RURAL INNOVATION ASSESSMENT TOOL (RIAT)
CONCEPT PAPER SERIES

INNOVATION METHODS – INDICATOR DEVELOPMENT

RIAT Concept Paper # 6

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The Department of Science and Technology (DST) contracted the Human Sciences Research Council (HSRC) to develop and pilot the Rural Innovation Assessment Toolbox (RIAT) in four rural district municipalities (RDMs). The RIAT aims to enhance the contribution of science and technology interventions to rural development, deepen understanding of the social and institutional dynamics of rural innovations and inform the work of the multi-stakeholder Rural Innovation Partnership. Based on the outcomes of this project, the team must also explore ways to institutionalise RIAT as a self-discovery diagnostic tool for innovators. This is the sixth in a series of concept notes to strengthen the conceptual framework and evidence base for RIAT. The early conceptual inputs from members of the RIAT Project Reference Team and other RIAT Project Team members, who are not authors of this specific paper, are acknowledged and appreciated. The views expressed are those of the authors and do not necessarily reflect those of any other party.

EXECUTIVE SUMMARY

Science, technology and innovation (STI) indicators have been used for many decades to collect data on science, technology and innovation and measure the level of STI in a country. Indicators are seen as an important tool for policy makers in '...developing evidence-based policies, assessing the impacts of investments in S&T and identifying the strengths and weaknesses in the innovation systems' (Chaturvedi and Srinivas 2012: 1640). Despite the fact that most developing countries adopt OECD manuals for the development of their STI indicators, it has been evident, especially from Latin American experiences, that it is imperative to modify these manuals to better fit with the conditions of developing countries and to address local development issues that are not covered by the OECD manuals (Lugones and Peirano 2005).

The aims of this concept paper are to review the existing literature on indicator development globally, illustrate common understandings of the various types and purposes of indicators, identify dominant and emerging methodologies for STI indicator development and identify any existing tools which may assist in measuring and developing rural innovation indicators relevant to RIAT.

Indicators are used to sum up information about a system, society, or economy and present it in an easy to understand form for policy makers, business people and other interested parties in the society. Indicators have a number of important features. Firstly, an indicator should be recurrent because its objective is to measure change. Secondly, it is argued that combining several statistics into an indicator provides a much more reliable result in contrast to a single statistic per indicator (Shavelson, McDonnell and Oakes 1991). Lastly, the development of indicators should be done using a conceptual framework. Indicators must be developed with an objective to test a hypothesis, assumption or theory, despite the fact that these are usually implicit to the model (Smith 2005). Indicators are used for monitoring, benchmarking, foresight and evaluation purposes. Some argue that they must also be SMART – specific, measurable, achievable, relevant and timely.

The basic framework for STI indicators includes five key components: actors, activities, linkages, outcomes and long-term impacts. Initially, in the understanding of the STI framework, the indicators for the actors and their activities are of primary importance, but gradually importance shifts to the other components as a better understanding of the STI indicator framework is required. Impacts are the long-term results of activities, linkages and outcomes.

Since the early 1960s the OECD has been compiling R&D and STI indicators. A solid methodology has been developed whereby STI indicators were divided into five distinct groups (Lugones and Suarez 2010):

- Research and development (R&D);
- Innovation;

- Human resources;
- Patents; and
- Technology balance of payments.

For each of these groups of indicators, the OECD created separate manuals which very quickly became internationally acknowledged and accepted as a reference point for the development of STI indicators:

- Frascati Manual – focuses on research and development (R&D) indicators;
- Oslo Manual – focuses on guidelines for developing and identifying innovation indicators and their measurement;
- Canberra Manual – focuses on the human resource indicators necessary to illustrate the development of human resources within a national system of innovation (NSI);
- Patent Manual – examines the types of indicators required and ways to measure patents and other intellectual property;
- Technology Balance of Payment (TBoP) Manual – focuses on the measurement of the transfer of technology at the international level using indicators of income and expenditure related to exchange of technology.

The Bogota Manual was developed in 2001 by a Latin American network (RICYT/OAS/CYTED 2001). One of the key reasons for using the Oslo Manual methodology of developing STI indicators is related to the ability to have international comparability between Latin America and other developing and developed countries or regions, which utilise the Oslo Manual (Lugones and Suarez 2010). A more important reason is the need to measure innovation processes in developing countries; this requires region-specific manuals with a standardised set of indicators to measure innovation activity. The Bogota Manual illustrates that in Latin America and the Caribbean the general situation is different to Europe and innovation is therefore different in many instances.

While some attempts have been initiated by NEPAD to develop a manual on STI for Africa, progress has been slow. NEPAD has indicated that the best route for Africa is the adoption of the Frascati and OSLO Manuals. However, others caution complete adoption and argue that some adaption is required. Innovation in Africa's informal economy has received very little attention, especially with regards to its conceptualisation and measurement because most innovation studies focus on formal sector easily identifiable research-intensive enterprises and ignore informal activities (Bhaduri and Sheikh 2013). Given that almost half of the world's population is living and working in the informal setting (Cozzens and Sutz 2012), it is important to develop indicators to incorporate innovation activities taking place in the informal sector, even though the complexity of this task is realised and considered significant. Some groups, comprised of Africans and other developing regions, as well as Europeans, have developed their own tools to identify, record and understand innovations. PROLINNOVA is one such network that functions in developing countries across the world with eleven of these country programmes based in Africa, including South Africa.

It has become quite popular to develop composite indicators to better address specific economic and social issues. Composite indicators, also known as indices, are nothing more than the combination of single indicators. The STI composite indicators include the Innovation Efficacy Index, the Technology Achievement Index and the Innovation Capacity Index. These are again macro level indicators; as we are interested in local indicators, we turn to the recently operationalised Indicator Pyramid Structure, which proposes the development of local level indicators, which can then be strengthened to provide indicators for sub-national and national level. After this, these indicators can be used to strengthen those used at the global comparative level.

It makes sense to use some of the experience of Europe and Latin America when compiling indicators for Africa and South Africa. However, this approach itself needs to be innovative and therefore must adapt the best and most relevant parts of these manuals, while ensuring further local level indicators can be developed. The Pyramid Structure, illustrated in Section 4, appears to us to be a reasonable way of ensuring that there is a mix of top-down and bottom-up approaches. However, this must be done cautiously so that the top-down approaches do not blur the reality at the local level and by doing so ignore the local needs and circumstances that direct local innovation. In many instances, local innovations in Africa and other developing regions of the world result from the need for survival, rather than the more business-directed need to maximise profits.

Despite the involvement of numerous research organisations, the development of local level indicators that can contribute to a framework such as the Pyramid Indicator Framework is lacking, or at best slow. Such contributions would enable the further development of stronger national and global level indicators, while ensuring that locally developed innovations are not ignored and their relevance to local people, as part of their own attempts to improve their socio-economic circumstances, are acknowledged and given value.

1. INTRODUCTION

1.1 BACKGROUND

Science, technology and innovation (STI) indicators have been used for many decades to collect data on science, technology and innovation and measure the level of STI in a country. Indicators are seen as an important tool for policy makers in ‘developing evidence-based policies, assessing the impacts of investments in S&T and identifying the strengths and weaknesses in the innovation systems’ (Chaturvedi and Srinivas 2012: 1640).

There is a large volume of literature that deals with developing STI indicators. The Organisation for Economic Cooperation and Development (OECD) is a key contributor to the literature on the development of STI indicators. The OECD supported the development of a set of manuals, known as the ‘Frascati Family’ of manuals, to assist countries in measuring their state of science, technology and innovation (Godin 2003). Many countries have adopted these manuals to measure STI levels. The manuals also have the key objective of enabling comparability across countries and to some extent across regions.

Despite the fact that most developing countries adopt OECD manuals for the development of their STI indicators, it has been evident, especially from Latin American experience, that it is imperative to modify these manuals to better fit with the conditions of developing countries and to address local development issues that are not covered by the OECD manuals (Lugones and Peirano, 2005). Consequently, it makes sense that each country or region should invest significant time and resources in developing their own manuals, indices and other composite indicators to measure the level of science, technology and innovation. This recommendation also applies in the case of South Africa, whose national system of innovation has had a fragmented, inequitable and problematic development path and whose STI surveys largely focus on OECD standards.

The aims of this concept paper are to review the existing literature on indicator development globally, illustrate common understandings of the various types and purposes of indicators, identify dominant and emerging methodologies for STI indicator development and identify any existing tools which may assist in measuring and developing rural innovation indicators relevant to RIAT.

1.2 METHODOLOGY

This concept paper is based on a review of the literature on the existing methodologies for developing science, technology and innovation indicators. The dominant literature in this paper is that of the Organisation for Economic Cooperation and Development (OECD), including the OSLO Manual (OECD/Eurostat 2005), the Frascati Manual OECD (2002) and the Bogota Manual

(RICYT/OAS/CYTED 2001). The more academic work of Fred Gault (2011), Smith (2005), Godin (2003) and other key papers produced by various academic experts in the broad field of STI indicator development are also reviewed. Some of the dominant African and South African literature includes publications produced by NEPAD (2005), the National Advisory Council on Innovation (NACI) 2010-2011 Annual Report, publications by the Human Sciences Research Council (HSRC) and Promoting Local Innovation in Agriculture and Natural Resource Management (PROLINNOVA). Literature was obtained at the suggestion of colleagues and various members of the RIAT Reference Group.

2. PRINCIPLES OF INDICATORS

The development of STI indicators arose from the need to measure and track the benefits and development of science, technology and innovation activities. Several key scholars and scientists in the field of innovation studies have contributed broadly to innovation indicator development, as well as to our understanding of this process. Smith (2005) illustrates the contribution made by Kline and Rosenberg in the mid-80s (1986). He states that their contribution to the literature on indicator development comprises two key components. First is the idea that novelty is not necessarily the development of an entirely new product or process. Novelty may also include any slight changes to the product, manufacturing processes or product performance. A good indicator should be able to identify and measure this type of innovation. Secondly, Rosenberg and Kline highlighted the importance of non-research and development (R&D) innovation such as design activities, marketing, etc. This contribution became particularly important for developing countries and sectors other than manufacturing, such as the service sector.

