# Conceptualising a Benefit Assessment Framework for the South African National Roads Agency Ltd SOC Research and Development Programme

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## ABSTRACT

In low-income countries Research and Development funding is limited and has to be invested with a view of optimum return, both economic return but also "softer" benefits such as human resource development. The assessment of these benefits is therefore important for the long-term sustainability of research and development programmes. Outputs from research and development in roads and transport are often not hard products aimed for the consumer market, but also include new design methods and techniques to enhance the performance of the transport system that cannot be easily quantified with benefit cost analysis alone. The article discusses the development of a framework for the monitoring of the performance of the South

African National Roads Agency Research & Development Programme. The framework consists of a Balanced Score Card and a proposed set of indicators that address benefit throughout the innovation value chain.

## INTRODUCTION

Research has shown that technological innovation benefits economic growth and social development (Bessant *et al.* 2014:1). However, in low-income countries Research and Development (R&D) expenditure is low compared with developed countries. The World Bank (2020) indicates that in high income countries 2.56% of Gross Domestic Product (GDP) is spent on R&D whereas in lower-middle income countries only 0.56%. South Africa is a point in case with only 0.82 % of GDP spent on R&D (CeSTII 2019:6). In low-income countries it is therefore vital to obtain maximum performance of such investment (Lazarotti *et al*. 2011:212), particularly in the case of public sector R&D (Maroto *et al*. 2016:564). There is therefore an increased emphasis on the measurement of the benefit and ultimate impact of R&D programmes in such countries.

Research on road and transport infrastructure points to a relationship between a country's investment in the development of its road and transport infrastructure and its socio-economic growth (Ding 2013:312; Zhang 2013:24; Ng *et al.* 2018:292; Cigu *et al.* 2019:22). Among the reasons cited for this is that road and transport infrastructure enable the effective and efficient movement of key products, services as well as people (Ng *et al*. 2018:292). Furthermore, the World Bank (2014) adds that transport contributes to the decrease of high levels of poverty and ensuring that global development goals are achieved. In this context, many organisations tasked with developing and maintaining a road and transport network, invest in road and transport R&D.

## CONCEPTUALISING RESEARCH, DEVELOPMENT AND INNOVATION

R&D refers to a systematic process undertaken by organisations in pursuit of new knowledge, for the purpose of discovering and developing new ideas, innovations, products or services (OECD [sa]). Likewise, R&D is described in the Oslo Manual as encompassing the body of a company's innovative efforts "undertaken on a systematic basis" in an effort to produce new knowledge that can be applied in ways that will provide economic benefits to an organisation (OECD 2005:15).

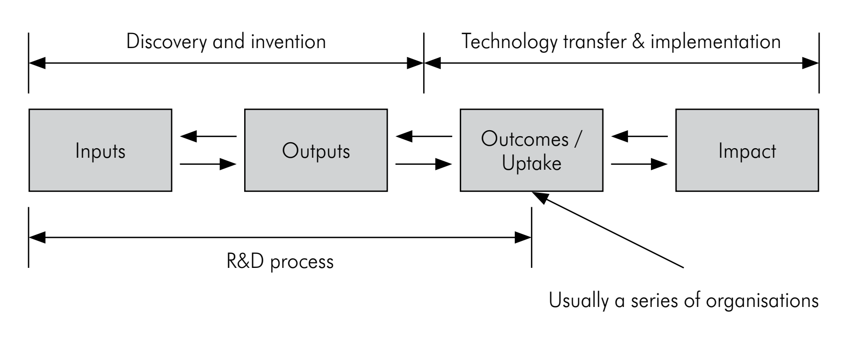
The OECD considers R&D as comprising three activities. The first of these activities is basic research, which refers to a theory-laden and empirical type of research conducted with the intent to develop insight regarding a phenomenon. The second activity is applied research, which also focuses on uncovering new knowledge; however, with the aim to apply the acquired knowledge to either solve a problem or to answer a specific question. The third and final activity is referred to as experimental development, which uses existing information acquired either through conducting research or through an observed or lived experience, to either develop a new product, service or process, or to make improvements to existing products, services or processes (OECD 2005:15). R&D is considered one of the most vital investments of technology-focused organisations (Link 1993:2) and is a fundamental input into the innovation process.

A number of definitions of innovation exist. These include the definition of innovation as the activity of producing new ideas or inventions and deploying them successfully in the market (Roberts 1988:14); innovation as the process of ensuring that developed ideas find implementation (Daglio *et al*. 2014:4); and more broadly, innovation as a stimulator of socio-economic growth in a country (Gault 2016:19). These definitions indicate that innovation is a process that not only requires the generation of new ideas or inventions, but also includes their development and implementation, as well as their ultimate creation of value either to society or within the context of the innovation. Edison *et al.* (2013:1390) describe more than 40 definitions of innovation, each focusing on a different aspect of innovation. This includes innovation type (product innovation, process innovation, market innovation and organisation innovation) or the degree of novelty (new to the firm, new to the market, new to the world). This article, however, will focus on technological innovation relating to the transport sector.

Open Innovation (OI) is arguably essential for the development of technological innovations in the transport sector. OI can be described as a mechanism to stimulate internal innovation in a company by in- and outflows of knowledge from and to that company (Chesbrough 2003:114). Thus, the R&D effort is accelerated through the sharing of knowledge between companies and their research facilities (Bessant *et al*. 2012:8). In the modern day, innovation in services must be open to be effective (Storey *et al*. 2015:511). The outputs of innovation in the roads and transport sector are usually knowledge-based solutions intended for general use in government as well as by engineers. Therefore, R&D and innovation programmes in the transport industry could benefit from OI.

