the model may act as a signalling device. The national AQO is provided with a mechanism for monitoring the provincial and local Air Quality Units' performance and progress. The model can therefore act as a signalling device that highlights problems with projects, as well as good practices. Once a problem or poor performance is identified, different steps can be taken to improve performance. Best practices can also be shared.
- greater emphasis on planning: the application of the model will result in improved planning and a move towards outcome focus in policy design and delivery. The emphasis on planning will help the Air Quality Units to become more systematic. Furthermore, the model provides a clear and logical design that ties resources and activities to expected results.

It must be noted that the statistical analysis for this study was limited by the number of organisations in the South African Air Quality Units (viz. 228 units), and the resource allocation model being developed with data from departments that were performing at 10% efficiency and above i.e. more than two of the mandated outputs were completed. The model therefore cannot be used for departments that have an output efficiency of less than 10%.

5.8 Conclusion

The resource allocation model was able to predict with a high degree of accuracy the output efficiency of the Air Quality Units based on actual resources allocated to PM, CM and KM. This provides a firm guideline for Air Quality Units in South Africa to increase their output efficiency and ultimately improve air quality. The model also showed that efficiency in the Air Quality Units could be encouraged through the following activities:

1. Greater understanding of the definition of performance efficiency in terms of using the desired outputs to define the allocation of resources to inputs and working towards planned targets;
2. Securing commitment from top management to operate as a PM learning organisation and developing and sustaining interdisciplinary project teams both within the departments and across the different spheres;
3. Coordinating efforts and exchanging technical information among different departments, industry sectors and NGOs to establish a comprehensive air quality knowledge system;
4. Emphasising the need within departments to prioritise and address systems failures and share lessons learnt within the entire air quality regime;
5. Increasing the focus on developing a 'collective brain' within government through an improved learning network system that would support the planned change in policies, institutional arrangement and behaviours within the air quality regime;
6. Allocating 10–20 % of their resources to KM activities; and
7. Clearly defining the 'Other tasks' that must be undertaken, and minimising the resources allocated to these tasks.

A major output of the study is that more is now known about the concept of public sector output efficiency, its different interpretations and the relationship between KM and output efficiency in the South African public sector. The main contribution is the methodological application of the logistic regression model to the Air Quality Units in South Africa. In addition, the study provides a novel methodological approach to test for efficiency in organisations, which can be extended into other fields based on an understanding of the inputs and outputs of the organisations.

5.9 Suggestions for Future Areas of Research

It is anticipated that future work will extend the current approach to include other public sector departments and private sector organisations in South Africa. In addition, the model should be tested with data from other countries – both in Africa and further afield – so that a broad comparison of the allocation of resources to KM and to *other* resources can be made and its impact on output efficiency understood.

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ANNEXURE 1: SURVEY QUESTIONNAIRE

Researcher: Urishanie Govender

Degree: Doctorate in Business Leadership – UNISA

- The aim of the research is to develop a model that will improve resource allocation in the public sector

- The model will evaluate public sector inputs with the view to optimise and improve output efficiency.

The designated Air Quality Officer in the Department must please respond to the questions.

Please only complete the green cells.

Section 1: Air Quality Officer and Air Quality Unit Details

Name of respondent				
Department Name				
Number of years in the Air Quality Unit				
Sphere of Government				
Total Number of Staff in Department	05/06		06/07	
Total Number of staff in the Air Quality Unit	05/06		06/07	
Number of **management** staff	05/06		06/07	
Average hourly compensation rate	05/06		06/07	
Number of **non-management** staff	05/06		06/07	
Average hourly compensation rate	05/06		06/07	

Financial Year Total Budget	Total Compensation for Personnel		Total Goods and Services		Total Other	
	B	A	B	A	B	A
2005/06						
2006/07						
Financial Year Budget for Air Quality Units	Compensation for Personnel		Goods and Services		Other	
	B	A	B	A	B	A
2005/06						
2006/07						

