IDENTIFICATION OF THE CRITICAL SUCCESS FACTORS FOR PUBLIC-FUNDED R&D PROJECTS IN SOUTH AFRICA

A Research Report presented to the
Department of Construction Economics and Management in partial fulfilment of the requirements for the degree MSc in Project Management

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ACKNOWLEDGEMENTS

I would like to acknowledge and thank the following individuals who have helped me make this very challenging process of completing this research work a success:

- Dr Nien-Tsu Tuan - Supervisor from UCT, for your guidance and patience;
- All the research participants, for volunteering your precious time;
- My family, particularly my husband and my boys, for providing me with unfailing support, patience and continued encouragement.

Thank you

ABSTRACT

South Africa (SA) is classified as a middle-income emerging market, with the most resource-rich economy in Sub-Saharan Africa (SAccess, 2012). Its Research and Development (R&D) journey is characterised by a history of imbalances and oppression. Since the introduction of SA's National R&D Strategy, recorded government R&D spending has been on the rise. However, the success rate for public-funded R&D projects has neither been satisfactory nor readily exposed for all to see. Factors considered critical for project success are largely contextual and tend to differ per project and industry. There appears to be no general consensus among scholars and authors on the common factors deemed critical in influencing the success of public-funded R&D projects. In SA, such factors still remain a mystery for further exploration. This research study sought to develop a model that will assist in achieving two key objectives, namely to identify the Critical Success Factors (CSF) of public-funded R&D projects in SA, as well as to exhume possible interrelationships between the identified critical success factors.

This paper argues for a systemic and structure-based holistic approach and adopts Warfield's Interactive Management (IM) in its endeavour to identify those factors that are deemed critical in the successful implementation of public-funded R&D projects in SA. The methodology comprises three key phases: a planning phase; a workshop phase; as well as a follow-up phase. The planning phase is a foundational phase that lays the basis and a plan for the ensuing two phases. The workshop, also known as the conversation phase, could be conceptualised as a process for building patterned interactions among the participants. It is in this phase that a relationship model, in the form of a diagraph, is constructed. The follow-up phase is the last phase and involves the implementation of the results to prove validity of solutions proposed in the workshop phase. However, since this last phase falls outside the scope of this paper, it has been excluded.

Through the application of the IM methodology, a total of 35 identified CSFs were reduced to 23 key to formulate the CSF relationship model using the Interpretive Structural Model (ISM). Based on the model results, the study is concluded by identifying "Product market viability" and "Executive management support" as the two primary success factors that are most significant and have the greatest leverage to influence other factors towards the successful completion of public-funded R&D projects in SA.

Keywords: Systemic Thinking; Interactive Management (IM); Research & Development (R&D); Critical Success Factors (CSFs).

CONTENTS

List of Abbreviations

CEO	Chief Executive Officer
CSF	Critical Success Factor
DST	Department of Science and Technology
DTI	Department of Trade and Industry
GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure on R&D
IM	Interactive Management
IDC	Industrial Development Corporation
ISM	Interpretive Structural Model
KSF	Key Success Factor
MIS	Management Information Systems
NGT	Nominal Group Technique
NPD	New Product Development
NRF	National Research Foundation
PBMR	Pebble Bed Modular Reactor
PGM	Platinum Group Metal
R&D	Research and Development
SA	South Africa
TIA	Technology Innovation Agency
TYIP	Ten-Year Innovation Plan
SANDF	South African National Defence Force

List of Tables

List of Figures

List of Annexures

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

1.1.1 Brief history of R&D in South Africa

South Africa (SA) is classified as a middle-income emerging market with the most resource-rich economy in Sub-Saharan Africa (SAccess, 2012). Its R&D journey is characterised by a history of imbalances and oppression, where resources were directed to benefit only a selected few – less than eight million people from among a population in excess of fifty million. Prior to 1994, the apartheid government decided to terminate its key technology missions, resulting in a drop in national R&D spending from 1.1% of Gross Domestic Product (GDP) in 1990 to 0.7% in 1994 (SAGovernment, 2002). The election of a new democratic government in 1994 meant the takeover of a somewhat chaotic governance system of science and technology (SAGovernment, 2002), which required an expeditious turnaround strategy to cater for the needs of all South Africans (SAGovernment, 2002).

The South African government, through its Department of Science and Technology (DST), is mandated by the 1996 White Paper on Science and Technology to promote science and innovation by funding R&D at public research institutes and universities. The DST's aim is to intensify R&D expenditure in order to improve SA's economic competitiveness based on the proclaimed correlation between R&D intensity and economic competitiveness (SAccess, 2012; Mustapha *et al.*, 2015; Walwyn and Cloete, 2016).

In 2002, SA's National R&D strategy was developed to be a key enabler of economic growth (SAGovernment, 2002), making SA government a key player in R&D funding since 2003 (Walwyn and Cloete, 2016) and a major R&D expender in its region. In 2005, Africa accounted for 0.7% of the world share of R&D expenditure, with SA representing 0.5% of the region's share (SAccess, 2012). In the period 1999 to 2008, SA dominated the scientific publication scene on the African continent with 47 000 published papers, whilst in the same period, Egypt produced 30 000 papers and Nigeria 10 000 (NHLS, 2010; SAccess, 2012)

In 2008, the DST adopted its Ten-Year Innovation Plan (TYIP), which, supported by other departments, aims to drive SA's transformation towards a knowledge-based economy (SAGovernment) by promoting focus and specialisation in the R&D sector (Walwyn and Cloete, 2016).

The TYIP 2008-2018 vision is based on the following aspirations (SAGovernment; SAccess, 2012):

- Be one of the top three emerging economies in the global pharmaceutical industry, based on an extensive innovation system that utilises the nation's indigenous knowledge and rich biodiversity
- Deploy satellites that provide a range of scientific, security and specialised services for the government, the public, as well as the private sector
- Be a diversified supplier of secured and sustainable energy
- Achieve a 25% share of the global hydrogen and fuel cell catalysts market with unique Platinum Group Metal (PGM) catalysts
- Be a world leader in climate science and in responding to climate change
- Meet the 2014 millennium Development Goal to reduce poverty by half

Based on the premise that R&D projects in SA are mainly funded by government, when referring to R&D projects in SA in the remainder of this paper, the inference will be to the public-funded R&D projects in SA.

1.1.2 Overview of South African R&D expenditure

Since the introduction of SA's National R&D Strategy in 2002, recorded government R&D spending has been on the rise, with increases in budget appropriations over the 2003-2012 period of 214% in real terms and 385% in nominal terms. In the same period, such increases were also reflected in the risen public funding of R&D projects from 28% to 45% of Gross Domestic Expenditure on R&D (GERD), making government a dominant source of funds (Walwyn and Cloete, 2016). Whilst the 2014/2015 survey shows 43.9% of GERD funding, which is slightly less than the previously recorded 45%, Government still remains the largest R&D funder with plans of doubling the annual 2014/2015 R&D investment of R29 billion to approximately R60 billion by year 2020 (Mail&Guardian, 2017). Such targets are in line with the Government's Medium-Term Strategic Framework (2014-2019), which includes a policy target that GERD should be increased to 1.5% of GDP in order to support growth and development (HSRC, 2014).

The South African business R&D spending has, however, taken the opposite direction to that of Government. The reasons behind this decease are not clear, but appear to be linked to the global financial crisis and declining business confidence in the economy. The latter manifests itself in a variety of ways, including in a general reluctance to invest in R&D (Mustapha *et al.*, 2015; Walwyn and Cloete, 2016). This situation presents an ongoing problem for Government, which requires an urgent novel solution (Walwyn and Cloete, 2016). It has consequently introduced the R&D tax incentive to encourage private sector spending on R&D, thereby increasing economic growth (Nicolaides, 2014; Mustapha *et al.*, 2015) and related commercial opportunities by creating new products and services, and improving on the old. Such activities are hoped to result in the creation of new enterprises, new industries and new jobs, which would ultimately lead to economic growth (Mail&Guardian, 2017).

1.1.3 A brief overview of public-funded R&D projects in South Africa

Generally, the results for public-funded R&D projects that have not achieved or that struggle to achieve their set goals are not readily exposed for all to see (Yamazaki *et al.*, 2012). This is based on the assumption that due to high public expectations from these projects, they are expected to succeed against all odds (Yamazaki *et al.*, 2012).

This section highlights a number of randomly selected, prominent R&D projects in SA that have failed to meet expectations. The significant amount of monetary, time and other resources ploughed into these projects could have been invested in other fruitful initiatives geared toward economic growth and the upliftment of the lives of the people of SA. These projects have not adequately achieved their intended goals, and there is no clear consensus on the reasons behind their disappointing results. Possible explanations include lack of government support; lack of political support; lack of project management; lack of community buy-in; introducing the project at the wrong time; ethical issues; and many others. The results of these projects and the varying reasons behind them are both a great concern and an incentive for probing into the CSFs of public-funded R&D projects in SA. Learning from our mistakes may influence the success of upcoming projects of a similar nature.

- **The Rooivalk: SA's attack helicopter**

Based on the 1976 study, the Rooivalk project was initiated by Denel Aviation of SA in 1984 (Campbell, 2007; Engelbrecht, 2010) to develop an attack helicopter. It was to be operated in a high-threat environment similar to the Southern African Cold War, but the latter never materialised due to the country's transition to democracy (Engelbrecht, 2010; Shear, 2013). The project costs remain vague at approximately $1 billion, which was estimated to equal R7 billion at the time of its first prototype in 1990 (Campbell, 2007). This figure increased to R8.1 billion in 2010 and 2011 reports (Engelbrecht, 2010; 2011).

In May 2007, Denel announced its intention to cease the development of the Rooivalk (Army-Technology; Campbell, 2007; Engelbrecht, 2010), and cited a lack of commercial viability as reason for its decision (Engelbrecht, 2010). The helicopter was hoped to be sold beyond the borders of SA, but that never happened, leaving the South African National Defence Force (SANDF) as the sole customer (Campbell, 2007; Engelbrecht, 2010; Shear, 2013). Project budget cuts followed the national defence budget cut, and the unit acquisition was cut from 36 to only 12. Project delays and Denel's inability to take advantage of economies of scale both contributed to the overall project demise (Army-Technology; Campbell, 2007). Other reports cited concerns surrounding the aged technology of the helicopter, which did not justify its cost (estimated at $40 million per unit) (Army-Technology).

- **Development of an HIV Microbicide trial**

The HIV microbicide trial project was a Phase III clinical trial conducted in SA, India, Uganda and Benin to test the effectiveness of the HIV microbicide Ushercell in a gel form. The microbicide was developed by the non-profit reproductive health organisation called CONRAD (Honey, 2007). In 2007, SA was reported to be the first African nation to make a major investment in HIV/AIDS clinical trials involving microbicides, with an estimated budget of R3 billion a year. Of this amount, R8.5 million, spread over a four-year period, was for the Phase III clinical trial under discussion (Smith, 2007). Microbicide clinical trials are known to be expensive due to the number of participants and the phases involved to test the formulation (Smith, 2007). The budget allocation was an indication of government's support for the trial, as confirmed by the then Deputy Minister of Science and Technology, Derek Hanekom. High expectations were held of the reduced scourge of HIV infections if the trials were proven to work (Smith, 2007). The HIV statistics at the time, as quoted by SA Medical Research Council president, Prof Anthony Mbewu, were estimated at 500 000 new annual infections, of which approximately 200 000 involved women younger than 25. The microbicide was anticipated to protect 100 000 women a year, even if it was proven to be 50% effective (Smith, 2007).

Unfortunately, SA and the microbicide field suffered a huge setback and great disappointment when it was announced that the trial was closed due to safety reasons (Ramjee *et al.*, 2007). The results of the interim data analysis showed an HIV infection rate increase in women using the Ushercell compared to the women using the placebo (Honey, 2007; Ramjee *et al.*, 2007). The discontinuation of the trial did not go without criticism, with some questioning the approach followed (Honey, 2007). The then health minister, Manto Tshabalala-Msimang, directed the National Health Research Ethics Council to conduct a probe into the matter (Wakabi, 2007). The investigation aimed to establish whether the trial had followed all ethical protocols and whether the women involved in the trial had been given adequate information to make informed decisions. Reports also suggested that some women were sharing their gel with friends who were not part of the study (Wakabi, 2007). The reaction of the health minister highlighted certain areas in the project that could have been managed differently, in particular, stakeholder engagement. The commissioning of the probe was an indication that the National Department of Health was questioning the ethical approvals of this project, a stance that annoyed the team conducting the trial (Ramjee *et al.*, 2007). The South African community at large also seemed unaware of the processes followed, as they blamed the trial and the R150 paid to the participant on the exploitation of the poor and illiterate group of SA.

- **Pebble Bed Modular Reactor**

The Pebble Bed Modular Reactor (PBMR) was established in 1999 to develop and market small-scale, high-temperature, energy-sustaining reactors in SA and abroad (PBMR-SOC). The project had an estimated value of more than R30 billion and was expected to commission its first plant in year 2016 (Graumann, 2010). Unfortunately, the project did not live long enough to realise its full potential, despite an investment of approximately R9.244 billion in the project – of which an estimated 80% was from tax payer's money (Sapa, 2010) – yet another disappointment for SA. In September 2010, the then South African Public Enterprise minister, Barbara Hogan, announced in Parliament the government's decision to abandon the project, citing fiscal constraints as the main contributing factor to the decision (BrandSouthAfrica, 2010). Whilst the minister blamed fiscal constraints and lack of investment support for the abandonment of the project, other people had different views related to political influence (or lack thereof) and project management (Sapa, 2010; Holtzhausen, 2011).

- **Joule: The Electric Car**

Joule, SA's first electric car, was to be sold throughout all major South African centres in Gauteng, Cape Town and Durban and later to the international market. It was planned to reach full production towards the end of 2010 (SAinforReporter, 2008). The then minister of Science and Technology, Naledi Pandor, reported that her department and its agencies, the Innovation Fund and the Technology Innovation Agency (TIA), had invested approximately R128 million in this research project. In addition, R119 million was invested by the Industrial Development Corporation (IDC) in its pre-commercialisation activities (Pressly, 2014). However, the project was not allowed to realise its full potential, as in 2012 it was abandoned, due to failure to secure further funding from the government and the IDC (Cokayne, 2012). The National Research Foundation (NRF) Chief Executive Officer (CEO), Dr Albert van Jaarsveld told News24 that the end of Joule did not mean the end of production of the car components, as they could still be used somewhere else (Alfreds, 2012). Sadly, the year 2017 marked the official end of Joule, when the production of its components was discontinued (List, 2017).

Whilst the SA government seemed to be in denial of the demise of this project or perhaps avoided facing up to the reality of yet another wasteful expenditure, the reality on the ground was different. Those outside of government were of the opinion that market readiness analysis was not properly done and argued that the introduction of the electric car in SA was a high-risk venture, ahead of its time. This indicated a risk that the automotive industry wasn't willing to take, as evidenced by the lack of commercialisation funding (Briant, 2012; Swart, 2015; Writer, 2017). Misalignment of various stakeholders, in particular, the DST and Department of Trade and Industry (DTI) in relation to the industrialisation requirements, is another reason that was cited for the project failure (Swart, 2015). High reliance on government as a major shareholder also contributed to Joule's downfall. In this case, government was positioned to use the project as a political tool, but at the same time, it was placed as a competitor against and thus disadvantaging the existing automotive industry (Swart, 2015).

The discussion above looked at failed projects from different sectors. While there appears to be different reasons behind the reported failures, there seems to be a common thread, yet to be discovered, highlighting the importance of stakeholder engagement and buy-in, as well as political support. Such observations require a thorough investigation, which is the motivation for this paper, which aims to identify those factors that are critical for R&D project success in SA.

1.2 PROBLEM STATEMENT

1.2.1 Context – defining Research and Development

R&D projects, which are mostly carried out by academic and R&D institutions (Nagesh and Thomas, 2015) are defined as the creative work that is systematically undertaken to increase the stock of knowledge (of humankind, culture and society) to devise new applications of available knowledge (Jain *et al.*, 2010; Nagesh and Thomas, 2015; OECD, 2015; Fernandes *et al.*, 2017). R&D activities could either be in the form of basic research, applied research or experimental product development (Jain *et al.*, 2010; OECD, 2015; Fernandes *et al.*, 2017). These activities should at least in principle be novel, creative, systematic, uncertain in their outcome, but intended to be transferrable and/or reproducible (OECD, 2015; Fernandes *et al.*, 2017). R&D activities may be aimed at new findings, based on original concepts or hypotheses for the achievement of either specific or general objectives, and they should have a largely uncertain final outcome and resources (EFCOG, 2010; OECD, 2015). Balachandra and Friar (1997) provide another dimension to R&D by highlighting key similarities with New Product Development (NPD) activities, thus justifying their popular interchangeable use in literature.

Nagesh and Thomas (2015) use the "seed in the soil" analogy to define R&D projects. They say the quality of the sprout and plant depends on the quality of the seed and soil as well as the caretakers. In this instance, the project is the seed, the organisation and its environment are the soil, and the caretakers are the project leader and the team associated with the project. The project may also need additional resources and collaboration when external knowledge and facilities are required. It has been a challenge to clarify what makes R&D projects successful, particularly those that are publicly funded (Yamazaki *et al.*, 2012), as the factors likely to influence their success vary considerably. They could be contextual, to some extent contradictory (Nagesh and Thomas, 2015) or controllable within the organisation, whereas others are external and uncontrollable (Balachandra and Friar, 1997). The public status of public-funded R&D projects increases their scope and complexity by including additional factors related to environmental issues, political and social implications and many other factors that are not naturally inherent to their counterparts (Radujkovic and Sjekavica, 2017).

1.2.2 Context – overview of R&D Critical Success Factors

Success factors are the inputs to the management system that may directly or indirectly lead to the success of the project. The most influential of these factors that are required to achieve the overall project goals are defined as the Critical Success Factors (Kulatunga *et al.*, 2009). They are the independent elements of a project which, when adequately influenced, may increase the likelihood of its success (Pinto and Slevin, 1987; Müller and Jugdev, 2012). Rockart (1979) introduced the CSF definition as those limited key areas where things must consistently go right for any undertaking to flourish (Bullen and Rockart, 1981; Martin, 1982; Barat, 1992; Remus and Wiener, 2010; Alias *et al.*, 2014; Khodaveysi *et al.*, 2016), thus requiring constant and careful attention from management (Bullen and Rockart, 1981; Martin, 1982; De Sousa, 2004; Amberg *et al.*, 2005; Remus and Wiener, 2010).

Over the years, a great deal of research has been conducted to determine the factors that are most critical to project success (Pinto and Slevin, 1989; Balachandra and Friar, 1997). Numerous authors have attempted to identify the factors that they deem critical and relevant to various contextual project settings, with Balachandra and Friar (1997) identifying 72 critical factors for R&D project success in a four-category classification (innovation; market; technology; industry). Smith *et al*. (2008) identified management style and leadership, knowledge management, employees, resources, organisational structure and culture, corporate strategy, innovation process and technology as the nine key influential factors for the R&D organisation to innovate successfully (Smith *et al.*, 2008; Nagesh and Thomas, 2015). Jain *et al*. (2010) identified people, ideas, funds and culture as the four basic elements to be coordinated with R&D management skill for R&D success (Nagesh and Thomas, 2015). On the other hand, Cooper and Kleinschmidt (2007) identified four critical factors for R&D success, which included R&D spending, processes, clear strategy and adequate project resourcing (Nagesh and Thomas, 2015).

Although there are some commonalities in the CSFs identified by various authors, there remains a wide variety, indicating a general lack of agreement among the authors (Shenhar *et al.*, 2002; Nagesh and Thomas, 2015). This supports the assertion that the factors considered critical for project success are largely contextual and may differ per project and industry (Kulatunga *et al.*, 2009; Ika *et al.*, 2012; Osorio *et al.*, 2014). The identification of these factors continues to be important, as it enables project managers and leadership to commit their thinly spread resources to specific factors that have the highest impact on project success (Ngacho and Das, 2017). In SA, such factors remain a mystery that must be explored further; hence the focus of this paper.

1.2.3 Research problem statement

In order to better understand factors that may be of great influence in increasing the success chances of R&D projects in SA, this paper seeks to investigate and examine the following problem:

The influential factors behind the successes of public-funded R&D projects in SA are neither well known nor properly documented, as evidenced by the reported projects that have not achieved their intended goals.

1.3 RESEARCH QUESTIONS

The research questions to be addressed in this study are as follows:

- What are the CSFs of public-funded R&D projects in SA?
- Are there any noticeable interrelationships between these identified CSFs?

1.4 RESEARCH AIM

The aim of this research is to develop a model to identify the CSFs for the public-funded R&D projects in SA, as well as to exhume possible interrelationships between the identified CSFs.

1.5 RESEARCH OBJECTIVES

The objectives of this research study are to identify

- The CSFs for public-funded R&D projects in SA; and
- Noticeable interplay between the identified success factors.

1.6 STRUCTURE OF THE RESEARCH REPORT

In order to achieve the research objectives, the rest of this paper is structured under the following topics:

- A literature review of matter pertinent to this study
- Presentation of the research methodology used in the study
- Analysis and interpretation of research findings
- Conclusion and recommendations

CHAPTER 2: LITERATURE REVIEW

2.1 DEFINITION OF KEY CONCEPTS

Before attempting a review and discussion of CSFs on R&D projects, it would be beneficial to first provide adequate definitions of the foundational key concepts used in this chapter. This will eliminate possible ambiguities that exist in respect of these concepts, which often result from a wide range of individual interpretations (Pinto and Slevin, 1988a).

2.1.1 Generic project vs R&D project

Developing a definition of what constitutes a project is often difficult, even though almost every individual has had some experience with projects in some form or other (Pinto and Slevin, 1988a). Pinto and Slevin (1988) suggest that any definition of a project should be general enough to include a wide variety of organisational activities that are considered to be project functions. In addition, this definition should also be narrow enough to include only those specific activities that researchers and practitioners can meaningfully describe as project oriented (Pinto and Slevin, 1988a).

Generally, projects are made up of people dedicated to a specific purpose or objectives involving large, expensive, unique or high-risk undertakings that have to be completed by a certain date, for a limited budgetary amount, within a certain level of performance target (Pinto and Slevin, 1988a). Therefore, all projects should at a minimum have well-defined objectives and sufficient resources to carry out all the required tasks (Pinto and Slevin, 1988b; 1988a). The Project Management Institute (PMI) (2008) defines a project as a unique but temporal undertaking (PMI, 2008). Therefore, taken from the PMI (2008) and Pinto and Slevin (1988a; 1988b), a project can be defined as possessing the following key characteristics:

- A unique undertaking
- A limited budget
- A temporal undertaking with a set timeframe, with a clear start and end date
- A specific, predetermined goal or set of goals, made up of a series of complex or interrelated activities

Building on this basic (generic) project definition with certain critical distinctions, R&D projects are not only characterised by complex activities that are interdependent and highly responsive to environmental changes, but also heavily reliant on expert judgement to maintain quality, relevance and performance (EFCOG, 2010). Typically, R&D projects are aimed at new findings and have largely uncertain final outcomes, based on uncertain timeframes and other resources that are required to achieve the intended goals (EFCOG, 2010; OECD, 2015). In principle, R&D activities have to be novel, creative, uncertain, systematic, as well as transferrable and / or reproducible (OECD, 2015). Public-funded R&D projects in particular have to ordinarily reflect a high degree of scope flexibility, as they are usually planned and budgeted for within a negotiated cost and schedule to accommodate fixed annual government funding and expected customer deliverables (EFCOG, 2010). In line with the views of EFCOG (2010) and OECD (2015), R&D projects could therefore display the following key characteristics in different settings:

- End goals may be defined in terms of milestones and deliverables, with unknown or unclear methods of achieving the set goals.
- Clear and well-known project execution methods would be applied to achieve an unknown or unclear end goal.
- In extreme cases, neither methods nor project end goals may be well known.
- Whilst project time and budget may be limited, the exact time and budget required to achieve project goals would be unknown.

These clearly visible distinctions between an R&D project and a generic project are an indication that they should be treated differently and that the factors behind their success are also likely to be different (EFCOG, 2010; Nagesh and Thomas, 2015; OECD, 2015) – a very important point of note in the context of this study.

2.1.2 Generic project success vs R&D project success

The term success appears simple to many because of its generic usage, but it is difficult to describe (Baccarini, 1999; Ika, 2009; Remus and Wiener, 2010). The ambiguity surrounding its understanding lingers on, despite the fact that several studies have been conducted in an attempt to find consensus on the subject (Pinto and Slevin, 1988b; Shenhar *et al.*, 1997; Dvir *et al.*, 1998; Liu and Walker, 1998; Ika, 2009). Different project stakeholders view success in different ways, different settings and at different times (Shenhar *et al.*, 1997; Liu and Walker, 1998; Ika, 2009). Therefore, in addition to defining the concept of projects and before discussing any factors deemed critical in influencing project success, it is important to describe exactly what project success is (Pinto and Slevin, 1988a) in the context of this paper.