The article argues that it is evident that the R&D process provides key inputs into the innovation process and is indeed a subset of the innovation process. This relationship between R&D and innovation is depicted in Figure 1 (Rust and Sampson 2019:547) that shows the full innovation value chain with R&D as a subset of the process.

**Figure 1: R&D as a subset of the innovation value chain**




**Source:** (Rust and Sampson 2019:547)

The terms in the innovation value chain can be described as (The National Research Council of the National Academies 2005:47):

- *"Input – tangible quantities put into a process to achieve a goal.*
- *Output – products and services delivered.*
- *Outcome/uptake – results that stem from the use of the outputs.*
- *Impact – the effect that an outcome has on something else."*

## THE CONTEXT: THE SOUTH AFRICAN NATIONAL ROADS AGENCY LTD SOC (SANRAL)

In an effort to redress the injustices of the past that are a legacy of South Africa's apartheid regime, one of the goals of the country's democratically elected government has been to use public expenditure to restore balance and justice to society, including eradicating inequalities concerning access to infrastructure and development. To achieve this goal, in 1998 the South African government established The South African National Roads Agency Ltd SOC (SANRAL), which was established in terms of The South African National Roads Agency Limited and National Roads Act, 1998 (South African Government 1998). According to the aforementioned Act, SANRAL was established with the mandate, "to manage and control the Republic's national roads system and take charge, amongst others, of the development, maintenance and rehabilitation of national roads within the framework of government policy" (South African Government 1998).

SANRAL operates independently from government, registered as a company, but with the country's Minister of Transport as the sole shareholder, which makes the institution a state-owned company. Currently, SANRAL exercises this mandate over a road network that spans 21,403 km and is also responsible for assets valued at an estimated R238 billion (SANRAL 2019). In order to stimulate socio-economic development in South Africa through a high-quality and high-performance road network, SANRAL maintains alignment between its overall objectives and those of key national government policies with similar goals. As such, SANRAL has ensured an alignment of its outputs with the country's National Development Plan 2030, which is aimed at achieving reduced levels of inequality, as well as eradicating the high levels of poverty that will plague South Africa by 2030. Consequently, SANRAL has developed the SANRAL 2030 Strategy, which is also referred to as 'Horizon 2030', which in part, serves to acknowledge SANRAL's commitment to ensuring that its mandate correlates with the South African government's objective to "build a capable and developmental state" (SANRAL 2017:3). The SANRAL Strategy: Horizon 2030, recognises four main pillars that shape its core mandate, namely: roads, safety, stakeholders and mobility. In Horizon 2030, harnessing existing professional skills and supporting the growth of new skills, as well as the use of technology and innovation to improve performance, mobility and road safety are highlighted. It furthermore highlights the efficient use of resources and acknowledges its strategic alignment with the United Nations Sustainable Development Goals in alleviating poverty, promoting economic growth, job creation, the development of sound infrastructure, as well as creating sustainable cities and communities (SANRAL 2017:3).

In view of the above, SANRAL has initiated a research programme in a number of focus areas associated with roads and transport. The performance monitoring of SANRAL's research programme is important in order to establish the benefit and eventual impact of the research programme and to establish the value of the investment. Due to the nature of the programme and the diversity of the focus areas, a simple economic return on investment process is not suitable. The end products of R&D and innovation in the roads and transport sector are sometimes new materials and products, but more often not hard products that can be commercialised, but rather new methodologies and processes such as new design methods or new processes for improving the performance of the transport system. These outputs are often packaged in free software for use by professionals. Additional benefits include human capital development, social impacts, technical guidelines and training programmes (Rust 2010:87). This type of research activity is increasing (Spieth *et al.* 2014:237). This implies that a more broad-based system for assessing benefit and impact is required rather than classical return on investment assessments (Rust and Sampson 2019:547). In such programmes, a novel approach is required that addresses inputs, outputs outcomes and impact across the full innovation value chain.

## RESEARCH METHOD

The research method comprised the following:

- A review of existing literature and methods with a special focus on R&D management models and R&D metrics to measure R&D performance, particularly in public funded programmes;
- Learning from previous R&D programmes including the R&D programme for the Research for Community Access Partnership (Rust and Sampson 2019), and the Transport R&D programme for the Council for Scientific and Industrial Research (CSIR) of South Africa;
- Interviews and discussions with the SANRAL R&D manager and the relevant SANRAL executive;
- A review of international transport indicators currently used;
- The definition of a preliminary indicator set within a Balanced Score Card particularly based on work by Demir and Tolga (2014) and Bigliardi and Dormio (2010:278); and
- A review of the indicator set and rating of the individual indicators by a group of SANRAL employees.

The resultant set of indicators spans the full innovation value chain and fits into the five perspectives of a Balanced Score Card (BSC) that would be suitable for the SANRAL R&D programme.