Freeman is considered to be another key figure who played a significant role in the development of STI indicators in Europe (Gault 2010). His contribution to the development of indicators was made through the development of a draft version of the first OECD Manual. This manual was known as the Frascati Manual, drawing its name from the town in Italy where Freeman and his team worked on developing the first indicators to measure R&D in the early 1960s (Van Bochove 2013).

Das, Arora and Bhattacharya (2012) argue that to be able to develop STI indicators it is necessary to establish two crucial things: firstly, the collection of regional, national and international statistics on all STI dimensions; secondly, the formulation of guidelines and manuals for the proper collection of these statistics.

However, indicators, whether they are used for measuring innovation performance or any other aspect of society, have a variety of definitions, come in different types and have different purposes. In the following section we present some of the more common meanings and understandings of indicator types and functions.

2.1 DEFINITIONS AND TYPES OF INDICATORS

Indicators are used to sum up information about a system, society, or economy and present it in an easy to understand form for policy makers, business people and other interested parties in the society. Indicators have been used for many years to 'summarise, focus and condense the enormous complexity of our dynamic environment to a manageable amount of meaningful information' (Godfrey and Todd 2001). The definition of indicators varies slightly across different disciplinary literature. From a scientific point of view, 'indicators are statistics or a combination of statistics that are populated by data' (Gault 2011: 3). From a more economic perspective, indicators are often a ‘statistic, such as Gross Domestic Product (GDP), or population, or a combination of statistics, such as GDP per capita, which tells the public and the policy maker about the state of the economy and the society’ (NEPAD 2005: 2).

Social indicators have increasingly gained in popularity amongst researchers and policy makers. Although there appears to be a thin line between social and economic indicators (Sartori and Pacheco 2007), Cummins (2012) reminds us that some of the oldest definitions of social indicators in summary indicate clearly that social indicators are statistics meant to assist with the understanding of social values, norms and goals and not simply with economic and demographic statistics.

For many years, the development of indicators was seen as a purely scientific exercise mostly dominated by statisticians (Lepori 2008). The recent emergence of community indicators was based on the need to incorporate and measure economic, social and environmental aspects of local communities (Holden 2007) and to ‘help make the society more sustainable’ (Reed et al. 2005: 406). Sustainability indicators can be defined as ‘indicators for measuring and monitoring the long-term health and vitality of the economic, social and environmental systems that are needed to maintain quality of life in a community’ (Communities Committee 2003: 1).

Godin (2003) identifies some of the key features of indicators. Firstly, an indicator should be recurrent because its objective is to measure change. Secondly, it is argued that combining several statistics into an indicator provides a much more reliable result in contrast to a single statistic per indicator (Shavelson, McDonnell and Oakes 1991). A good example is GDP versus GDP per capita. Lastly, the development of indicators should be done using a conceptual framework. Indicators must be developed with an objective to test a hypothesis, assumption or theory, despite the fact that these are usually implicit to the model (Smith 2005).

2.2 COMPOSITE INDICATORS

It has become quite popular to develop composite indicators to better address specific economic and social issues. Composite indicators, also known as indices, are nothing more than a combination of single indicators, often developed by NGOs, universities and research institutions (Tijssen and Hollanders 2006). As Grupp and Mogee (2005) acknowledge, most STI-related studies conducted in Europe rely on the use of composite indicators. This is because composite indicators have the capacity to ‘...integrate large amounts of information into easily understood formats for a general audience’ (Freudenberg 2003: 5). Nardo et al. (2005) and OECD (2008) present some of the key advantages and disadvantages of using composite indicators. These are summarised in Table 1 below:

Table 1: Summary of advantages and disadvantages of using composite indicators of innovation

Advantages	Disadvantages
Summarise complex or multi-dimensional issues, in order to support decision-makers	May send misleading policy messages, if they are poorly constructed or misinterpreted
Are easier to interpret than trying to find a trend in many separate indicators	May invite drawing simplistic policy conclusions, if not used in combination with the indicators, especially more qualitative ones
Facilitate the task of ranking countries on complex issues in a benchmarking exercise	May lend themselves to instrumental use (e.g. be built to support the desired policy), if the various stages (e.g. selection of indicators, choice of model, weights) are not transparent and based on sound statistical or conceptual principles
Assess progress of countries over time on complex issues	The selection of indicators and weights could be the target of political challenge
Reduce the size of a set of indicators or include more information within the existing size limit	May disguise serious failings in some dimensions of the phenomenon, and thus increase the difficulty in identifying the proper remedial action
Place issues of countries performance and progress at the centre of the policy arena	May lead to wrong policies, if dimensions of performance that are difficult to measure are ignored
Facilitate communication with ordinary citizens and promote accountability.	May not be understood by many ordinary citizens in both developing and developed countries and therefore continue to disempower the poor and reduce accountability of the policy makers

Source: Nardo et al. (2005) and OECD (2008)

In recent years, there has been a huge increase in developing indices for the purpose of cross-national comparisons of country performance (Freudenberg 2003). The popularity of indices has also spread to developing countries. As a result, a number of indices such as the Technology Achievement Index (TAI), Human Development Index (HDI) and Innovation Capacity Index (ICI) have been extensively applied on the African continent to measure and analyse the level of STI and related activities[1].

2.3 FUNCTIONS OF INDICATORS

Indicators can serve many different functions. As stated by United Nations Department of Economic and Social Affairs (UNDESA) in 2007, indicators can improve policy makers' decision making by simplifying and clarifying available information. They can also serve as warning signs to prevent economic, social and environmental setbacks, as well as simply serve as a tool to '...communicate ideas, thoughts and values' (UNDESA 2007: 3).

Gault (2007) states that indicators are developed mainly for the community of indicator users (usually scientists and researchers). However, in recent years, indicators have gained considerable popularity amongst policy makers as a guide to decision-making. Popularity has a lot to do with the use of technical and business ideas and practices in monitoring and assessing society, the economy and the environment. We briefly explain the four key functions of indicators in terms of their use in innovation studies, namely monitoring, benchmarking, evaluation and foresight.

[1] A thorough analysis of STI indices goes beyond this paper. For more information about mention indices refer to UNDP (2001), Porter and Stern (2002), Neumayer (2001).

2.2.1 Monitoring

Indicators are most often used to monitor innovation systems. In this instance indicators are compared over time whereby past indicators are compared to present indicators (NEPAD 2005: 3). Gault (2010) further adds that monitoring public spending on STI is one essential function performed by this type of indicator. Monitoring also promotes a culture of learning and should improve the performance of actors through better accountability (UNDESA 2007). Moreover, Ecorys and IDEA Consult (2005) state that for effective monitoring of the system, it is critical to perform the following three activities on a regular basis: data collection, data reporting and data analysis. NEPAD (2005) illustrates some examples of monitoring indicators namely the ratio of gross domestic expenditure on R&D to the gross domestic product (GDP) of the country, the number of university graduates in science and engineering or the value of imports of capital equipment.

2.2.2 Benchmarking

Benchmarking involves setting target indicators and trying to achieve them within a specific time frame. From an organisational perspective, as illustrated by de la Porte, Pochet and Room (2001), benchmarking allows an organisation to evaluate how well they are meeting organisational objectives and what can be done to meet them more efficiently. They further add that there are two main approaches to benchmarking: bottom-up and top-down approaches. In the bottom-up approach, an organisation will search for other organisations with best practices in order to compare itself. In the top-down approach, the benchmarking is initiated outside the organisation, usually by a public body by setting performance targets and other quality assurance policies (Lundvall et al. 2002). In this respect, such benchmarks may well become industry or sub-sector standards. The indicators used in benchmarking can be used for monitoring. However, benchmarking indicators serve a different purpose, as we have illustrated.

2.2.3 Foresight

As Miles (2010) indicates, the term foresight was first introduced into the innovation literature by Irvine and Martin, whereby Martin (1995) defined foresight as a process which involves looking into the long-term future of science, technology, the economy and society, with the objective of identifying the areas of strategic research and the emerging generic technologies likely to yield the greatest economic and social benefits. Foresight is similar to outlook: it is known that there are many possible outcomes in the future, but by making decisions in the present, only one outcome will definitely occur (Su and Lee 2010). Foresight is a concept often used in the science, technology and innovation discipline.

2.2.4 Evaluation

Evaluation indicators are typically used in a project or a programme where inputs and outputs can be measured (Gault 2010). During the evaluation process, current indicators are collected and compared to past indicators. In other words, evaluation indicators focus on whether the objectives of the project or a programme have been achieved and whether they have been achieved in the most effective and efficient manner (NEPAD 2005). There are various methods of evaluation, such as qualitative, quantitative and participatory, as well as combinations of these types. Quantitative methods include audits, bibliometric[2] analysis and turnover. An example of the qualitative method is peer review. In participatory methods, the actors participate in the selection or compilation of indicators, as well as the actual review and analysis. Additionally, when evaluating a project or a programme, it is possible to evaluate most aspects of it, such as the design or conceptualisation, management, implementation, results and impact (Ecorys and IDEA Consult 2005).

2.4 QUALITY CRITERIA FOR INDICATORS

When developing indicators, there are certain quality criteria that should be taken into consideration. The five key criteria, often referred to in the literature as SMART, are the following (EC 2006):

- Specific
  Indicators should be precise, simple and focused to avoid generalisation and vague results (Ecorys and IDEA Consult 2005). Indicators should measure exactly what they intended to when they are developed.
- Measurable
  The indicator should be measurable in practice and in theory. Indicators can also be either quantitative or qualitative (Jennings 2005) or even participatory.
- Achievable/Feasible
  It is critical that the outcomes are achievable in terms of resource availability and cost-effectiveness (Mainguet and Baye 2006). It is also important that the prerequisite data can be collected.
- Relevant
  Indicators should provide information that is useful for the community and policymakers (Jennings 2005).
- Timely
  It is important that indicators are collected and reported on at the right time, as well as measured regularly to illustrate their development over time (Ecorys and IDEA Consult 2005).