Ika (2009) suggests that the definition of project success should be guided by the Canadian Oxford Dictionary of 1998, where success is defined as the achievement of a goal or a favourable outcome. He asserts that project success should focus on the efficiency and effectiveness of project outcomes (Baccarini, 1999; Ika, 2009). This definition is supported by various other authors who state that project success should not only focus on the efficient use of available resources, but also address a much wider spectrum of needs, concerns and issues presented by a diverse mix of project stakeholders (Shenhar *et al.*, 1997; Liu and Walker, 1998; Baccarini, 1999; Alias *et al.*, 2014). Baccarini (1999) suggests that effectiveness should be seen as a synonym for success, and that an added soft dimension of customer satisfaction and welfare should continue to receive attention, particularly for R&D projects (Pinto and Slevin, 1988b; Shenhar *et al.*, 1997). Baker *et al*. (1986) suggest that for an R&D project to be considered for success, it should be evaluated against four principal sources of uncertainty:

- Relevance of the business objective
- The fit between business and technical objectives
- Transfer of project results to the end user
- Effective use of the product by the end user, in terms of its marketability and distribution, among other things

Like others, Baker *et al*. (1986) have highlighted the importance of end-user satisfaction in R&D project success, thus supporting the notion that it could be fitting to rather refer to "perceived" project success (Liu and Walker, 1998), because in the end, what really matters is whether the stakeholders associated with and affected by the project are indeed satisfied with its outcomes (Pinto and Slevin, 1988b). In their 2012 paper, Ika *et* al. (2012) conclude that project success is a matter of perspective and that there is a positive correlation between CSFs and project success. Therefore, due to numerous uncertainties and sometimes conflicting expectations from a variety of stakeholders (predominantly in public-funded R&D projects), there is an ever-growing need to better understand the CSF concept, which is what the next section attempts to do.

2.2 IN-DEPTH REVIEW OF THE CSF CONCEPT

This section of the chapter attempts to provide an in-depth review of the term "Critical Success Factors" as used in the reviewed literature. The focus will be on its history and evolution, definition, dimensions, as well as the various approaches used to identify it, with particular emphasis on the identification of the R&D-related CSFs. This background and understanding will provide a solid foundation for this paper, which is aimed at the identification of the CSFs of public-funded R&D projects in SA.

2.2.1 History and evolution of CSFs

The term Critical Success Factors was introduced in 1979 by John F Rockart, who at the time was a director of the Centre for Information Systems Research in the Sloan School of Management (Martin, 1982; Boynton and Zmud, 1984; Amberg *et al.*, 2005; Khodaveysi *et al.*, 2016). He asserted that organisations in the same industry may exhibit different CSFs due to different geographical locations, strategies and various other factors (Amberg *et al.*, 2005). The idea was adopted from the concept of Success Factors as put forth in management literature by Ronald D. Daniel in 1961 (Leidecker and Bruno, 1984; Grunert and Ellegaard, 1992; Amberg *et al.*, 2005; Remus and Wiener, 2010; Khodaveysi *et al.*, 2016) as well as the three musts of any system that were proposed by Anthony, Dearden and Vancil in 1972 (Rockart, 1979). These authors emphasised a need to tailor CSFs to a company's strategic objectives as well as to its managers (Rockart, 1979; Leidecker and Bruno, 1984; Amberg *et al.*, 2005; Remus and Wiener, 2010).

Rockart (1979) proposed the CSF method to assist senior executives in defining matters related to their own information needs and critical to the optimal management of their organisations (Leidecker and Bruno, 1984; Barat, 1992; Grunert and Ellegaard, 1992; Amberg *et al.*, 2005; Khodaveysi *et al.*, 2016). As an extension of Rockart's prior work, Bullen and Rockart devised an approach that embodied the principles of success factors as a way to identify the information needs of senior executives (Bullen and Rockart, 1981; Khodaveysi *et al.*, 2016). Their approach was tested in the Rockart (1982) study and its results indicated that although the CSFs as stated by each executive may differ from company to company, they still converge at certain key areas to present a few distinct executive-relevant CSFs (Rockart, 1982; Barat, 1992).

Since its emergence in the 1970s, Rockart's CSF approach has found its way into a variety of formalised information or business systems and project management arenas and is often used by various executives and consultants in their domains (Grunert and Ellegaard, 1992; De Sousa, 2004; Amberg *et al.*, 2005; Khodaveysi *et al.*, 2016). The main intended purpose of the CSF approach was to identify and control critical data for management to be used to monitor and improve existing business areas (Amberg *et al.*, 2005). However, several studies investigating the applicability of the CSF method have unearthed a variety of uses (Boynton and Zmud, 1984; Leidecker and Bruno, 1984; Barat, 1992; Williams and

Ramaprasad, 1996; Khodaveysi *et al.*, 2016), which are summarised by Khodaveysi *et al.* (2016) as follows:

- Identification of key concerns for senior management
- Assistance with the development of strategic plans and processes (particularly to assess environmental threats and opportunities, and analyse organisational resources (Leidecker and Bruno, 1984))
- Identification of key focus areas in each stage of a project life cycle, as well as causes of project failure
- Evaluation of the reliability of an information system
- Identification of business threats and opportunities
- Measuring of staff productivity

Whilst the above by no means reflects an exhaustive list, it provides an indication of the broad applicability of the CSF approach and its possible usefulness in assisting organisations to focus on and validate many of the critical activities they perform in pursuit of their endeavours (Boynton and Zmud, 1984; Khodaveysi *et al.*, 2016).

2.2.2 Definition of CSFs

Rockart (1979) introduced the definition of CSFs as those limited key areas where things must consistently go right for any undertaking to flourish (Bullen and Rockart, 1981; Martin, 1982; Barat, 1992; Williams and Ramaprasad, 1996; Shah and Siddiqui, 2006; Remus and Wiener, 2010; Alias *et al.*, 2014; Khodaveysi *et al.*, 2016). These key areas therefore require constant and careful attention from management (Bullen and Rockart, 1981; Martin, 1982; De Sousa, 2004; Amberg *et al.*, 2005; Remus and Wiener, 2010). Information about their performance status should be shared at appropriate levels and in a timely manner (Rockart, 1979; De Sousa, 2004). Ferguson and Dickinson (1982) provided their own CSF definition and classify them as those factors inside or outside the organisation that must be identified and reckoned with, as they could either support or threaten the achievement of company objectives. They further define CSFs as those internal or external events or circumstances that require special management attention due to their significance to the organisation (Ferguson and Dickinson, 1982).

Expanding on Rockart's (1979) definition, Boynton and Zmud (1984) defined CSFs as those few things that must go well to ensure success for a manager or organisation. They represent those organisational or managerial areas that must be given special and continual attention to secure high organisation performance (Boynton and Zmud, 1984). Motivated by the different definitions of CSFs in the literature, Leidecker and Bruno (1984) opted to define CSFs as those characteristics, conditions or variables that, when appropriately sustained, maintained or managed, could have a significant impact on the success of an organisation competing in a particular industry (Flynn and Arce, 1997; De Sousa, 2004; Amberg *et al.*, 2005; Remus and Wiener, 2010). In 1987, Pinto and Slevin decided to define CSFs as those factors which, if properly addressed, will significantly improve a project's chances of attaining its goal (Pinto and Slevin, 1987; Amberg *et al.*, 2005; Remus and Wiener, 2010). Notably, despite the general support of both Pinto and Slevin (1987) and Leidecker and Bruno (1984) as evidenced in literature, De Sousa (2004) identified a flaw in these definitions in that they fail to address the optimal concept provided by Rockart (1979), which aims to identify an ideal match between the environmental conditions and business characteristics (Grunert and Ellegaard, 1992) of a particular organisation (Amberg *et al.*, 2005).

In the Management Information Systems (MIS) and Strategic Management fields, the definition of CSFs is closely related to that of Key Success Factors (KSFs), as advocated by Grunert and Ellegaard (1992), (Grunert and Sørensen, 1996; De Sousa, 2004; Amberg *et al.*, 2005). They define KSF as skills and resources with high leverage on perceived customer value and relative business costs (Grunert and Ellegaard, 1992; Grunert and Sørensen, 1996). The term was first introduced in the early 1970s by Anthony and colleagues who built on Ronald F Daniel's concept of CSFs (Rockart, 1979; Leidecker and Bruno, 1984) and indicated that the management control system not only measures profitability, but also identifies certain key variables such as strategic factors, KSFs, key result areas, as well as pulse points that have a significant impact on profitability (Leidecker and Bruno, 1984). In 1996, Grunert and Sørensen broadened the KSF definition by describing it as a skill or resource that an organisation can invest in. This accounts for a major part of the observable differences in perceived value and / or relative costs in the organisation's market (Grunert and Sørensen, 1996; Amberg *et al.*, 2005). Whilst this definition of KSFs appears to be slightly different from the CSF definition that has been noted so far, in literature these two terms are often used interchangeably (De Sousa, 2004; Amberg *et al.*, 2005).

2.2.3 Primary sources and dimensions of CSFs

In recognising that CSFs are not only applicable to any company operating in a particular industry, but that they must also be tailored to a particular company, the MIT team discovered that CSFs could have a variety of sources (Rockart, 1979). In 1979, Rockart and the MIT team discovered four primary sources of CSFs, namely:

- Structure of the particular industry
- Competitive strategy
- Industry position and geographical location
- Environmental factors

A fifth and temporal factor, managerial position, was highlighted by Bullen and Rockart (1981) as well as various other authors (Barat, 1992; Grunert and Ellegaard, 1992; Khodaveysi *et al.*, 2016). Over the years, the primary sources of Rockart and the MIT team's CSFs were further extended. Based on the evolution of the CSF method and the progress made in CSF research, several dimensions of the CSF emerged in literature (Bullen and Rockart, 1981; De Sousa, 2004; Amberg *et al.*, 2005). Some of these are discussed in the subsections below:

i. Hierarchy vs group of CSFs

Different management levels introduce different types of operating environments and thus different levels of CSFs (Khodaveysi *et al.*, 2016). Rockart defined a hierarchy of CSFs, which is primarily dependent on the hierarchical nature of the organisation and the level at which strategic issues are discussed (Barat, 1992; Amberg *et al.*, 2005). In line with this approach, four different hierarchical CSF levels emerged, namely industry, corporate, sub-organisational, as well as individualistic CSFs (Bullen and Rockart, 1981; Barat, 1992; Amberg *et al.*, 2005; Khodaveysi *et al.*, 2016). Barat (1992) argues that while a CSF hierarchy may be formed on a pre-defined level of structure, it may also be built upon logical dependencies, such as those that exist between business aims and the factors influencing these aims (Barat, 1992; Amberg *et al.*, 2005).

Studies have also shown that CSFs can be synthesised in such a way that each manager in an organisation may have different, individual CSFs, while the organisation may have its own aggregated set of CSFs, resulting in a certain grouping of CSFs (De Sousa, 2004). As such, Industry CSFs may be recognised, resulting from the CSFs for a group of organisations belonging to a same industry or so-called Occupational CSFs (made up of CSFs for a group of managers in a particular role but belonging to different organisations) (De Sousa, 2004; Amberg *et al.*, 2005). These groups have introduced the concept of a group of CSFs (De Sousa, 2004). The primary source of this CSF dimension may be traced back to the managerial position, which refers to the various functional managerial positions in a business that may each generate its own generic set of associated CSFs (Bullen and Rockart, 1981; Barat, 1992; Grunert and Ellegaard, 1992; Khodaveysi *et al.*, 2016).

ii. Temporary vs ongoing CSFs

According to Bullen and Rockart (1981), CSFs will undoubtedly differ from manager to manager in accordance with the manager's place in the organisational hierarchy. Also, they often change as the industry's environment changes, as the organisation's position within an industry is altered, or as particular problems or opportunities arise for a particular manager (Bullen and Rockart, 1981; Khodaveysi *et al.*, 2016). Such changes provide a base for this dimension of CSFs, stating that they could either be temporal or ongoing in that a senior executive who occupies the role of project champion may be seen as an ongoing CSF because of his/her continuous influence on all project phases. On the other hand, a defined project scope may represent a temporary CSF as its criticality may cease on successful implementation of the project (De Sousa, 2004; Amberg *et al.*, 2005). These observations of temporal versus ongoing CSFs have caused other authors to suggest that all CSFs may be very well defined in line with the generic project definition, thereby making them temporal at differing levels, with some spanning a larger timeframe than others (De Sousa, 2004; Amberg *et al.*, 2005). The key is therefore to recognise the individual relevance of each CSF for the different stages within a project lifecycle (Amberg *et al.*, 2005). This dimension indicates traces of various primary sources, including environmental factors, which refer to the macroeconomic influences affecting all competitors within an industry, over which the affected parties have minimal or no influence; temporal factors, being those internal organisational considerations that are significant for the targeted business mission but cause time-limited distress due to the occurrence of an unusual and unexpected event (Bullen and Rockart, 1981; Barat, 1992; Grunert and Ellegaard, 1992; Khodaveysi *et al.*, 2016); as well as the managerial position.

iii. Internal vs external CSFs

Another dimension in distinguishing CSFs is the extent to which they are internal (endogenous) or external (exogenous) to the particular organisation or unit to which they are applied (Grunert and Ellegaard, 1992; De Sousa, 2004; Amberg *et al.*, 2005). The primary characteristic of internal CSFs is that they are concerned with issues and situations within the manager's scope of influence and control, whereas external CSFs pertain to situations generally out of the manager's control (Bullen and Rockart, 1981; De Sousa, 2004) and show traces of environmental factors as their primary source. De Sousa (2004) and Amberg *et al*. (2005) assert that this dimension's relevance becomes important when determining the proper sources of information within the process of data collection.

iv. Monitoring vs building CSFs

A typical manager is expected to have a combination of these two CSFs (Bullen and Rockart, 1981). Both refer to the amount of control on the part of management and to the monitoring or building nature of the actions taken (Grunert and Ellegaard, 1992; De Sousa, 2004; Amberg *et al.*, 2005). Bullen and Rockart (1981) differentiate between these two concepts and suggest that monitoring CSFs are those CSFs that involve continued scrutiny of existing situations by managers. Building CSFs, on the other hand, refer to future-oriented managers whose primary purpose is to implement major programmes aimed at changing the organisation to adapt to a perceived new environment (Grunert and Ellegaard, 1992; De Sousa, 2004; Amberg *et al.*, 2005). The diversity of this dimension could also be reflected in the multiplicity of its perceived key primary sources – the managerial position and competitive strategy; the industry position and geographical location – with the latter referring to the company's competitive position within the industry as determined by its history and current competitive strategy (Bullen and Rockart, 1981; Barat, 1992; Grunert and Ellegaard, 1992; Khodaveysi *et al.*, 2016).

v. Strategic vs tactical CSFs

This dimension is related to the strategic and tactical planning that happens within an organisation, thus the different strategic and tactical CSFs (De Sousa, 2004; Amberg *et al.*, 2005). Strategic factors are concerned with the identification of the goals to be attained, while tactical factors describe possible alternatives in terms of how and when these goals will be met (De Sousa, 2004; Amberg *et al.*, 2005). The strategic factors, primarily executed by senior executives, are known to be risky and require long-term planning. Tactical factors, on the other hand, are often performed by middle management, require short or medium-term planning, and focuses mainly on resource utilisation for the attainment of objectives set at strategic level (De Sousa, 2004; Amberg *et al.*, 2005). This dimension could be linked to its predecessor – the monitoring vs building CSF – as also reflected in similar primary sources, namely managerial position, competitive strategy, industry position and geographical location.

vi. Perceived vs actual CSFs

Literature has shown that CSFs in one organisation are not necessarily applicable to all other organisations; rather, each organisation needs to align its individual CSFs with its own specific goals and requirements (De Sousa, 2004; Amberg *et al.*, 2005). These goals and requirements are determined by the uniqueness of their structure and characteristics as reflected in the first listed primary source, i.e. the structure of a particular industry (Rockart, 1979; Barat, 1992; Khodaveysi *et al.*, 2016). This realisation has given birth to the concept of perceived versus actual CSFs, as initially proposed by Grunert and Ellegard (1993), (De Sousa, 2004; Amberg *et al.*, 2005). Managers would perceive their CSFs in terms of their projects, and the organisation would do so in line with their specific goals and needs. These would then in future constitute the actual CSFs for specific organisational projects, which would also be identified as perceived CSFs for other similar projects (De Sousa, 2004). The manager-perceived CSFs need not be identical to the actual CSFs in a market (Grunert and Sørensen, 1996). This concept could shed light on the knowledge concerning discrepancies between actual and perceived CSFs, leading to more prolific strategy formulations and implementations (Amberg *et al.*, 2005). Even though measuring the actual CSF is not an attainable goal (De Sousa, 2004; Amberg *et al.*, 2005), certain authors have suggested a direct confrontation with key decision makers to gain insight into their perceptions with regard to both truly relevant success factors and those that are merely perceived to be relevant (De Sousa, 2004; Amberg *et al.*, 2005).

By reflecting on these dimensions and related primary sources, the reader could therefore understand whether CSFs are characterised by the extent to which they are internal or external to the organisation (or that part of it over which the manager has control), and whether they refer to something that should be monitored or built (Grunert and Ellegaard, 1992). It would be plausible to expect that organisations in the same industry may exhibit different CSFs due to differences in geographical settings, strategies and various other factors (Rockart, 1979).

2.2.4 Techniques for identifying CSFs

According to Rockart (1979), the identified CSFs in their study emerged from a structured series of dialogues in the form of two to three interviews with each executive (Boynton and Zmud, 1984; Barat, 1992; Grunert and Ellegaard, 1992; Khodaveysi *et al.*, 2016). Typically, a two-step process based on Rockart's (9179) approach would start with a first round of open interviews, asking the interviewees about their views on the CSFs relevant to the business. From this step, a preliminary list of factors would be compiled to be rated on an importance dimension in a second round (Rockart, 1979; Boynton and Zmud, 1984; Grunert and Ellegaard, 1992). A third round could sometimes be necessary to obtain final consensus on the CSF measures and reporting sequence (Martin, 1982).

Since its introduction in the late 70s, the Rockart (1979) CSF identification approach has been advocated and applied by a number of researchers, such as Munro and Wheeler (1980), Rockart (1982), Shank and Boynton (1985), Grunert and Sørensen (1996), as well as Shah and Siddiqui (2006) (to mention a few). However, its application has been criticised by various authors, stating that the intensive participation of the interviewer may expose the results to researcher bias and influence (Martin, 1982; Boynton and Zmud, 1984; Finney and Corbett, 2007) and that the re-examination of different interviewees' views may be time consuming (Boynton and Zmud, 1984; Barat, 1992).

Numerous new and complementary approaches have since emerged, for instance the Caralli five-step method of scope definition, data collection and analysis; CSF extraction and analysis (Khodaveysi *et al.*, 2016); Scenario analysis (Barat, 1992); Case Tool to support CSF analysis (Flynn and Arce, 1997); Multivariate analysis (Dvir *et al.*, 1998); Multi-method research (Belassi and Tukel, 1996; Remus and Wiener, 2010) and many others as reflected in the table below:

Table 2-1: CSF identification techniques

Research Method	Example References
Interviews	(Mahmood *et al.*, 2014) (Shah and Siddiqui, 2006) (Shank *et al.*, 1985) (Bullen and Rockart, 1981) (Munro and Wheeler, 1980) (Rockart, 1979)
Analytic Hierarchy Process (AHP)	(Chua *et al.*, 1999)
Case Studies	(Brockhoff, 2003) (Bizan, 2003) (Cooke-Davies, 2002) (Balachandra and Raelin, 1984) (Rockart, 1982)
Combination of Methods	(Khodaveysi *et al.*, 2016) (Barragán-Ocaña and Zubieta-García, 2013) (Yamazaki *et al.*, 2012)

	(Kulatunga *et al.*, 2011) (Kulatunga *et al.*, 2009) (Belassi and Tukel, 1996) (Pinto and Slevin, 1989) (Leidecker and Bruno, 1984)
Questionnaire	(Ika *et al.*, 2012) (Lee and Park, 2006) (Baccarini and Collins, 2003) (Martin, 1982) (Baker *et al.*, 1986)
Chi-Squared Test Statistics	(Hyvari, 2006)
Literature Review	(Nagesh and Thomas, 2015) (Finney and Corbett, 2007) (Balachandra and Friar, 1997)
Multivariate Analysis	(Dvir *et al.*, 1998) (Shenhar *et al.*, 2002)
Scenario Analysis	(Barat, 1992)

The next section provides a brief description of how the frequently used CSF identification techniques have been employed to study CSFs in various contexts. The immediately succeeding section will review some of the commonly used CSF identification techniques in greater depth.

2.3 AN OVERVIEW OF R&D AS WELL AS RELATED PROJECT CSFs AND THEIR APPLIED IDENTIFICATION APPROACHES

Nagesh and Thomas (2015) reviewed various literatures to come up with a group of public-funded R&D project CSFs. These are clustered into three categories: Project, Resources and Environment. The project category includes the Project Type and the Degree of Difficulty of the project. The resources category is further broken down into Human Resources, which comprises Leader, Team and Non-human Resources (Funds, Equipment and Space). The last category is also further sub-categorised into Internal and External Environment. The Internal Environment represents matters related to Organisational Culture and Top Management Support, while the External Environment only covers matters pertinent to Collaboration with other organisations (Nagesh and Thomas, 2015).

Mahmood *et al*. (2014) conducted multiple semi-structured interviews to identify success factors on research projects at a university (Mahmood *et al.*, 2014). Their study concluded that administrative support and team members' relationship are the two most important categories of crucial factors for research project success (Mahmood *et al.*, 2014). Administrative support, which includes Top Management Support, encompassed important factors such as behaviour, interest, encouragement and positive feedback, whilst team members' positive relationship incorporated critical factors such as cooperation, competency, commitment, communication and training – all identified as the CSFs for a research projects (Mahmood *et al.*, 2014).

In 2013, Barragán-Ocaña and Zubieta-García used a mixed method approach – case study review, interviews and questionnaires – to conduct a CSF study on R&D Projects in Public Research Centres. Their research identified a mixure of 71 factors that could have either a positive or negative impact on the R&D project outcome (Barragán-Ocaña and Zubieta-García, 2013). These factors were grouped into the following eight categories of R&D Process; Project Planning; Work and Collaboration networks; Human Resources; Market; Financial Resources; Organisation; Quality. Focusing on the factors that were aimed at having a positive influence on the success of the R&D projects, the study highlighted six fundamental areas within the identified categories, namely processes, human resources, organisations, markets, technology transfer and client involvement (Barragán-Ocaña and Zubieta-García, 2013). The outcome of the case study stressed the importance and influence of key CSF variables such as Scientific competence; Technological and material capacity; Trained personnel; Favourable work environments; Project decision-making authority; Client interest and commitment; and Adequate interpretation of client needs (Barragán-Ocaña and Zubieta-García, 2013).

Yamazaki *et al.* (2012) used statistical methods to analyse the results of a questionnaire survey and interviews from various R&D firms using public funds. In order to extract the CSFs, their study looked at both the firms that had achieved their set goals, and at those that had not achieved their project goals (Yamazaki *et al.*, 2012). Five CSFs were identified:

- The existence of R&D preceding the project in question inter alia highlights the feasibility of achieving the technical development objectives.
- The clear position of an R&D theme in the organisation's medium-term management plan and other efforts increase not only top management support, but also its chances of success.

- A close cooperative relationship among operating divisions increases the project's feasibility due to its understanding of the product market, user needs, as well as the environmental-related constraints of the R&D project.
- A clear understating of core customers and their needs increases the product's future commercialisation likelihood.
- A key dedicated and full-time researcher is present on a project. Whilst this CSF is noted as of less importance in influencing the project success since some projects have not managed to achieve their goals even in the presence of a dedicated researcher, it is included due to its inherent ability to lead a project to success (Yamazaki *et al.*, 2012).

In their study aimed at developing a structured approach to measure the performance of collaborative construction R&D, Kulatunga *et al*. (2011) used a mixed approach of semi-structured interviews, literature reviews and a questionnaire to identify construction R&D CSFs across the project's life cycle. The results highlighted the importance of establishing a clear research problem to ensure clarity and focus of the research work during the early stages of initiation and conceptualisation (Kulatunga *et al.*, 2011). Also, adequate resources – particularly human resources in the form of skilled, committed and motivated team members – were noted to be critical during the conceptualisation and development phases (Kulatunga *et al.*, 2011). In the last phase, effective dissemination of work to the relevant stakeholders was highlighted as being critical. However, project coordination and resource management were emphasised as being critical throughout all the project phases (Kulatunga *et al.*, 2011).

Kulatunga *et al*. (2009) used a mixed method approach to identify their construction R&D project CSFs. The process started with semi-structured interviews carried out with people who have been involved in the related construction R&D projects. Their responses were analysed utilising NVivo software in order to derive the CSFs (Kulatunga *et al.*, 2009). The process was followed by a construction project life cycle structured questionnaire, which was compiled using content from interview results as well as reviewed literature (Kulatunga *et al.*, 2009). The research results revealed that from the initiation phase to the project launch, stakeholder satisfaction received the greatest emphasis, followed by the principal investigator's commitment and active role in leading the projects as opposed to satisfying the researchers' requirements (Kulatunga *et al.*, 2009). Of notable interest was the finding that the two studies by Kulatunga *et al.* in 2009 and 2011 yielded different results, thus supporting Rockart's assertion in 1979 that organisations in the same industry could exhibit different CSFs due to differences in their geographical settings, strategies and various other factors (Rockart, 1979).

Hyvari (2006) used a chi-squared statistical method to analyse the results of a survey study that utilised results from previous qualitative, descriptive case studies in the literature to identify CSFs applicable to a variety of organisational settings, such as manufacturing, IT, R&D, and many others. The results showed that clear goals / objectives, end-user commitment and adequate funds / resources were the most critical factors to influence project success (Hyvari, 2006).

Lee and Park (2006) used a questionnaire to identify critical factors for organisational R&D success. Out of the presented seven possible factors for success (which included scale of R&D; increased R&D project duration; project personnel; equipment used for R&D; technical know-how; spur of market demand; and rapid commercialisation), only three stood out as most critical for success (Lee and Park, 2006). These were technical know-how, personnel, and commercial process, with technical know-how ranking the highest in terms of importance in influencing R&D project success, regardless of the type of innovation being pursued (Lee and Park, 2006).