B- Budgeted; A- Actual Spend

Section 2: Inputs into the Model

Financial Years	2005/06	2006/07	Comments
Man-hours to perform routine tasks			
Man-hours spent on managing strategic project (business plans)			
Man-hours spent on air quality monitoring stations (1) setting up (2)maintaining			
Man-hours spent on developing legislation and decision support tools			
Man-hours spent on documenting learnings			
Man-hours spent on Communication with other Department			
Man-hours spent on Training and Development			
Man-hours spent on managing Outsourcing			

Financial Years	**2005/06**	**2006/07**	**Comments**
Man-hours spent on prioritising and addressing system failures			
Man-hours spent on Partnering with other organisations			
Man-hours spent on centralised reporting system			
Other input activities			

End of Section 2

<u>Section 3:</u> **<u>In this part, the researcher would like to obtain information on the outputs of the Air Quality Units</u>**

Financial Years	2005/06	2006/07	Comments
Air quality indicators (Annual averages)			
• Dust levels (ug/m^{3})			
• NOx levels (ug/m^{3})			
• SO_2 levels (ug/m^{3})			
Number of industrial applications reviewed			
Number of non-compliances: Identified Managed			
Number of completed outsourced projects			
Number of industry-NGO-government forums			
Number of cross-functional project teams			
Number of operational air quality monitoring stations			

Financial Years	2005/06	2006/07	Comments
Number of knowledge systems operational (air quality, industry application database etc)			
Number of cleaner alternatives implemented to manage air quality			
Other Outputs			

End of Section 3

<u>Section 4:</u> **<u>The last section of the questionnaire will evaluate the allocating weights to priorities and other information from the respondents</u>**

Please comments on the allocation of weights to the outputs in the Air Quality Unit.

Please comment on the applicability of the proposed model to your Unit and Department.

Please add any other aspect that you think should be addressed by the proposed model.

Any further contributions from the respondent.

The researcher wishes to thank you for your time and valuable contribution.

Urishanie Govender

ANNEXURE 2: DATA SET USED IN LOGISTIC REGRESSION

DATA SETS USED IN BINARY LOGISTIC REGRESSION ANALYSES														
TEST DATA							N	HOLD DATA						
Year	% y	Routine	PM	KM	CM	Other		Year	% y	Routine	PM	KM	CM	Other
2005/06	100%	21%	48%	13%	12%	6%	1	2006/07	100%	20%	51%	12%	15%	2%
2005/06	100%	24%	31%	22%	7%	16%	2	2006/07	100%	23%	32%	22%	7%	16%
2005/06	93%	32%	43%	11%	10%	3%	3	2006/07	93%	33%	37%	13%	10%	8%
2005/06	93%	23%	9%	16%	2%	50%	4	2006/07	93%	23%	9%	16%	2%	50%
2005/06	93%	32%	43%	11%	10%	3%	5	2006/07	93%	33%	43%	11%	11%	2%
2005/06	93%	24%	32%	22%	7%	15%	6	2006/07	93%	24%	32%	22%	7%	16%
2005/06	93%	31%	31%	21%	12%	5%	7	2006/07	93%	27%	31%	23%	10%	9%
2005/06	87%	23%	9%	16%	2%	50%	8	2006/07	87%	23%	9%	16%	2%	49%
2005/06	87%	24%	31%	22%	7%	15%	9	2006/07	87%	24%	31%	22%	7%	15%
2005/06	87%	23%	9%	16%	2%	50%	10	2006/07	87%	23%	9%	16%	2%	50%
2005/06	87%	32%	43%	11%	10%	3%	11	2006/07	87%	32%	43%	11%	10%	3%
2005/06	87%	23%	9%	21%	2%	45%	12	2006/07	87%	24%	9%	22%	2%	42%