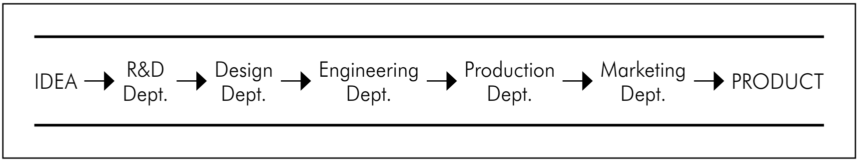
## LITERATURE AND THEORETICAL BACKGROUND

### Research management models

Rothwell (1985:97) described a number of classes of R&D and innovation management models. These are:

- First generation technology push models that are simple and linear;
- Second-generation needs pull models that are based on a simple linear sequential process linked to market needs;
- The third-generation coupling model that is still sequential but with feedback loops and a combination of technology push and market pull;
- The fourth-generation integrated model that focuses on parallel development with integrated development teams, strong upstream supplier linkages and close coupling with leading-edge customers.
- The fifth-generation systems integration and networking model that consists of fully integrated parallel development, the use of expert systems and simulation

**Figure 2: The Department Stage Model**




**Source:** (Saren 1984:11)

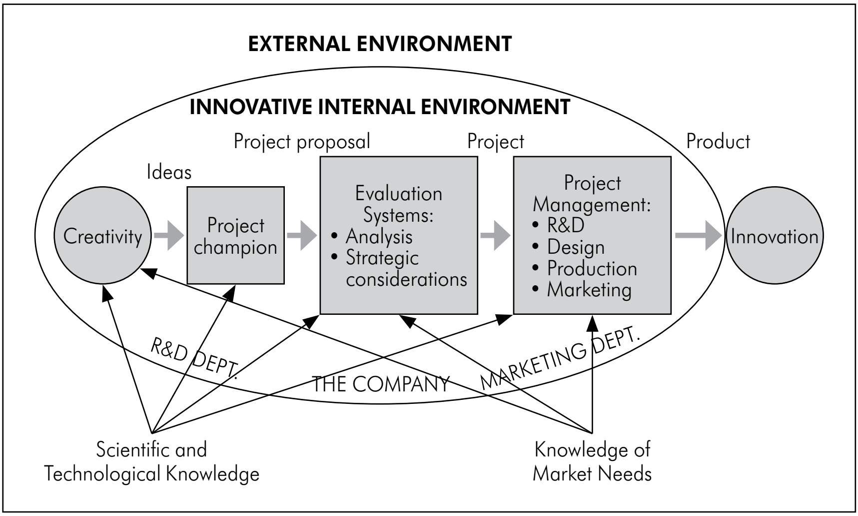
modelling in R&D, strong linkages with leading-edge customers and co-development of new products with suppliers.

However, these models are very linear and do not take cognisance of the iterative and complex systems nature of the R&D process (Rust 2009; Rust and Sampson 2019:547). A typical example of a linear model was described by Saren (1984:11). This model, named the 'Department Stage Model' is shown in Figure 2.

The management process is linear from Idea to Product with no feedback loops. This implies that the nature of the market need is not fully assessed in the conceptualisation of the idea. In the case of engineering methodology and knowledge-based solutions, this is insufficient (Roussel *et al*. 1991:59).

Other models such as Twiss's Activity Stage Model (Twiss 1980:95) include some feedback loops as depicted in Figure 3. However, the activities still move linearly forward from creativity to innovation.

**Figure 3: The Activity Stage Model**

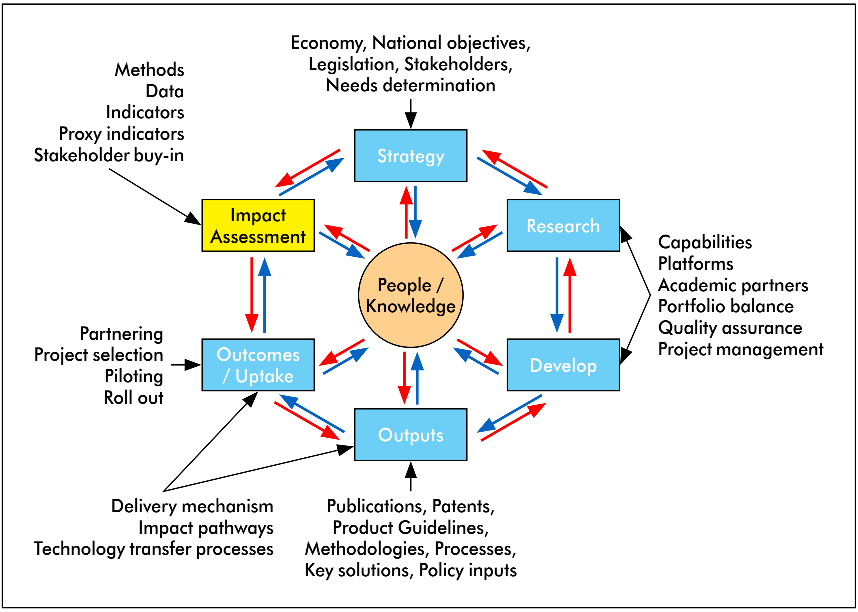



**Source:** (Twiss 1980)

A number of authors discuss processes to improve R&D project management but do not provide a conceptual model for a holistic management process. Examples are research management in the Fisheries sector (Shaoxuan 2018:20); the creation of and architecture and structure for virtual research enterprises (Sharifi *et al*. 2013:41); and knowledge management processes (Vicheanpanya 2015:33; Guevara *et al*. 2018). Similarly, Graves *et al*. (2000:47) discuss a linear programme to optimise financial return versus risk of a project, but do not provide a model for managing a programme of projects with additional benefits. Others only address one aspect of research and innovation such as portfolio management to optimise productivity in manufacturing companies (Lee and Cho 2015:20).