In 2003, Baccarini and Collins used a survey questionnaire to identify – across a variety of industries – what they refer to as the set of circumstances, fact or influences that contribute to the project outcomes, which are the CSFs (Baccarini and Collins, 2003). Their study identified 15 CSFs that were ranked from one to fifteen, in order of response popularity and importance. These were (1) Project Understanding; (2) Competent project team; (3) Communication; (4) Realistic Time and Cost Estimates; (5) Adequate Project Control; (6) Client Involvement; (7) Risk Management; (8) Resources; (9) Teamwork; (10) Project Planning; (11) Senior Management Support; (12) Stakeholder Involvement; (13) Project Manager's Authority; (14) External Factors; and (15) Problem Solving (Baccarini and Collins, 2003). Numbers 1, 2, 3, 4, 5, 6, 11, 13 and 15 are CSFs that were also identified in reviewed literature, with Project Understanding and Competent Team ranked as the foremost important CSFs (Baccarini and Collins, 2003). Of key importance is that their overall findings did not reveal any significant variation in responses among industries, thereby supporting the notion that CSFs are mostly generalisable to a wide variety of project types and organisations (Baccarini and Collins, 2003).

Also in 2003, Klaus Brockhoff initiated a study to identify strategic R&D success factors for profit-making and non-profit-making organisations that produce R&D results for proprietary use (Brockhoff, 2003). He used a case study approach based on case examples of six types of organisations selected by using profit orientation classification criteria, as well as on the internal or external usage of R&D results (Brockhoff, 2003). The analysis of the identified sample organisations resulted in 14 CSFs, with nine of the fourteen receiving heightened attention (Brockhoff, 2003). The nine included factors such as

- the embedding of R&D into the scientific community;
- specialisation of the R&D units on core competencies;
- the securing appropriability of returns, particularly for profit-making organisations;
- the securing of market positions for customer orientation or by patenting non-customer-related research results;
- the selection of appropriate organisation structures to support existing process control;
- interface management supported by appropriate incentive structures and the development of joint objectives;
- securing secrecy noted as important in maintaining a good supplier-customer relationship for both past and future customers;
- the buffering of a volatile ordering process, dominant customers and equity shares and
- the fighting of unfair competition pressures, both from within and external to the organisation (Brockhoff, 2003).

In addition to the above-listed CSFs, for optimal success, Brockhoff (2003) also advised against the traditional organisational separation of units performing basic research, applied research or developmental work.

In 2003, Oded Bizan also applied a case study approach by studying the performance of a selected 142 government-supported research projects to identify the factors that determine the technical success of these projects as well as the “duration to commercialisation” of these projects (Bizan, 2003). The study concluded that the size and form of an organisation may have a sizable impact on the R&D project’s success. In particular, it was discovered that the probability of technical success increases with increased project duration; and if participating organisations are related through ownership, their abilities must be complementary (Bizan, 2003). In relation to commercialisation, the study concluded that time to commercialisation is likely to decrease if the project budget increases, and the larger firm’s revenue in the alliance increases if involved organisations are related through ownership (Bizan, 2003). Of notable interest are the contradictory findings in relation to the influence of the project duration. In particular, the 2002 study by Cooke-Davies suggests that limiting project duration, even to less than a year, is likely to increase the project’s success chances, which is in contradiction to the views expressed by Bizan (2003) and Lee and Park (2006) who argue that limited R&D activity duration could be detrimental to the R&D project’s success.

Cooke-Davies (2002) conducted an empirical research study to identify what was referred to at the *real* success factors on projects. The study was based on an analysis of 136 selected projects from more than 70 large multi-national and national organisations (Cooke-Davies, 2002). The analysis aimed to extract hard and soft data evidence to answer three key research questions related to the factors leading to successful project management, a successful project, and consistently successful projects (Cooke-Davies, 2002). The research identified 12 CSFs:

- The effect of adequate company-wide education on the concepts of risk management
- The organisational process maturity for assigning risk ownership
- The accuracy and visibility of a risk register
- The adequacy of an up-to-date risk management plan
- The accurate documentation of project responsibilities
- The limiting of the project duration to no more than three years
- The application of scope changes through the relevant change control processes
- The maintenance of integrity of the performance measurement baseline
- The existence of an effective benefits delivery and management process
- The visibility of portfolio and programme management practices that allow the enterprise to fully resource priority projects
- The availability of a portfolio, programme and project metrics that provides feedback on current project performance and anticipated future success for better alignment of project, portfolio and corporate decisions
- The application of lessons learnt from other projects

Although the above list of 12 identified factors do not appear to reflect any human element, Cooke-Davies (2002) asserts that because people perform every process, it is the people who determine the adequacy and success of every factor and ultimately the project. Thus, the people factor is embodied in each and every one of the identified 12 factors, and there is no need to identify it as a separate factor (Cooke-Davies, 2002). This assertion is supported by Shenhar *et al*. (2002) and Dvir *et al*. (1998) who quoted Rubinstein *et al*. (1976) by stating that individuals, rather than organisations, are behind the success of an R&D project.

Shenhar *et al*. (2002) used a multivariate, typological approach to identify project success factors. Their study evaluated the effects of a set of managerial variables on several dimensions of project success for various levels of technological uncertainty and system scope (Shenhar *et al.*, 2002). The study results revealed three different types of success factors, namely those that are independent of the project characteristics; those that are exclusively influenced by uncertainty; and those that are solely influenced by scope

(Shenhar *et al.*, 2002). Of note is the finding that the overall study results strongly suggest that successful project management is influenced by a wide spectrum of variables rather than by only a few major variables, as suggested by other authors in the literature (Shenhar *et al.*, 2002).

Balachandra and Friar (1997) reviewed the available literature and identified 72 factors that were deemed important for R&D project success, thus showing the level of differing views and opinions on the matter. They subsequently identified and suggested a grouping of four major contextual variables for R&D and NPD, namely Nature of the Market; Nature of the Innovation; Nature of the Technology; and Nature of the Industry. The first three have been noted to have the greatest influence on the outcome of an R&D or NPD project (Balachandra and Friar, 1997).

In their identification of CSFs, Belassi and Tukel (1996) adopted a new approach that focused on classifying and analysing the impact of the identified factors on project performance (Belassi and Tukel, 1996). The emphasis of their study was to analyse the CSF grouping and existing interrelations (Belassi and Tukel, 1996) and resulted in the grouping of CSFs into a number of interrelated categories. They highlighted factors related to the project and the project manager, the project team members, the organisation, as well as the external environment (Belassi and Tukel, 1996). The notable result across all industries reviewed was that a project manager's performance on the job and the team members' technical background and commitment are the two most crucial factors for project success (Belassi and Tukel, 1996).

In 1989, Pinto and Slevin conducted a study to identify R&D CSFs as an extension of their Ten Success Factor Model (developed in 1987), and to look at the importance of these CSFs across the R&D project life cycle. The Pinto and Slevin (1987) study was based on a literature review and used a procedure called Project Echo to identify a Ten Factor Model for successful project implementation. The Project Echo process relied on inputs from over 50 people with the latest two-year project management experience. Their responses were sorted by two experts, and the results were subsequently matched to the reviewed literature results. The ten CSFs identified by Pinto and Slevin (1987) included the following:

- Project mission, in relation to clearly defined goals and direction
- Top management support, in relation to the willingness of senior management to provide adequate resources and authority required for project success
- Project schedule or plans

- Client consultation, in relation to adequate and thorough communication and consultation with all affected stakeholders
- Personnel-related issues, including recruitment, selection and training of project personnel
- Technical tasks, in relation to the availability of the required technology and expertise for the accomplishment of the specific technical steps
- Client acceptance, in relation to the acceptance and usability of the final product by the end user
- Monitoring and feedback
- Communication
- Troubleshooting, which refers to the project's ability to respond to unexpected crises and deviations from the project plans

In addition, Pinto and Slevin's (1989) focus on the R&D projects highlighted the importance of four exogenous factors which, though beyond the project team's control, have a strong influence on the intended project success. These additional exogenous factors included the characteristics of the project team leader and the amount of authority to perform his/her duties; power and politics, referring to the political activity within the organisation; perceptions about the project within the organisation; environmental events referring to the probability that external organisational and environmental factors may affect the project team's operations; and project urgency, referring to the perceptions about the importance of the project and / or the burning need to implement it (Pinto and Slevin, 1989). Their study results supported the assertion that the relative importance of the CSFs tended to change with each project life-cycle stage (Pinto and Slevin, 1989). Project mission, client consultation, personnel and urgency were found to account for over 92% of the variance in project success in the Conceptual stage of the project. In the Planning stage, project mission, accompanied by environmental events, schedule, monitoring and feedback accounted for 63% variance in project success (Pinto and Slevin, 1989). In the Execution phase, project mission, technical tasks and top management support accounted for 54% of project success, whilst in the Final stage, mission, schedule client acceptance, technical tasks and personnel accounted for 72% of the variance in project success (Pinto and Slevin, 1989).

Balachandra and Raelin (1984) applied a case study approach and analysed 51 high-tech R&D projects from various organisations to identify factors that signal the prospects for success of an ongoing R&D project. This exercise revealed 12 CSFs, with top management support and effective project leadership being identified as the critical factors contributing to the successful continuation of a high-tech R&D project (Balachandra and Raelin, 1984). The 12 CSFs that were identified included top management support; the rate of new product introduction (with a high rate signalling positive opportunities to be explored); probability of technical success; technological route clarity (seen as a prerequisite for project success); project manager as project champion; the association between marketing and technical aspects; end-uses; effectiveness of the project manager; commitment of project workers; the life cycle of the product; internal competition from another project for similar resources; as well as cost schedules (Balachandra and Raelin, 1984).

2.3.1 Analysis of the reviewed CSF literature

The analysis of the reviewed CSF literature is best presented in a table format as depicted in Tables 2-2 and 2-3. The tables show a list of CSFs and the CSF categories respectively. Table 2-2 provides a consolidated view in a matrix format of the list of top CSFs identified by Nagesh and Thomas (2015), Mahmood *et al.* (2014), Barragán-Ocaña and Zubieta-García (2013), Yamazaki *et al.* (2012), Kulatunga *et al.* (2011), Kulatunga *et al.* (2009), Lee and Park (2006), Hyvari (2006), Baccarini and Collins (2003), Klaus Brockhoff (2003), Bizan (2003), Cooke-Davies (2002), Shenhar *et al.* (2002), Pinto and Slevin (1989 & 1987), and Balachandra and Raelin (1984).

Table 2-3 also provides a matrix table depicting CSF categories as suggested by Nagesh and Thomas (2015), Mahmood *et al.* (2014), Barragán-Ocaña and Zubieta-García (2013), Balachandra and Friar (1997), and Belassi and Tukel (1996).

The matrices in Tables 2-2 and 2-3 provide for better analysis of the identified CSF lists as well as the CSF categories as they appear in the reviewed literature. The last column in each table indicates the frequency of appearance of each of the CSFs or the CSF category in the publications of the listed authors. Blank spaces in the last column denote no repetitions. The black X marks the list of top CSFs or CSF categories identified by a particular author, whilst the blue X indicates the repeated identification of the same factor by other authors in their respective lists. The bold and shaded X's in the last column of both tables indicate those CSFs or the CSF categories that have been identified repeatedly by most of the reviewed authors, that is, the CSFs that have appeared more than five times and those categories that have been identified more than three times.

Table 2-2: CSF Matrix

Critical Success Factor List	Authors															
	Nagesh	Mahmood	Barragán-Ocaña	Yamazaki	Kulatunga (a)	Kulatunga (b)	Lee	Hyvari	Baccarini	Klaus	Bizan	Cooke-Davies	Shenhar	Pinto	Balachandra	Total Appearances
Nagesh and Thomas (2015)																
Project Type	X															
Degree of Difficulty	X															
Project Leader	X		X						X					X	X	5
Project Team	X				X		X		X							4
Project Funds	X							X								2
Equipment	X		X				X									3
Working Space	X		X													2
Organisational Culture	X													X		2
Top Management Support	X	X		X					X					X	X	6
Collaboration with other organisations	X															
Mahmood et al. (2014)																
Top Management Support	X	X		X					X					X	X	6
Behaviour		X														
Interest		X	X													2
Encouragement		X			X											2
Positive Feedback		X												X		2
Cooperation		X														
Competency		X	X						X							3
Commitment		X	X		X	X		X							X	6
Communication		X							X					X		3
Training		X	X													2

Table 2-2: CSF Matrix

Critical Success Factor List	**Authors**															
	Nagesh	**Mahmood**	**Barragán-Ocaña**	**Yamazaki**	**Kulatunga (a)**	**Kulatunga (b)**	**Lee**	**Hyvari**	**Baccarini**	**Klaus**	**Bizan**	**Cooke-Davies**	**Shenhar**	**Pinto**	**Balachandra**	**Total Appearances**
Barragán-Ocaña and Zubieta-García (2013)																
Scientific competence		X	X				X		X							4
Technological and material capacity	X		X													2
Trained personnel		X	X													**2**
Favourable work environments	X		X													2
Project decision making authority	X		X											X	X	4
Client interest and commitment			X						X							**2**
Adequate interpretation of client needs			X	X												**2**
Yamazaki et al (2012)																
Existence of R&D preceding the project in question				X												
Clear position of R&D theme in the Organisational strategic plans, influences *Top Management Support*	X	X		X					X					X	X	**6**
Understanding of the product market				X			X								X	3
Understanding of user needs			X	X												2
Undertstanding of environmental-related constraints				X					X					X		3
Kulatunga et al. (2011) (a)																
Establishment of a clear research problem					X			X	X					X		4
Skilled human resources	X				X		X		X							4
Committed and motivated team members		X	X		X	X			X							5
Effective dissemination of work to the relevant stakeholders					X										X	2
Project Coordination					X											
Resource Management					X											
Kulatunga et al. (2009) (b)																
Stakeholder satisfaction						X								X		2
Principal investigator's commitment		X	X		X	X									X	5
Lee and Park (2006)																
scale of R&D							X									
R&D project duration							X				X	X				3
Project personnel	X				X		X		X							4
Equipment used for R&D	X						X									2
Technical know-how		X	X				X									3
Spur of market demand				X			X								X	3
Rapid commercialisation							X									
Hyvari (2006)																
Clear goals & objectives					X			X	X					X		4
End-user commitment		X	X		X	X		X	X					X	X	**8**
Adequate funds	X							X								2
Adequate resources	X		X		X		X	X	X					X		**7**
Baccarini and Collins (2003)																
Project Understanding					X			X	X					X		4
Competent project team	X				X		X		X							4
Communication		X							X					X		3
Realistic Time and Cost Estimates	X								X					X	X	5
Adequate Project Control									X							
Client Involvement			X						X							2
Risk Management									X			X				2
Resources								X	X					X		3
Teamwork					X				X							2
Project Planning									X					X		2
Senior Management Support	X	X		X					X					X	X	**6**
Stakeholder Involvement									X							
Project Manager's Authority	X								X					X	X	4
External Factors				X					X	X				X		4
Problem Solving									X							

Table 2-2: CSF Matrix

Critical Success Factor List	Authors															Total Appearances
	Nagesh	Mahmood	Barragán-Ocaña	Yamazaki	Kulatunga (a)	Kulatunga (b)	Lee	Hyvari	Baccarini	Klaus	Bizan	Cooke-Davies	Shenhar	Pinto	Balachandra	
Klaus Brockhoff (2003)																
Embedding R&D into the scientific community										X						
Specialisation of the R&D units on core competencies										X						
Securing appropriability of returns										X						
Securing market positions for customer orientation										X						
Selection of appropriate organisation structures										X						
Securing secrecy										X						
Buffering of volatile ordering process										X						
Fighting unfair competition pressures									X	X					X	3
Bizan (2003)																
Increased project duration							X				X					2
Increased project budget											X					
Cooke-Davies (2002)																
Risk management										X		X				2
Process maturity for assigning risk ownership												X				
Accuracy and visibility of a risk register												X				
Adequacy of an up-to-date risk management plan												X				
Accurate documentation of project												X				
Minimised project duration							X					X				2
Scope changes control processes												X				
Integrity of the performance measurement baseline												X				
Effective benefits delivery and management process												X				
Availability of a portfolio, programme and project metrics												X				
Application of lessons learnt from other projects												X				
Shenhar et al. (2002)																
Factors which are independent of the project characteristics													X			
Factors that are exclusively influenced by uncertainty													X			
Factors solely influenced by scope													X			
Pinto and Slevin (1989 & 1987)																
Project Mission					X			X	X					X		4
Top Management Support	X	X		X					X					X	X	6
Project Schedule or Plans									X					X	X	3
Client Consultation									X					X		2
Personnel Related Issues			X						X					X		3
Technical Tasks														X		
Client Acceptance														X		
Monitoring and Feedback		X												X		2
Communication		X							X					X		3
Troubleshooting														X		
Characteristics of the Project Team Leader	X													X		2
Project Team Leader authority	X								X					X	X	4
Power and Politics within an organisation	X		X											X		3
Environmental Events				X					X					X		3
Project Urgency														X	X	2
Balachandra and Raelin (1984)																
Top management support	X	X		X					X					X	X	6
Rate of new product introduction				X			X								X	3
Probability of technical success															X	
Technological route clarity															X	
Project manager as project champion	X													X	X	3
Association between marketing and technical aspects															X	
End-uses								X							X	2
Effectiveness of project manager	X		X						X						X	4
Commitment of project workers		X	X		X	X								X	X	6
Life cycle of product															X	
Internal resource competition					X										X	2
Cost schedules	X								X					X	X	4

Table 2-3: CSF Category Matrix

Critical Success Factor Categories	Authors					Total Appearances
	Nagesh	Mahmood	Barragán-Ocaña	Balachandra	Belassi	
Nagesh and Thomas (2015)						
Project	X		X		X	3
Resources	X	X	X		X	4
Environment	X		X	X	X	4
Mahmood et al. (2014)						
Administrative support		X	X		X	3
Team members' relationship	X	X	X		X	4
Barragán-Ocaña and Zubieta-García (2013)						
R&D process	X		X			2
Project Planning	X		X		X	3
Work and Collaboration networks		X	X		X	3
Human Resources	X	X	X		X	4
Market			X	X		2
Financial Resources			X		X	2
Organisation	X		X		X	3
Quality	X		X		X	3
Balachandra and Friar (1997)						
Nature of the Market			X	X		2
Nature of the innovation				X	X	2
Nature of the technology				X		
Nature of the industry				X	X	2
Belassi and Tukel (1996)						
Factors related to the project	X		X	X	X	4
Factors related to the project manager	X	X	X		X	4
Factors related to the project team members	X	X	X		X	4
Factors related to the organisation	X		X	X	X	4
Factors related to the external environment	X		X	X	X	4

The CSF category in Table 2-3 shows much more commonality across the five reviewed authors with the five categories identified by Belassi and Tukel (1996) related to project, project manager, project team members, organisation, as well as external environment – all appearing four times. Others with similar labels such as resources, human resources and environment also appeared four times across the five reviewed authors. On the other hand, the CSF list shows great disparity across the fifteen reviewed authors. For instance, end-user commitment tops the list, being the only CSF with eight appearances across the various reviewed authors, followed by adequate resources with seven appearances. Top / senior management support and commitment took a third spot with six appearances. The rest of the CSFs, identified by their respective authors as topping their lists, are either not recognised at all by the other authors, or generally make between two and five appearances in the fifteen reviewed authors.

Ultimately, what Table 2-2 and Table 2-3 prove at face value – through the continuous offering of myriad lists and categories of CSFs – is the temporal nature of the CSFs that are at times found to be quite contradictory (De Sousa, 2004; Amberg *et al.*, 2005; Nagesh and Thomas, 2015). In addition, one may also be compelled to appreciate the unique characteristics of a project, in that it should be expected that the CSFs linked to a unique project would follow suit and be as temporal and unique as the projects they are linked to.

However, the author of this paper also concedes that these results could still be proven otherwise as they are likely to have been muddied up by the prevalent ambiguities and possible bias or misinterpretation of the presented labels and terms. The latter was fully reliant on the authors' individual interpretations based on their understanding of the subject, with no form of interrogation (Pinto and Slevin, 1988a). This obviously reflects a potential flaw or limitation in some of the reviewed literature, where the authors concerned have based their results on a similar non-holistic and unsystematic approach, or on the candidates' interpretation of the questions and terms presented in the surveys or questionnaires, without any further interrogation by their counterparts (Martin, 1982; Boynton and Zmud, 1984; Finney and Corbett, 2007). As was noted by other authors, the evidence supporting certain CSFs often seems lacking, as it is usually anecdotal, a single-case study, or theory based rather than empirical (Pinto and Slevin, 1987; Shenhar *et al.*, 2002).

2.4 CRITICAL REVIEW OF THE COMMONLY ADOPTED CSF IDENTIFICATION APPROACHES

CSF identification approaches refer to tools and techniques applied in conducting research related to the identification of the CSFs. Research is the term liberally used for any kind of investigation that is intended to discover interesting or new facts (Walliman, 2017), or it generally refers to a way of finding answers to certain unanswered questions (Kumar, 2011). As with many activities, the rigour with which research activities are carried out, is reflected in the quality of the results (Walliman, 2017). The concept of validity may be applied to any aspect of the research process to ensure correctness of the procedures applied in finding answers to a question (Kumar, 2011) or their ability to measure what is to be measured (Adams and Cox, 2008). Reliability in research refers to the quality of a measurement procedure that provides consistency and truthfulness in the results (Adams and Cox, 2008; Kumar, 2011). Another important research concept involves unbiased and objective results, and requires from the researcher to undertake the each step of the research in an unbiased manner and to draw each conclusion without introducing his/her own vested interest (Kumar, 2011).

Pressure from users and the enhanced diversity of skills influence the type of research conducted, as well as the questions asked and the manner in which they are addressed. This ultimately affects how research is written up for different audiences or users groups (Brannen, 2005). Rockart (1979), the initiator of the CSF method, reportedly used the interview technique in a CSF identification study (Boynton and Zmud, 1984; Barat, 1992; Grunert and Ellegaard, 1992; Khodaveysi *et al.*, 2016). Over the years, numerous other approaches have emerged to either challenge or complement the interview technique introduced by Rockart and his team. However, while there are good reasons for their application, these old and new techniques are also found to be lacking in a number of areas, as will be reflected in the next sub-sections. It aims to provide an in-depth review of the commonly used CSF identification approaches, and also highlights their key advantages and disadvantages.

2.4.1 The interview and focus group approach

An interview is a particular kind of controlled two-person conversation, initiated by the interviewer, where the actors talk to a specific and conscious purpose of obtaining research-relevant information (Akbayrak, 2000). Any person-to-person interaction, whether face to face or otherwise between two or more people with a specific purpose in mind is called an interview (Luna-Reyes and Andersen, 2003; Kumar, 2011). Interviews are used by researchers to obtain more detailed and in-depth information on a topic (Adams and Cox, 2008). They may be structured for minimal to no flexibility, or semi-structured to allow for a deeper understanding of the matter and for the participants to feel at ease and reveal important and relevant issues important to the study (Akbayrak, 2000; Adams and Cox, 2008; Kumar, 2011). Focus groups discussions are similar to the interview process but with the clear distinction that – unlike in a one-on-one interview setup – the focus group could be made up of three or more participants (Adams and Cox, 2008). This could be viewed as interviewing a group of respondents (Kumar, 2011).

Advantages

- The semi-structured option is flexible and allows the interviewer, where necessary, to deviate from a set a questions in order to probe further and maximise the quality of information obtained (Akbayrak, 2000; Luna-Reyes and Andersen, 2003; Adams and Cox, 2008; Kumar, 2011).

- There is greater confidence in the validity and reliability of the responses (Akbayrak, 2000; Luna-Reyes and Andersen, 2003; Bowling, 2005) obtained by means of the structured interview process (Kumar, 2011).
- Interviews have shown to have a higher response rate, compared to the questionnaire approach (Bowling, 2005).
- The interview is a preferred approach for studying complex and sensitive areas as the interviewer is able to prepare a respondent about sensitive questions and to explain complex ones to if required (Kumar, 2011).
- Focus groups allow for better and easier reflection on collaborative experiences (Adams and Cox, 2008).

Disadvantages

- This approach requires careful planning, and it is time consuming and expensive (Akbayrak, 2000; Luna-Reyes and Andersen, 2003; Adams and Cox, 2008; Kumar, 2011).
- Interview participants may leave or quit the survey before completion, thus requiring their replacement, which may involve costs (Akbayrak, 2000).
- Results from the semi-structured interview may be harder to analyse, whereas structured interviews provide less flexibility and sensitivity to individual differences (Akbayrak, 2000; Adams and Cox, 2008).
- Since lengthy interviews and focus group sessions may be unfavourable to the targeted participants, the number of participants may be reduced – thus leading to sample bias (Akbayrak, 2000).
- Finding the desired population sample may be challenging as the interviewer has to find and schedule an interview appointment with a specific individual at a particular location (Akbayrak, 2000).
- Researchers may be compelled to reduce their sample size in order to accommodate the lengthy process of recording and transcribing conversations (Akbayrak, 2000).
- The interviewer factor poses a larger risk of bias, which could be induced by the manner in which the questions are worded or expressed by the interviewer or focus group leader (Akbayrak, 2000; Bowling, 2005; Kumar, 2011).

2.4.2 The questionnaire approach

A questionnaire in its simplest form is merely a list of questions to which answers, recorded by respondents, are sought (Akbayrak, 2000; Kumar, 2011). It is a self-report instrument used for data collection (Akbayrak, 2000). As a research tool, it must be designed such that it is short, easily usable and understandable, with minimal ambiguities, so that the reader can read, interpret and complete it with ease, in order to increase the accuracy of responses (Akbayrak, 2000; Adams and Cox, 2008; Kumar, 2011). If the tool is to accurately assess respondents' attitudes and opinion, it is important to consider reliability and validity. These concepts must be applied concurrently when designing a questionnaire, as one without the other may be rendered useless (Adams and Cox, 2008). Also, it is important to consider underlying biases that may be relayed by the wording of a questionnaire, as these may produce a biased set of responses (Adams and Cox, 2008).