Metcalfe and Riedlinger (2009) found SMART criteria to be the most effective guide for assessing social indicators in the area of natural resource management in their environmental study on river health.

[2] Counting publications and citations (Godin 2005).

3. THE BASIC FRAMEWORK FOR STI INDICATORS

When discussing the development of STI indicators, one cannot overlook the importance of the national system of innovation (NSI), which is a framework that illustrates the national '...flow of technology and information among people, enterprises and institutions' (OECD 1997: 7). In RIAT Concept Paper #3, Hart, Jacobs and Mhula (2013) spend some time in explaining the historical development of the NSI in South Africa and this need not be repeated here. What is perhaps important is to say that the pre-1994 NSI was a triple helix structure, composed of government, research and health institutes and the private sector. Government and research institutes historically made up the largest portion of the helix. The post-1994 NSI is a quadruple helix which now includes the non-profit sector as the fourth part of the helix. Still, the largest portion of the helix remains the government and the research and health institutes. Other important actors, such as the informal sector and household actors such consumers, are still not given sufficient recognition in the NSI and thus it remains unequal and imbalanced in terms of innovation strategy and understanding the contributions of the various underemphasised role-players towards economic, environmental and social development.

When developed in terms of the NSI framework, indicators should be able to provide information about the different actors of the NSI and their interaction (Lugones and Suarez 2010). The starting point in developing indicators is to establish an indicator framework which will assist in observing and monitoring the entire system of innovation (Boyed and Charles 2006), ideally including sub-national and sectoral systems. Sonntag (2010) illustrates that there are various indicator frameworks found in the literature and that their differences may depend on conceptualisation of key dimensions and the assumptions underlying the selection of indicators. However, to better understand how STI indicators work in the economic and social system and to assist policymakers with the planning of the STI strategy in South Africa, a basic framework similar to the one developed by NEPAD[3] (2005) is presented in Figure 1 below. The reason NEPAD's framework is selected and illustrated in this Concept Paper is due to its simplicity in illustrating how different actors and activities interact in the system of innovation. Additionally, NEPAD is a key player in developing African science, technology and innovation indicators (ASTII). Their STI framework will eventually serve to develop an African STI Manual. Despite the fact that this framework may not be adopted by South Africa as it is, it is still useful for the purpose of this study to illustrate some of the attempts on the African continent to develop STI frameworks.

Figure 1 below is based on the systems of innovation approach, which according to Dantas (2005) is valuable for understanding the NSI and is also becoming increasingly popular amongst policymakers

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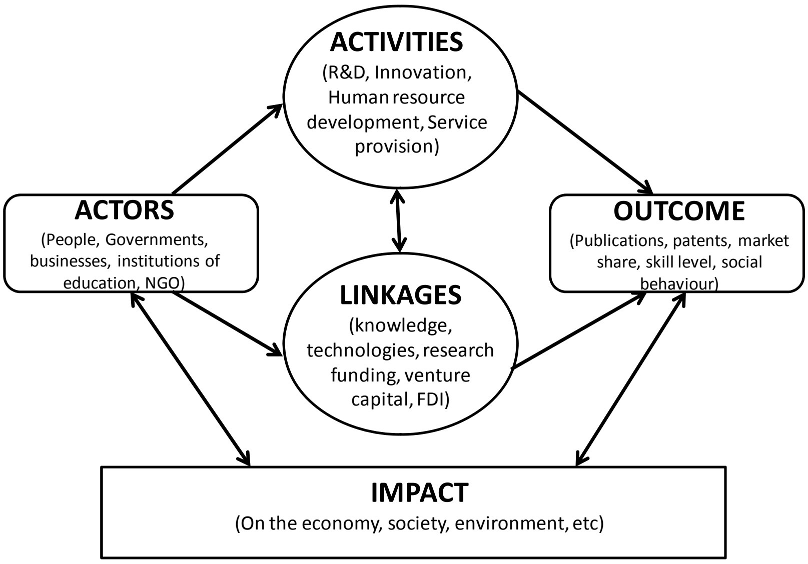
[3] It is important to mention here that although NEPAD takes credit for this simple STI framework, Ertl et al. (2007) illustrate that a similar framework was developed by Statistics Canada in 1998, shortly after the first Blue Sky Conference. The conceptual model developed by Statistics Canada is quite similar to the NEPAD model.

in developed and developing countries as a guide to decision making about optimising STI (see also Gault 2010). Moreover, a systems approach is often used to link the framework of STI indicators with existing national and regional systems of innovation. Put simply by NEPAD (2005), a systems approach means that there is a pool of actors that engage in science, technology and innovation activities.

Figure 1 – Basic framework for STI indicators



Source: NEPAD (2005: 7-9) and Ertl et al. (2007)

There are five key components in this simple framework. The first essential component is the *actors*. The actors in the system and consequently the indicators for actors can be individuals, groups or communities of practice, businesses, educational institutions, non-profit organisations (NGOs) and government etc. These actors do not typically act in isolation, but engage in a series of activities with one another. Dantas (2005) suggests that this engagement amongst multiple actors is out of necessity, as most individual actors do not have all the knowledge necessary for the entire process of innovation; therefore there is a need to combine scientific, design, engineering and operation knowledge from different sources. Furthermore, given the presence of physical, natural resources or skills constraints, actors are unable to act independently within the innovation system. Lastly, Dantas (2005) adds that the actors in the system have to obey the rules of the system. These rules can be formal, such as policies, regulations and laws or informal, such as norms and procedures.

The second key component in the framework is *activities*. Actors in the system perform a number of activities. Some common examples of these activities and example of indicators are R&D, innovation, human resource development, diffusion of technologies and practices and service provision.

Because activities do not occur in isolation from other events within and outside the economy or the society, there are *linkages* between actors and activities and other factors external to the system

(NEPAD 2005). Examples of linkages and their respective indicators include knowledge, technologies, research funding, venture capital, foreign direct investment (FDI) or policy incentives or restrictions (NEPAD 2005).

In the centre of Figure 1, we see that the activities performed by actors, together with the linkages in the system, result in *outcomes*. Some of these outcomes are more difficult to measure compared to activities and linkages, but outcome indicators are fundamental for gathering knowledge about the capabilities of the system. Examples of outcomes indicators include publications, patents, trademarks, market share, skill level, gender distribution, level of exports or imports, diffusion of ICTs and social behaviour (Gault 2007).

The fifth important component of the system is *impact*. Over time, activities and outcomes begin to have impact. A good example of impact is the introduction of personal computers (PC) and the development of portable computers, such as laptops, notebooks and tablets in the market economy. This introduction and further development has had a tremendous impact on enterprise management, as well as on individual and group social behaviour in recent years. Impacts, along with indicators thereof, are typically the most difficult component of the framework to measure because these are indicators that address complex socio-economic realities. However, these indicators are becoming more and more important (Ertl et al 2007) because they present long-term effects on the goals and objectives of policy makers and thus accurate measurement is increasingly required.

Ertl et al. (2007) further explain that in the initial stages of measuring and assessing the NSI and consequently the development of indicators, the indicators for actors and activities are of major importance because they capture the information about who is doing what STI activities, where and how. Over time, as a need develops for deeper understanding of why the system is performing in a certain way, the focus of interest shifts to indicators that measure linkages and what effect they have on the system. Gradually, outcomes and then impacts of STI activities become crucial to develop an even deeper understanding of the workings of the system and its contributions to economic and social development. When outcomes are a direct result of STI activities they are considered medium or short-term results of STI activities. Impacts, on the other hand, are long-term results of actors' activities, linkages and outcomes.

4. EVALUATION OF STI INDICATORS AND INDICES

4.1 THE DEVELOPMENT OF STI INDICATORS IN OECD COUNTRIES

In the early 1960s, the OECD embarked on a path of developing S&T indicators (Godin 2003) and currently leads the development of benchmark indicators worldwide. As a result of decades of research and collaborative meetings with numerous international organisations such as European Statistics (Eurostat), United Nations Educational, Scientific and Cultural Organization (UNESCO), Nordic Fund for Industrial Development (NFID) and National Experts on Science and Technology Indicators (NESTI), a solid methodology has been developed whereby STI indicators were divided into five distinct groups (Lugones and Suarez 2010):

- Research and development (R&D);
- Innovation;
- Human resources;
- Patents; and
- Technology balance of payments.

For each of these groups of indicators the OECD created separate manuals, which very quickly became internationally acknowledged and accepted as a reference point for the development of STI indicators. Below is a list of OECD-developed manuals and their respective sets of indicators. These are summarised briefly in the sub-sections that follow:

- Frascati Manual – focuses on R&D indicators;
- Oslo Manual – focuses on guidelines for developing and identifying innovation indicators and their measurement;
- Canberra Manual – focuses on the human resource indicators necessary to illustrate the development of human resources within an NSI;
- Patent Manual – examines the types of indicators required and ways to measure patents (and other intellectual property);
- Technology Balance of Payment (TBoP) Manual – focuses on the measurement of the transfer of technology at the international level.

4.1.1 Frascati Manual

The first manual developed and published by the OECD in 1963 was the Frascati Manual (OECD 2002). This manual has been revised several times and is currently in its sixth edition. When the manual was first developed its objective was to measure '...human and financial resources devoted to research and experimental development (R&D) often referred to as R&D input data' (OECD 2002: 14). Consequently, in the early versions of the manual, indicators were used to collect and interpret traditional R&D data. However, especially with the emergence of knowledge-based economies[4] it

[4] In RIAT Concept Paper #2, Hart, Jacobs and Mangqalaza (2012) briefly explain the idea of a knowledge economy.

was realised that R&D goes beyond input data and that the conceptual framework should incorporate other R&D activities besides simply the traditional inputs. As a result, more attention was given to the collection of data on human resources for R&D and there has been significant improvement in R&D statistics in the service sector, which was previously completely excluded. In addition to that, R&D included institutional classification, such as the origins of the funds and performing sector, how R&D is financed, as well as functional classification, such as type of activity, scientific field, socio-economic objectives (Lugones and Suarez 2010). These new developments, together with increased importance of the concept of innovation, gave rise to the Oslo Manual, which is probably the most internationally used manual for developing innovation indicators.