Caro-Gonzalez (2019:105) discusses the 6i model that provides guidelines for improved processes in research. The aspects addressed are: international, interdisciplinary, intersectoral, innovative, impactful and inclusive. However, it comprises steps to improve the research process of individual projects and not the management of a programme of R&D and innovation. The Chorus model (Owens *et al*. 2015:17) is a linear process for drug discovery which is not suitable for the transport sector that delivers a number of "soft" outputs.

**Figure 4: Conceptual systems-based, non-linear model for R&D management**




**Source:** (Rust and Sampson 2019:547)

In research conducted by Rust (2009:127) and Rust and Sampson (2019:547) they described the development of a systems-based R&D and innovation management model for the roads industry, which aligns with the previous section's assertion that R&D and innovation management should span the full innovation value chain. The model consists of a number of elements that interact with each other in a multidirectional manner. These elements operate in an environment with which it interacts and that influences it. The elements of the model are: strategy, R&D, outputs, outcomes/uptake, impact assessment and people/knowledge, and is shown in Figure 4.

The model includes an element for impact assessment which acts as a "sensor" for the health of the process and allows for feedback and correction of the system and process. R&D and innovation management should take cognisance of all the elements of the model and as such benefit/impact assessment should be an integral part of the process and not a stand-alone activity. The researcher should also conduct "back-casting" when planning research projects. This implies first defining the intended impact, then the required delivery system for uptake, then the nature of the output and only then the nature of the R&D to be conducted.

The model in Figure 2 was adopted by SANRAL for management of their R&D programme including the aspect of benefit/impact assessment through a BSC and a set of appropriate indicators.

## Impact and benefit assessment of R&D

One of the key considerations in the management of an R&D programme is the manner in which the performance of the programme will be assessed (Demir and Tolga 2014). Given the resource-intensive nature of the R&D process, in a time where many organisations have very limited resources to realise their organisational objectives, there is a greater focus on ensuring that the investment in an R&D programme is worthwhile, and accountability for the performance of the programme is fostered (Werner and Souder 1997:28). Therefore, the performance assessment of a research programme does not only serve to justify its existence but can also assist in the identification of areas within the programme where interventions to improve its overall effectiveness are required (Bozeman and Melkers 1993:115). Jyoti *et al.* (2006:879) add that the focus of R&D programmes should be on how its overall performance can be improved, as well as creating clear lines of feedback on the performance of the programme in order to facilitate the necessary improvements.

Thus, the assessment of the impact and benefits of the research programme as well as an assessment of the value of the return on the investment are important. However due to the nature of the research programme and the diversity of the focus areas in the SANRAL R&D programme, which is a public sector programme, a simple economic return on investment is usually not suitable (Bloch and Brugge 2013:133). In publicly funded research programmes, a number of "soft" returns or benefits such as human capital development, transformation, social impacts, technological advances, technical guidelines and training programmes should also be taken into account in assessing the impact of the programme (Demir and Tolga 2014). Link (1993:15) adds that when the fact that research programmes often have different focus areas is considered, coupled with the diverse groups of people that must see the development of an idea through to the end of the innovation value chain, it often becomes challenging to achieve consensus on which programme assessment process and technique to apply.

In the roads and transport field, impact measurement is equally challenging because of the diverse nature of the R&D activities, ranging from basic science, materials science and engineering to transport planning research and social research (Rust and Sampson 2019:247). A specially designed approach is therefore required and should address R&D performance assessment through the full innovation value chain as discussed above.

A number of approaches exist for R&D performance assessment (Brady 1995) as briefly discussed below.

- *The Innovation Management Tool Kit (IMTK)* was developed for the UK National Economic Development Office in 1989. Managers assess performance measured through 10 key characteristics of companies: company culture, employees, internal communication, organisation, customers, finance, suppliers, competitors, technology, new products and processes, However, the 13 handbooks are focused on product development for the consumer market (Brady 1995:252).
- *The UK DTI workbook* promotes a simpler process based on a series of questions and involves benchmarking of the company (DTI 1993:1–30).
- *The Managing of Integration of New Technology (MINT) programme* is part of the European Community SPRINT (Specific PRogramme for INnovation and Technology transfer) initiative. Their tool guide includes innovation audits, a business review tool, technology audits, technology opportunity reviews, value-based innovation and diagnosis, product management audits and quality management audits (Brady 1995:253).
- *Technology mapping* that comprises various mapping processes to analyse technologies including chronological mapping; co-word-based mapping; cognitive mapping and conceptual mapping (Gaynor 1996:23).
- *Technology audits* involving the use of technology space maps to determine the scope and depth of present capabilities; to determine the scope and depth of capabilities required to achieve goals implied by strategic objectives, and to determine the scope and content of technology development and technology transfer activities to fill the gaps identified in the process (De Wet 1989, 2005).

- *Technology forecasting tools and techniques* that include scenario writing; the Delphi process; relevance trees; trend impact analysis; probabilistic system dynamics, and morphological analysis (Brady 1995:117).

A number of these methods are not suitable for measuring the performance of a transport research programme. This is due to the specific nature of complex solutions and products (such as those developed for the roads and transport sector), that render the applicability of these models, tools and techniques in managing innovation in complex projects less effective (Brady 1995). This is mostly due to these models and techniques having been developed for managing hard product development for the consumer market. Current practice in technology management is mainly aimed at products for the consumer market (non-intelligent buyers) as opposed to the road infrastructure industry (intelligent buyers) and company strategies are mainly aimed at the performance of private companies rather than at an industry. This is not applicable for a public sector research programme (Demir and Tolga 2014) such as the SANRAL programme.