Advantages

- The key advantage of the questionnaire method is its cost effectiveness, compared to other research approaches such as the interview (Akbayrak, 2000; Kumar, 2011).
- Data processing and analysis is generally easier and cheaper (Akbayrak, 2000).
- Questionnaires that are completed by individual respondents are efficient in terms of researcher time and effort (Akbayrak, 2000).
- The questionnaire has greater potential of covering a larger sample at a modest cost (Akbayrak, 2000).
- A more accurate and representative population sample can generally be covered by using this approach (Akbayrak, 2000).
- Interviewees are allowed to respond in the same language that the questions are asked (Bowling, 2005).
- There is a greater level of anonymity and confidentiality in the questionnaire approach, which promotes openness and generates a higher and better quality of responses (Akbayrak, 2000; Kumar, 2011).

Disadvantages

- There is a risk of a low response rate, which may render the approach expensive if it is to be repeated to increase the response rate (Akbayrak, 2000; Kumar, 2011).
- The inherent complexity and / or ambiguity in certain questions may compel the respondents to develop their own meaning, which may be incorrect. This could have a negative impact on the quality of the data and the overall research results (Podsakoff *et al.*, 2003).

- Simplifying the questions with close-ended questions may irritate respondents who find none of the alternative answers suitable and possibly force them to choose inappropriate responses. This may also have a negative impact on the quality of results (Akbayrak, 2000).
- A certain level of cognitive burden is placed on the respondent, especially in respect of the literacy requirements for self-administered questionnaires (Bowling, 2005; Kumar, 2011).
- Incomplete or unreturned questionnaires may have a negative influence on the response rate, reliability and validity of the research (Akbayrak, 2000; Bowling, 2005).
- There is no concrete way of ensuring that the questionnaire is completed by the targeted respondent for whom the questionnaire was intended (Akbayrak, 2000).
- A certain level of bias may be imposed by the type of questions, mainly the closed-ended questions, which compels the respondent to select answers from a limited list of predetermined alternatives (Akbayrak, 2000; Podsakoff *et al.*, 2003; Kumar, 2011).
- There is little or no verification regarding the honesty or seriousness of the responses provided (Akbayrak, 2000; Kumar, 2011).

2.4.3 The case study approach

The case study approach enables researchers to carefully examine data within a specific context. The latter could involve the selection of a small geographical area or a very limited number of individuals as the study subjects (Gable, 1994; Zainal, 2007). A case study is often used when an empirical enquiry is required to investigate a contemporary phenomenon in its real-life context, mostly when the boundaries between the phenomenon and context are not clearly known (Yin, 1981) and multiple sources of evidence are used (Zainal, 2007). Yin (1984) is quoted by Zainal (2007) who defines a case study as a unique way of observing any natural occurrence that manifests in a set of data subjects. The uniqueness of this definition means that only a small geographical area or number of subjects of interest are thoroughly examined (Zainal, 2007). In certain case studies, an in-depth longitudinal examination of a single case or event is done, thereby providing a systematic way of observing the events, collecting information, analysing data and reporting the results over a long period (Zainal, 2007). Through a variety of data collection methods, the case study approach provides the opportunity to probe penetrating questions and to capture the richness of the matter under investigation (Gable, 1994).

Advantages

- A case study is able to uncover both a contemporary phenomenon and its context (Yin, 1981; Gable, 1994; Dubois and Gadde, 2002; Zainal, 2007).
- A case study is useful for generating and testing a hypothesis (Yin, 1981; Flyvbjerg, 2006).
- Variations in case study approaches allow for both quantitative and qualitative analyses of data (Zainal, 2007).
- Through reports of past studies, this approach allows for the exploration and understanding of complex issues (Gable, 1994; Zainal, 2007).
- The detailed qualitative accounts produced in case studies not only assist in exploring or describing the data in a real-life environment, but also help to explain the complexities of real-life situations, which may not be captured through experimental or survey research (Gable, 1994; Flyvbjerg, 2006; Zainal, 2007).
- The usage of a multiple-case design increases the level of confidence in the robustness of the case study method (Zainal, 2007), allowing for cross-case analysis and theory extension (Gable, 1994).

Disadvantages

- There is a perceived lack of rigour and of researcher bias in data collection and interpretation (Gable, 1994; Dubois and Gadde, 2002; Flyvbjerg, 2006; Zainal, 2007).
- A case study is unable to provide reliable, generalised and confirmable conclusions when a small sample is used (Yin, 1981; Gable, 1994; Dubois and Gadde, 2002; Bazeley, 2004; Flyvbjerg, 2006; Zainal, 2007).
- A single case study or small sampling lacks robustness (Zainal, 2007).
- A multiple-case study design could be expensive due to the replication of the case through, for example, pattern matching (Zainal, 2007).
- High complexity in data analysis (Yin, 1981).
- A case study may be too lengthy, often difficult to conduct and produces a large amount of documentation, which may pose a challenge in data analysis, particularly when the data is not managed and organised systematically (Dubois and Gadde, 2002; Flyvbjerg, 2006; Zainal, 2007).

2.4.4 The mixed method approach

The mixed method approach refers to a form of investigation that applies different approaches at any or all of a number of research stages (Bazeley, 2004; Brannen, 2005). This may either refer to a side-by-side or sequential utilisation of different methods or the integration of different methods in a single analysis (Bazeley, 2004). The mixed method approach is often thought of in terms of some combination of qualitative and quantitative tactics to conduct research (Bazeley, 2004; Brannen, 2005; Malina *et al.*, 2011). Qualitative and quantitative approaches have been defined by distinguishing them on the basis of the type of data used, the logic employed, the type of investigation, the method of analysis, the approach to explanation and for others, on the basis of the presumed underlying paradigm (Bazeley, 2004). Generally, mixed methods are utilised to enrich understanding of a particular issue or experience through confirmation of conclusions, extension of knowledge, or by initiating novel ways of thinking about the research subject (Bazeley, 2004; Brannen, 2005).

Advantages

- The limitations of the traditional methods can be overcome / modified (Bazeley, 2004; Adams and Cox, 2008).
- Employing both qualitative and quantitative approaches iteratively or simultaneously creates a research outcome that is better than when either methods are applied individually (Malina *et al.*, 2011).
- Mixed methods are useful in theoretical, methodological and practical research (Brannen, 2005).
- While the qualitative research approach would typically address the "why" and "how" of the questions, the quantitative research would provide answers to the "how many" and "how often" – thereby providing a well-rounded empirical insight into the topic researched (Malina *et al.*, 2011).
- A blended method enables the researcher to answer both confirmatory and exploratory questions concurrently, thus verifying and generating theory in one study (Malina *et al.*, 2011).
- The iterations of qualitative and quantitative data provoke fresh lines of thinking through attention to certain paradoxes, turning ideas around and providing new insights (Malina *et al.*, 2011).
- Mixing the methods leads to an integrated and holistic technique for viewing data both nomothetically and ideographically (Bazeley, 2004).

Disadvantages

- Full and correct integration of the approaches may be difficult and potentially lead to the inappropriate application of rules, which may distort and invalidate the collected data (Bazeley, 2004).

- Confusion often arises in the research design phase due to lack of clarity from the researcher on the motivation behind a selected mixed method design (Bazeley, 2004).
- Cases where few observations are made or interviews are conducted to supplement collected quantitative data may be seen as corrupt, thus compromising the credibility of research results (Bazeley, 2004).
- The process may be time consuming, thus promoting corruption in the form of taking shortcuts to cope with the higher time pressures on the research (Bazeley, 2004).
- It may be difficult to integrate and analyse different data types to obtain accurate research results (Bazeley, 2004).
- Publication of mixed method results is an issue that often causes separate publication of the same study in different journals to satisfy the requirements for different audiences (Malina *et al.*, 2011).
- Lack of independence in observations for certain types of data can create a problem of multicollinearity, as different approaches to data analysis treat variations and exceptions differently (Bazeley, 2004).

The relative advantages and disadvantages of the reviewed approaches appear to suggest that an advantage of one technique is the disadvantage of another, rendering them similar (Locander *et al.*, 1976; Akbayrak, 2000). Of note is the lingering question of subjectivism and bias towards result verification (Flyvbjerg, 2006), as well as the lack of a holistic, systemic and structure-based approach that seems pertinent across all approaches (Dvir *et al.*, 1998; Shenhar *et al.*, 2002). Whilst a number of stakeholders were consulted in the data-gathering process, they were not exposed to others' ideas in an interactive way (Nthunya *et al.*, 2017), and the analysis and coordinated view of inputs were left to the researchers. This shows the seemingly heavy reliance of these approaches on the reductionism principles which say that whilst a project may be unique, many of its constituent elements have been experienced before. This makes it possible to make reasonable estimates for the better management of a new project by decomposing project work into individual elements and channelling the investigation and analysis to each of these elements (Rodrigues and Bowers, 1996). Reductionism stems from the premise that everything in the world and every experience of it can be reduced, decomposed or disassembled down to its simplest, indivisible parts (Ackoff, 1973).

In an attempt to address these and other related concerns, various scholars have conducted studies applying quantitative and qualitative techniques in numerous approaches such as interviews, questionnaires, mixed methodologies and many others (Remus and

Wiener, 2010) (as already identified in the preceding sections of this paper). The ongoing research and its inconclusive findings in this area could be linked to a number of factors:

- Firstly, the commonly applied approaches neglect to view the project as a whole, thus failing to recognise and appreciate the important intra-project forces and relationships that may be much greater than the sum of the individual parts (Rodrigues and Bowers, 1996; Nthunya *et al.*, 2017). For instance, many times the assessment of project success has not been linked to the search for project success factors (Dvir *et al.*, 1998; Shenhar *et al.*, 2002); it has often been done in isolation and yet these variables are clearly interrelated.
- Secondly, little attention has been given to the project type and its relation to strategic and managerial variables, thus neglecting the context in which the project is implemented (Dvir *et al.*, 1998; Shenhar *et al.*, 2002).
- Thirdly (but not least), a range of project management variables are available in literature, which are also viewed as independent by some. A greater part of research into R&D projects and their related CSFs focused on a single major successful aspect of a project, such as the management of human resources; communication patterns; organisational structure; team performance; resource selection. Others even went as far as asking their study participants to identify a single action that was deemed influential in the successful implementation of their projects (Dvir *et al.*, 1998; Shenhar *et al.*, 2002). Perhaps, and not surprisingly, considering the reductionist-centred definition of CSFs as the independent elements of a project may, when adequately influenced, increase the likelihood of its success (Pinto and Slevin, 1987; Müller and Jugdev, 2012).

Nonetheless, these are only few of the examples that show how CSF identification approaches are mostly based on the reductionist approach. They fail to show a clear appreciation of the interrelatedness of project variables and the complexity of a project environment by simply dissecting the whole problematic project situation into elements, focusing only on selected variables for investigation, and recommending solutions that treat the dissected perceived problematic elements as distinct variables (Nthunya *et al.*, 2017). Implicit in the concept of complexity is the notion that complex situations are problematic (Cardenas *et al.*, 1997), such that they could never be ultimately indivisible to a point of having only one problem (Ackoff, 1973). From a systems point of view, a problematic situation would normally contain two or more interrelated problems conceptualised as a system of problems (Ackoff, 1973). Moreover, organisations and various other groups internal or external to the organisation are always confronted by a system of problematic situations. Each of these would normally consist of a system of problems, proving that every problematic situation is itself seen as part of a sequence of situations and that problems in temporally different settings do interact (Ackoff, 1973).

The traditional reductionist principle assumes projects to be linear, or static and closed, with minimal chaos, requiring basic management to keep them on track on all the hard targets (Rodrigues and Bowers, 1996). However, this is far from the reality of any modern project. The deployment of diverse and complex projects in today's organisations increases the importance of finding the main factors that affect project success (Shenhar *et al.*, 2002) and that these factors reflect the evolving nature of such projects. The mere definition of a project as a specific predetermined goal or set of goals, made up of a series of complex or interrelated activities (Pinto and Slevin, 1988a; 1988b; EFCOG, 2010), makes the management thereof a complex undertaking (Dvir *et al.*, 1998; Shenhar *et al.*, 2002). Bringing a project to successful completion is a highly complex and multifaceted endeavour that requires the integration of various management functions (e.g. management of risk and technical issues; cost and schedule management; communication; stakeholder and conflict management; overall lifecycle management and many other related functions) (Dvir *et al.*, 1998; Shenhar *et al.*, 2002). The large variety of project management tasks and the related factors required for the successful completion of a project have gradually fostered the adoption of systems and systemic thinking into project management, in an attempt to assist managers to better understand the intricate and wholeness nature of a project (Dvir *et al.*, 1998; Shenhar *et al.*, 2002). Echoing this assertion, Rodrigues and Bowers (1996) also identified the factors which in their view have influenced the application of the systems dynamics to project management. These included a resounding need for a holistic approach towards projects, which encourages treating a project as a whole rather than as a sum of individual elements; a need to investigate the key non-linear aspects described by balancing or reinforcing feedback loops; and the overall failure of the traditional approaches to solve the ever-growing complexity of project management problems (Rodrigues and Bowers, 1996). All of these ultimately have an impact on the coherent and holistic identification of the critical factors behind the success of these projects.

In appreciating the complexity of a public-funded R&D project and the interrelatedness of the many factors that need to be considered to complete such an environment, this paper proposes a systemic and structure-based approach for the identification of the CSFs of public-funded R&D projects in SA. Through this approach, which promotes a participatory and interpretive process of soliciting stakeholder views, existing relationships between the identified CSFs will also be explored.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 THE EVOLUTION OF SYSTEMS THINKING

The introduction of the Systems Age was supposedly preceded by what others call the Machine Age. The Machine Age was founded on two ideologies about the nature of the world and a way of seeking its understanding, viewed from the reductionist and mechanistic perspective (Ackoff, 1973).

Reductionism stems from the belief that everything in the world and every experience of it is reducible or decomposable and could ultimately be disassembled down to its simplest and indivisible parts or elements (Ackoff, 1973; Flood, 2010). The Reductionists' rationale led to an analytical way of thinking about the world, a way of seeking explanations and gaining understanding. This approach to thinking consists of many parts. Firstly, it is concerned with disassembling something down to its independent and indivisible parts; secondly, it focuses on clarifying the behaviour of these parts; and lastly, it attempts to aggregate these partial explanations into clarifying the whole (Ackoff, 1973). Thus, an analysis of a problem would consist of breaking it down into a set of simple problems, solving each and assembling their solutions into a solution of the whole (Ackoff, 1973). Furthermore, it is alleged that when these reductionists succeed in their effort of decomposing the problem into simpler problems that are independent of each other, then the aggregation of the partial solutions is not required – the solution to the whole is said to be the sum of the solutions to its independent parts (Ackoff, 1973). The understanding of the world from a reductionist point of view was therefore simply a sum or the result of understanding its parts. These were conceptualised to be as independent of each other as possible, thus making it possible to divide the labour of seeking an understanding of the world into a number of fundamentally independent disciplines (Ackoff, 1973).

The mechanistic ideology arose from the belief that all phenomena could be explainable by using one simplistic cause-and-effect relationship, namely that one thing or event was taken to be the cause of another (Ackoff, 1973; Flood, 2010). It effectively employed what is called closed-system thinking, because according to this ideology, a cause was understood to be enough for its effect. This meant that nothing was required to explain the effect other than the cause, making the pursuit for causes environment-free and implying that effects are completely determined by causes (Ackoff, 1973). The prevailing view of the world was in essence deterministic but also mechanistic, in that science found no need for teleological concepts, goals, functions, purposes and free will in explaining any natural phenomenon.

Teleological concepts were basically considered to be either superfluous, illusive or pointless (Ackoff, 1973). Therefore, the commitment to causal thinking led to the conception of the world as a machine, a self-contained mechanism whose behaviour was completely determined by its own structure (Ackoff, 1973). A fast forward to the 1940s marked the beginning of the end of the Machine Age and the birth of the Systems Age (Ackoff, 1973; Jackson, 2003). A myriad of terms were introduced, such as the Symbol, by Suzzanne Langer in 1941; Languages, by Charles W. Morris in 1946; Communication, by Claude Shannon in 1949; and Control, by Nobert Wiener in 1948 (Ackoff, 1973). Later on, in the late 1960s, Ludwig von Bertalanffy highlighted the systems phenomenon in his work (Ackoff, 1973) and essentially exposed the weaknesses of the concepts of reductionism in appreciating the dynamics of organisms (Jackson, 2003; Flood, 2010).

The System Age is the product of the intellectual framework in which the doctrines of reductionism and other analytical modes of thought were supplemented by the doctrines of expansionism and teleology (fundamentally the synthetic systems mode of thinking) (Ackoff, 1973; Flood, 2010). Expansionism is based on the belief that all objects and events and their experiences are parts of larger wholes. It does not deny that they have parts, but focuses on the wholes of which they are part (Ackoff, 1973; Nthunya *et al.*, 2017). Expansionism essentially focuses the attention away from the reductionists' independent elements to wholes with interrelated parts, i.e. systems (Ackoff, 1973).

A system is a set of any kind of interrelated elements, which could include concepts like the number of systems; objects, like a telephone system or human body; or people in a society (Ackoff, 1973; Morris, 1983). Ackoff (1973) postulates that the set of interrelated system elements would contain the following three properties:

1. The properties or behaviour of each part of the set has an effect on the properties or behaviour of the set as a whole.
2. The properties and behaviour of each part and the way they affect the whole are dependent on the properties and behaviour of at least one other part in the set – meaning that no part has an independent effect on the whole.
3. Every conceivable subgroup of elements in the set has the first two properties; in other words, each would have an effect, and none would have an independent effect on the whole, meaning that the elements could never be organised into independent subgroups.

Consequently, due to these three properties, a conclusion was drawn that a set of elements that form a system would always possess some characteristics or display certain behaviour that none of its elements or subgroups can (Ackoff, 1973). Moreover, membership of the set would either decrease or increase the capabilities of each element, and would not leave them unaffected (Ackoff, 1973). The parts of the system may themselves be systems and every system may also be a part of a bigger system, thus making a system more than just a sum of its parts, but an indivisible whole, in that some of its essential properties may be lost in taking it apart (Ackoff, 1973; Morris, 1983; Flood, 2010).

Systems thinking, which effectively stems from the Systems Age, is essentially more interested in putting things together than in taking them apart (Jackson, 2003). It is based on the systems principle that brings with it the synthetic mode of thinking, which stems from the belief that something that needs explanation, is viewed as part of a larger system and is explained in terms of its role in that larger system (Ackoff, 1973; Flood, 2010; Nthunya *et al.*, 2017). Synthetic thinking is said to be outwardly oriented, while the analytical reductionist thinking is seen as inwardly oriented. The Systems Approach basically refers to the application of the outwardly oriented synthetic mode of thinking to systems problems (Ackoff, 1973). This way of thinking is founded on the observation that when each element of the system performs as well as possible, the system as a whole will rarely perform as well as possible, due to the fact that the sum of the functioning of the parts is rarely equal to the functioning of the whole (Ackoff, 1973; Morris, 1983). Essentially, system performance is critically reliant on how the parts fit and work together, not just on how well each performs independently (Ackoff, 1973), as is advocated by the reductionists. A system's performance also depends on how it relates to its environment – the larger system of which it is a part – and to other systems that are part of that environment. Ultimately, in systems thinking, the performance of a system is evaluated by assessing its functioning as a part of the larger system that contains it (Ackoff, 1973; Morris, 1983). Ackoff (1973) postulates that because the Systems Age is teleologically oriented, it is preoccupied with the purposeful or goal-seeking systems that reflect a problematic situation. Systems of problematic situations are also referred to as messes, derived from the modern groups and organisations that are always confronted by a system of interdependent problematic situations, each of which usually consists of a system of complex problems (Ackoff, 1973).

3.2 A SYSTEMIC VIEW OF PROBLEMS

Flood (2010), echoed by Nthunya *et al.* (2017), asserts that systemic thinking and systems thinking are two lines of thought that argue for two different convictions about inquiry. Ludwig von Bertalanffy, a biologist, is said to be one of the pioneers of Systems Thinking (Ackoff, 1973; Nthunya *et al.*, 2017) who developed the General Systems Theory, which describes commonalities across all systems (Nthunya *et al.*, 2017). Von Bertalanffy demonstrated through his work that the reductionist concepts were less useful in appreciating the dynamics of an organism (Flood, 2010). According to Nthunya *et al.* (2017), system dynamics was promoted by Forrester (1968) in modelling and predicting organisational behaviour. In a quest to find new ideas of explaining new concepts such as interrelatedness and emergence, the open systems theory (widely known as Bertalanffy's General Systems Theory (Jackson, 2003)) was developed (Flood, 2010). The key features of open system, organic whole, self-regulation and adaptation exist in the living systems (Flood, 2010; Nthunya *et al.*, 2017). In addition, Wiener (1961), also quoted by Nthunya *et al.* (2017), is said to have employed cybernetics to analyse animals and machines. Building on the biological metaphor, Miller (1978) suggested that there are seven levels of living systems – each system comprising nineteen critical subsystems, of which behaviour is governed by proposed hypotheses (Nthunya *et al.*, 2017). Systems thinking accentuates holistic ideas, governing laws and complexity in the observed systems (Dvir *et al.*, 1998; Shenhar *et al.*, 2002; Remus and Wiener, 2010; Nthunya *et al.*, 2017). In terms of problem identification, it is argued that any specific problem is connected to other problems (Nthunya *et al.*, 2017), as was indicated in the preceding section on the evolution of the Systems Age. Ackoff (1973) states that all objects and events as well as their experiences are part of a larger whole. Therefore, the understanding of a system has shifted from the traditional, reductionist approach and has expanded into larger systems (Nthunya *et al.*, 2017).

However, there is complexity in the observed systems governed by objective laws that also govern human beings (Nthunya *et al.*, 2017). Implicit in the concept of complexity is the idea that complex situations are problematic in that they often result in confusing interpretations. Their perceptions normally also lead to some discomfort or dissatisfaction on the part of some human being (Ackoff, 1973; Cardenas *et al.*, 1997). These are the typical characteristics reflected in the efforts of this study to identify the CSFs for public-funded R&D projects in SA. A generic notion of complex problem solving considers it as a purposeful activity aimed at changing an existing state of doubt and dissatisfaction into a state of satisfaction with regard to a particular situation (Ackoff, 1973; Cardenas *et al.*, 1997). This view of problem solving encompasses a human component whose perceptions and interests define the levels of dissatisfaction and satisfaction; a situation; and a set of activities organised to produce the sought-after change from dissatisfaction to satisfaction (Cardenas *et al.*, 1997). Human beings are differentiated from animals because they have brains and a reasoning capability that comes with self-consciousness – a key differentiating characteristic from other creatures (Boulding, 1956). The human mind shapes part of the organisation's characteristics and behaviour, which is said to be affected by human views of the time process in which they exist (Boulding, 1956; Nthunya *et al.*, 2017). According to Tuan and Jay, the mind has the capacity to accommodate inconsistencies at any given time, because at the time of making the choice or decision, the individual is most likely to have contradictory beliefs in their minds (Tuan and Jay, 2016). Such an assertion is questioning the adequacy of applying causal laws to the study of human behaviour, thus supporting Ackoff and Emery's (1972) proclamation that mental activities of humans do not succumb to causal analysis (Nthunya *et al.*, 2017). If the studied systems are social or human activity systems, developing a model depicting an objective representation of a problem or system by the people with different perspectives is not simple and straightforward (Nthunya *et al.*, 2017). According to Nthunya *et al.* (2017), Wolstenholme (1990) suggested that the creation of a cause-and-effect diagram in the qualitative part of systems dynamics is for translating individual actors' views and thoughts into usable ideas that could be communicated to others. This suggestion could therefore be taken to mean that reaching consensus among diverse views to construct the qualitative model is inseparable from systems dynamics, in spite of its positivistic orientation (Nthunya *et al.*, 2017). Luna-Reyes and Andersen (2003) propose the incorporation of subjective perspectives into qualitative modelling in system dynamics (such as interviews, focus group discussions, content analysis and the like (Luna-Reyes and Andersen, 2003; Nthunya *et al.*, 2017)) and continuously conducting tests to ascertain whether the data mirrors the reality of the system being studied or the client's mental models (Luna-Reyes and Andersen, 2003).

The two disparate ideals in the systems age manifest disparate belief about the source of complexity. One suggests that system dynamics believe that complexity exists in the observed system and shut out the human being as the active component of a system (Warfield, 1999), whilst the other, structure-based thinking, suggests that complexity is in the mind, thus embracing subjectivity to the enquiry process (Warfield, 1999; Nthunya *et al.*, 2017). Warfield's interpretation is seen to suggest that the two ideals are at opposite ends in the systems age spectrum, thus highlighting the possible overburdening of the systems thinking approach, due to the generic understanding that it actually embodies both of these two seemingly disparate ideals. Flood (2010) suggests that systems thinking should be distinguished from systemic thinking, in that systemic thinking would assume that knowledge is subjective, while systems thinking would assume that knowledge is objective (Tuan and Jay, 2016; Nthunya *et al.*, 2017). The noted differences between systemic thinking and systems thinking are not necessarily at odds (Nthunya *et al.*, 2017) as advocated by Warfield (1999). Warfield asserts that the structure-based approach is not intended to compete with other approaches, but rather aims to complement their efforts so as to accomplish what is required for all of them to add value to a situation that is rife with complexity (Warfield, 1999).