4.1.2 Oslo Manual

The Oslo Manual focuses on data collection and analysis of innovation (OECD and Eurostat 2005). This manual is in its third edition and, as with the Frascati Manual, it has changed quite significantly over a period of thirteen years.

An important common factor in all the revisions of the Oslo Manual is in the definition of innovation, which explicitly stated that innovation needs to be connected to the market. Gault (2010) makes similar statements. In other words, for activity to be considered innovation it needs to be commercialised. This point is of particular interest to this study, as not all perceived innovation activities in developing countries are commercialised or should be. In RIAT Concept Paper #2, Hart, Jacobs and Mangqalaza (2012) challenge this idea about what constitutes an innovation activity and other concerns around the current definitions of the concept of innovation, based on European and North American experiences.

The key focus of the first edition of the Oslo Manual was on technological product and process innovation (Hansen 2008). The focus is also on the manufacturing sector, due to the fact that, at that time, most innovation surveys[5] included firms from the manufacturing sector. Moreover, as explained above, innovation activities were limited and only included those activities and types that were connected to the market. Despite the fact that the focus of the first edition is on manufacturing, it was already argued that it is important to include in the manual that part of the service sector that is directly connected to manufacturing, given the significant amount of innovation activities reported in this sector (Beyhan et al. 2009). This gave rise to the first revision of the Oslo Manual.

Changes to the second edition of the Oslo Manual were mainly incorporated as a result of the survey experiences of the European Community Innovation Survey (CIS)[6] and policy debates. Despite the

[5] Innovation surveys are the primary source of information and indicators for the OECD manuals.
[6] CIS is implemented every two years in all European countries and serves as a good source for providing feedback for the OECD manuals.

fact that the definition remained constant, in that innovation only included technological products and processes, the sector coverage has increased significantly. In fact, the arguments to include the part of the service sector that is directly connected to the manufacturing sector resulted in the inclusion of the entire market economy, leaving out only the public sector (Gault 2010).

In the third and current edition of the Oslo Manual significant change occurred with regard to the definition of innovation. As noted by Hart, Jacobs and Mangqalaza (2012), the revised definition of innovation included not only technological, but also non-technological, innovation, such as innovation within organisations. Another important addition to this revision was the development and inclusion of an annexure named *Innovation surveys in developing countries* that provided guidelines for innovation surveys in developing countries (OECD and Eurostat 2005). This annexure was developed from the experience of innovation surveys in Latin America. It was realised that innovation in OECD countries differs significantly from innovation in developing countries, as many shortcomings arose through the simple unmodified application of the Oslo Manual in Latin American countries (Lugones and Peirano 2005). Consequently, '...in order to capture the particular characteristics of innovation processes in countries with economic and social structures different from those of the more developed OECD countries' (OECD and Eurostat 2005: 135) it was imperative to amend the manual to increase its relevance to developing countries.

The next three manuals, namely the Canberra, Patent and Technology Balance of Payment Manuals, are less popular, especially in developing countries, but are part of the 'Frascati Family' of manuals and deserve attention in order to appreciate their respective contributions to the growing number of innovation indicators and measurement tools.

4.1.3 Canberra Manual

The Canberra Manual was developed through joint collaboration between OECD and Eurostat and supported by UNESCO and other national experts. The introduction of the first draft of the manual to the Group of National Experts on Science and Technology Indicators (NESTI) took place in Canberra, Australia, thereby giving rise to the more common name of the manual (OECD 1995). The purpose of the Canberra Manual is to '...provide a framework for compiling data on stock and flows of Human Resources in Science and Technology (HRST), for analysing profiles and trends and for preparing up-to-date series for the users...'(OECD 1995: 9).

Unlike other OECD manuals, the Canberra Manual has never been revised; this, as suggested by Lugones and Suarez (2010), is probably due to the predominance of the Frascati Manual, which incorporates a significant number of essential indicators related to Human Resources in Science and Technology (HRST).

4.1.4 Patent Manual

The Patent Manual was first published in 1994 and only revised in 2009. Its purpose is to '...provide basic information about patent data used in the measurement of science and technology (S&T), the construction of indicators of technological activity, as well as guidelines for the compilation and interpretation of patent indicators' (OECD 2009: 12). According to Das, Arora and Bhattacharya (2012), the aim of this manual is to illustrate what purposes patent statistics can and cannot be used for and how to use patent data in analysing various topics related to technical change and patenting activity.

Patent indicators are a good source of information on inventive activities and are especially useful when used together with other sources of data, such as R&D and innovation because they provide cross-validation and assist with interpretation and understanding (OECD 2009). Patents are important for firms, institutions and individuals in protecting their inventions. Additionally, because patents are considered administrative data, one can reasonably easily access various databases on patents around the world at a relatively low cost (OECD 2009). Other surveys are undoubtedly more expensive and require more resources, but provide a somewhat deeper level of understanding of the status of the innovation systems being studied.

4.1.5 Technology Balance of Payment (TBP) Manual

The idea for the development of the TBP Manual was conceptualised during a seminar on Technological Balance of Payments in 1987. Three years later, in 1990, the TBP Manual was published (OECD 1990).

The objective of this manual is to '...serve as a standard method for surveys and data collection for trade in disembodied technology between countries which continue to be difficult to compare because of differences in the groupings of categories of data' (OECD 1990: 1). This manual measures the transfer of technology at the international level, using indicators of income and expenditure related to the exchange of technology (Lugones and Suarez 2010). Despite the fact that the TBP Manual has not been revised in more than two decades, Lugones and Suarez (2010) argue that it presents all the classifications and criteria currently used to measure the international transfer of technology.

From the above presentation of the development and types of innovation-related manuals, we note that the OECD has developed a very sophisticated methodology for developing STI indicators. This methodology is applicable to many and used in most countries around the world, whether they are developed or developing, for the purposes of assessing the status of the NSI within a country and comparing it to other countries or regions around the world. Many developing countries have adopted the OECD methodology for the purpose of STI indicator development. However, in doing so, some countries made sure that the methodology is adjusted to better fit their socio-economic conditions. The Bogota Manual, developed by RICyT (Ibero-American Network on Science and Technology Indicators – Red Iberoamericana de Indicadores de Ciencia y Tecnologia) in Latin

America, is an excellent example of adaption of the OECD OSLO Manual for the developing country context. We cover this manual separately in the section below because of the importance and need for local adaptation of the manual's guidelines and indicators.

4.2 STI INDICATORS IN LATIN AMERICA

It is safe to say that RICyT network is the largest contributor to the methodology on STI development in Latin America, thus making it more relevant to developing countries in general. This network developed the Bogota Manual based on Latin American and Caribbean experiences and contributed to the development of an annexure to the most recent edition of the Oslo Manual that reflects specific characteristics not present in developed countries, but which are significant in the developing country context.

The Bogota Manual was developed in 2001 and named after the capital city of Colombia, Bogota, as this was where most of the discussions on the development of the manual took place (RICYT/OAS/CYTED 2001). One of the key reasons for using the Oslo Manual methodology of developing STI indicators is related to the ability to have international comparability between Latin America and other developing and developed countries or regions which utilise the Oslo Manual (Lugones and Suarez 2010).

The development of the manual took several years. It began with a project that focused on technology indicator standardisation in the region - 'Standardization of Technological Innovation Indicators in Latin America and the Caribbean'. This was followed by the need to develop norms and methodologies for constructing a Latin American manual of science and technology statistics and indicators. RICYT/OAS/CYTED (2001) lists all the key papers and working documents that contributed to the construction of the final manual. The manual also explains reasons for measuring innovation processes in developing countries and the importance of having region-specific manuals with a standardised set of indicators to measure innovation activity. The Bogota Manual illustrates that in Latin America and the Caribbean the general situation is different to Europe and innovation is therefore different in many instances.

It is worth noting at least four important contributions of the Bogota Manual to the development of STI indicators for developing countries generally. These are considered key characteristics of innovation processes in developing countries (RICYT/OAS/CYTED 2001).

1. The acquisition of embodied technology (equipment and machinery) for product and process innovation usually happens through the importation of capital goods, such as machinery or equipment into the country. This process may lead to significant innovation outcomes through adaptation and learning in the presence of technological capabilities. In other words, the

presence of technological skills is crucial for the country to be able to adopt and adapt embodied technology and innovate further.

2. A significant amount of empirical evidence suggests that ‘radical’ innovations rarely happen in developing countries. Minor or incremental changes are much more common, along with the innovative adaption and application of existing products or processes.
3. Innovations in the agricultural sector generally have a relatively higher economic impact on a developing country. This is due to the importance and contribution of this sector in the economy in many developing countries. However, this is not necessarily the case in all developing countries or even within regions.
4. Organisational change is important in the innovation process. This enables the absorption of new technologies and improves performance.

Based on these general developing country characteristics, Intarakumnerd (2007) adds that developing countries should focus on improving their innovation capability by strengthening the following four aspects of the NSI.

1. Human resources (number of skilled employees, level of qualification, numbers of training hours, technological training linked to new processes and products, management and administrative training);
2. Linkages (frequency by type of linkage, frequency by agents or institutions, causal objects/actor relationships, degree of satisfaction obtained from links and link assessments);
3. Quality assurance systems (sector and national standards and associated regulation thereof); and
4. Incorporation and use of ICTs.