## The Balanced Score Card Approach

A BSC comprises a set of indicators to measure R&D programme performance to support strategy planning of the programme (Bremser and Barsky 2004:229; Kaplan and Norton 2001:95). The performance indicators can be used at various levels from corporate to the business unit, and eventually the employee level. A BSC incorporates not only financial measures but also non-financial measures that describe the "soft" benefits of the programme (Jyoti *et al.* 2006:879). The BSC is able to communicate an organisation's strategic objectives through a set of indicators and targets; aligns the goals of a department with that of the overall organisation; serves as a guide for all employees on the performance targets of the organisation; and it encourages regular feedback of the organisation's performance.

Jyoti *et al.* (2006:879) add that the BSC essentially creates a relationship between four areas of performance measurement in an organisation: "measures of organisational learning and growth" that are drivers of the "measures of internal business processes". Measures of these processes are in turn the drivers of measures of the customer perspective, and lastly of financial measures (Jyoti *et al.* 2006:879). A BSC can be used to evaluate the performance of individuals, but this should be done with care, so as not to discourage researchers dealing with the uncertainty of the research process (Pogrebnyakov *et al.* 2017:67).

The use of a BSC has many benefits (Bremser and Barsky 2004:229). These include, for example, the use of causal sets of performance measures to monitor results that can provide insight into strategic performance and the consequent effect on operational decisions. It is also a basis and reference point for all company operations and communication with stakeholders. It is a powerful tool to determine where targets are not being met and can be used to evaluate alternative actions. If well used it can motivate employees.

Technology is paramount to innovation, but it is difficult to measure its impact using traditional financial metrics (Bremser and Barsky 2004:229; Coombs and Bierly 2006:421). However, the BSC can link both financial and non-financial measures to strategy. A BSC should therefore have an adequate balance of both outcome and performance indicators that integrates quantitative and qualitative measures.

Bigliardi and Dormio (2010:278) describe the use of a BSC to monitor the performance of R&D in an automotive company. The BSC was successfully implemented although the indicators are not suitable for a public-funded R&D programme in roads and transport. A number of the indicators are also not quantifiable, for example, "core competences of R&D personnel" and "involvement in the R&D process". Nevertheless, they report a successful implementation for this industry.

## Cost benefit analysis

Organisations such as the World Bank, prescribe the use of a Cost Benefit Analysis (CBA) for the assessment of projects especially in developing countries and particularly in the roads and transport sector. A number of guidelines are available for the use of a CBA on road projects in developing countries. These include the "Transport Research Laboratory's Overseas Road Note 5–A Guide to Road Project Appraisal" (1988); and "Guidance on planning rural transport infrastructure and services–SSATP Working Paper No. 100" (Hine 2014). However, these guidelines address road construction projects and not a research programme.

CBA in simple terms considers the characteristics and costs for a "project case", and an alternative "do nothing case" or counterfactual case (Link and Scott 2013:15). The benefit is calculated as the difference between the two scenarios, using the Internal Rate of Return and Nett Present Value. Savings in, for example, travel time and vehicle operating calculated with computer-based programs such as HDM4 (The World Bank 2010).

Although easy to use, CBA has limited value within more complexly defined social phenomena such as road safety. In addition, there is relatively little evidence in the literature of the use of CBA techniques to evaluate the benefits of research (Salter and Martin 2001:509). "No simple model of the nature of the economic benefits from basic research is possible" (Salter and Martin 2001:509). Thus, it is evident that the use of CBA to evaluate research is much more challenging than evaluating the economic benefits of infrastructure investment. The main challenge lies in calculating the monetary value of benefits derived and the inherent unpredictability of research. Similarly, the World Bank did not use CBA to evaluate its research activity between 1998 and 2005 (Banerjee *et al*. 2006:40).

The European Commission (Clarke *et al*. 2013; Sartori *et al*. 2014:349) noted some success with the use of CBA to evaluate R&D although it focused only on economic benefits (Sartori *et al*. 2014:349). It is therefore evident that although CBA analysis can be used to understand the direct financial benefit from an R&D programme at the project level, it is more difficult at the programme level where non-financial aspects should also be considered.

## Transport indicators

Much work has been conducted on indicators for general transport system performance. Vulevic (2016:58) lists a number of indicators in the following categories:

- Transport infrastructure supply, typically length of road, number of ports, cost to motorway entrances etc.
- Transport infrastructure capacity, typically capacity of roads and railway lines.
- Transport services, typically number of cars, number of trains, travel time etc.
- Network vulnerability, typically structural vulnerability and climatic vulnerability.

The OECD (2001:35) listed a number of indicators for road performance that included, for example, road user costs, allocation of resources for roads, value of assets, road roughness etc. Similarly, the National Academy of Sciences (2002) listed indicators for road safety, mobility and economic growth. Litman (2007:10) presented a comprehensive list of indicators for sustainable transport planning in three aspects of sustainability: economic aspects, social aspects and environmental aspects.

Although most of the indicators mentioned above are mainly aimed at the performance of the transport network and do not address the research process and associated outputs and outcomes, some of these indicators could be used to assess uptake and impact of the research process (OECD 2001:35; National Academy of Sciences 2002; Litman 2007:10):

- Average freight transport speed and reliability;
- Per capita traffic crashes and fatalities;
- Overall satisfaction rating of transport system;
- Per capita energy consumption;
- Energy consumption per freight ton mile;
- Per capita air pollution emissions;
- Air and noise pollution exposure;
- Job opportunities created;
- Community impacts; and
- Transport facility resource efficiency.