TEST DATA							N	HOLD DATA						
Year	% y	Routine	PM	KM	CM	Other		Year	% y	Routine	PM	KM	CM	Other
2005/06	80%	2%	1%	1%	0%	96%	13	2006/07	80%	2%	1%	1%	0%	96%
2005/06	80%	23%	9%	16%	2%	50%	14	2006/07	80%	23%	9%	16%	2%	50%
2005/06	80%	13%	44%	31%	7%	5%	15	2006/07	80%	13%	44%	31%	7%	5%
2005/06	80%	23%	9%	16%	2%	50%	16	2006/07	80%	23%	9%	17%	2%	49%
2005/06	80%	23%	9%	16%	2%	50%	17	2006/07	80%	23%	9%	16%	2%	50%
2005/06	80%	33%	43%	11%	10%	2%	18	2006/07	80%	33%	43%	11%	11%	3%
2005/06	80%	13%	26%	31%	7%	23%	19	2006/07	80%	13%	26%	31%	7%	23%
2005/06	80%	27%	46%	16%	7%	4%	20	2006/07	80%	27%	46%	16%	7%	4%
2005/06	80%	23%	47%	10%	8%	12%	21	2006/07	80%	23%	45%	10%	7%	15%
2005/06	80%	45%	23%	20%	5%	7%	22	2006/07	80%	43%	23%	20%	6%	8%
2005/06	73%	23%	9%	16%	2%	50%	23	2006/07	73%	23%	9%	16%	2%	50%
2005/06	73%	13%	44%	31%	7%	5%	24	2006/07	73%	13%	44%	31%	7%	5%
2005/06	60%	52%	19%	24%	2%	2%	25	2006/07	60%	53%	20%	24%	2%	1%
2005/06	60%	29%	10%	1%	2%	58%	26	2006/07	60%	30%	10%	1%	1%	57%
2005/06	60%	40%	33%	14%	2%	11%	27	2006/07	60%	40%	34%	15%	2%	9%

TEST DATA							N	HOLD DATA						
Year	% y	Routine	PM	KM	CM	Other		Year	% y	Routine	PM	KM	CM	Other
2005/06	60%	40%	34%	14%	2%	11%	28	2006/07	60%	41%	34%	14%	2%	9%
2005/06	60%	40%	33%	13%	2%	12%	29	2006/07	60%	39%	34%	14%	2%	12%
2005/06	60%	36%	33%	13%	2%	16%	30	2006/07	60%	36%	35%	14%	2%	14%
2005/06	60%	52%	20%	24%	2%	2%	31	2006/07	60%	53%	20%	24%	2%	1%
2005/06	60%	40%	33%	14%	2%	12%	32	2006/07	60%	40%	33%	14%	2%	12%
2005/06	60%	40%	33%	14%	2%	12%	33	2006/07	60%	40%	33%	14%	2%	12%
2005/06	60%	53%	20%	25%	2%	1%	34	2006/07	60%	53%	20%	25%	2%	0%
2005/06	60%	40%	33%	14%	2%	12%	35	2006/07	60%	40%	33%	14%	2%	12%
2005/06	60%	52%	19%	24%	2%	2%	36	2006/07	60%	53%	20%	24%	2%	1%
2005/06	53%	45%	13%	6%	0%	35%	37	2006/07	53%	47%	13%	6%	0%	33%
2005/06	53%	45%	13%	6%	0%	35%	38	2006/07	53%	45%	14%	6%	0%	35%
2005/06	53%	45%	13%	6%	0%	35%	39	2006/07	53%	44%	14%	7%	0%	35%
2005/06	53%	52%	20%	24%	2%	2%	40	2006/07	53%	53%	20%	24%	2%	1%
2005/06	47%	2%	21%	23%	1%	52%	41	2006/07	47%	2%	21%	23%	1%	53%
2005/06	47%	1%	50%	26%	3%	19%	42	2006/07	47%	2%	56%	28%	4%	11%