The ability to effectively deal with complexity is a major focus of systemic and structure-based methodologies (Cardenas *et al.*, 1997; Warfield, 1999), and the IM methodology is identified as one of the outstanding efforts (Cardenas *et al.*, 1997) aimed at addressing complexity based on an explicit acknowledgement of a participatory principle (Warfield and Cárdenas, 1993; Cardenas *et al.*, 1997; Warfield, 1999). The proposal by various authors of a more holistic systemic approach towards CSFs identification (Dvir *et al.*, 1998; Shenhar *et al.*, 2002; Remus and Wiener, 2010) is also advocated in this paper. In its quest of identifying the CSFs for public-funded R&D projects in SA, this paper echoes the systemic thinking that complexity emanates from multiple views, but also accommodates certain aspects of systems thinking related to interconnectedness. The study therefore aims to explore the usage of the IM methodology – a systemic, structure-based approach – to identify CSFs and further investigate existing interrelationships between the identified CSFs responsible for the successful completion of the inherently complex public-funded R&D projects in SA.

3.3 RESEARCH METHODOLOGY: INTERACTIVE MANAGEMENT

Banathy (1996), as quoted by Alexander (2002), asserts that the concept of IM was developed by Warfield and Christakis at the University of Virginia in 1980. It has since been successfully utilised in large groups facing crisis situations (Warfield and Cárdenas, 1993; Alexander, 2002). IM is based on the systems design framework, and uses collaborative teamwork to define and resolve highly complex issues (Warfield and Cárdenas, 1993; Alexander, 2002). It is a participatory process (Alexander, 2002) that enhances learning by allowing the participants to be open minded and view the situation through another's eyes (Warfield and Cárdenas, 1993; Nthunya *et al.*, 2017). It is essentially used to construct alternative designs for resolving complex situations (Warfield and Cárdenas, 1993). IM stems from the recognition that in order to cope with complex and unusual situations, there is a need for a group of knowledgeable individuals to tackle the main aspects of the situation together, to develop a deep understanding of the situation under review, and to propose an effective solution and elaborate on it. IM is therefore best suited for use in environments where there is no readily available solution to the issue being confronted (Warfield and Cárdenas, 1993). IM management is a decision-oriented disciplined enquiry, which is essentially based on the thinking that today's times are characterised by increasing complexity, thus necessitating a need to approach this complexity by means of systems design (Warfield and Cárdenas, 1993; Cardenas *et al.*, 1997; Alexander, 2002). The design would be made up of a group of knowledgeable people who could tackle the main aspects of the situation and develop a deep understanding of the situation being analysed, thus elaborating the basis for effective action (Warfield and Cárdenas, 1993; Alexander, 2002).

The focus of IM group work is on the development of shared representations of complex situations and the generation of consensus-based design solutions for addressing those situations, thus termed the enquiring system (Cardenas *et al.*, 1997; Alexander, 2002). As a democratic process, the IM participants are not induced to agree to a substandard decision for the sake of agreeing; they are encouraged by their need to succeed in defining the issue and finding adequate solutions for resolving it (Alexander, 2002). The concept of complexity in the IM literature is described in terms of three interrelated components of situational complexity, cognitive complexity and pluralistic complexity, highlighting that any definition of complexity ought to recognise the sensitivity of the concept of how humans are being viewed (Cardenas *et al.*, 1997). Typically, IM would involve three phases (Warfield and Cardenas, 1993) as detailed below:

- **Planning Phase**: This is a foundation phase that lays the basis and a plan for the next two phases. In this phase, people, information and facility requirements for the remaining two phases are identified (Warfield and Cárdenas, 1993; Alexander, 2002). Also, the key information relevant to the area of concern is gathered from various sources and will provide a clearly defined and well-understood context or problem statement to be used to provide focus of the workshop process (Alexander, 2002; Christakis and Dye, 2007). The criticality of the planning phase is to ensure fruitful utilisation of the participants' time in the IM workshop (Warfield and Cárdenas, 1993; Alexander, 2002).

- **Workshop Phase:** The workshop or conversation phase should be conceptualised as a process for building patterned interactions among the participants (Alexander, 2002). It is suggested that the workshop team be constituted of a group of between six and twelve individuals, led by an experienced facilitator (Warfield and Cárdenas, 1993). According to Alexander (2002), active participants in the workshop have the following five crucial roles:
    - Stakeholders are encouraged to freely engage through open and focused dialogue (Christakis and Dye, 2007), thereby encouraging all involved to generate and clarify the meaning of a large number of ideas to produce team-based rational patterns.

- The participants are encouraged to bring a broadening perspective to the design process. Through the dialogue, the participants discover how their diverse ideas may be intertwined into one big mosaic.
- Participants agree on the identification of visible relationships among ideas.
- The views represented in the discussion should mirror some constituency in the community.
- Throughout the workshop process, participants should adopt the posture of individual and collective learning.

The many goals of the workshop process may be summed up as follows: defining a vision, heightening consensus about accomplishing the vision, and enhancing teamwork and commitment to the evolutionary development fostered through learning and understanding that occur during the process (Warfield and Cárdenas, 1993; Alexander, 2002).

- **Follow-up phase:** This last phase involves the implementation of the results, which in other cases may require a further iteration of the first two phases (Warfield and Cárdenas, 1993). This phase is assumed to be idiosyncratic to each project and is mainly concerned with answering the question of "When will we do what we can do?" (Alexander, 2002). Whilst this may be important in proving the validity of the solutions proposed during the workshop phase, it falls outside the scope of this study. It will therefore not be included in this paper, which is predominantly focused on identifying those factors perceived to be critical in influencing the successful completion of public-funded R&D projects in SA.

The process of achieving the objectives of this research will be centred on the two key phases of the IM methodology, namely the pre-workshop phase and the actual workshop phase. The two phases will culminate in a five-step approach, with the last three steps conducted in a workshop setting as adopted from Warfield's IM and further simplified by Nthunya *et al*. (Warfield and Cárdenas, 1993; Nthunya *et al.*, 2017). The following sub-sections provide an overview of each of the five stages:

3.3.1 Pre-workshop preparation

This phase focuses on identifying stakeholder participants, formulating concepts, as well as preparing for the workshop facility (Warfield and Cárdenas, 1993). Jackson (2003) asserts that the term stakeholder is used to denote any group with an interest in what the system is doing, while Warfield and Cárdenas (1993) define participants as those individuals who produce the substantive content related to the design situation or issue. Furthermore, they produce the designs of possible solutions, based on their learning and augmented by the experience of the workshop (Warfield and Cárdenas, 1993). Because stakeholders are participants in the issue, a good stakeholder representation is markedly a key success factor for the IM workshop (Warfield and Cárdenas, 1993). The workshop participants are expected to furnish the knowledge required to develop the patterns that will encompass the bulk of the workshop products (Warfield and Cárdenas, 1993). It is therefore crucial that the selected participants be individuals who are knowledgeable about the matter under review, such that their collective knowledge and experience is comprehensive in relation to the context statement (Warfield and Cárdenas, 1993). Janes (1988) suggests that a good stakeholder participant representation should encompass four potentially overlapping categories of people: firstly, the specialists who would have content knowledge relevant to the various aspects of the situation; secondly, the stakeholders who are people who may at some point be affected by the outcome of the study; thirdly, the structural modellers who can assist in structuring the issue; and lastly, the facilitator who will direct the workshop discussion.

In the pursuit of Jane's (1988) suggested four-category stakeholder representation, the participant selection for this paper will be guided by the responses received in a questionnaire (see Annexure A) which will be sent out to potential participants at different managerial levels, in various R&D institutions across the Gauteng province. The questionnaire will be used to ascertain their level of knowledge and experience in the subject under review so as to ensure that the selected participants are adequately knowledgeable and suited to enrich the IM workshop discussions and outcomes. The number of workshop participants will be in the range of five and twelve, excluding the IM facilitator. This range is guided by Warfield and Cárdenas's (1993) suggestion of six to 12 participants and that of Christakis and Dye (2007) and Janes (1988) of five to nine participants. The latter participant number is based on the assertion quoted from Miller (1956), namely that human beings can only simultaneously deal with between five and nine observations at a time. Therefore the design conversations should also not require process designers to deal with more than nine items simultaneously, with the lesser number being the most preferred (Christakis and Dye, 2007). For this paper, it is therefore proposed that the number of participants be limited to seven participants, which the author perceives to be a reasonable median in a five to 12 range. Ultimately, regardless of the final number, the participant grouping for this study will be such that there is a diverse, yet highly knowledgeable group with mostly opposing perspectives. This will result in a richly participative and adversarial discussion among individuals at different managerial and non-managerial levels in a variety of organisations (Jackson, 2003) across Gauteng.

In conducting the workshop, the person controlling the whole process is the IM facilitator, who may also play the role of workshop planner, computer operator, scribe and many other roles (Warfield and Cárdenas, 1993). While the multiple-role scenario may be acceptable, the general exclusion is that the person who takes the facilitator role is not allowed to also take on the role of participant in a given design situation. The credibility and effectiveness of the facilitator role is highly dependent on strict adherence to this requirement (Warfield and Cárdenas, 1993). The facilitator effectively and efficiently drives the activity towards an outcome that evolves towards a constructed design solution (Warfield and Cárdenas, 1993; Alexander, 2002). To enable this, the stakeholder questionnaire in Annexure A will also assist the IM facilitator to gather key information relevant to the area of concern. This will provide a clearly defined and well-understood context or problem statement to be used to focus the workshop process. For the purposes of this study, the author will assume the role of the IM facilitator.

Another important aspect of the planning phase, which is said to have a major influence on the success of the workshop, is the preparation of the workshop facility, which Warfield and Cárdenas (1993) term a *Demosophia* facility. *Demosophia* originates from two Greek words, the first (*demo*) referring to democracy and the second (*sophia*) to wisdom as associated with the latter part of the word philo*sophy* (Warfield and Cárdenas, 1993). Combined, the two words create a concept such as the wisdom of the people, which effectively implies that the facility is specifically tailored to a desire to collect and organise collective wisdom of a group (Warfield and Cárdenas, 1993). The facility chosen for the IM workshop for this study will be guided by the IM principles of a *Demosophia* facility, which will reflect a working environment that focuses on eliminating detractions and recognises a need for personal comfort for human beings engaged in long complex tasks (Warfield and Cárdenas, 1993).

3.3.2 Idea generation

This phase is intended to elicit different elements of a system from the relevant stakeholder participants (Warfield and Cárdenas, 1993). It is in the idea generation stage that the participants get to frame a consensual understanding of the problem and generate content by responding to a triggering question (Warfield and Cárdenas, 1993; Alexander, 2002). The triggering question is the stimulus to generate ideas (Warfield and Cárdenas, 1993). It synthesises and drives workshop deliberations, thereby assisting the IM facilitator to maintain focus of the workshop for a purposive outcome (Alexander, 2002). It is suggested by Warfield and Cárdenas (1993) that for a triggering question to be successful, it should typically satisfy the following criteria:

- It should be such that only a single focus is given to trigger a response, which means that if a question requires more than oner response, then a separate question and process should be used for each.
- It should be understandable and unambiguous so that it will be feasible for participants to adequately respond to it.
- To be useful, the words used in the triggering question should be neither too general nor too specific, thereby restricting the flow of ideas.
- The triggering question should be responsive to and associated with the context in which the issue is embedded.
- Most importantly, its contextual implication should be compatible with the background of the participants and the scope of the workshop.

The proposed triggering question for this study is as follows:
What do you perceive to be the CSFs that can lead to the successful completion of Public-funded R&D projects in SA?

In response to this triggering question, ideas will be individually generated by the participants from their vantage points. These ideas will also assist each participant to obtain an initial understanding of others' perception of the issue under review (Nthunya *et al.*, 2017). The idea generation phase is normally conducted in a workshop setup; however, for the purposes of this study, a slight deviation will be noted as this process will be initiated prior to the workshop by using the questionnaire contained in Annexure A of this paper. Workshop time efficiency and the difficulty of securing the presence of all participants in a day workshop are the key motivators for this non-conformance. The content generated from this process will be utilised in the ensuing clarification stage (Warfield and Cárdenas, 1993).

3.3.3 Clarifying, editing and recording

This stage of the process, which is largely based on the general Nominal Group Technique (NGT), prescripts that guide the generation and clarification of ideas, as well as the preliminary partitioning of a set of generated ideas (Janes, 1988; Warfield and Cárdenas, 1993) are intended to provide clarity on the generated ideas and eliminate existing ambiguities. Each individual idea from the list of ideas generated in the preceding stage will be collectively clarified by all participants for common understanding. While the ideas are being clarified, they will also be edited as deemed necessary by the participants under the leadership of the IM facilitator (Warfield and Cárdenas, 1993). This process may require some generated ideas to be rephrased, merged or deleted from the list (Warfield and Cárdenas, 1993; Nthunya *et al.*, 2017). Whilst it is understood that some of the generated ideas may have no real merit, it will be crucial at this stage for the facilitator to restrain the group from entering into an evaluative tone while the ideas are being expressed and clarified, because the ideas are not to be judged at this point (Warfield and Cárdenas, 1993). In order to generate a comprehensive list of ideas for use in the next stage of idea structuring it will also be vital for the facilitator to continuously promote and encourage free speech from every participant. Each participant should be reminded that all ideas are acceptable, no perceived negative judgement is allowed and the focus should be on learning and understanding each individual's views (Warfield and Cárdenas, 1993).

3.3.4 Idea structuring: Interpretive Structural Modelling

In this phase, the participants examine possible existing, transitive relationships between a pair of system elements that were identified in the prior two phases (Janes, 1988; Warfield and Cárdenas, 1993). Having completed the idea generation and clarification phases, the next step is to structure these ideas so as to produce a list of ranked ideas and explore possible interrelationships between these elements. However, because it is the general understanding that not all ideas produced in the preceding phases will have real merit, the facilitator will, before the process continues, need to first select the most important or meaningful set of elements from the long list generated in the previous stages (Warfield and Cárdenas, 1993). The long list of ideas may require a shortening strategy should it exceed the supposedly practical number of thirty ideas (Sorach_Inc, 2014).

The permissible strategy to be followed at this point is one suggested by Warfield and Cárdenas (1993), which would be for individual participants to vote for what they each perceive to be the top five CSFs for public-funded R&D projects in SA, and to also rank them according to their importance. The selection will be from the consolidated list of all CSF ideas generated in the preceding stages of the methodology. The result of the voting process will be used to place the listed CSFs into two subsets, the first referring to those CSFs that received at least one vote as belonging to the top five, and the second referring to those CSFs that received no vote to be placed in the top five.

The advantage of this process is that it enables the facilitator to sequence the ideas to be structured according to the judgements made by the participants without being influenced

(Warfield and Cárdenas, 1993) by either the facilitator or fellow participants. On completion of the partitioning and ranking of the ideas, the next step is to identify existing interrelationships (Janes, 1988). In order to analyse the factors and ascertain if a relationship does exist between a pair of elements, a contextual relationship type of "help to achieve" (Nthunya *et al.*, 2017), "leads to" or "influences" (Attri *et al.*, 2013) is to be selected. For the purposes of this study, the "significantly help to achieve" type will be utilised as opposed to the "leads to" type, due to the clear positive connotation it carries. This highlights the leverage one element has over the other, in that a yes vote denotes a solid relationship between the reviewed elements (Sorach_Inc, 1999; 2014). The "leads to" type is less favourable for this study as it could be used to denote either a positive or a negative contextual relationship. This process, as well as the ranking process, is better facilitated with the assistance of computerised Interpretive Structural Modelling software (ISM) (Janes, 1988; Warfield and Cárdenas, 1993).

According to Warfield (1982) as quoted by Janes (1988), ISM is described as a computer-assisted learning process that enables an individual or user group to develop a structure or map showing interrelations among predetermined elements in accordance with a selected contextual relationship. Waller (1983), also quoted by Janes (1988), perceived ISM to be context-free in that it could be applied in any complex situation, irrespective of the content of the situation, as long as the set of elements could be identified and accompanied by an appropriate contextual relation. The ISM process is asserted to force the user to pick the elements of importance in the issue under exploration and to explicitly state the interrelations between them according to specific contextual relations (Janes, 1988). Therefore the ISM, which is powered by Sorach's Concept Star software (Sorach_Inc, 2014), assists in the recording and structuring of ideas and observations, the clarification of meanings, the exploration of interrelationships among the observations, and the production of relationship patterns among ideas, while it has the flexibility to continuously amend recorded ideas and patterns as deemed necessary by the participants (Warfield and Cárdenas, 1993; Alexander, 2002). In completing a binary matrix of element interactions when using the ISM software, the group will need to discuss and agree on the existence of a relationship between two chosen elements (Nthunya *et al.*, 2017), as guided by the facilitator who will direct the discussions by asking a contextual question (Janes, 1988).

<u>The proposed contextual question for this study is as follows</u>:
In the case of failed public-funded R&D projects in SA, would "CSF A" significantly help to achieve "CSF B"?

This means that the interrelationship being explored between the selected CSFs is that of an Intent Structure for a set of public-funded R&D project CSFs, using a contextual relationship "would help to achieve" (Janes, 1988). In response, a "yes" or "no" answer to the contextual questions will be agreed upon after the group vote, in which case "1" will indicate the existence of a relationship and "0" will mean no relationship exists (Janes, 1988; Nthunya *et al.*, 2017). The binary matrix that is constructed will therefore be representing a binary relation of a set on itself (Janes, 1988). On completion of the binary matrix, a multilevel diagraph would be extracted from the matrix (Janes, 1988; Nthunya *et al.*, 2017).

It is worth noting that the mathematics underpinning ISM always assumes that the contextual relationship is transitive, which allows asymmetric inferences to be made, thus highlighting the importance of selecting the contextual relations to ensure they have transitivity properties (Janes, 1988). Such transitive relationships could therefore be used for inference (Nthunya *et al.*, 2017), such that, if "A" is a higher priority than "B" and "B" is a higher priority than "C", then it can be transitively inferred that "A" is a higher priority than "C" (Janes, 1988). The overall time required for the ISM process ranges between two and eight hours, depending on the number of elements in the set and their complexity (Warfield and Cárdenas, 1993).

3.3.5 Interpretation of the structured ideas

This is an output review stage of a produced model, in a form of a diagraph that displays the interrelationships among the system elements. In this phase of the IM methodology, the participants are allowed to change the voting record if deemed necessary, resulting in a revised model (Nthunya *et al.*, 2017).

IM provides the stimulus for social action (Alexander, 2002). The IM process promotes the integration of diverse perceptions of the participants with regard to the given situation and the building of consensus and joint ownership of the process and outcome (Alexander, 2002; Christakis and Dye, 2007). The principal but intangible outcomes from this process include reflective participation and individual learning that occurs among the community of all stakeholders involved in the process (Alexander, 2002; Christakis and Dye, 2007). Whilst this study does not intend continuing with the implementation phase of the IM methodology, individual participants will be encouraged to pursue follow-up activities outside the scope of this study, aimed at addressing those unaddressed issues and concerns from the workshop phase.

The main goal of this chapter was to introduce the IM methodology as the approach that will be applied in this study in the quest of identifying the CSFs of public-funded R&D projects in SA. The next chapter provides a detailed overview of the actual application of the IM methodology in this research study and contains a thorough analysis of and discussion on the study findings based on the application of the various stages of the IM methodology.

CHAPTER 4: RESEARCH FINDINGS AND DISCUSSION

The research and analysis of this paper adopted a two-pronged approach – a pre-workshop phase, followed by the actual workshop phase. This chapter is intended to provide a detailed account of the actual application of the IM methodology that was introduced in Chapter 3 (i.e. from the pre-workshop phase to the conclusion of the workshop phase). The last section of this chapter highlights the key findings of what the participants collectively identified as the CSFs that can lead to successful completion of public-funded R&D projects in SA – in comparison to what was discovered in the reviewed literature.

4.1 PRE-WORKSHOP PHASE

The pre-workshop phase for this study entailed the identification of stakeholder participants and idea generation by using a questionnaire, as well as the preparation for the workshop facility. In this research findings and discussion chapter, the discussion on the pre-workshop phase will focus on the activities and findings of the processes of identifying stakeholder participants and idea generation.

4.1.1 Participant identification and selection

As previously mentioned, IM stems from the recognition that in order to cope with complex and unusual situations, there is a need for a diverse group of knowledgeable individuals to collectively tackle the main aspects of the situation, develop a deep understanding of the situation under review, and propose an effective solution (Warfield and Cárdenas, 1993). As such, the stakeholder participant selection for this paper followed a process that was aimed at achieving richness and diversity in its stakeholder representation. A questionnaire sample (see Appendix A) was sent out to 16 potential participants, holding various stakeholder roles and responsibilities in a variety of R&D institutions across Gauteng. Out of the 16 potential participants, 11 responses were received from persons with experience in the following industries: Aerospace; Manufacturing; Technology and Innovation development; Telecoms; Consulting; Financial Services; Information and Communication Technology; Research, Development and Implementation; Government and Science Councils; and Energy Research and Development. All eleven of the completed and unaltered questionnaires are presented in Appendix B. Note, however, that to maintain strict confidentiality, all the names have been removed from the questionnaire and replaced by the participant identification number that the author allocated to each participant. In addition, none of the participants knew which identification number was allocated to which participant. Whilst there were 11 questionnaire responses, the selection pool for potential participants was only 10, due to the eleventh participant being disqualified as a result of the late submission of the completed questionnaire.

In order to determine the level of project management experience and potential knowledge of each respondent, the potential participants were asked to indicate their current position or managerial level held, as well as the number of years in the project management field. In addition, they were asked to respond to the following key questions:

- As a Project Manager, have you managed any public-funded R&D projects?
- If you answered yes, how many R&D projects have you managed in the last 10 years?
- How many of the R&D projects you managed over the last 10 years were deemed successful?

Based on their responses to these questions, the author was able to identify in which category each participant fell, as well as the level of R&D project management experience. The latter was deemed key in enabling a meaningful contribution from the selected participants. The information collected from the questionnaires resulted in the selection of only seven out of a pool of 10 potential participants. The three that showed a significant lack of project management experience, particularly with regard to R&D project management, were not selected. The selected group reflected a well-rounded stakeholder participation group which encompassed all three core categories of specialists, stakeholders and structural modellers as suggested by Jane (1988). This grouping is represented in Table 4.1. The fourth category is that of a facilitator, which the author excluded from the core participation group of categories because his/her involvement was limited to the conducting of the workshop.

Table 4-1: IM Workshop participant categories

Participant Category	**Description**	**Participant Identification Number**
Specialist	Those who have content knowledge relevant to the various aspects of the situation	P1, P2, P3, P4
Stakeholder	People who may at some point be affected by the outcome of the study	P1, P2, P3, P4, P5, P6, P7
Structural Modellers	Those who can assist in structuring the issue	P1, P2, P3, P4, P5, P6, P7

According to Warfield and Cárdenas (1993), an adequate number of workshop participants ranges between six and 12 participants, whilst Christakis and Dye (2007) and Janes (1988) suggest that five to nine participants are sufficient to hold a good quality discussion in an IM workshop. In line with the suggested guidelines regarding the number of research participants, the author aimed in this paper for a maximum of seven participants, which appeared reasonable so as to accommodate the suggested range of between five and 12 participants. However, while seven potential participants were selected from the pool of 10, the researcher only managed to secure the participation of six for the first session of the workshop and five for the last two sessions (see Table 4-2).

Table 4-2: IM Workshop participation schedule

Participant Identification Number	IM Session Attendance (Yes / No)		
	IM 1	IM 2	IM 3
1	Yes	Yes	Yes
2	No	No	No
3	Yes	Yes	Yes
4	Yes	No	No
5	Yes	Yes	Yes
6	Yes	Yes	Yes
7	Yes	Yes	Yes

4.1.2 Idea generation

The idea generation process followed in this paper is in line with the NGT that was introduced in Section 3.3.3 of this paper. The NGT process has multiple properties, which include the generation of ideas intended to elicit different elements of a system from the relevant stakeholder participants (Warfield and Cárdenas, 1993). Following the NGT process, participants get to frame a consensual understanding of the problem and generate content by responding to a triggering question, which is the stimulus for idea generation (Warfield and Cárdenas, 1993). The idea generation process usually forms part of the IM workshop. However, as indicated in Section 3.3.2 of this paper, this study deviated from the prescribed process by using a questionnaire at the pre-workshop phase to initiate idea generation.

Responding to a triggering question that was included in the questionnaire, the respondents were asked to list up to five CSFs which they perceived to lead to successful completion of public-funded R&D projects in SA. In addition, the respondents were asked to provide a description of each of the identified CSFs, so as to avoid possible ambiguities and duplications. The CSF number limitation was motivated by the workshop time limitations, that is, the amount of time required to structure the model. Although the number limitation was not explicitly mentioned, it was implied by the number of spaces provided in the questionnaire. The triggering question was as follows:

What do you perceive to be the CSFs that can lead to the successful completion of public-funded R&D projects in SA?

A total of 35 unedited elements were generated from the questionnaire responses received from the selected seven participants (see Table 4-3). The findings regarding the analysis of these generated ideas are elaborated on in the ensuing subsections of the workshop phase.

Table 4-3: Original, unedited list of generated ideas

PHASE: IDEA GENERATION LIST OF PROPOSED CSFS		
Ref No	**CSF**	**Description**
1	Ability to manage the process whereby technology/R&D is matured/developed	A person with a thorough understanding of how technology/R&D is developed, matured and commercialised. This includes knowledge on technology/R&D management; systems engineering and project management.
2	Ability to manage complex projects	Understanding and ability to manage the R&D project, but the related environment is also crucial.
3	Ability to source funding	Familiar with and having knowledge of local and foreign funding sources, potential R&D partners, as well as sources/partners for commercialisation.
4	Ability to network with other stakeholders outside the field of focus	A keen interest in technology development as a whole, and rated technology developments in the field of technology/R&D. In addition, knowledge and interest in related fields (which might yield spin-ups into the current R&D activity) is essential.
5	Ability to lead a multi-skilled team consisting of various specialists and support personnel	Leading a multi-talented team is crucial. In addition, the ability to change the technical leadership within the technology/R&D team as the technology progress is essential.
6	Project Manager Knowledge Management skills	The ability of a project manager to know who knows what and how that knowledge can be applied to the project to achieve success.
7	Project Manager Maturity, which includes leadership skills	The ability of a project manager to know what must be done next and by whom so as to achieve success. Project management knowledge, experience, domain knowledge and the application of relevant processes, tools and techniques.
8	Good project governance	Clear, transparent and enforceable governance structures.
9	Effective stakeholder relationships	Doing what is necessary to develop and control relationships with all individuals affected by the project.
10	Competent project resources	Resources that possess the capability to optimally perform the roles that they have been assigned.