Some of the experiences of developing STI indicators, surveys and the Bogota Manual in Latin America have been studied by African countries, as the interest towards developing their own manual grows on the continent. Consequently the section below sheds some light on recent advances in the area of STI development in Africa.

4.3 STI Indicators in Africa

Most scholars agree that it is critical to develop STI indicators for the African continent in order to be able to monitor the progress of STI in Africa (NEPAD 2005; Gault 2008; Kahn 2008). In 2007 the Intergovernmental Committee on African Science, Technology and Innovation Indicators (ASTII), which is a programme under the auspices of the New Partnership for African Development (NEPAD), met to discuss the methodology, definitions, standards and use of STI indicators in Africa (Gault 2008). The result of the meeting was the development of the African Innovation Outlook (AIO), whose purpose is to inform African people and all other interested parties about STI activities in Africa and the state of STI on the continent (AU-NEPAD 2010). Das, Arora and Bhattacharya (2012) note that the development and adaptation of STI indicators should be globally competitive, whereby the STI indicators are well developed and capture the facilitation of opportunities for African countries to participate in international STI programmes.

AU-NEPAD (2010) suggested that, when implementing STI surveys in African countries, the methodology of the Frascati Manual should be adopted for R&D surveys. For innovation surveys, the methodology of the third edition of the Oslo Manual, with its annexure devoted to developing countries, should be used. Despite this clear indication of adaptation of European methods and methodologies, an earlier NEPAD statement (NEPAD 2005) identifies special topics that should be central to African STI indicator development.

Firstly, the informal economy in Africa is considered to be a significant area of innovation activity. However, innovation in the informal economy has received very little attention, especially with regard to its conceptualisation and measurement, because most innovation studies focus on formal sector easily identifiable research-intensive enterprises and ignore informal activities (Bhaduri and Sheikh 2013). Given that almost half of the world's population is living and working in the informal setting (Cozzens and Sutz 2012), it is important to develop indicators to incorporate innovation activities taking place in the informal sector, even though the complexity of this task is realised and considered significant.

Secondly, indigenous knowledge is an important source of innovation in developing countries. Indigenous knowledge is a type of skill, belief and practice that individuals or groups in specific geographic areas use to assist them in achieving resilient livelihoods (Luka and Yahaya 2012). This type of knowledge and skill is acquired from previous generations, adopted and transformed to address current local needs. In Africa this type of innovation plays a significant role, especially in rural areas and areas of medicine, agriculture, fisheries and art, just to name a few. There is no established definition of indigenous knowledge and it is often viewed as a traditional, local (Kalua et al. 2009) or geographically bound knowledge (NEPAD 2005), and can include elements of conventional scientific and other types of knowledge (Warren, Slikkerveer and Brokesha 1995).

Thirdly, biodiversity and biotechnology also deserve special mention when it comes to STI indicator development in Africa. Africa's rich biodiversity can play a crucial role in Africa's livelihoods. Some see this rich biodiversity as being especially important in the area of natural resource-based eco-tourism. This is in view of the fact that many politically stable African countries attract European and other tourists, who see Africa's rich biodiversity as a means of escaping from their own industrialised countries. Others, within and outside of Africa, see Africa's rich biodiversity as being something to exploit. Such interest groups identify African biodiversity as having significant input into biotechnology activities, pharmaceutical manufacturing, fuel development and other high-tech industries. Biotechnology, sometimes with an emphasis on genetic modification, is believed to be able to assist with current challenges across Africa in the areas of agriculture and environment.

Essentially there are two competing groups targeting Africa's resource-rich biodiversity, based on competing understandings of sustainability.

Fourth, major diseases, such as HIV/AIDS, malaria and TB, can both provide threats to and opportunities for development. The biggest threat to economic development is the effect these diseases have on the supply of labour, especially highly skilled labour. On a more positive side, there is an opportunity to study these diseases and in so doing acquire a significant amount of knowledge on how to treat and manage them.

Various studies are being conducted on the above-mentioned four topics across Africa, which can contribute to the development of indicators (see Kalua et al. 2009; Morris 2011; Bhaduri and Sheikh 2013). A global non-profit based programme in developing countries, including Africa, Asia and Latin America, that particularly stands out in the literature on local innovation is Prolinnova (Promoting Local Innovation in Ecologically-oriented Agriculture and Natural Resource Management) and is discussed below.

4.3.1 PROLINNOVA

Prolinnova is a non-governmental multi-stakeholder platform of various non-profit organisations and some government organisations and agencies that has taken a stand in addressing local innovation in Latin America, Asia and Africa and developing innovation indicators (Wettasinha, Wongtschowski and Waters-Bayer 2008). It was informally established during the 1990s, with formal conceptualisation in 2004. A primary purpose has been to recognise and link innovations, mainly involving agriculture in local areas, to formal research agencies. Given that one of the objectives of RIAT is to develop indicators that address local rural innovation it is critical to explore some of the work Prolinnova has done in Africa, where it operates with little external financial support in twelve African countries – Ethiopia, Ghana, Niger, South Africa, Sudan, Tanzania, Mozambique, Nigeria, Kenya, Cameroon, Mali and Uganda (Waters-Bayer, Wettasinha and Van Veldhuizen 2007).

The programme seeks to develop locally appropriate technologies and institutions that improve the lives of resource-poor farmers. It also seeks to strengthen the links between farmers, NGOs, extension, research and other stakeholders in agricultural R&D and increase the capacities of partnering amongst each other to address the new challenges of the developing world (Wettasinha, Wongtschowski and Waters-Bayer 2008). It also moves beyond the simple idea of innovation in products and processes and considers innovations within organisational arrangements and marketing strategies.

The idea of local innovation is derived from the idea of indigenous knowledge found in a specific locality, although not confined to that locality. Therefore, local innovation is considered a process of discovery or development of new or better ways of doing things by using locally available resources, local knowledge (derived from a combination of indigenous as well as external knowledge) and own initiative, without pressure of influence or direct support from formal research or development agents (Waters-Bayer, Wettasinha and Van Veldhuizen 2007).

Local innovation activities of this type can open a door of opportunities for participatory innovation development (PID) – the combined learning by informal experimenters (rural inhabitants of many occupations or livelihoods) and formal researchers. Given the participatory learning and empowerment dimension of RIAT, it will be useful to shed some light on methodological paradigms around PID and sustainability indicators.

Reed, Fraser and Dougill (2006) illustrate that there are two primary approaches in the area of participatory learning and development: the top-down (or expert-led) and bottom-up (or community-led) approaches[7]. The top-down approach explicitly uses quantitative indicators. The key advantage identified by Reed, Fraser and Dougill (2006) of using this approach is that it allows for the capturing of trends which might be missed by a more casual observation, which is a technique often used in the bottom-up approach. This may be true in some instances; however, it is important to state that rigorous bottom-up approaches, especially in anthropology and ethnography, may involve qualitative methods as well. Nevertheless, the top-down approach provides a bigger picture of social, environmental or economic phenomena on hand. The bottom-up approach, on the other hand, brings forward the importance of involving communities in research processes to stimulate social action. The bottom-up approach provides additional benefits to both researchers and the community, because it is not only an additional source of valuable information for the researchers, but also an important source of learning and understanding for the community and researchers (Reed, Fraser and Dougill 2006).

PID involves jointly analysing the local situation, looking for things to try to improve it, if need be; trying them out in community-led participatory experimentation; jointly analysing and sharing the results; and strengthening this ongoing process of PID, often through reinforcing and supporting local organisations and linkages with other actors (Wettasinha, Wongtschowski and Waters-Bayer 2008). Put simply, PID involves collaboration between various rural actors, such as farmers and formal researchers, or farmers and development agents, in sharing their knowledge and experience and reaping positive benefits from this collaboration.

According to Wettasinha, Wongtschowski and Waters-Bayer (2008), the first step in identifying the potential for local development is discovering local innovations and identifying local innovators. Prolinnova has conducted a number of studies around Africa which attempt to do this. One such study, conducted in Uganda, is of particular interest for RIAT. Environmental Alert developed an

[7] These two approaches are also referred to by Reed et al. (2001: 3) as ‘reductionist’ and ‘participatory’ respectively.

Innovation Characterisation and Scoring Sheet, which they used during the formal innovation survey in Uganda. This scoring sheet consists of eleven key criteria (refer to Table 2 below), which can be used to develop important innovation indicators.

Table 2: Innovation scoring sheet

Practical Issues	**Comments**
Originality	*Where did the idea come from – who and location. Is it novel (a new idea) or an improvement of an existing innovation?*
Usefulness	*What was the purpose of coming up with the innovation? Was this achieved – completely, partially?*
Adaptability	*How can it be modified*
Problem solving ability	*What problem is solved by the innovation or what improvement does the innovation make*
Replicability *Locally?* *Elsewhere?*	*Is the innovation replicable locally, nationally, internationally?*
Acceptability *Locally* *Elsewhere* *Technical viability*	*Policy –wise* *Socially* *Culturally* *Ecologically?* *Simplicity, solving technical problems, effectiveness in so doing?*
Economic viability	*Does it help save or generate more income?* *Is it cost- effective?* *Is it marketable?*
Environmental viability and acceptability	*Does it improve the local environment and natural resource base or deteriorate it further?*
Social viability and acceptability	*Does everybody benefit from innovation or only a specific group (e.g. gender/age/class/culture)*
Gender and social responsiveness	*Can either sex use the innovation?*
Further Research Potential *Required?*	*Requirements for further research/experimentation to find out reasons for success, research for validity.* *Potential for combining other knowledge systems with this innovation.* *Will further research result in further value addition?*
Affordability	*Are materials required available locally?* *If not at what financial cost?*

Source: Wettasinha, Wongtschowski and Waters-Bayer (2008)

This instrument shows how significant amounts of information can be captured fairly simply in the survey and can be a good example of collecting additional innovation data at local level (Wettasinha, Wongtschowski and Waters-Bayer 2008).