TEST DATA							N	HOLD DATA						
Year	% y	Routine	PM	KM	CM	Other		Year	% y	Routine	PM	KM	CM	Other
2005/06	40%	1%	1%	0%	0%	48%	43	2006/07	40%	1%	1%	0%	0%	48%
2005/06	40%	1%	1%	0%	0%	98%	44	2006/07	40%	1%	8%	0%	0%	90%
2005/06	33%	72%	4%	0%	1%	23%	45	2006/07	33%	72%	4%	0%	1%	23%
2005/06	33%	2%	1%	0%	0%	96%	46	2006/07	33%	3%	1%	0%	0%	96%
2005/06	33%	3%	1%	0%	0%	96%	47	2006/07	33%	3%	1%	0%	0%	96%
2005/06	33%	52%	30%	6%	2%	11%	48	2006/07	33%	50%	30%	6%	1%	13%
2005/06	33%	35%	11%	7%	12%	35%	49	2006/07	33%	35%	11%	8%	12%	34%
2005/06	33%	9%	10%	0%	18%	63%	50	2006/07	33%	9%	10%	0%	18%	63%
2005/06	33%	14%	3%	3%	1%	79%	51	2006/07	33%	15%	2%	4%	1%	77%
2005/06	33%	43%	4%	1%	0%	52%	52	2006/07	33%	42%	4%	1%	0%	52%
2005/06	33%	15%	4%	4%	1%	76%	53	2006/07	33%	15%	3%	1%	0%	81%
2005/06	33%	15%	3%	4%	1%	76%	54	2006/07	33%	15%	2%	1%	1%	80%
2005/06	33%	15%	2%	4%	1%	77%	55	2006/07	33%	15%	1%	1%	0%	82%
2005/06	27%	2%	21%	23%	1%	52%	56	2006/07	27%	2%	21%	23%	1%	52%
2005/06	27%	59%	13%	8%	4%	17%	57	2006/07	27%	59%	13%	8%	4%	17%

TEST DATA							N	HOLD DATA						
Year	**% y**	**Routine**	**PM**	**KM**	**CM**	**Other**		**Year**	**% y**	**Routine**	**PM**	**KM**	**CM**	**Other**
2005/06	27%	23%	7%	3%	0%	67%	58	2006/07	27%	23%	6%	3%	0%	68%
2005/06	27%	23%	6%	3%	0%	68%	59	2006/07	27%	22%	7%	3%	0%	68%
2005/06	27%	22%	7%	3%	0%	68%	60	2006/07	27%	22%	7%	3%	0%	68%
2005/06	27%	23%	7%	3%	0%	68%	61	2006/07	27%	23%	7%	3%	0%	68%
2005/06	27%	2%	21%	23%	1%	53%	62	2006/07	27%	2%	21%	24%	1%	52%
2005/06	27%	2%	21%	23%	1%	53%	63	2006/07	27%	2%	21%	23%	1%	53%
2005/06	27%	23%	9%	16%	2%	50%	64	2006/07	27%	23%	9%	16%	2%	50%
2005/06	27%	9%	10%	0%	15%	66%	65	2006/07	27%	9%	10%	0%	15%	66%
2005/06	27%	9%	10%	0%	18%	63%	66	2006/07	27%	9%	10%	0%	18%	63%
2005/06	27%	12%	1%	8%	2%	77%	67	2006/07	27%	12%	0%	8%	3%	77%
2005/06	27%	3%	21%	2%	1%	73%	68	2006/07	27%	2%	22%	2%	1%	74%
2005/06	27%	63%	12%	1%	5%	19%	69	2006/07	27%	62%	13%	1%	5%	18%
2005/06	20%	2%	21%	23%	1%	52%	70	2006/07	20%	3%	22%	24%	2%	50%
2005/06	20%	2%	21%	23%	1%	53%	71	2006/07	20%	2%	22%	23%	1%	52%
2005/06	20%	3%	21%	23%	1%	52%	72	2006/07	20%	3%	21%	23%	1%	52%