11	A willing sponsor, owner (or key stakeholder)	The owners or sponsors of a project and their willingness to see the project succeed is a CSF for the project, as they will do everything in their power and capacity to ensure the realisation of their envisaged benefits, resulting from the success of the project.
12	Support from Senior Management	Could be the same as sponsor/owner but could also be different, for example senior managers of the project-implementing agency (who may not be the sponsor).
13	Clear goals	Clarity of goals is a prerequisite for achieving them, hence a CSF for any project.
14	Competent Project Manager	A highly skilled, knowledgeable and experienced project manager, with a good understanding of the industry sector to which the project work applies.
15	Clear communication channels	Project execution relies on transfer and/or sharing of information among project participants and/or stakeholders. Clear communication channels are necessary to make this possible.
16	Supportive and competent Project Sponsor	A highly experienced, skilled and influential project sponsor with good stakeholder management skills
17	Competent Project Manager with duly delegated authority	Delegation of authority to the project manager, empowering him/her to manager the project without unreasonable interference from senior management.
18	Active stakeholder engagement and management	Management of external stakeholders such as Government department officials is very important as their buy-in and involvement can result in fast tracking the approval process for the project.
19	Relevant/appropriate project management system within the performing organisation	Organisational project management policies, process, standards and templates are critical in ensuring that the PM team manages projects that are properly selected and executed in a formal, professional and standardised manner.
20	Training and development of project management teams	Generally, project management team members are not properly trained in Project Management in the public sector. Public sector organisations have to develop an appropriate Project Development Competency Framework with a clear and implementable training and development plan for personnel assigned to projects.
21	Executive management support	Executive management support on any project or programme is imperative. This support is filtered from the top level of the organisation to all members within the organisation or projects.
22	Efficient and skilled human resources	Members of the project or programme team need to possess a positive attitude, coupled with the correct skills set in order to execute efficiently.
23	Adequate interpretation of client requirements	Understanding the requirements of the client and transforming the requirements into meaningful outcomes for the client.
24	Use of proven methodologies and effective change management	The use of methodologies that will provide governance as well operational structure and effectiveness in the execution of the project. Effective change management procedures and processes.
25	Stakeholder management	The effective management of stakeholder expectation and buy-in is imperative for the project.
26	Project objective	Clearly stated project objectives that are specific, measurable and achievable.
27	Leadership support	Willingness of management to provide the necessary support and commitment in terms of resources and PM empowerment throughout the project.
28	Effective risks analysis	Identification and mitigation of high and medium risks in the project, i.e. complexity, technology, cash flow.
29	Proficient resource levelling	Appropriate allocation of limited resources.
30	Capable technical resources	An efficient and resilient team with the appropriate technology skills set and clear role clarification.
31	Team continuity	Continuity of team members during the project and, more importantly, the Technical Lead(s)/Senior Supplier(s) being involved from conceptualisation through to project closure.
32	Implementation partner	Having a solid implementation partner, preferably before the proposal stage. This partner needs to be willing to collaborate during the R&D phase and should not expect a market ready product.

33	Environment that supports project management	The environment in which the project is being run needs to be supportive of project management (i.e. there needs to be buy-in as well as understanding), particularly from the Technical Lead(s)/Senior Supplier(s), the RGLs/CAMS/Project Executive, as well as the Funder.
34	User requirements	Understanding the user requirements and being willing to prioritise these requirements.
35	Detailed acceptance criteria	Defining detailed acceptance criteria between the relevant parties.

4.2 WORKSHOP PHASE

In order to accommodate time limitations for various participants, the workshop phase was for the purposes of this paper not run on one day. Instead, it was divided into three sessions held on two-weekly intervals. The IM facilitator opened the first session by explaining and reiterating the intended outcome of the workshop and how it was to be run. In particular, the IM facilitator stressed the point that the IM workshop would be run in a democratic manner, so that the IM participants would not be induced to agree to a substandard decision for the sake of agreeing. They would be encouraged to air their views and opinions in order to find adequate solutions for the issues under review.

The first session, which lasted for a total of three hours with short intervals in between, was aimed at idea clarification. It was attended by six out of the seven identified participants. The second session of idea structuring was attended by five of the six participants who had attended the idea clarification session. This session lasted for a total of six hours, including mini intervals and a thirty-minute lunch break. Lastly, the relationship model interpretation session which was gladly accepted by all participants and lasted for only an hour, was also attended by the five participants who had attended both the idea-clarification and idea-structuring sessions. The seventh participant who failed to attend the first session of idea clarification was not allowed to attend the remaining two sessions, which rendered the final list of participants to be six – instead of the initially identified and confirmed seven from the list of ten potential participants. The ensuing subsections provide thorough details on the proceedings of each of these sessions.

4.2.1 Idea clarification, editing and recording

Same as the preceding idea generation process, the idea clarification process included idea editing and recording, and it also followed the NGT prescripts as detailed in Section 3.3.3 above. This process was intended to provide clarity on the generated ideas and to eliminate existing ambiguities. At the start of the workshop, Table 4-3 was projected in full view of all participants. The list was anonymised such that none of the participants knew or could tell which idea was generated from which participant. Each individual idea from the list of ideas generated in the idea generation stage was collectively clarified by all participants for common understanding. This resulted in the editing of some of the ideas to present a better reflection of the identified CSF, while other ideas were combined to eliminate duplication and others were completely eliminated from the list (as deemed necessary by all participants).

Table 4-4 provides a clarified list of ideas which was reduced from the initial list of 35 generated ideas to 23 clarified, edited and combined ideas resulting from the idea clarification process. The five lightly shaded blocks labelled "new elements" on the CSF column indicate those ideas that were collectively identified for addition by the participants as they were reviewing, amending or consolidating each of the ideas from the consolidated list of ideas generated at the pre-workshop phase (see Table 4-3). Resulting from the same process, the last two dark shaded rows indicate those ideas that the team of participants collectively agreed to have removed from the list of clarified elements as they either did not agree with what they represented (project manager knowledge management skills), or it was a duplication of an already identified CSF (stakeholder relationship management). The reference number allocated to each CSF element represents the priority level collectively allocated to each CSF element by the participants. Consensus was reached on the allocation of the priority levels following a long discussion and deliberation where all participants had to be convinced of each priority level allocated to each CSF element.

Table 4-4: Clarified, edited and recorded prioritised list of ideas

PHASE: IDEA CLARIFICATION, EDITING & RECORDING CONSOLIDATED LIST OF CLARIFIED, EDITED AND RECORDED CSFS			
Ref No	**CSF Element**	**Clarified CSF element**	**Description**
1	Ability to manage the process whereby technology/R&D is matured/developed	Competent Project Manager *with duly delegated authority*	A person with a thorough understanding of how technology/R&D is developed, matured and commercialised. This includes knowledge on technology/R&D management; systems engineering and project management.
	Competent Project Manager	Competent Project Manager *with duly delegated authority*	A highly skilled, knowledgeable and experienced Project Manager, with a good understanding of the industry sector to which the project work applies.
	Ability to manage complex projects	Competent Project Manager *with duly delegated authority*	Understanding and ability to manage the R&D project, but the related environment is also crucial.

	Competent Project Manager with duly delegated authority	Competent Project Manager *with duly delegated authority*	In addition to appropriately skilled project manager, delegation of authority to the project manager empowering him/her to manage the project without unreasonable interference from senior management.
2	Ability to source funding	Accessibility to funding sources	Familiar with and having knowledge of local and foreign funding sources.
3	*** New element***	Availability and willingness of R&D partners	Potential R&D partners
	Implementation partner	Availability and willingness of R&D partners	Having a solid implementation partner, preferably before the proposal stage. This partner needs to be willing to collaborate during the R&D phase and should not expect a market ready product.
4	*** New element***	Accessibility to commercialisation partners	Sources/partners for commercialisation.
5	*** New element***	Product market viability	Studies should be done to determine if there is a viable market for the R&D product.
6	Good project governance	Good project governance	Clear, transparent and enforceable governance structures.
	Relevant/appropriate project management system within the performing organisation	Good project governance	Organisational project management policies, processes, standards and templates are critical in ensuring that the PM team manages projects that are properly selected and executed in a formal, professional and standardised manner.
	Use of proven methodologies and effective change management	Project governance	The use of methodologies that will provide governance as well operational structure and effectiveness in the execution of the project.
7	Ability to lead a multi-skilled team consisting of various specialists and support personnel	Strong leadership skills of project manager	Leading a multi-talented team is crucial. In addition, the ability to change the technical leadership within the technology/R&D team as technology progresses, is essential.
	Project Manager Maturity which includes Leadership skills	Strong leadership skills of project manager	The ability of a project manager to know what must be done next and by whom to achieve success. Project management knowledge, experience, domain knowledge and the application of relevant processes, tools and techniques.
8	Competent project resources	Adequately skilled project resources	Resources that possess the capability to optimally perform the roles that they have been assigned.
	Efficient and skilled human resources	Adequately skilled project resources	Members of the project or programme team need to possess a positive attitude coupled with the correct skills set in order to execute efficiently.
	Capable technical resources	Adequately skilled project resources	An efficient and resilient team with the appropriate technology skills set and clear role clarification.

9	Support from Senior Management	Executive management support	Could be the same as Sponsor/Owner but could also be different, for example senior managers of the project-implementing agency (who may not be the sponsor).
	Executive management support	Executive management support	Executive management support on any project or programme is imperative. This support is filtered from the top level of the organisation to all members within the organisation or projects.
	Leadership Support	Executive management support	Willingness of management to provide the necessary support and commitment in terms of resources and PM empowerment throughout the project.
10	A willing sponsor, owner (or key stakeholder)	Supportive project sponsor	The owners or sponsors of a project and their willingness to see the project succeed is a CSF for the project, as they will do everything in their power and capacity to ensure the realisation of their envisaged benefits, resulting from the success of the project.
	Supportive and competent project sponsor	Supportive project sponsor	A highly experienced, skilled and influential project sponsor with good stakeholder management skills.
11	Active stakeholder engagement and management	Active stakeholder engagement and management	Management of external stakeholders such as Government department officials is very important as their buy-in and involvement can result in fast tracking the approval process for the project.
	Stakeholder management	Active stakeholder engagement and relationship management	The effective management of stakeholder expectation and buy-in is imperative for the project.
12	Clear goals	Clear project goals and objectives	Clarity of goals is a prerequisite for achieving them, hence a CSF for any project.
	Project objective	Clear project goals and objectives	Clearly stated project objectives that are specific, measurable and achievable.
13	Adequate interpretation of client requirements	Correct interpretation of client requirements	Understanding the requirements of the client and transforming the requirements into meaningful outcomes for the client.
	User requirements	Correct interpretation of client requirements	Understanding the user requirements and being willing to prioritise these requirements.
14	Clear communication channels	Clear communication channels	Project execution relies on transfer and/or sharing of information among project participants and/or stakeholders. Clear communication channels are necessary to make this possible.
15	*** New element***	Effective change management	Effective change management procedures and processes.
16	*** New element***	Adequate and appropriate project management tools	Availability of relevant, adequate and appropriate project management tools.

17	Effective risk analysis	Effective project risks management	Identify and mitigate high and medium risks in the project, i.e. complexity, technology, cash flow.
18	Proficient resource levelling	Efficient resource levelling	Appropriate allocation of limited resources.
19	Team continuity	Team continuity	Continuity of team members during the project and, more importantly, the Technical Lead(s)/Senior Supplier(s) being involved from conceptualisation through to project closure.
20	Environment that supports project management	Matured and enabling project environment	The environment in which the project is run needs to be supportive of project management (i.e. there needs to be buy-in as well as understanding), particularly from the Technical Lead(s)/Senior Supplier(s), the RGLs/CAMS/Project Executive, as well as the Funder.
21	Training and development of project management teams	Ongoing training and development of project resources	Generally, project management team members are not properly trained in Project Management in the public sector. Public sector organisations have to develop an appropriate Project Development Competency Framework with clear and implementable training and a development plan for personnel assigned to projects.
22	Detailed acceptance criteria	Clearly defined acceptance criteria	Defining detailed acceptance criteria between the relevant parties.
23	Ability to network with other stakeholders outside the field of focus	Good networking skills of project manager	A keen interest in technology development as a whole, and in rated technology developments in the field of technology/R&D. In addition, knowledge and interest in related fields (which might yield spin-ups into the current R&D activity) is essential.
24	Project Manager Knowledge Management Skills.		The ability of a project manager to know who knows what and how that knowledge can be applied to the project to achieve success.
25	Effective Stakeholder Relationships	Stakeholder relationship management	Doing what is necessary to develop and control relationships with all individuals affected by the project.

The overall formation and reduction of the CSF list from the original 35 ideas to the final number of 23 resulted due to a number of reasons. For example, those ideas that had similar resemblance were grouped into themes, which led to a grouping of similar-themed CSFs into one CSF. One such example is that of a CSF themed “Competent Project Manager with duly delegated authority”, which was suggested by four participants who offered slightly different descriptions that ultimately carried the same underlying connotation. Therefore, the participants decided to group all four suggested ideas into one CSF. There was also an unbundling process that split ideas that appeared to carry more than one theme into various CSFs, as collectively agreed by all participants. One generated idea that had to be unbundled was originally labelled “Ability to source funding” which, based on the provided description, the participants collectively decided to split it into three CSFs: Accessibility to funding sources; Availability and willingness of R&D partners; Accessibility to commercialisation partners. In this case, one CSF became three. These three CSFs either formed a theme with other previously existing similar CSFs or remained individual CSFs. As already mentioned, other CSFs were completely deleted from the list because the participants could not collectively agree on their meaning or they were duplicated in other listed CSF elements.

4.2.2 Idea structuring: Interpretive Structural Modelling

The Interpretive Structural Modelling (ISM) tool, supported by Sorach's Concept Star software, is a computer-aided method for developing graphical representations of system composition and structure (Attri *et al.*, 2013). It uses pair-wise analyses of ideas to transform each complex issue (involving a variety of ideas) into a structured relationship model that is easier to comprehend (Sorach_Inc, 2014). As already alluded to in Section 3.3.4, ISM is a methodology for identifying relationships among specific items by following a process of transforming unclear or poorly articulated mental models of systems into a visible and well-defined model (Attri *et al.*, 2013).

The process of constructing a relationship model for this paper involved two key activities, namely entering the text information and actual creating the model (as suggested by Sorach_Inc, 2014).

1. Entering text information refers to the loading of all 23 CSFs projected in the clarified and edited list of ideas shown in Table 4-4.
2. Creating the model required all participants to debate and collectively vote on the relationship between the system selected and to present pairs of elements in order to produce the relationship model.

On completion of loading the ideas, the debating and voting process followed for the construction of the relationship model. Figure 4-2 provides a screen illustration of how the system-led debating and voting process, facilitated by the IM facilitator, was conducted in response to the contextual question that was discussed in Section 3.3.4.

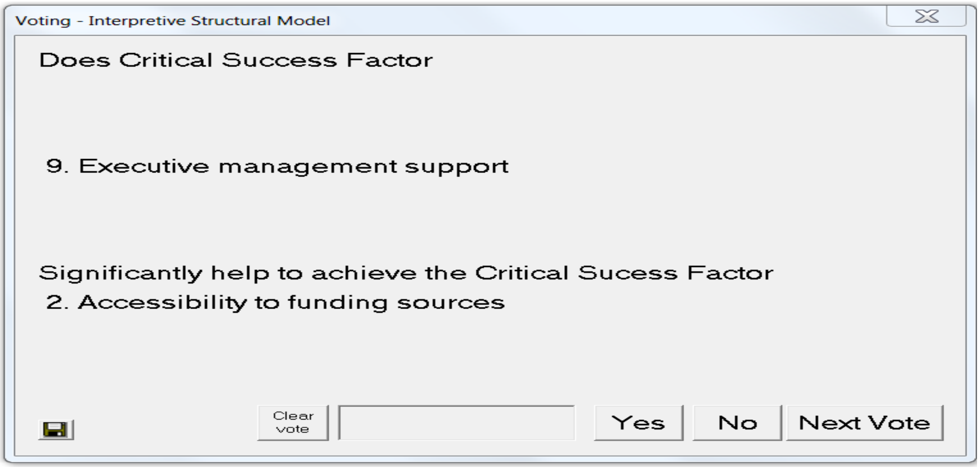

Figure 4-2: Example of a pairwise comparison for debating and voting purposes

The facilitator explained the voting process to the participants. They would be asked to respond to a computer-generated series of questions by selecting a "yes" or "no" answer in order to determine whether a relationship exists between the presented pairs of ideas (Sorach_Inc, 2014). The process would require from the participants to engage in deep discussions and deliberations on each issue presented, in order to reach an agreement on each vote, because a "yes" vote would represent a significant (not merely a minor) relationship between the two pairs.

During the debate and voting process, participants were allowed the opportunity to review and assess the relationship between the two presented elements before they could decide on whether or not a relationship does exist. This iterative process, whereby for each system-selected pair of elements participants were afforded the opportunity to interrogate and deliberate on the possibility of an underlying relationship, involved each participant airing his/her views for or against the relationship of the presented pair. On reaching consensus, participants were requested to cast a vote on the presented pairwise comparison in order to proceed to the review of the next relationship pair for review. The process continued until all system-presented pairs of ideas were debated and voted on. At the end of the voting process, a total of 101 decisions were presented as illustrated in Figure 4-3.

Figure 4-3 shows a total list of votes used to link ideas (Sorach_Inc, 2014), as well as the group decisions taken in relation to the prospects of the existence of a relationship between the elements being voted on. All arrows (→) in Figure 4-3 represent the contextual relationship "significantly help to achieve". Each cell shows the computer-posed contextual question for a pair of system elements and the participants' decisions on whether or not the relationship does exist between the two system elements (Tuan, 2018). For example, the first cell “1 → 2 No” denotes that the computer presented the contextual question, “Does element 1 significantly help to achieve element 2?”, with element 1 being the “Competent project manager” and element 2 “Accessibility to funding sources”. The record “No” in this case indicates the group’s decision that element 1 does not significantly help to achieve element 2. This, of course, is in response to the computer-posed contextual question, “Does element 1 significantly help to achieve element 2?”.

Votes:

1) 1---> 2 No
2) 2---> 1 No
3) 1---> 3 No
4) 3---> 1 No
5) 2---> 3 Yes
6) 3---> 2 Yes
7) 1---> 4 No
8) 4---> 1 No
9) 2---> 4 Yes
10) 4---> 2 Yes
11) 1---> 5 No
12) 5---> 1 No
13) 2---> 5 No
14) 5---> 2 Yes
15) 1---> 6 Yes
16) 6---> 1 Yes
17) 1---> 7 Yes
18) 7---> 1 Yes
19) 1---> 8 No
20) 8---> 1 Yes
21) 8---> 2 No
22) 1---> 9 No
23) 9---> 1 Yes
24) 9---> 2 Yes
25) 9---> 5 No
26) 9---> 8 Yes
27) 1--->10 Yes
28) 10---> 1 Yes
29) 1--->11 Yes
30) 11---> 1 No
31) 2--->11 No
32) 5--->11 No
33) 1--->12 Yes
34) 12---> 1 Yes
35) 1--->13 Yes
36) 13---> 1 No
37) 2--->13 No
38) 5--->13 No
39) 11--->13 Yes
40) 13--->11 No
41) 1--->14 Yes
42) 14---> 1 No
43) 2--->14 No
44) 5--->14 No
45) 11--->14 No
46) 14--->11 Yes
47) 1--->15 Yes
48) 15---> 1 No
49) 2--->15 Yes
50) 11--->15 Yes
51) 13--->15 No
52) 1--->16 No
53) 16---> 1 Yes
54) 16---> 2 No
55) 8--->16 No
56) 16---> 8 No
57) 9--->16 Yes
58) 1--->17 Yes
59) 17---> 1 Yes
60) 1--->18 Yes
61) 18---> 1 No
62) 2--->18 No
63) 5--->18 No
64) 11--->18 No
65) 18--->11 No
66) 18--->13 No
67) 14--->18 Yes
68) 18--->15 No
69) 1--->19 Yes
70) 19---> 1 No
71) 2--->19 Yes
72) 11--->19 No
73) 14--->19 No
74) 19--->15 No
75) 1--->20 No
76) 20---> 1 Yes
77) 20---> 2 No
78) 8--->20 No
79) 20---> 8 No
80) 9--->20 Yes
81) 16--->20 Yes
82) 20--->16 Yes
83) 1--->21 Yes
84) 21---> 1 No
85) 2--->21 Yes
86) 11--->21 No
87) 14--->21 No
88) 21--->15 No
89) 19--->21 No
90) 21--->19 Yes
91) 1--->22 Yes
92) 22---> 1 No
93) 2--->22 No
94) 5--->22 No
95) 11--->22 Yes
96) 22--->11 No
97) 13--->22 Yes
98) 22--->13 No
99) 18--->22 No
100) 1--->23 Yes
101) 23---> 1 Yes

Figure 4-3: ISM voting decision results

It is at this point also worthy to reiterate that the ISM uses the mathematical concept of full transitive logic inferences in the construction of a relationship model (Sorach_Inc, 2014). A transitive relationship could be used for inference (Nthunya *et al.*, 2017), such that, if CSF “A” significantly helps to achieve CSF “B”, and CSF “B” significantly helps to achieve CSF “C”, then it could be inferred that CSF “A” also significantly helps to achieve CSF “C”. Applying such logic provides the greatest advantage in reducing the number of pairwise analyses, the time required to formulate the model, as well as its topology (Sorach_Inc, 2014).

4.2.3 Interpretation of the structured ideas

The completion of the voting process implied the completion of the relationship model construction process, which resulted in a relationship model as depicted in Figure 4-4. This figure represents a relationship model constructed by a team of participants during the IM workshop for the identification of CSFs for public-funded R&D projects in SA, using the ISM tool.

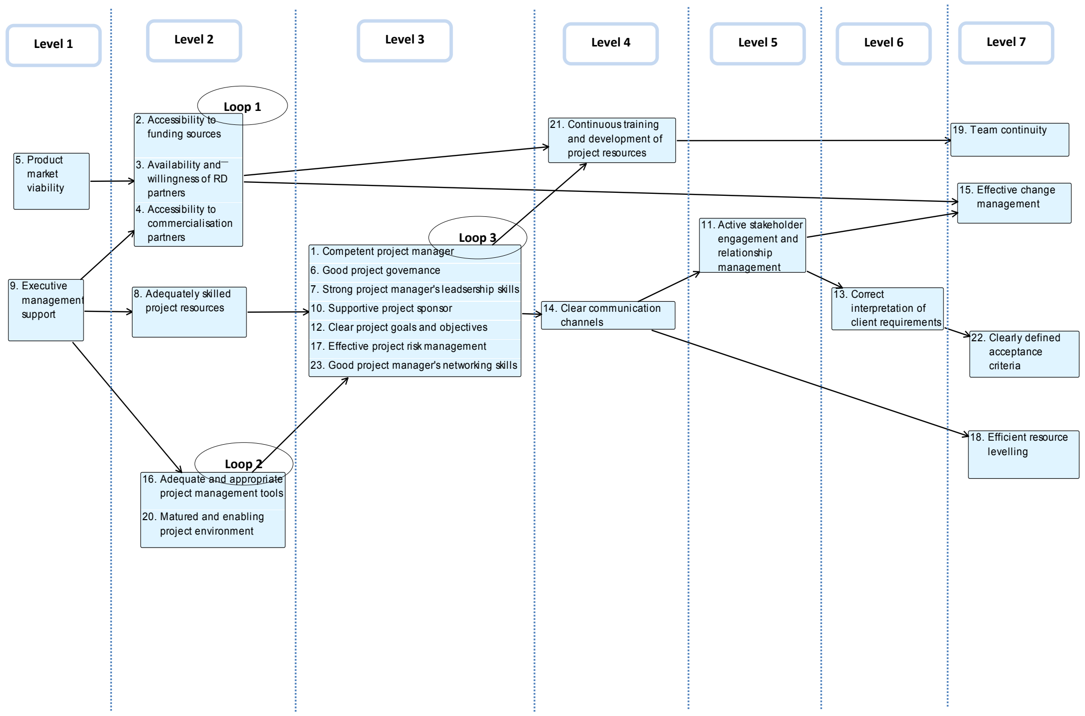

Figure 4-4: CSF relationship model for public-funded R&D projects in SA

The CSF relationship model depicted in Figure 4-4 – henceforth referred to as the CSF relationship model – demonstrates interrelationships between the different CSF elements identified by the workshop participants through a voting process. Most ideas are displayed in individual boxes, with the exception of those elements whose relationships indicate a feedback loop. They are therefore grouped and displayed in one box, labelled Loop 1, Loop 2 and Loop 3. The loop elements are grouped in their respective boxes due to their intertwined relationship, in that a positive impact on any one of the elements in the loop can positively influence other elements in the loop in the same fashion. The arrows show the direction of the relationship “significantly help to achieve” between the CSF elements. The CSF relationship model in Figure 4-4 also has a seven-level hierarchical structure with Level 1 having two elements indicating the highest most critical elements of the CSF hierarchy. This is followed by Level 2 elements, with the remaining elements on the far right up to Level 7 indicating those CSF elements with less or no power to influence other elements. The numbers placed in front of each CSF element denotes the level of priority that was collectively allocated to them by the participants during the CSF element prioritisation session. This session occurred prior to the construction of the relationship model through a system-led voting process. For example, number 9 was allocated to CSF “Executive management support", meaning that this CSF was ranked 9 out of a total of 23 CSFs under review.