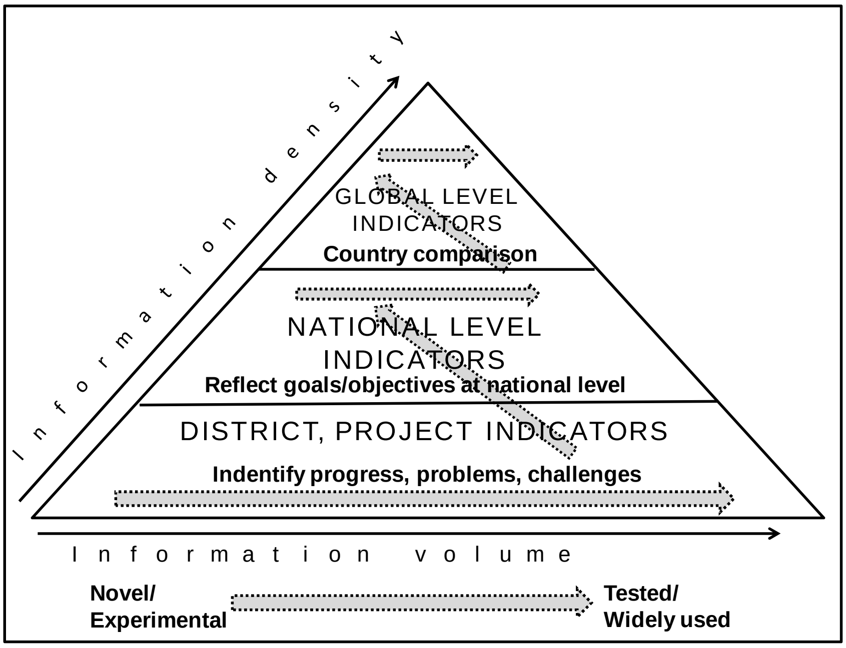
To sum up, it appears that there is a trend in Africa, where Europeans facilitate the development of indicators in two different ways. One involves the top-down imposition of indicators by scientists and researchers from Africa and Europe, while the other is more participatory, in that it involves the actual innovations in the decision making and identification process with African and European scientists. It makes sense to use both approaches when compiling indicators for Africa and South

Africa; however, the mix of approaches should be well balanced to ensure that the top-down approaches do not blur the reality at the local level and by doing so ignore local needs and circumstances that direct local innovation. The Indicator Pyramid is a good illustration of this mix and how we should go about it in developing indicators. The Indicator Pyramid is explained in the next section.

4.4 INDICATOR PYRAMID

The Indicator Pyramid is referred to by Letty, Shezi and Mudhara (2012) as the Iceberg Structure. It is a relatively new approach that has gained popularity in recent years across various disciplines. It is especially popular in energy, health and environmental studies (Leboux, Mertens and Wolff 2005; Sheu and Lo 2005; Stoeglehner and Narodoslavsky 2008; UNAIDS 2010) and could be useful in developing STI indicators. Letty, Shezi and Mudhara (2012), following the uncited but acknowledged work of Professor Bell, illustrate how it can be used in understanding rural innovation. As illustrated in Figure 2 below, the Indicator Pyramid consists of three levels of indicators.

Figure 2: Indicator Pyramid



Source: Adapted from UNAIDS (2010); Sheu and Lo (2005)

According to this approach, most indicators are developed at the bottom of the pyramid (UNAIDS 2010). These indicators are more focused and provide information about a specific project, programme or problem at the local level. Indicators collected at this level can be aggregated to provide information for the development of indicators in the middle level. These are indicators of national or sub-national level and often give a broad overview of the country's response to a specific problem. Some indicators for this level can be obtained from existing data that have been compiled for a different purpose, such as national surveys or other statistical databases (Letty, Shezi and

Mudhara 2012). The top of the pyramid can be classified as the regional or global-level indicators and provides indicators for comparison between countries or regions around the world.

As indicated by Sheu and Lo (2005), indicators developed and used in the same level should serve as a tool for sharing information amongst the actors involved in this level. They also argue that the indicators developed in the three levels as they progress from the lower level to the upper level should become less complex, easily understandable and fewer in number.

Moreover, indicators not only evolve from level to level but also within each level. This is illustrated by the arrows in Figure 2. When a new indicator is developed it is considered to be a novel or experimental indicator. Over time, and only if this indicator was found to be useful, it may be replicated and used in different studies, thereby becoming a standardised indicator used to analyse common problems and challenges (Letty, Shezi and Mudhara 2012). Sometimes this indicator may move, not only horizontally, but also vertically, in the pyramid. Consequently an indicator developed at the project level may become a well-established indicator at a country comparison level and vice versa. It is evident that the process of developing indicators is not a simple one; it takes a huge amount of time and effort and involves numerous experiments, research, analyses, tests, surveys and a variety of qualitative studies to develop a final standardised indicator. Of course, over time this may also be challenged.

If we consider the development of STI indicators using the Indicator Pyramid framework, the following story can be told. The OECD, which can now be considered to be at the top of the global pyramid, has developed a set of indicators through their manual to illustrate the condition of science, technology and innovation in European countries (not Latin American, Asian or African countries, or even North American countries, where greater similarities exist). The development of the manual took a significant amount of time and relied on information provided by actors from the national system of innovation such as CISs, National Experts on Science and Technology Indicators (NESTI), and various OECD and UNESCO panels or focus groups. These indicators were developed over decades of tests and experiments and were ‘grown endogenously within a deep system of research and analysis’, especially at the project and national levels (Letty, Shezi and Mudhara 2012: 11).

In Latin America, the development of their regional STI manual underwent a similar path of development. The OECD Manual was used as a starting point for the development of indicators, making use of its core methodology and indicators. However, local research at the bottom of the pyramid indicated some differences in socio-economic characteristics of Latin American countries and the indicators used to collect this information were different from those suggested in the OECD Manual. Consequently, project-level indicators impacted on national-level indicators; for this reason, the Bogota Manual contains indicators that are not present in the OECD Manual. Furthermore, to allow for international comparability, the OECD added some of the indicators used in the Bogota Manual as an annexure to the Oslo Manual.

The same principle could apply to the development of an African manual. The benefit of using the OECD manuals, as well as experiences of the development of the Bogota Manual, is that this will save costs and time associated in developing some methodologies and indicators (Letty, Shezi and Mudhara 2012). Although these manuals provide important STI indicators, these are not sufficient for African country contexts and thus for the development of a range of African STI indicators. Projects like RIAT are attempting to develop and test indicators at the local level. These indicators will serve as a foundation for the development of indicators at the national level and should enrich the available indicators at the global level; at least for some developing countries. This pyramid illustrates that projects such as RIAT, which focus on sub-national and to some extent spatially bounded systems of innovation and innovation activities, directly contribute to the direction of the STI indicator development at the national and global level and to innovation policy in general.

Furthermore, the Pyramid Structure illustrates that it is important for indicators at national and global level to have a basis in empirical evidence at the local level. The value of the model indicates how this can be achieved as indicators are strengthened or combined as they move horizontally and vertically, but still retain a link with local empirical evidence. The model indicates clear pathways for indicator development and consolidation. However, if indicators and approaches simply adopted from the Frascati and Oslo Manuals are implemented, they will have no solid basis in the local level conditions of the country. As a result, the picture presented to policymakers from the data collected using these guidelines would be far from ideal.

The next section considers the various indicator development activities happening in South Africa and the progress achieved so far in developing rural innovation indicators, i.e. those that reflect rural innovation activities and experiences more accurately and which could contribute to the development of the various tools to be included in the RIAT.

5. STI INDICATOR DEVELOPMENTS IN SOUTH AFRICA: RURAL INNOVATION INDICATORS

South Africa is an important player and contributor to the development of African STI indicators, as it has one of the most developed NSIs on the continent, despite the fact that Hart, Jacobs and Mhula (2013) argue in the third concept note that South African NSI is currently far from ideal; especially in acknowledging local and informal innovation systems in rural areas. They also argue that South Africa is focusing too much on following the dominant European paradigms of innovation and policy development, which are closely linked to the top-down approach. This is because there is an overwhelming desire to simply adopt all the components, rather than adapt the best parts of the Frascati and Oslo Manuals for the development of indicators in the national innovation and R&D surveys in South Africa (Blankely, Sithole and Moses 2011).

The Department of Science and Technology (DST) is the key innovation actor facilitating most of STI development in the public sector through organisations such as the National Advisory Council of Innovation (NACI), Technology Innovation Agency (TIA), Mintek and parastatal research organisations, such as the Council for Scientific and Industrial Research (CSIR) and the Human Sciences Research Council (HSRC). Other institutions that have played a role in innovation in South Africa and worth mentioning here are the Maraka Institute, The Da Vinci Group and universities such as the Tshwane University of Technology through the Institute for Economic Research on Innovation (TUT - IERI). There have also been collaborative programmes with other countries led by the DST, but involving a range of the above organisations. One such recent example is the Cooperation Framework on Innovation Systems between Finland and South Africa (COFISA).

Some of these organisations have made significant contributions to the development of STI indicators in South Africa. NACI, for example, has as its mandate the provision of evidence-based advice to the Minister of Science and Technology on how STI can contribute to the national objectives of the country. Based on the National Research and Development Strategy (NRDS), NACI has been developing indicators on an annual basis, whereby it supports other organisations to develop these indicators under its auspices. According to the most recent NACI report on these activities, these indicators can be clustered into the following pillars (NACI 2010):

Table 3: Key S&T system performance indicators at a macro level

Pillars	Indicators
Future R&D capacity	S&T proportion of higher education (HE) enrolments S&T postgraduate degrees Matriculants with mathematics and science
Current R&D capacity	Publications Global share of publications R&D intensity
Imported know-how	Technology balance of payments Imported high-technology equipment Imported information and communication technologies
Science, engineering and technology human capital	Researchers per thousand workforce S&T demography
Technical progress (improvement and innovation)	Patents, high-technology start-ups Business innovation investment Key technology missions
Business performance	Technology trade mix Proportion of high-technology firms Sectoral performance
Quality of life	Technology achievement
Wealth creation	Technology-based growth

Source: NACI (2010)

From this it is evident that these indicators capture many of the crucial socio-economic issues in South Africa and developing countries in general. However, they do this from a national perspective based on national data and do not capture much of the innovation activities in rural areas, nor do they capture informal innovation activities and systems.