## PROPOSED IMPACT/ BENEFIT ASSESSMENT FRAMEWORK FOR SANRAL RESEARCH PROGRAMME

In the roads and transport field impact measurement is challenging because of the diverse nature of the R&D activities, ranging from basic science, materials science and engineering to transport planning research and social research. A specially designed approach is therefore required and should address impact, benefit and effectiveness monitoring through the full innovation value chain shown in Figure 1. A framework for benefit assessment should also take cognisance of the systems nature of the R&D and innovation processes as depicted in Figure 4.

Based on the systems R&D management model in Figure 4 as well as work by Demir and Tolga (2014) and Bigliardi and Dormio (2010:278), SANRAL elected to combine the systems R&D management model with a BSC and appropriate set of indicators for performance measurement of its R&D programme. The benefit of the approach is that the systems model provides a clear link to the needs in the industry and therefore the nature of the associated outcomes from the research. In addition, the BSC provides a basis for evaluating the progress of performance indicators across the full innovation value chain in time through trend analysis. Of particular importance is measuring and monitoring indicators at the uptake level, seeing that these are the precursors to eventual impact.

Long-term impact is notoriously difficult to measure, especially non-financial impact (Coombs and Brierly 2006:421) and the use of, for example, proxy indicators to assess impact is important. The indicators in the SANRAL BSC cover financial and cost benefits (for example, savings to government) as well as the "softer", non-financial benefits of research such as human capital development and the impact on communities and the environment. The set of indicators discussed below will be monitored over time using trend analysis to provide input into strategic management processes.

It has been shown that simple measurement systems perform better (Cozzens 2000:5), especially because the link between research outcomes and socio-economic impact is complex and difficult to determine. R&D performance indicators are difficult to develop, however, once developed, they should be easily understood by stakeholders (Osawa and Yamasaki 2005:455).

The SANRAL BSC and indicators as well as their ratings are summarised below.

### Process indicators

It is important to monitor the management process for the SANRAL R&D programme. The following were proposed as indicators to assess these processes:

- Number of needs determination processes;
- Number of foresight studies;

- Establishment of a Research Advisory Panel;
- Establish research focus area steering committees;
- Number of SANRAL staff and researchers trained in research methodology;
- Number of SANRAL staff and researchers trained in research ethics; and
- Number of Research Focus Area technology development strategies (R&D plans) developed.

## Input indicators

To enable "return on investment" assessments, it is important to record and measure the inputs into the SANRAL R&D programme. These indicators will also provide an overview of the quality of the input effort. The proposed indicators in this instance were:

- Number of researchers active in SANRAL research programme;
- Number of SA black researchers active in SANRAL research programme;
- Number of SA black research project leaders;
- Number of SA female researchers active in the SANRAL research programme;
- Number of active researchers with a PhD;
- Frascati distribution of research funding (basic, applied, experimental development, piloting and implementation);
- The amount of funding employed for research infrastructure;
- The amount of research funding spent; and
- The number and size of collaborative partnerships.

## Output indicators

Output indicators should be designed to assess the volume, quality and the implementability of output achieved through the SANRAL R&D programme. The proposed output indicators were:

- Number of publication equivalents;
- Number of new technology/knowledge packages;
- Number of SANRAL endorsed national research reports;
- Number of new or updated national guidelines;
- Number of new Master's degrees completed;
- Number of new PhDs completed; and
- Quality assessment of publications (for example, journal impact factors).

## Outcome indicators

Outcomes are defined as the uptake of R&D results by industry outside of the R&D programme. This is one of the most important categories of indicator to monitor because it assesses the transfer and implementation of R&D results as well as acts as a precursor to impact. Without uptake there can be no impact. The proposed indicators for this category were:

- Number of technology demonstration projects where new knowledge/technology was implemented;
- Monetary value of demonstration projects;
- Number and size of social impact;
- Number of projects where positive environmental impact is made;
- Number of practitioners trained in use of new technology or knowledge package;
- Cumulative cost/benefit ratio; and
- Number of small contractors involved in projects emanating from research programme.

In addition, it was proposed that qualitative information such as success stories be recorded.

## Impact proxy indicators

Although it is generally difficult to measure impact directly, the potential for eventual impact can be described through proxy indicators. The following proxy indicators for assessing the potential impact of the SANRAL R&D programme were proposed:

- Number of retrospective studies to determine current impact resulting from past R&D;
- Fatalities per 100,000 trips on roads where new solutions have been implemented;
- Traffic through-flow rate at crucial bottlenecks;
- Number of job opportunities created;
- Road condition index;
- Facility performance index;
- User satisfaction index;
- Number and nature of community involvement projects;
- Cumulative monetary value of SANRAL involvement in communities; and
- Freight flow rates on road where new technology has been implemented.

The above indicators were proposed based on their alignment with SANRAL's overall mandate and strategic objectives. The indicators will, however, need to be tested with SANRAL stakeholders and SANRAL Research Focus Areas members to ensure that the BSC is indeed "balanced" and consists of the relevant indicators, after which it can be revised for implementation.

## SANRAL RATING OF THE INDICATOR SET

A total of 15 SANRAL R&D focus group members were asked to rate the indicators on a five-point Lickert scale. The results are shown in Table 1.