According to the CSF relationship model in Figure 4-4, CSF 5, "Product market viability", and CSF 9, "Executive management support", placed on Level 1 to the far left of the model, are the primary and most influential CSFs that would significantly help to achieve other important success factors in the ensuing lower levels, and would ultimately lead to the successful completion of public-funded R&D projects in SA. "Product market viability" appeared to have an influence only on a circular feedback loop 1 (see Figure 4-5), which is located on Level 2 of the model hierarchy. In contrast, "Executive management support" showed influential linkage to all the Level 2 elements, being the two circular feedback loops (1 and 2), as well as CSF 8, "Adequately skilled project resources", which is also the only Level 2 element with influence on loop 3 located in Level 3.

The additional most influential CSF elements, following the two identified Level 1 elements, are those listed on Level 2 of the CSF relationship model in Figure 4-4. Level 2 elements included CSF 2, "Accessibility to funding sources"; 3 "Availability and willingness of R&D partners"; 4 "Accessibility to commercialisation partners"; 8 "Adequately skilled project resources"; 16 "Adequate and appropriate project management tools"; and 20 "Matured and enabling project environment". CSFs 2, 3 and 4 have a causal relationship, same as CSFs 16 and 20, which is reflected in Loops 1 and 2 as displayed in Figure 4-5 and Figure 4-6 respectively.

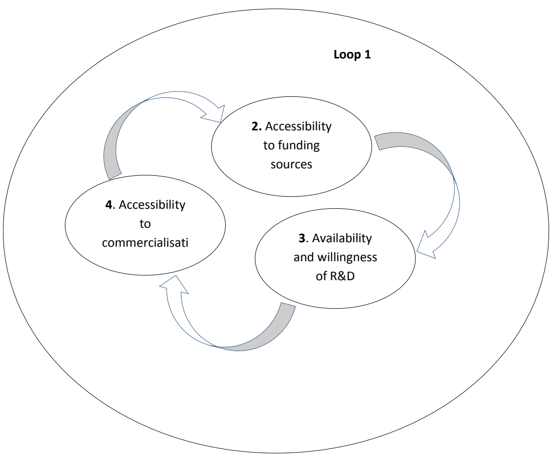

Figure 4-5: CSF Relationship loop 1

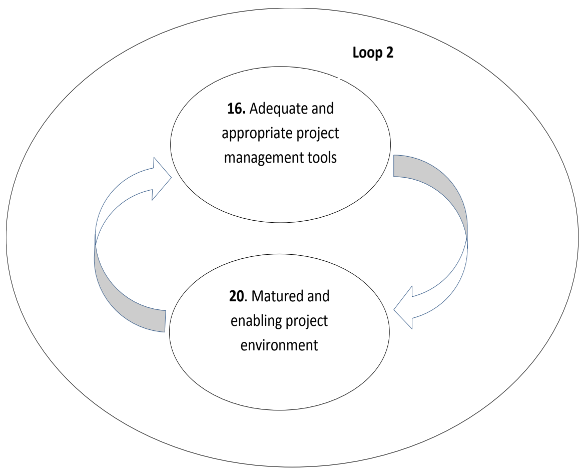

Figure 4-6: CSF Relationship loop 2

Loop 1, as depicted in Figure 4-5, shows that a circular feedback loop exists between three CSF elements – 2 "Accessibility to funding sources"; 3 "Availability and willingness of R&D

partners"; and 4 "Accessibility to commercialisation partners". This resulted from the voting process for constructing the CSF relationship model. Vote numbers 5 and 6, as reflected in Figure 4-3 show that CSF 2 significantly helps to achieve CSF 3, and CSF 3 helps significantly to achieve CSF 2. In addition, vote numbers 9 and 10, also reflected in Figure 4-3, show that CSF 2 helps significantly to achieve CSF 4 and that that CSF 4 helps significantly to achieve CSF 2. Based on these voting results, it could therefore be deduced that the ISM tool grouped all three elements to indicate a feedback relationship loop among them, without the team voting on the relationship between elements 3 and 4.

The same principle was also applied in the construction of Loop 2, as illustrated in Figure 4-6. It shows an intertwined relationship between CSF elements 16, "Adequate and appropriate project management tools" and 20, "Matured and enabling project environment", also resulting from the voting process of constructing the CSF relationship model. Vote numbers 81 and 82 (see Figure 4-3) show that CSF 1 does significantly help to achieve CSF "20" and also that CSF 20 does significantly help to achieve CSF 16.

As previously indicated, while level 1 carries those elements with the greatest leverage, level 2 elements are also important as they generate a certain leverage of significance as influenced by level 1 elements. Elements in level 3 and beyond have less power and influence to generate benefits, as compared to elements in levels 1 and 2, and it is therefore not advisable to invest a project's limited resources in them. The researcher followed the same logic in analysing the model elements by focusing on the elements in levels 1 and 2 of the CSF relationship model shown in Figure 4-4. An in-depth discussion of level 1 and 2 CSF elements follows in Section 4.2.4.

4.2.4 A reflection on the Level 1 and 2 elements

The results from the model depicted in Figure 4-4 indicate that the elements "Product market viability" and "Executive management support", which were allocated priority numbers 5 and 9 respectively during a manual group prioritisation session (see Table 4-4), were – ironically – found on Level 1 of the model hierarchy, following the debating and voting process. In contrast, "Competent project manager", which was given highest priority of all the identified CSF elements (see again Table 4-4), is neither on Level 1 nor on Level 2 of the CSF relationship model hierarchy. Instead, it is found on Level 3 of the model, which is leaning towards the elements on the far right that have less or no power to influence other CSF elements, compared to those elements listed on the first two levels. The interrelationships highlighted by the model indicated that whilst a "Competent project manager” is required for the smooth execution of the project, it does not have much power or influence to make the project a success without the necessary executive management support or the proven viability of the product market, which are the two primary CSFs on Level 1.

The participants were somewhat taken aback by the results that emerged from the CSF relationship model. However, a quick reflection on their discussion during the model development process made it apparent that on many levels “Executive management support” was extremely critical in influencing the success of public-funded R&D projects in SA. For instance, the participants agreed that a project manager, no matter how competent, had no power to make the project a success without the full support of a team that is adequately skilled. Also, for the project manager to secure adequately skilled resources for the successful execution of the project, the support of executive management is critical in making that endeavour a success. Furthermore, executive management support was seen as the backbone of a mature and enabling project environment with adequate and appropriate project management tools, which constitute Loop 2 of the CSF relationship model. The participants were also in agreement that executive management support is crucial in influencing the three Loop 1 elements, being “Accessibility to funding sources”; “Availability and willingness of R&D partners”; and “Accessibility to commercialisation partners”. This was on the basis that the executive is responsible for the development of a solid business case in order to secure project funding. Also, in order to secure project funding, the business case would have to indicate that enough has been done to secure accessibility to commercialisation partners and that willing R&D partners have been identified. For all of this to happen, executive management has to take the lead, which highlights the importance of executive management support in the successful execution of a public-funded R&D project in SA.

“Product market viability” is another primary CSF element on the Level 1 hierarchy of the CSF relationship model. For this element to make it to the primary CSF list, the participants were of the strong view that the project would not take off or be a success without securing necessary funding and having access to the necessary funding sources. It was clear from the discussion that product market viability was crucial and had to be proven to secure the required project funding. In addition, product market viability had to be confirmed and clearly demonstrated in order to significantly influence the availability and willingness of potential R&D partners, as well as accessibility to commercialisation partners.

Based on the above discussion, it is therefore clear why the two primary CSFs are placed on Level 1 of the model hierarchy. “Product market viability” is shown as the CSF that would significantly help to achieve the Loop 1 elements located on Level 2 of the hierarchy. In addition, “Executive management support” is reflected as one other CSF with significant influence on all the Level 2 elements (i.e. Loops 1 and 2, as well as “Adequately skilled project resources”). While the Level 1 primary elements are critical and of high significance, they are not the only important elements requiring attention; Level 2 elements are also important in the overall endeavour of achieving success in the completion of public-funded R&D projects in SA.

Level 2 elements (according to the CSF relationship model depicted in Figure 4-4) include loops 1 and 2 as well as the “Adequately skilled project resources” CSF element. Of the three listed Level 2 elements, Loop 1 appears to be the least important and has an influence on two elements, “Continuous training and development of project resources” and “Team continuity”, which are located in Levels 4 and 7 respectively. In contrast, Loop 2 and “Adequately skilled project resources” both have an influence on Loop 3, which is located in Level 3 of the CSF model hierarchy. Because the elements closest to the left of the hierarchy are known to be the most influential, it is logical to draw the conclusion that of the three Level 2 elements, Loop 2 and “Adequately skilled project resources” are the most important. However, it should also be highlighted that, because the power to generate benefits from Level 3 elements is not as great as at Level 1 and 2 (with Level 1 elements carrying the greatest leverage), it is not advisable to invest project resources in the elements on the far right – which in this case also includes Level 3 elements.

Based on the above discussion, “Product market viability” and “Executive management support” are the most significant CSFs with the greatest leverage of influencing other CSFs for the successful completion of public-funded R&D projects. In addition, Loop 2 and “Adequately skilled project resources” from the Level 2 elements are the other (second) set of most important elements in the CSF relationship model, with sizable power to generate benefits towards the successful completion of public-funded R&D projects in SA. This means that Loop 1 has lower priority when compared to all the Level 2 elements. Elements located on these two levels, with the exception of loop 1, are of great importance and influence for all of the 23 CSFs elements, therefore significant attention and project resources should be invested in them to generate the most benefits geared towards the successful completion of public-funded R&D projects in SA.

4.2.5 Comparison of research CSFs and literature CSFs

Table 4-4 presents the results of a high-level comparison conducted in this study between the 23 CSFs identified in the interviews and the CSFs uncovered in the reviewed literature. It is important when reviewing Table 4-4 to note that the groupings of the literature CSFs versus the research findings CSFs are based on the researcher's interpretation, which may differ when reviewed by another individual. The number of CSF appearances is aligned to the number of appearances that was earlier noted in Table 2-2.

Table 4-4: Research CSFs vs Reviewed Literature CSFs

Comparison of CSFs from research findings and CSFs from the reviewed literature				No. of Appearances
Ref No.	Research findings CSFs	CSFs from Reviewed Literature		
		CSF	Author	
1	Competent Project Manager with duly delegated authority	Project leader	Nagesh and Thomas (2015)	4
		Project manager's authority	Baccarini and Collins (2003)	
		Project team leader authority	Pinto and Slevin (1989 & 1987)	
		Effectiveness of project manager	Balachandra and Raelin (1984)	
2	Accessibility to funding sources	Project funds	Nagesh and Thomas (2015)	3
		Adequate funds	Hyvari (2006)	
		Increased budget	Bizan (2003)	
3	Availability and willingness of R&D partners	Collaboration with other organisations	Nagesh and Thomas (2015)	1
4	Accessibility to commercialisation partners	Rapid commercialisation	Lee and Park (2006)	1
5	Product market viability	Understanding the product market	Yamazaki *et al.* (2012)	3
		Spur of market demand	Lee and Park (2006)	
		Rate of new product introduction	Balachandra and Raelin (1984)	
6	Good project governance			
7	Strong leadership skills of project manager			
8	Adequately skilled project resources	Project team	Nagesh and Thomas (2015)	4
		Skilled human resources	Kulatunga *et al.* (2011) (a)	
		Project personnel	Lee and Park (2006)	
		Competent project team	Baccarini and Collins (2003)	

9	Executive management support	Top management support	Nagesh and Thomas (2015) Mahmood *et al.* (2014) Yamazaki *et al.* (2012) Pinto and Slevin (1989 & 1897) Balachandra and Raelin (1984)	**6**
		Senior management support	Baccarini and Collins (2003)	
10	Supportive project sponsor	Client interest and commitment	Barragán-Ocaña and Zubieta-García (2013)	2
		Client involvement	Baccarini and Collins (2003)	
11	Active stakeholder engagement and relationship management	Stakeholder involvement	Baccarini and Collins (2003)	2
		Client consultation	Pinto and Slevin (1989 & 1987)	
12	Clear project goals and objectives	Establishment of a clear research problem	Kulatunga *et al.* (2011) (a)	**4**
		Clear goals and objectives	Hyvari (2006)	
		Project understanding	Baccarini and Collins (2003)	
		Project mission	Pinto and Slevin (1989 & 1987)	
13	Correct interpretation of client requirements	Adequate interpretation of client needs	Barragán-Ocaña and Zubieta-García (2013)	2
		Understanding user needs	Yamazaki *et al.* (2012)	
14	Clear communication channels	Communication	Mahmood *et al.* (2014)	3
		Communication	Baccarini and Collins (2003)	
		Communication	Pinto and Slevin (1989 & 1987)	
15	Effective change management	Scope change process	Cooke-Davies (2002)	1
16	Adequate and appropriate project management tools			
17	Effective project risk management	Risk management	Baccarini and Collins (2003)	2
		Risk management	Cooke-Davies (2002)	
18	Efficient resource levelling	Effective dissemination of work to the relevant stakeholders	Kulatunga *et al.* (2011) (a)	2
		Internal resource competition	Balachandra and Raelin (1984)	
19	Team continuity			
20	Mature and enabling project environment	Working space	Nagesh and Thomas (2015)	2
		Favourable work environment	Barragán-Ocaña and Zubieta-García (2013)	
21	Ongoing training and development of project resources	Training	Mahmood *et al.* (2014)	2
		Trained personnel	Barragán-Ocaña and Zubieta-García (2013)	

22	Clearly defined acceptance criteria	Client acceptance	Pinto and Slevin (1989 & 1987)	1
23	Good networking skills of project manager			

An important and key observation from Table 4-4 above is that five of the 23 CSFs identified by the participants – “Good project governance”; “Strong leadership skills of project manager”; “Team continuity”; “Accessibility to funding sources”; and “Good networking skills of project manager” (in lightly shaded grey rows) – could not be found in the reviewed literature. According to the researcher, the appearance of these five elements on the participants’ CSF list indicates that they are deemed important in the South African context (and perhaps within the Gauteng province, given that the selected study participants all reside in Gauteng). It is also noteworthy to highlight that while these CSFs made it to the participants’ prioritised list, the completed relationship model indicates that these CSFs may after all not be of paramount importance. This is because, except for “Accessibility to funding sources”; which is placed in loop 1 on Level 2 of the model, they are all listed on Level 3 or beyond on the model hierarchy. “Team continuity” is considered the least important as it appears on Level 7 of the hierarchy.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 REVIEW OF RESEARCH OBJECTIVES AND FINDINGS

This section aims to provide an overall review of the report and concludes whether or not the research aim and objectives that had been set to address the problem statement posed by this study, were achieved. The reader is reminded that the problem statement for this study was as follows:

The influential factors behind the successes of public-funded R&D projects in SA are neither well known nor properly documented, as evidenced by the reported projects that have not achieved their intended goals.

In an attempt to address the set problem statement, the research sought to develop a model to identify the CSFs of public-funded R&D projects in SA, as well as to reveal possible interrelationships between the identified CSFs. This was done through the adoption of an IM methodology, which is based on the systems design framework and uses collaborative teamwork to define and resolve highly complex issues (Warfield and Cárdenas, 1993; Alexander, 2002). The methodology adopted a two-pronged approach, with multiple stages targeted to address the two key objectives that were set in congruence with the research aim. Ensuing below is a review of the potential study successes and failures that were identified in achieving the intended research objectives.

Identify the CSFs of public-funded R&D projects in SA

In order to identify the CSFs for public-funded R&D projects in SA, the research participants, who represented a variety of organisations across Gauteng, were asked to complete a research questionnaire to identify what they each perceived to be the CSFs that may lead to the successful completion of public-funded R&D projects in SA. This was part of Phase one of the IM methodology. From this questionnaire exercise, 35 ideas were generated (refer to Section 4.1.2 and Table 4-3), followed by an idea clarification and editing process which was done as part of the second phase of the IM methodology. A total of 23 CSF ideas or elements were listed and prioritised by the participants through a manual voting process, done in a workshop setting (refer to Section 4.2.1 and Table 4-4).

Extract noticeable interplay between the identified success factors

In order to reveal possible interrelationships between the identified CSFs, a CSF relationship model was constructed using the ISM tool. The completed CSF relationship model is depicted in Figure 4-4. The relationship model (see Section 4.2.2) was also constructed in a workshop setting, with five participants in attendance. The relationship model construction process required all participants to collectively examine the existence or non-existence of a relationship between the system selected and presented pairs of elements. Both these control phrases were important in the construction of the relationship model. During the voting stage of the ISM construction process, a context phrase "*Does Critical Success Factor*" was used to assist in guiding the discussion and decision making, whereas the relation phrase "*Significantly help to achieve the Critical Success Factor*" helped to determine the meaning and structure of the model. The relationship model was completed showing existing interrelationships among the 23 identified CSFs at varying degrees of influence. The interpretation and analysis of the model (see Section 4.2.3) revealed the following key findings:

1. "Product market viability" and "Executive management support" are the most significant CSFs with the greatest leverage to influence other CSFs for the successful completion of public-funded R&D projects. "Product market viability" appeared to have an influence on a circular feedback Loop 1 (see Figure 4-5), which is located on Level 2 of the model hierarchy. Loop 1 has direct influence on "Continuous training and development of project resources", which is located on Level 4 of the hierarchy, as well as on "Effective change management" which is located on the last level (Level 7) of the hierarchy. In contrast, "Executive management support" showed influential linkage with all the Level 2 elements (i.e. the two circular feedback loops (1 and 2) as well as CSF "Adequately skilled project resources"). This led to the conclusion that while both the two primary CSFs are of high significance, more focus should be placed on "Executive management support", since it has an influence on all of the elements and loops listed on Level 2.

2. Three circular feedback loops labelled Loop 1, Loop 2 and Loop 3 exist in the model, with Loops 1 and 2 ranked as of higher importance than Loop 3 as they are both placed on Level 2 of the model hierarchy. Between the two feedback loops located on level 2 of the hierarchy, Loop 2 is ranked as of higher importance than loops 1 due to the level of influence it has on the other CSFs in the model hierarchy. Loop 1, as depicted in Figure 4-5, shows a circular feedback loop among the three CSF elements – 2 "Accessibility to funding sources"; 3 "Availability and willingness of R&D partners"; and 4 "Accessibility to commercialisation partners". Loop 2 in Figure 4-6 shows an intertwined relationship

between the two CSF elements, 16 “Adequate and appropriate project management tools” and 20 “Matured and enabling project environment”. The existence of a feedback loop indicates a causal relationship between the elements in the loop, such that a positive impact on any one of the elements in the loop can potentially result in the same type of influence on other elements in the same loop.

3. The completed CSF relationship model displays relationships between the different elements. This indicates that in order to significantly increase the likelihood of successfully completing public-funded R&D projects in SA, more resources should be invested on the level 1 and 2 elements located on the far left side of the model hierarchy, with less priority given to Loop 1 elements, located in level 2 of the hierarchy.

To summarise, the application of the IM methodology, which is a systemic, democratic and structure-based approach, enabled the researcher to identify the CSFs and reveal existing interrelationships between the identified CSFs – thereby highlighting those CSFs deemed most significant in influencing the successful completion of public-funded R&D projects in SA. This is especially important as IM challenges and addresses the many shortcomings of the traditional reductionist approaches that assume projects to be linear, static and closed, with minimal chaos, requiring basic management to keep them on track on all the hard targets (Rodrigues and Bowers, 1996). Unlike the IM methodology, the traditional reductionist approaches (mostly discussed in Section 2.4) fail to show a clear appreciation of the causal relationship that exists between project variables and of the complexity of a project environment. The reductionist approach simply dissects the whole problematic project situation into elements, focuses on selected variables for investigation, and recommends solutions that treat the perceived problematic elements as distinct variables (Nthunya *et al.*, 2017).

5.2 FINDINGS IMPLICATIONS

The implications of the research findings could first be directed to project managers and senior management of various organisations in the application of the IM model as a preventative tool - whilst the IM is essentially used to construct solutions for resolving crisis situations (Warfield and Cárdenas, 1993), the study shows that it could also be used as a preventative measure to identify priority CSFs in order to positively influence project success and prevent project failure in public-funded R&D projects in South Africa.

Because projects are known to be unique endeavours, it then follows that their CSFs would also be unique, thus requiring that various ISM workshops be held for various projects to identify the relevant primary CSFs for each project in a particular organisations through the CSF relationship model. The CSF relationship model would, for example, help them identify priority areas requiring special attention from senior management and the project team and also help them to understand the interrelationships existing amongst various CSFs, in terms of the influence one has over the other. Thereby, providing a sound justification for the investment of limited project resources on high priority areas with less focus on lower priority CSFs, thus increasing chances for project success.

At a process or policy level – supported by senior management, organisations would therefore need to start embedding the IM approach and tools in their project initiation processes, in order to identify those factors deemed critical for the successful completion of each of their various projects. This would also require that all project managers in such organisations be trained as ISM workshop facilitators, to ensure that the workshops are conducted in an efficient and effective manner.

Furthermore, in relation to the project management researchers, the results of the study provide a conceptual framework to build further research on. A series of hypothesises could be tested by applying different contextual questions within the Gauteng province or using the same contextual question as was applied in this research but at different provinces, in order to strengthen and possibly improve the findings from this study.

5.3 RESEARCH LIMITATIONS

Time turned out to be the most limiting factor in conducting the study. Securing the commitment and active participation of the ISM workshop participants was proven to be a challenge because of their limited availability due to their conflicting priorities with the ISM workshop schedules. The study results were therefore, based on the opinions and experiences of no more than six participants from the Gauteng province only. Whilst this number is within acceptable limits (according to Christakis and Dye (2007) and Janes (1988)), a wider participation by stakeholders from a variety of provinces would have enriched the workshop discussion and results. Time limitations also prevented the study from continuing with the final implementation phase of the IM methodology, which could have enriched the overall results of the study.

Another constraint for the study was the restricted availability of the literature relevant to the South African context, thus making it difficult to verify some of the study findings – especially when comparing the 23 CSFs identified by the participants to the CSFs uncovered from the reviewed literature.

Lastly, of key importance is noting that because systemic thinking is not about achieving universal law but emphasises learning (Nthunya *et al.*, 2017), it therefore, cannot be concluded that the identified CSFs are the ultimate CSFs for public-funded R&D projects in SA. However, different results obtained from another IM workshop with similar elements should also *not* be taken to imply that the results of this research paper are invalid.

5.4 RECOMMENDATIONS FOR FURTHER RESEARCH

Five CSFs ("Good project governance"; "Strong leadership skills of project manager"; "Team continuity"; "Accessibility to funding sources"; and "Good networking skills of project manager") that made it to the list of CSFs that the research participants found to be important were not found in the reviewed literature. This could mean that these CSFs are important only in the South African context and probably within the Gauteng province. Further research could be conducted to investigate whether or not such CSFs would still be rated as important or make it to the participants' CSF list in other provinces within SA, and the reasons for deviations, if any.

Also, a high-level but unfounded research survey was conducted as part of the main study, whereby participants were requested to indicate in their completed questionnaires (see Annexure B) if their identified CSFs could be controlled from within or outside the organisation. This survey was done to test the consistency of understanding in this regard and to assess if this could be a possible area for further research. Indeed, inconsistencies were spotted in the completed questionnaires. For example, three of the seven selected participants identified stakeholder relationship management as a CSF. Two of these three participants stated that this CSF (stakeholder relationship management) is controlled from outside the organisation, whereas the third participant identified it as being controlled both from within and external to the organisation. Although the results that emerged from the questionnaire responses are not enough to reach any conclusions, they have indicated a possible area of interest for further research.

5.5 CONCLUSION

The intention of this research was to identify those factors that are deemed critical in influencing the successful completion of public-funded R&D projects in SA. In her definition of an R&D project, the researcher argued that such projects are to be viewed as purposeful and systemic systems, which require a more holistic, systemic approach to CSFs identification (Dvir *et al.*, 1998; Shenhar *et al.*, 2002; Remus and Wiener, 2010). As such, this research applied the IM methodology – a systemic, structure-based approach – to identify the CSFs and further investigate existing interrelationships between the identified CSFs that are responsible for the successful completion of the inherently complex public-funded R&D projects in SA.

In its application of the IM methodology, 23 CSFs were identified and modelled by using Concept Star's Interpretive Structural Modelling software. The completed ISM relationship model discovered two primary CSFs that were deemed most significant in influencing the successful completion of public-funded R&D projects in SA. Whilst not conclusive, the results of this study have demonstrated that, in the participants' opinion, system elements are indeed interrelated and that loops do exist between system elements. In addition, the IM workshop revealed emergent ideas that were not conceptualised by the participants through questionnaire surveys and other manual processes. For example, "Competent project manager" which, through the NGT process was ranked highest in terms of CSF priority, turned out to be of no significant importance in influencing the successful completion of public-funded R&D projects in SA. In contract, "Executive management support", which was ranked ninth out of the 23 identified CSFs, was revealed by the ISM relationship model to be the highest and most influential CSF of the identified 23 CSFs. By focusing on and examining the possible existence of interrelationships between the different CSF elements, the construction of the model helped to reveal underlying leverage from the causal relationships of the identified CSF elements. This could not have been uncovered otherwise by simply looking at the identified CSF elements independently.