An important unit established within the HSRC is the Centre for Science, Technology and Innovation Indicators (CeSTII), with the objective of developing indicators on R&D and innovation activities. Since 2002, CeSTII has implemented various innovation and R&D surveys at the national level (CeSTII 2011). However, surveys and methodology used by CeSTII are directly comparable with OECD methodology and surveys. They fail to capture some of the local and space-bounded aspects of the South African economy as their primary focus is on macro-level analysis and reporting. Again, the key advantage of using OECD methodology for a developing country like South Africa is international comparability and this has become an entrenched component of national innovation and R&D surveys.

Nevertheless, prior to the initiation of RIAT by the DST, other organisations have attempted to develop tools that would measure rural innovation. One example is the COFISA programme, which was established in 2006 with the aim to better direct South African innovation policy and develop relevant programmes to support development in the country and address poverty (COFISA 2010). To achieve this objective COFISA (2010) identified three areas of engagement:

- Enhancement of the use of ICTs in rural projects;
- Identification of opportunities for research funding to support new initiatives aimed at R&D in rural and social innovation; and
- Identification and adaptation of best practices for the promotion of sustainable rural and social innovations for local development.

A series of supportive sub-programmes and associated projects were developed and implemented by COFISA to address rural innovation systems in South Africa. These projects were predominantly based on the concept of 'living-labs'. Again, living-lab is a European developed and tested project which has recently been tested in developing countries. According to the COFISA report, '[a] living lab is a new concept for R&D innovation which has at its core a human-centric approach and the potential for the development of new ICT-based products and services' (COFISA 2010: 77). The living lab concept is based on a quadruple helix framework of the NSI (see Hart, Jacobs and Mangqalaza 2012).

The whole idea of 'living labs' is to engage and empower local people to participate in research, development and innovation (RDI) processes. This is more of a combination of top-down and bottom up approaches, in which it is argued that local people are a fundamental source of innovations; therefore they should participate in the creation of new products and services, especially those based on ICTs. The 'living labs' were intended to provide a platform for these local actors or their representatives to engage and link with national and other organisations and individuals in various sectors of the economy, such as e-commerce, transport, tourism and healthcare. Although the concept and programme developed by COFISA was considered by some to be a good initiative, there are a number of constraints, including conceptualisation, which prevented the COFISA programme on rural innovation from achieving much of what was proposed (see the discussion in Hart, Jacobs and Mangqalaza 2012). In brief, the living lab projects could not function optimally in rural areas that did not have competencies and the infrastructure required to support the use of ICTs; one project was more or less relocated to the CSIR in Pretoria, while another was implemented in the Athlone community in Cape Town. Neither locality resembles rural areas in any sense. The tourism-based rural innovation projects had a little more success when they engaged directly with local groups, who organised themselves to promote and conserve certain areas for tourism.

The CSIR, through the Meraka Institute, was one of the South African partners of COFISA that reapplied the methodology of living labs when conducting a study on rural innovation in Limpopo province (Mulder et al. 2008). Reapplication was based on attempting to overcome some of the problems experienced in the initial COFISA rural innovation programme. The reason they adopted this methodology is based on the argument that living labs 'will overcome many of the problems faced in introducing technology into new environments' (Mulder et al. 2008: 8). The adopted methodology for the project is the living lab harmonisation cube, which focuses on harmonising methods and tools of different living labs and enables them to work together and share their experiences. It is suggested by the Meraka Institute that this methodology be used in other similar programmes of telemedicine because living labs are good sources of information on rural innovation, which should play a role in shaping various policies in South Africa.

In summary, most of the innovation indicator development work in South Africa has been confined to national-level indicator development. This has been largely facilitated by the NACI. The most significant attempt, although arguably poorly conceptualised for and implemented in rural areas (often not implemented in these areas), is the COFISA Programme. However, when it comes to developing local level indicators, these have not been forthcoming from COFISA. Despite the involvement of numerous research organisations the development of local level indicators that can contribute to a framework such as the Pyramid Indicator Framework is lacking. Such contributions would enable the further development of stronger national and global level indicators.

CONCLUSION

This concept paper has highlighted the various global and South African processes of identifying and developing indicators that can inform us more about innovation activities in countries and their contribution to social and economic development within developed and developing countries. While the largely European-based manuals and guides, as well as the specific indicators, are often used outside Europe and have become included in the innovation assessments of developing countries, these often ignore local realities and innovations. Consequently the Bogota Manual revised the OECD Manual to make it more relevant to innovation experiences in Latin America and the Caribbean. These changes were acknowledged to some extent by the OECD as they were included into the Annexure of the current version (third edition).

It makes sense to use some of the experience of Europe and Latin America when compiling indicators for Africa and South Africa. However, this approach itself needs to be innovative and therefore must adapt the best and most relevant parts of these manuals, while ensuring further local level indicators are developed. The pyramid structure, illustrated in Section 4, appears to us to be a reasonable way of ensuring that there is a mix of top-down and bottom-up approaches. However, this must be done cautiously so that the top-down approaches do not blur the reality at the local level and by doing so ignore local needs and circumstances that direct local innovation. In many instances, local innovations in Africa and other developing regions of the world result from the need for survival, rather than the more business directed need to maximise profits.

Despite the involvement of numerous research organisations, the development of local level indicators that can contribute to a framework such as the Pyramid Indicator Framework is lacking, or at best slow. Such contributions would enable the further development of stronger national and global level indicators, while ensuring that locally developed innovations are not ignored and their relevance to local people as part of their own attempts to improve their socio-economic circumstances are acknowledged and given value.

REFERENCES

AU-NEPAD. 2010. *African innovation outlook*. Pretoria: AU-NEPAD.

Beyhan, B., Dayar, E., Findik, D. and Tandoğan, S. 2009. *Comments and critique on the discrepancies between the Oslo Manual and the Community Innovation Surveys in developed and developing countries*. TEKPOL Working Paper # 09/02.

Bhaduri, S. and Sheikh, F.A. 2013. *Measuring informal innovations: Study of grassroots innovation of Kashmir*.
http://www.globelicsacademy.net/2013_pdf/Full%20papers/Sheikh%20full%20paper.pdf

Blankley, W., Sithole, M. and Moses, C. 2011. The South African 2008 Innovation Survey findings. *Workshop on the review of innovation measurement in South Africa*. South Africa: Human Sciences Research Council.

Boyd, H. and Charles, A. 2006. Creating community-based indicators to monitor sustainability of local fisheries. *Ocean and Coastal Management,* 49: 237-258

CeSTII. 2011. *South African innovation survey: Main results 2008*. South Africa: Human Sciences Research Council.

Chaturvedi, S. and Srinivas, K.R. 2012. Science and technology indicators: New issues and challenges. *Current Science* 102 (12): 1640-1644.

COFISA. 2010. *Enhancing innovation in South Africa: The COFISA experience*. Pretoria: Department of Science and Technology.

Communities Committee. 2003. *Forest Sustainability Indicator Tools for Communities Indicator Toolkit*. Accessed 15 June 2013. www.communitiescommittee.org/fsitool/index.html

Cozzens, S. and Sutz, J. 2012. Innovation in informal settings: A research agenda. Paper. *The annual meeting of the 4S Annual Meeting,* Copenhagen Business School, Frederiksberg, Denmark.

Cummins. R. 2012. Social indicators and social development. *International Conference on Social Indicator and Social Development* 2012. Civil Service Development Institute, Taipei, Taiwan.

Dantas, E. 2005. *The systems of 'innovation approach', and its relevance to developing countries*. Accessed 17 May 2013. http://www.scidev.net/en/policy-briefs/the-system-of-innovation-approach-and-its-relevanc.html

Das, A.K., Arora, P. and Bhattacharya, S. 2012. Webliography of STI indicator databases and related publications. *Journal of Scientometric Research* 1 (1): 86-93.

de la Porte, C., Pochet, P. and Room, B.G. 2001. Social benchmarking, policy making and new governance in the EU. *Journal of European Social Policy* 11 (4): 291-307.

Desai, M., Fukuda-Parr, S., Johansson, C. and Sagasti, F. 2002. Measuring the technology achievement of nations and the capacity to participate in the network age. *Journal of Human Development* 3 (1): 95-122.

EC (European Commission). 2006. *Rural Development Policy 2007–2013. Common Monitoring and Evaluation Framework*. Directorate General for Agriculture and Rural Development. Accessed 25 June 2013. http://ec.europa.eu/agriculture/rurdev/eval/index_en.htm

Ecorys and Idea Consult. 2005. *Impact analysis: Study on baseline and impact indicators for rural development programming 2007 – 2013*. Synthesis Report, AGRI/2004/G2/02.

Ertl, H., Bordt, M., Earl, L., Lacroix, A., Lonmo, C., McNiven, C., Schaan, S., Uhrbach. M., Van Tol, B. and Veenhof, B. 2007. Towards understanding the impacts of science, technology and innovation activity. In OECD, *Science, technology and innovation indicators in a changing world: Responding to policy needs.* Paris: OECD.

Freudenberg, M. 2003. *Composite indicators of country performance: A critical assessment*. OECD Science, Technology and Industry Working Papers #2003/16. Paris: OECD.

Gault, F. 2006. Measuring knowledge and its economic effects: The role of official statistics. In Kahin, B. and Foray, D. (Eds) *Advancing knowledge and knowledge economy.* Cambridge MA: MIT Press.

Gault, F. 2007. Science, technology and innovation indicators: The context of change. In OECD, *Science, technology and innovation indicators in a changing world: Responding to policy needs.* Paris: OECD.