TEST DATA							N	HOLD DATA						
Year	% y	Routine	PM	KM	CM	Other		Year	% y	Routine	PM	KM	CM	Other
2005/06	20%	2%	21%	23%	1%	53%	73	2006/07	20%	2%	21%	23%	1%	52%
2005/06	20%	2%	22%	23%	2%	51%	74	2006/07	20%	2%	21%	23%	1%	53%
2005/06	20%	34%	24%	1%	2%	39%	75	2006/07	20%	35%	24%	1%	3%	36%
2005/06	20%	2%	21%	23%	1%	53%	76	2006/07	20%	2%	21%	23%	1%	53%
2005/06	20%	45%	23%	20%	5%	7%	77	2006/07	20%	45%	23%	20%	5%	7%
2005/06	20%	2%	21%	23%	1%	53%	78	2006/07	20%	2%	21%	23%	1%	53%
2005/06	20%	88%	0%	3%	0%	9%	79	2006/07	20%	88%	7%	3%	0%	2%
2005/06	20%	23%	7%	3%	0%	68%	80	2006/07	20%	23%	7%	3%	0%	68%
2005/06	20%	42%	4%	1%	0%	53%	81	2006/07	20%	42%	4%	1%	0%	53%
2005/06	20%	2%	21%	23%	1%	53%	82	2006/07	20%	2%	22%	23%	1%	53%
2005/06	20%	2%	21%	2%	3%	72%	83	2006/07	20%	2%	21%	2%	3%	73%
2005/06	20%	2%	21%	23%	1%	53%	84	2006/07	20%	2%	21%	25%	1%	51%
2005/06	20%	2%	21%	23%	1%	53%	85	2006/07	20%	2%	21%	23%	1%	53%
2005/06	20%	2%	23%	21%	1%	53%	86	2006/07	20%	3%	21%	23%	2%	52%
2005/06	20%	2%	21%	24%	2%	52%	87	2006/07	20%	3%	21%	23%	1%	52%

TEST DATA							N	HOLD DATA						
Year	**% y**	**Routine**	**PM**	**KM**	**CM**	**Other**		**Year**	**% y**	**Routine**	**PM**	**KM**	**CM**	**Other**
2005/06	20%	2%	21%	23%	1%	53%	88	2006/07	20%	3%	21%	24%	1%	52%
2005/06	20%	2%	21%	23%	1%	52%	89	2006/07	20%	3%	21%	24%	1%	52%
2005/06	20%	2%	21%	23%	1%	53%	90	2006/07	20%	2%	21%	23%	1%	53%
2005/06	20%	2%	21%	23%	1%	53%	91	2006/07	20%	2%	21%	23%	1%	53%
2005/06	20%	17%	54%	8%	0%	21%	92	2006/07	20%	17%	55%	8%	0%	21%
2005/06	20%	29%	11%	5%	6%	48%	93	2006/07	20%	31%	11%	7%	6%	45%
2005/06	20%	15%	1%	0%	0%	83%	94	2006/07	20%	15%	1%	1%	0%	82%
2005/06	20%	44%	4%	1%	0%	50%	95	2006/07	20%	43%	5%	1%	0%	51%
2005/06	13%	3%	1%	0%	0%	96%	96	2006/07	13%	3%	1%	0%	0%	96%
2005/06	13%	9%	10%	0%	18%	63%	97	2006/07	13%	9%	10%	0%	18%	63%
2005/06	13%	44%	4%	1%	0%	51%	98	2006/07	13%	44%	4%	1%	0%	51%
2005/06	13%	2%	21%	7%	1%	69%	99	2006/07	13%	2%	21%	8%	1%	67%
2005/06	13%	2%	21%	6%	1%	70%	100	2006/07	13%	2%	21%	5%	1%	71%
2005/06	13%	2%	21%	6%	1%	70%	101	2006/07	13%	3%	21%	6%	1%	69%
2005/06	13%	3%	2%	0%	0%	94%	102	2006/07	13%	4%	2%	0%	0%	94%

TEST DATA							N	HOLD DATA						
Year	**% y**	**Routine**	**PM**	**KM**	**CM**	**Other**		**Year**	**% y**	**Routine**	**PM**	**KM**	**CM**	**Other**
2005/06	13%	2%	21%	23%	1%	52%	103	2006/07	13%	2%	21%	23%	1%	53%
2005/06	13%	24%	4%	4%	0%	68%	104	Data not used						