Because systemic thinking is not about achieving universal law but emphasises learning (Nthunya *et al.*, 2017), it is important to point out that the findings of this study are not conclusive. The identification of CSFs only contributes to the ongoing endeavour of discovering those CSFs that have the greatest influence on the successful completion of public-funded R&D projects in SA.

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7 ANNEXURES

ANNEXURE A: Sample Questionnaire Form

ANNEXURE B: Completed Questionnaire Form

ANNEXURE C: Ethics in Research Approval

ANNEXURE D: Plagiarism Declaration

ANNEXURE A: Sample Questionnaire Form

Research Title:
Identification of the Critical Success Factors for Public Funded R&D Projects in South Africa

Researcher:
Ms Bahle Mkhize

Important Notes:
- Research Study is conducted to assist the researcher to complete her studies towards the MSC in Project Management through the University of Cape Town (UCT)
- Participants personal details will be kept confidential by the researcher and UCT and will not be made available for public use
- The results of the study might be published in a research journal or book
- The research document will be available to readers in a university library in printed form, and possibly in electronic form as well

Please complete all sections below

Sections 1: Personal Information

Name (Optional):	
Current Position / Level	
PM Experience (Yrs)	
Industry(s)	
Project Management Qualification(s)	
PM Association Membership(s)	

Sections 2: Project Management Experience
Please put an X to mark your response

2.1. As a Project Manager, have you managed any public funded R&D projects?

Yes	
No	

2.2. If you answered yes to 2.1 above, how many R&D projects have you managed in the last 10 years?

2.3.How many of the R&D projects you managed over the last 10 years were deemed successful?

Sections 3: Identification of the Critical Success Factors (CSF)
In your opinion, what do you perceive to be Critical Success Factors that can lead to successful completion of the Public Funded R&D projects in South Africa?:

1. Please identify the Critical Success Factor and provide an appropriate description
2. Please mark an X next to those CSFs, which in your opinion are internal to the organisation or external to the organisation

CSF		Description	Control Factor	
			Organisation	**External**
Example	Competent Project Manager	A highly skilled and experienced Project Manager, with a good understanding of the R&D industry	X	
1				
2				
3				
4				
5				

ANNEXURE B: Completed Questionnaire Forms

Research Title:
Identification of the Critical Success Factors for Public Funded R&D Projects in South Africa

Researcher:
Ms Bahle Mkhize

Important Notes:
- Research Study is conducted to assist the researcher to complete her studies towards the MSC in Project Management through the University of Cape Town (UCT)
- Participants personal details will be kept confidential by the researcher and UCT and will not be made available for public use
- The results of the study might be published in a research journal or book
- The research document will be available to readers in a university library in printed form, and possibly in electronic form as well

Please complete all sections below

Sections 1: Personal Information

Name (Optional):	**P1**
Current Position / Level	Senior Manager
PM Experience (Yrs)	30
Industry(s)	Aerospace, Manufacturing, Technology & Innovation development
Project Management Qualification(s)	Project management as part of Masters in Engineering Management degree
PM Association Membership(s)	None

Sections 2: Project Management Experience
Please put an X to mark your response

2.1. As a Project Manager, have you managed any public funded R&D projects?

Yes	x
No	

2.2. If you answered yes to 2.1 above, how many R&D projects have you managed in the last 10 years?

> 40

2.3.How many of the R&D projects you managed over the last 10 years were deemed successful?

~75%

Sections 3: Identification of the Critical Success Factors (CSF)
In your opinion, what do you perceive to be Critical Success Factors that can lead to successful completion of the Public Funded R&D projects in South Africa?:

1. Please identify the Critical Success Factor and provide an appropriate description
2. Please mark an X next to those CSFs, which in your opinion are internal to the organisation or external to the organisation

Note: The CSF is viewed rather as a skill/capability than a person/job/role

CSF		Description	Control Factor	
			Organisation	External
1	ability to manage the process whereby technology/R&D is matured/developed	A person with a thorough understanding of how technology/R&D is developed, matured and commercialised. This includes knowledge on technology/R&D management; systems		
2	Abillity to manage complex projects	Understanding and ability to manage the R&D project, but also the related environment is crucial	x	
3	Ability to source funding	familiarity and knowledge of local and foreign funding sources, and potential R&D partners as well as sources/partners for commercialisation	x	
4	Ability to network with other stakeholders outside the field of focus	a keen interest in technology development as a whole, and ralted technology developments in the field of technology/R&D. In addition, knowledge and interest in related fields (which might yield spin-ups into the current R&D activitiy) is essential.	x	
5	Ability to lead a multi-skilled team consisting of various specialists and support personnel	leading a multi-talented team is crucial. In addition, the ability to change the technical leadership within the technology/R&D team as the technology progress is essential.	x	

Research Title:
Identification of the Critical Success Factors for Public Funded R&D Projects in South Africa

Researcher:
Ms Bahle Mkhize

Important Notes:
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- Participants personal details will be kept confidential by the researcher and UCT and will not be made available for public use
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Please complete all sections below

Sections 1: Personal Information

Name (Optional):	**P2**
Current Position / Level	Manager
PM Experience (Yrs)	16 Yrs
Industry(s)	Telecoms, Consulting, Research, Financial Services
Project Management Qualification(s)	Programme in Project Management(UP), PRINCE 2
PM Association Membership(s)	PRINCE 2

Sections 2: Project Management Experience

Please put an X to mark your response

2.1. As a Project Manager, have you managed any public funded R&D projects?

Yes	X
No	

2.2. If you answered yes to 2.1 above, how many R&D projects have you managed in the last 10 years?

35 +

2.3.How many of the R&D projects you managed over the last 10 years were deemed successful?

All

Sections 3: Identification of the Critical Success Factors (CSF)

In your opinion, what do you perceive to be Critical Success Factors that can lead to successful completion of the Public Funded R&D projects in South Africa?:

1. Please identify the Critical Success Factor and provide an appropriate description
2. Please mark an X next to those CSFs, which in your opinion are internal to the organisation or external to the organisation

CSF		Description	Control Factor	
			Organisation	**External**
Example	Competent Project Manager	A highly skilled and experienced Project Manager, with a good understanding of the R&D industry	X	
1	Project Manager Knowledge Management Skills.	The ability of a project manager to know who knows what and how that knowledge can be applied to the project to achieve success.	X	
2	Project Manager Maturity which includes Leadership skills	The ability of a project manager to know what must be done next and by whom to achieve success. Project management knowledge, experience, domain knowledge and the application of relevant processes, tools and techniques.	X	
3	Good Project Governance	Clear, transparent and enforcable governance structures	X	X
4	Effective Stakeholder Relationships	Doing what is necessary to develop and control relationships with all individuals that the project impacts	X	X
5	Competent Project Resources	Resources that possess the capability to optimaly perform the roles that they have been assigned.	X	

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Please complete all sections below

Sections 1: Personal Information

Name (Optional):	P3
Current Position / Level	PMO Manager
PM Experience (Yrs)	12
Industry(s)	Energy Research and Developemnt
Project Management Qualification(s)	M Eng (Final Year) Project Management
PM Association Membership(s)	PMI

Sections 2: Project Management Experience
Please put an X to mark your response

2.1. As a Project Manager, have you managed any public funded R&D projects?

Yes	X
No	

2.2. If you answered yes to 2.1 above, how many R&D projects have you managed in the last 10 years?

8

2.3.How many of the R&D projects you managed over the last 10 years were deemed successful?

5

Sections 3: Identification of the Critical Success Factors (CSF)
In your opinion, what do you perceive to be Critical Success Factors that can lead to successful completion of the Public Funded R&D projects in South Africa?:

1. Please identify the Critical Success Factor and provide an appropriate description
2. Please mark an X next to those CSFs, which in your opinion are internal to the organisation or external to the organisation

CSF		Description	Control Factor	
			Organisation	External
Example	Competent Project Manager	A highly skilled and experienced Project Manager, with a good understanding of the R&D industry	x	
1	Supportive and competent Project Sponsor	A highly experienced, skilled and influenctial Project Sponsor with good stakeholder management skills	x	
2	Competent Project Manager with dully delegated authority	In addition to appropriately skilled project manager, delagtion of authority to the project manager empowering him/her to manager the project without unroiasonable intereference from senior management	x	
3	Active stakeholder engagement and management	Management of external stakeholders such as Government department offcials is very important as their buy in and invlovement can result in fast tracking of approval process for the project		x
4	Relevant/approriate project management system within the performing organisation	organisational project managemnt policies, process, stantards and templates are critical in ensuring that the PM team manages projects that properly selected and are exceuted in a formal, professional and standardised manner	x	
5	Trainign and development of project management teams	Generally project management team memebers are not properly trained in Project Management in the public sector. Public sector organisations have to develop appropriate Project Development Competency Frameowork with clear and implemntable traning and development plan for personell assigned to projects	x	

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Please complete all sections below

Sections 1: Personal Information

Name (Optional):	**P4**
Current Position / Level	Principal Project Manager
PM Experience (Yrs)	Over 20
Industry(s)	Information Technology
Project Management Qualification(s)	PMP, MSc
PM Association Membership(s)	PMI

Sections 2: Project Management Experience

Please put an X to mark your response

2.1. As a Project Manager, have you managed any public funded R&D projects?

Yes	X
No	

2.2. If you answered yes to 2.1 above, how many R&D projects have you managed in the last 10 years?

Over 6

2.3.How many of the R&D projects you managed over the last 10 years were deemed successful?

All

Sections 3: Identification of the Critical Success Factors (CSF)

In your opinion, what do you perceive to be Critical Success Factors that can lead to successful completion of the Public Funded R&D projects in South Africa?:

1. Please identify the Critical Success Factor and provide an appropriate description
2. Please mark an X next to those CSFs, which in your opinion are internal to the organisation or external to the organisation

CSF		Description	Control Factor	
			Organisation	External
Example	Competent Project Manager	A highly skilled and experienced Project Manager, with a good understanding of the R&D industry	x	
1	A willing sponsor, owner (or Key stakeholder)	The owners or sponsors of a project and their willingness to see the project succeed is a CSF for the project, as they will do everything in their power and capacity to ensure realization of their envisaged benefits from the success of the project.	x	x
2	Spport from Senior Management	Could be the same as Sponsor/Owner but could also be different, for example senior managers of the project implementing agency (who may not be the sponsor)	x	
3	Clear Goals	Clarity of goals is a prerequisite for achieving them, hence a CSF for any project.	x	
4	Competent Project Manager	A highly skilled, knowledgeable and experienced Project Manager, with a good understanding of the industry sector to which the project work applies	x	
5	Clear Communication Channels	Project execution relies on transfer and/or sharing of information among project participants and/or stakeholders. Clear communication channels are necessary to make this possible.	x	

Research Title:
Identification of the Critical Success Factors for Public Funded R&D Projects in South Africa

Researcher:
Ms Bahle Mkhize

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Please complete all sections below

Sections 1: Personal Information

Name (Optional):	**P5**
Current Position / Level	Project Manager
PM Experience (Yrs)	16
Industry(s)	Financial, R&D
Project Management Qualification(s)	Prince II Practitioner, Post Graduate PM, Masters PM (current)
PM Association Membership(s)	

Sections 2: Project Management Experience

Please put an X to mark your response

2.1. As a Project Manager, have you managed any public funded R&D projects?

Yes	X
No	

2.2. If you answered yes to 2.1 above, how many R&D projects have you managed in the last 10 years?

about 10

2.3.How many of the R&D projects you managed over the last 10 years were deemed successful?

about 6

Sections 3: Identification of the Critical Success Factors (CSF)

In your opinion, what do you perceive to be Critical Success Factors that can lead to successful completion of the Public Funded R&D projects in South Africa?:

1. Please identify the Critical Success Factor and provide an appropriate description
2. Please mark an X next to those CSFs, which in your opinion are internal to the organisation or external to the organisation

CSF		Description	Control Factor	
			Organisation	External
Example	Competent Project Manager	A highly skilled and experienced Project Manager, with a good understanding of the R&D industry	X	
1	Project Objective	Clearly stated project objectives which are specific, measurable and achievable	X	
2	Leadership Support	Willingness of management to provide the necessary support and commitment ito resources and PM empowerment throughout the project	X	
3	Effective Risks Analysis	Identify and mitigate high and medium risks in the project, i.e. complexity, technology, cash flow	X	
4	Proficient Resource Levelling	Appropriate allocation of limited resources	X	
5	Capable technical resources	An efficient and resilient team with the appropriate technology skill set and clear role clarification	X	

Research Title:
Identification of the Critical Success Factors for Public Funded R&D Projects in South Africa

Researcher:
Ms Bahle Mkhize

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Please complete all sections below

Sections 1: Personal Information

Name (Optional):	**P6**
Current Position / Level	Senior Project Manager
PM Experience (Yrs)	7 years
Industry(s)	ICT
Project Management Qualification(s)	Fundamentals in Project Management (University of the Witwatersrand) Programme in Project Management (University of Pretoria) PRINCE2 Foundation and Practitioner
PM Association Membership(s)	N/A

Sections 2: Project Management Experience
Please put an X to mark your response

2.1. As a Project Manager, have you managed any public funded R&D projects?

Yes	X
No	

2.2. If you answered yes to 2.1 above, how many R&D projects have you managed in the last 10 years?

28

2.3.How many of the R&D projects you managed over the last 10 years were deemed successful?

About 75%

Sections 3: Identification of the Critical Success Factors (CSF)

In your opinion, what do you perceive to be Critical Success Factors that can lead to successful completion of the Public Funded R&D projects in South Africa?:

1. Please identify the Critical Success Factor and provide an appropriate description
2. Please mark an X next to those CSFs, which in your opinion are internal to the organisation or external to the organisation

CSF		Description	Control Factor	
			Organisation	External
Example	Competent Project Manager	A highly skilled and experienced Project Manager, with a good understanding of the R&D industry	X	
1	Team continuity	Continuity of team members during the project and more importantly the Technical Lead(s)/Senior Supplier(s) being involved from conceptualisation through to project closure.	X	
2	Implementation partner	Having a solid implementation partner, preferably before the proposal stage. This partner needs to be willing to collaborate during the R&D phase and not expect a market ready product.		X
3	Environment that supports project management	The environment in which the project is being run needs to be supportive of project management (i.e. there needs to be buy in as well as an understanding), particularly from the Technical Lead(s)/Senior Supplier(s) and the RGLs/CAMS/Project Executive, as well as the Funder.	X	X
4	User requirements	Understanding the user requirements and being willing to prioritise these requirements	X	
5	Detailed acceptance criteria	Defining detailed acceptance criteria between the relevant parties	X	X

Research Title:
Identification of the Critical Success Factors for Public Funded R&D Projects in South Africa

Researcher:
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Please complete all sections below

Sections 1: Personal Information

Name (Optional):	**P7**
Current Position / Level	Principal Project Manager
PM Experience (Yrs)	20
Industry(s)	Consulting, Research and Development
Project Management Qualification(s)	Diploma and Prince 2 certified
PM Association Membership(s)	

Sections 2: Project Management Experience
Please put an X to mark your response

2.1. As a Project Manager, have you managed any public funded R&D projects?

Yes	x
No	

2.2. If you answered yes to 2.1 above, how many R&D projects have you managed in the last 10 years?

2

2.3.How many of the R&D projects you managed over the last 10 years were deemed successful?

2

Sections 3: Identification of the Critical Success Factors (CSF)

In your opinion, what do you perceive to be Critical Success Factors that can lead to successful completion of the Public Funded R&D projects in South Africa?:

1. Please identify the Critical Success Factor and provide an appropriate description
2. Please mark an X next to those CSFs, which in your opinion are internal to the organisation or external to the organisation

CSF		Description	Control Factor	
			Organisation	**External**
Example	Competent Project Manager	A highly skilled and experienced Project Manager, with a good understanding of the R&D industry	x	
1	Executive management support	Executive management support on any project or program is imperative. This support is filtered from the top level of the organisation to all members within the organisation or projects.	x	
2	Efficient and skilled human resources	Members of the project or program team need to possess a positive attitude coupled with the correct skill set in order to execute efficiently.	x	
3	Adequate intrpretation of client requirements	Understanding the requirements of the client and transforming the requirements into a meaningful outcomes for the client	x	
4	Use of proven methodologies and effective change management	The use of methodolgies that will provide governance as well operational structure and effectiveness in the execution of the project. Effective change management procedures and	x	
5	Stakeholder management	The effective management of stakeholder expectation and buy in is imperative on the project	x	x

Research Title:
Identification of the Critical Success Factors for Public Funded R&D Projects in South Africa

Researcher:
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Please complete all sections below

Sections 1: Personal Information

Name (Optional):	P8
Current Position / Level	Principal Project Manager
PM Experience (Yrs)	10
Industry(s)	Information and Communication Technology, Research, Development and Implementation
Project Management Qualification(s)	Postgraduate and Advanced Diploman in Project and Programme Management (Cranefield College); PRINCE2 Practitioner; AgilePM Practitioner
PM Association Membership(s)	none

Sections 2: Project Management Experience
Please put an X to mark your response

2.1. As a Project Manager, have you managed any public funded R&D projects?

Yes	X
No	

2.2. If you answered yes to 2.1 above, how many R&D projects have you managed in the last 10 years?

40 approximately

2.3.How many of the R&D projects you managed over the last 10 years were deemed successful?

40 approximately

Sections 3: Identification of the Critical Success Factors (CSF)

In your opinion, what do you perceive to be Critical Success Factors that can lead to successful completion of the Public Funded R&D projects in South Africa?:

1. Please identify the Critical Success Factor and provide an appropriate description
2. Please mark an X next to those CSFs, which in your opinion are internal to the organisation or external to the organisation

CSF		Description	Control Factor	
			Organisation	External
Example	Competent Project Manager	A highly skilled and experienced Project Manager, with a good understanding of the R&D industry	X	
1	Domain Knowledge	An understanding of the domain in which the project is being executed	x	
2	Research and Development and Implementation Knowledge	An understanding of the R&D process with eventual production of prototypes that have to implemented	x	
3	Technology transfer knowledge	An understanding of the process to transfer R&D prototypes to an entity/organisation that will scale it to meet the desired need for the identified market.	x	
4	Good governance	Management of all stakeholders to ensure smooth resolution of issues when they occur and timeous approvals of work in progress to reflect revenue	x	
5	Competent Project Manager	A highly skilled and experienced Project Manager, with a good understanding of the R&D industry	x	

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Please complete all sections below

Sections 1: Personal Information

Name (Optional):	P9
Current Position / Level	Senior Project Coordinator
PM Experience (Yrs)	5
Industry(s)	Government
Project Management Qualification(s)	PPM, AgilePM, Prince 2
PM Association Membership(s)	None

Sections 2: Project Management Experience

Please put an X to mark your response

2.1. As a Project Manager, have you managed any public funded R&D projects?

Yes	
No	X

2.2. If you answered yes to 2.1 above, how many R&D projects have you managed in the last 10 years?

N/A

2.3.How many of the R&D projects you managed over the last 10 years were deemed successful?

None

Sections 3: Identification of the Critical Success Factors (CSF)

In your opinion, what do you perceive to be Critical Success Factors that can lead to successful completion of the Public Funded R&D projects in South Africa?:

1. Please identify the Critical Success Factor and provide an appropriate description
2. Please mark an X next to those CSFs, which in your opinion are internal to the organisation or external to the organisation

CSF		Description	Control Factor	
			Organisation	External
Example	Competent Project Manager	A highly skilled and experienced Project Manager, with a good understanding of the R&D industry	x	
1	Project Mission	All projects in nature must have a defined mission, i.e there must be a clearly defined pupose, planning, organising and control of activities to ensure that benefits are realised.	x	
2	Client consultation	This is the platform to gather clients needs and requirements. The output will be a well documented and signed-off requirement specification that will serve a guide in development phase.	x	x
3	Communication	High -level communication plan to engage with internal and external stakeholders, this should highlight the communication methods and their frequency.	x	x
4	Monitoring and reporting	It is critical to monitor how project activities are progressing in the project and project an update to all stakeholders involved.	x	x
5	Staff capability	If there aren't capabilities to execute the project , the project might as well be nullified. Once R&D concept has been defined, it is therefore critical to have skilled resources with execute project work.	x	

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Researcher:
Ms Bahle Mkhize

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Please complete all sections below

Sections 1: Personal Information

Name (Optional):	**P10**
Current Position / Level	
PM Experience (Yrs)	
Industry(s)	
Project Management Qualification(s)	
PM Association Membership(s)	

Sections 2: Project Management Experience
Please put an X to mark your response

2.1. As a Project Manager, have you managed any public funded R&D projects?

Yes	
No	x

2.2. If you answered yes to 2.1 above, how many R&D projects have you managed in the last 10 years?

2.3.How many of the R&D projects you managed over the last 10 years were deemed successful?

Sections 3: Identification of the Critical Success Factors (CSF)
In your opinion, what do you perceive to be Critical Success Factors that can lead to successful completion of the Public Funded R&D projects in South Africa?:

1. Please identify the Critical Success Factor and provide an appropriate description
2. Please mark an X next to those CSFs, which in your opinion are internal to the organisation or external to the organisation

CSF		Description	Control Factor	
			Organisation	External
Example	Competent Project Manager	A highly skilled and experienced Project Manager, with a good understanding of the R&D industry	X	
1	effective leadership	this includes project manager, and leadership at an executive level that clearly articulates the purpose of the project and where it fits in within the big picture	x	
2	Clear aim and objective	project must have a specific aim and objective towards which the efforts are directed.	x	
3	adequeate personnel capacity	right mix of skills to execute the required tasks	x	
4	operational systems	appropriate IT systems and organisational processes to support execution, track progress, and ensure efficiency; and a clear interface with project beneficiaries/ customers	x	x
5	effective partnerships	right partners, whose roles are stated clearly in project documents; the partners who make the agreed contributions in a		x

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Please complete all sections below

Sections 1: Personal Information

Name (Optional):	**P11**
Current Position / Level	Chief Director: Hydrogen and Energy
PM Experience (Yrs)	10 years
Industry(s)	Government and Science Councils
Project Management Qualification(s)	None
PM Association Membership(s)	None

Sections 2: Project Management Experience

Please put an X to mark your response

2.1. As a Project Manager, have you managed any public funded R&D projects?

Yes	x
No	

2.2. If you answered yes to 2.1 above, how many R&D projects have you managed in the last 10 years?

2

2.3.How many of the R&D projects you managed over the last 10 years were deemed successful?

2

Sections 3: Identification of the Critical Success Factors (CSF)

In your opinion, what do you perceive to be Critical Success Factors that can lead to successful completion of the Public Funded R&D projects in South Africa?:

1. Please identify the Critical Success Factor and provide an appropriate description
2. Please mark an X next to those CSFs, which in your opinion are internal to the organisation or external to the organisation

CSF		Description	Control Factor	
			Organisation	External
Example	Competent Project Manager	A highly skilled and experienced Project Manager, with a good understanding of the R&D industry	X	
1	A clear mandate as well as objectives for the programme	There are many reasons for a publically funded R&D project. If the expected outcome is a commercial products, decision support tool or to create new knowledge then the work plan, stakeholders involved are different. It is very difficult to take a project which is put in place for just creating new knowledge and then expect to change the objective to commercialisation.		x
2	Sufficienct funds which are transferred on time	Sufficent funds over a long enough time frame (5 years and upward) is needed to ensure that progress is made.		x
3				
4				
5				

ANNEXURE C: Ethics in Research Approval

Application for Approval of Ethics in Research (EIR) Projects
Faculty of Engineering and the Built Environment, University of Cape Town

APPLICATION FORM

Please Note:
Any person planning to undertake research in the Faculty of Engineering and the Built Environment (EBE) at the University of Cape Town is required to complete this form **before** collecting or analysing data. The objective of submitting this application *prior* to embarking on research is to ensure that the highest ethical standards in research, conducted under the auspices of the EBE Faculty, are met. Please ensure that you have read, and understood the **EBE Ethics in Research Handbook** (available from the UCT EBE, Research Ethics website) prior to completing this application form: http://www.ebe.uct.ac.za/ebe/research/ethics1

APPLICANT'S DETAILS		
Name of principal researcher, student or external applicant		Bahle Mkhize
Department		Construction, Economics and Management
Preferred email address of applicant		Bahlep.mkhize@gmail.com
If Student	Your Degree: e.g., MSc, PhD, etc.	Msc in Project Management
	Credit Value of Research: e.g., 60/120/180/360 etc.	60
	Name of Supervisor (if supervised):	Nien-Tsu Tuan
If this is a research contract, indicate the source of funding/sponsorship		Click here to enter text.
Project Title		Identification of the Critical Success Factors for public funded R&D projects in South Africa

I hereby undertake to carry out my research in such a way that:

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

SIGNED BY	Full name	Signature	Date
Principal Researcher/ Student/External applicant	Bahle Mkhize	[signature]	18 Jun 2018

APPLICATION APPROVED BY	Full name	Signature	Date
Supervisor (where applicable)	Nien-Tsu Tuan	[signature]	22 June 2018 Click here to enter a date.
HOD (or delegated nominee) Final authority for all applicants who have answered NO to all questions in Section1; and for all Undergraduate research (including Honours).	Click here to enter text.	[signature]	13/7/2018 Click here to enter a date.
Chair : Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.			

Page 1 of 1

ANNEXURE D: Plagiarism Declaration

UNIVERSITY OF CAPE TOWN

CONSTRUCTION ECONOMICS & MANAGEMENT

PLAGIARISM DECLARATION

Declaration

1. I know the meaning of plagiarism and declare that all of the work in the dissertation, save for that which is properly acknowledged, is my own.
2. This thesis/dissertation has been submitted to the Turnitin module (or equivalent similarity and originality checking software) and I confirm that my supervisor has seen my report and any concerns revealed by such have been resolved with my supervisor.
3. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.

Signature: ________________

Stu No: NTLBAH001