As can be noted from Table 1, the following indicators were rated as very important (score > 4):

- Number of foresight studies;
- Establishment of a Research Advisory Panel;
- Number of SANRAL endorsed national research reports;
- Number of new or updated national guidelines;
- Number of technology demonstration projects where new knowledge/technology was implemented;
- Cumulative cost/benefit ratio;
- Number and size of social impact;
- Number of practitioners trained in use of new technology or knowledge package;
- User satisfaction index;
- Road condition index;
- Fatalities/100,000 trips on roads where new solutions have been implemented;
- Facility performance index; and
- Number of job opportunities created.

The following indicators received a relatively lower importance rating (score < 3,5):

- Number of active researchers with a PhD;
- Number of researchers active in SANRAL research programme;
- The amount of funding employed for research infrastructure;
- The amount of research funding spent;
- Number of new PhDs completed;
- Number of new Master's degrees completed;
- Number of small contractors involved in projects emanating from research programme;
- Monetary value of demonstration projects;
- Number and nature of community involvement projects; and
- Cumulative monetary value of SANRAL involvement in communities.

Only one indicator scored less than three: Monetary value of demonstration projects.

The above ratings should be seen in the light of the participants, being middle-management and technical SANRAL staff tasked mostly with implementation. Hence, the relatively low scores for "academic" research performance indicators such as completion of tertiary degrees. The indicator set should be subjected to ratings by a broader spectrum of stakeholders.

The SANRAL participants also proposed some additional indicators:

- Monetary value of indirect economic impact;
- Behavioural changes of drivers;
- Public perception of interventions;
- Effective communication measures;
- Network benefits of interventions;
- $CO_2$ levels near roads;
- Energy footprint of operations; and
- Road safety index.

Some of these suggestions such as, for example, "network benefits of interventions" are not measurable and therefore difficult to include in an indicator set without extensive work to develop an indicator.

**Table 1: Indicator ratings by the SANRAL technical managers**

| Process Indicators | Ratings | | | | | | | | | | | | | | Avg | Std Dev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of needs determination processes | 5 | 4 | 2 | 4 | 5 | 5 | 1 | 4 | 3 | 3 | 5 | 3 | 5 | 5 | 3.857 | 1.292 |
| Number of foresight studies | 5 | 4 | 4 | 5 | 5 | 5 | 1 | 4 | 4 | 4 | 3 | 4 | 4 | 5 | 4.071 | 1.072 |
| Establishment of a Research Advisory Panel | 5 | 4 | 1 | 3 | 2 | 5 | 3 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 4.071 | 1.328 |
| Establish research focus area steering committees | 1 | 5 | 3 | 4 | 4 | 5 | 3 | 5 | 5 | 5 | 2 | 5 | 5 | 2 | 3.857 | 1.406 |
| Number of SANRAL staff and researchers trained in research methodology | 5 | 5 | 3 | 4 | 4 | 3 | 4 | 3 | 1 | 2 | 3 | 4 | 4 | 5 | 3.571 | 1.158 |
| Number of SANRAL staff and researchers trained in research ethics | 4 | 5 | 3 | 4 | 4 | 3 | 4 | 4 | 3 | 2 | 4 | 5 | 4 | 5 | 3.857 | 0.864 |
| Number of Research Panel technology development strategies developed according to the template | 3 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 5 | 4 | 3 | 3 | 3.571 | 0.646 |

| Input Indicators | Ratings | | | | | | | | | | | | | | Avg | Std Dev |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of researchers active in SANRAL research programme | 5 | 2 | 3 | 3 | 5 | 4 | 2 | 4 | 3 | 2 | 5 | 2 | 2 | 4 | 3.286 | 1.204 |
| Number of SA black researchers active in SANRAL research programme | 5 | 4 | 2 | 5 | 5 | 3 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 3.786 | 0.893 |
| Number of SA black research project leaders | 5 | 3 | 5 | 5 | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 2 | 4 | 3.714 | 0.914 |
| Number of SA female researchers active in the SANRAL research programme | 5 | 4 | 4 | 5 | 5 | 4 | 4 | 3 | 4 | 3 | 4 | 3 | 2 | 4 | 3.857 | 0.864 |
| Number of active researchers with a PhD | 4 | 3 | 3 | 3 | 4 | 4 | 3 | 4 | 3 | 2 | 2 | 4 | 5 | 3 | 3.357 | 0.842 |
| Frascati distribution of research funding (basic, applied, experimental development, piloting and implementation) | 3 | 3 | 3 | 5 | 3 | 3 | 3 | 4 | 3 | 3 | 3 | 5 | 5 | 3 | 3.500 | 0.855 |
| The amount of funding employed for research infrastructure | 1 | 3 | 4 | 4 | 2 | 4 | 2 | 5 | 4 | 4 | 2 | 3 | 5 | 3 | 3.286 | 1.204 |
| The amount of research funding spent | 3 | 3 | 1 | 3 | 2 | 4 | 2 | 5 | 4 | 4 | 5 | 2 | 5 | 3 | 3.286 | 1.267 |
| The number and size of collaborative partnerships | 4 | 4 | 4 | 5 | 4 | 4 | 3 | 4 | 3 | 3 | 4 | 4 | 4 | 4 | 3.857 | 0.535 |
| **Output Indicators** | **Ratings** | | | | | | | | | | | | | | **Avg** | **Std Dev** |
| Number of publication equivalents (DoE formula) | 5 | 4 | 1 | 3 | 5 | 3 | 5 | 4 | 3 | 2 | 4 | 5 | 3 | 5 | 3.714 | 1.267 |
| Number of new technology/ knowledge packages | 5 | 4 | 1 | 5 | 2 | 4 | 5 | 4 | 4 | 3 | 5 | 4 | 4 | 5 | 3.929 | 1.207 |
| Number of SANRAL endorsed national research reports | 4 | 4 | 3 | 5 | 4 | 4 | 5 | 5 | 4 | 4 | 4 | 3 | 5 | 5 | 4.214 | 0.699 |
| Number of new or updated national guidelines | 5 | 4 | 3 | 5 | 2 | 5 | 5 | 4 | 5 | 5 | 5 | 3 | 3 | 4 | 4.143 | 1.027 |
| Number of new Master's degrees completed | 3 | 4 | 3 | 1 | 5 | 2 | 3 | 4 | 3 | 2 | 3 | 3 | 4 | 4 | 3.143 | 1.027 |
| Number of new PhDs completed | 3 | 3 | 4 | 1 | 5 | 3 | | 4 | 3 | 2 | 3 | 3 | 4 | 4 | 3.231 | 1.013 |
| Quality assessment of publications (eg journal impact factors) | 3 | 4 | 3 | 3 | 5 | 3 | | 5 | 4 | 3 | 5 | 4 | 3 | 4 | 3.769 | 0.832 |

| **Outcomes Indicators** | **Ratings** | | | | | | | | | | | | | | **Avg** | **Std Dev** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of technology demonstration projects where new knowledge/ technology was implemented | 5 | 4 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 4 | 4.429 | 0.514 |
| Monetary value of demonstration projects | 1 | 3 | 2 | 2 | 1 | 2 | 2 | 5 | 3 | 4 | 4 | 2 | 4 | 2 | 2.643 | 1.216 |
| Number and size of social impact | 5 | 5 | 4 | 5 | 5 | 3 | 3 | 5 | 3 | 2 | 5 | 5 | 3 | 4 | 4.071 | 1.072 |
| Number of projects where positive environmental impact is made | 4 | 4 | 4 | 4 | 5 | 3 | 4 | 4 | 4 | 3 | 5 | 3 | 4 | 3 | 3.857 | 0.663 |
| Number of practitioners trained in use of new technology or knowledge package | 4 | 3 | 3 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 3 | 4.000 | 0.679 |
| Cumulative cost/benefit ratio | 4 | 4 | 4 | 3 | 3 | 3 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 4.286 | 0.825 |
| Number of small contractors involved in projects emanating from research programme | 5 | 5 | 1 | 4 | 5 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3.429 | 1.089 |
| Life stories and success stories of new technologies implemented | 5 | 4 | 3 | 5 | 5 | 4 | 3 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 3.857 | 0.770 |
| **Impact Proxy Indicators** | **Ratings** | | | | | | | | | | | | | | **Avg** | **Std Dev** |
| Number of retrospective studies to determine current impact resulting from past R&D | 4 | 3 | 4 | 3 | 3 | 5 | 1 | 5 | 4 | 3 | 4 | 4 | 4 | 4 | 3.643 | 1.008 |
| Fatalities/ 100,000 trips on roads where new solutions have been implemented | 5 | 4 | 3 | | 4 | 5 | 4 | 5 | 5 | 4 | 5 | 2 | 4 | 3 | 4.077 | 0.954 |
| Traffic through-flow rate at crucial bottlenecks | 5 | 3 | 3 | | 4 | 5 | 5 | 4 | 4 | 5 | 3 | | 3 | 3 | 3.917 | 0.900 |
| Number of job opportunities created | 5 | 4 | 3 | | 5 | 3 | 3 | 5 | 4 | 3 | 3 | 5 | 4 | 5 | 4.000 | 0.913 |
| Road condition index | 5 | 3 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 3 | 3 | 4 | 5 | 4.286 | 0.914 |
| Facility performance index | 5 | 3 | 4 | | 5 | 4 | 4 | 5 | 4 | 4 | 3 | 3 | 4 | 5 | 4.077 | 0.760 |
| User satisfaction index | 5 | 5 | 4 | | 5 | 4 | 3 | 5 | 4 | 5 | 5 | 2 | 5 | 5 | 4.385 | 0.961 |
| Number and nature of community involvement projects | 1 | 5 | 4 | 3 | 5 | 4 | 2 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 3.500 | 1.092 |
| Cumulative monetary value of SANRAL involvement in communities | 1 | 5 | 5 | 3 | 1 | 4 | 2 | 5 | 3 | 3 | 5 | 3 | 3 | 4 | 3.357 | 1.393 |
| Freight flow rates on road where new technology has been implemented | 1 | 4 | 5 | | 4 | 4 | 3 | 5 | 4 | 4 | 4 | 2 | 5 | 4 | 3.769 | 1.166 |

## CONCLUSION

This article contributes to the knowledge pool of Research Management and an R&D benefit/impact assessment by offering a set of indicators across the full innovation value chain that can be used in a BSC to assess the performance of a roads and transport focused R&D programme. The indicator set was developed taking cognisance of a systems approach to R&D management and provides the vital element of assessment through a "performance sensor" to provide strategic feedback to the R&D manager. This indicator set can be used as the basis for developing a framework for any roads and transport research programme. The approach can also be used to develop a BSC with indicators for any R&D programme that requires assessment through more than mere financial return on investment tools.

## NOTE

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