Gault, F. 2008. Science, technology and innovation indicators: Opportunities for Africa. *The African Statistical Journal* 6: 141-162.

Gault, F. 2010. Innovation strategies for a global development: Development, implementation measurement and management. Ottawa: International Development Research Centre.

Gault, F. 2011. *Social impact of the development of science, technology and innovation indicators*. UNU-MERIT Working Paper #211/008.

Godfrey, L. and Todd, C. 2001. Defining thresholds for freshwater sustainability indicators within the context of South African water resource management. *2nd WARFA/Waternet Symposium: Integrated Water Resource Management: Theory, Practice, Cases*. Cape Town.

Godin, B. 2003. The emergence of science and technology indicators: Why did government supplement statistics with indicators? *Research Policy* 32 (4): 671-691.

Godin, B. 2005. Measurements and statistics on science and technology: 1920 to the present. London: Routledge.

Grupp, H. and Mogee, M. E. 2005. Indicators for national science and technology policy. In Moed, H.F., Glänzel, W and Schmoch, U. (Eds). *Handbook of quantitative science and technology research: The use of publication and patent statistics in studies of S&T systems*. Berlin: Springer Science + Business Media, Inc.

Hansen, H.L. 2008. Measures of innovation. Presented at Mew practices of entrepreneurship and innovation – taking stock for the OECD innovation strategy. Copenhagen, 28-29 May.

Hart, T., Jacobs, P. and Mangqalaza, H. 2012. *Key concepts in innovation studies – Towards working definitions.* RIAT Concept Paper Series – Concept Paper 2. Pretoria: Human Sciences Research Council.

Hart, T. Jacobs, P. and Mhula, A.L. 2013. Review of South African innovation policy and strategy 1994–2012: Innovation for rural development. RIAT Concept Paper Series – Concept Paper 3. Pretoria: Human Sciences Research Council.

Holden, M. 2007. Revisiting the local impact of community indicators projects: Sustainable Seattle as prophet in its own land. *Applied Research in Quality of Life* 1 (3-4): 253-277.

INSEAD. 2011. *Innovation efficacy index: Mapping innovation capacity in 21 natural resource rich countries: A snapshot review*. INSEAD Innovation and Policy Initiative, Abu Dhabi, United Arab Emirates.

Intarakumnerd, P. 2007. Measuring innovation in catching-up economies: An experience from Thailand. *CAS Workshop on* '*innovation in firms*', 30 October - 1 November 2007, Norway.

Jennings, S. 2005. Indicators to support an ecosystem approach to fisheries. *Fish and Fisheries* 6: 212-232.

Kahn, M.J. 2008. Africa's plan of action for science and technology and indicators: South African experience. *The African Statistical Journal* 6: 163-176.

Kalua, F., Awotedu, A., Kamwanja, L. and Saka, J. 2009. *Science, technology and innovation for public health in Africa*. Monograph. NEPAD Office of Science and Technology. Pretoria: NEPAD.

Kelley, A.C. 1991. The human development index: 'Handle with care'. *Population and Development Review* 17 (2): 315-324.

Kline, S. and Rosenberg, N. 1986. An overview of innovation. In Landau, R. and Rosenberg, N. (Eds) *The positive sum strategy: Harnessing technology for economic growth*. Washington, D.C.: National Academy Press.

Leboux, L., Mertens, R. and Wolff, P. 2005. EU sustainable development indicators: An overview. *Natural Resource Forum,* 29: 392-403.

Lepori, B. 2008. New perspectives on science, technology and innovation indicators: Introduction to special section. *Research Evaluation* (17) 1: 2-3.

Letty, B., Shezi, Z. and Mudhara, M. 2012. *An exploration of agricultural grassroots innovation in South Africa and implications for innovation indicator development*. UNU-MERIT Working Paper Series #2012/023

Lugones, G. 2008. *Training module for the recollection and analysis of innovation indicators.* Inter-American Development Bank Working Paper #2008/ 8.

Lugones, G. and Peirano, F. 2005. *Proposal for an annex to the Oslo manual as a guide for innovation surveys in less developed countries non-member of the OECD*. Redes Working Document # 25/RICYT.

Lugones, G. and Suarez, D. 2010. Science, technology and innovation indicators for policymaking in developing countries: An overview of experience and lessons learned. Prepared for Trade and Development Board: Multi-year expert meeting on enterprise development policies and capacity building in science, technology and innovation, 20-22 January, Geneva.

Luka, E.G. and Yahaya, H. 2012. Perceived constraints to use of indigenous soil management practices among yam producers in Nasarawa State, Nigeria. *Journal of Sustainable Development in Africa* 12 (2): 115-125.

Lundvall, B.A., Esping-Andersen, G., Soete, L., Castells, M., Telo, M., Tomlinson, M., Boyer, R. and Lindley, R.M. 2002. *The new knowledge economy in Europe: A strategy for international competitiveness and social cohesion*. UK: Edward Edgar Publishing Limited.

Mainguet, C. and Baye, A. 2006. Defining a framework of indicators to measure the social outcomes of learning. In Desjardins, R. and Schuller, T. (Eds) *Measuring the effects of education on health and civic engagement: Proceedings of the Copenhagen symposium*. Paris: CERI, OECD.

Martin, B.R. 1995. Foresight in science and technology. *Technology Analysis and Strategic Management* 7(2): 139-168.

Metcalfe, J. and Riedlinger, M. 2009. Identifying and testing engagement and public literacy indicators for river health. *Science, Technology and Society* 14 (2): 241-267.

Miles, I. 2010. The development of technology foresight: A review. *Technological Forecasting and Social Change* 77: 1448-1456.

Morris, E.J. 2011. Modern biotechnology: Potential contributions and challenges for sustainable food production in sub-Sahara Africa. *Sustainability* 3: 809-822.

Mulder, I., Bohle, W., Boshomane, S., Morris, S., Tempelman, H. and Velthausz, D. 2008. Real world innovation in rural South Africa. *The Electronic Journal for Virtual Organization and Networks* 10: 7-20.

NACI (National Advisory Council on Innovation). 2010. *South African science and technology indicators 2010*. Pretoria: National Advisory Council on Innovation.

NACI (National Advisory Council on Innovation). 2010-2011. Annual report 2010-2011. Pretoria: National Advisory Council on Innovation

Nardo, M., Saisana, M., Saltelli, A. and Tarantola, S. 2005. *Tools for composite indicators building*. Ispra: JRC, European Commission.

NEPAD. 2005. African science, technology and innovation indicators (ASTII): Towards African indicators manuals. Discussion Paper. Pretoria: NEPAD.

Neumayer, E. 2001. The human development index and sustainability: A constructive proposal. *Ecological Economics* 39: 101-114.

OECD (Organisation for Economic Co-operation and Development). 1990. *Proposed standard method of compiling and interpreting Technology Balance of Payment data: Technology Balance of Payment Manual*. Paris: OECD.

OECD (Organisation for Economic Co-operation and Development). 1995. *The measurement of scientific and technological activities: Manual on the measurement of human resources devoted to S&T: CANBERRA MANUAL.* Brussels, Luxemburg: OECD.

OECD (Organisation for Economic Co-operation and Development). 1997. *National systems of innovation*. Paris: OECD.

OECD (Organisation for Economic Co-operation and Development). 2002. *Proposed standard practice for surveys on research and experimental development: FRASCATI MANUAL*. Paris: OECD.

Nardo, M. and Saisana, M. 2004. *The OECD-JRC handbook on practices for developing composite indicators*. OECD Committee on Statistics, 7-8 June 2004. Paris: OECD.
Neumayer, E. 2001. The human development index and sustainability: A constructive proposal. *Ecological Economics* 39: 101-114
OECD. 2008. *Handbook on constructing composite indicators: Methodology and user guide*. Ispra: OECD.
OECD. 2009. *OECD patent statistics manual*. Paris: OECD.
OECD/Eurostat (Organisation for Economic Co-operation and Development/Statistical Office of the European Communities). 2005. *The measurement of scientific and technological activities – OSLO MANUAL: Guidelines for collecting and interpreting innovation data (3rd Edition).* Paris: OECD.
Porter, M.E. and Stern S. 2002. National innovation capacity. In Porter M.E., Sachs J.D., Cornelius P.K., McArthur J.W. and Schwab, K. (Eds) *The Global Competitiveness Report 2001-2002.* World Economic Forum. New York: Oxford University Press.
Reed, M., E. D. G. Fraser, S. Morse, and A. J. Dougill. 2005. Integrating methods for developing sustainability indicators to facilitate learning and action. Ecology and Society 10(1): r3. Accessed 25 July 2013. http://www.ecologyandsociety.org/vol10/iss1/resp3/
Reed, M., Fraser, E.D.G. and Dougill, A.J. 2006. An adaptive learning process for developing and applying sustainability indicators with local communities. *Ecological Economics* 59: 406-418.
Reed, M., Fraser, E.D.G., Morse, S. and Dougill, A.J. 2005. Integrating methods for developing sustainability indicators to facilitate learning and action. *Ecology and Society* 10 (1), r3.
RICYT/OAS/CYTED. 2001. *Standardisation of indicators of technological innovation in Latin American and Caribbean countries: BOGOTA MANUAL*. Bogota, Colombia: Iberoamerican Network of Science and Technology Indicators/Organisation of American States/CYTED PROGRAM.
Sartori, R. and Pacheco, R.C.S. 2007. Science, technology and innovation indicators: Human interaction in research groups. *19th International Conference on Production Research*. Valparaiso: Chile.
Shavelson, R.J., McDonnell, L. and Oakes, J. 1991. What are educational indicators and indicator systems? *Practical Assessment, Research & Evaluation* 2 (11).
Sheu, H.J. and Lo, S.F. 2005. A new conceptual framework integrating environment into corporate performance evaluation. *Sustainable Development* 13: 79-90.
Smith, K.H. 2005. Measuring innovation. In *The Oxford Handbook of Innovation*. New York: Oxford University Press.
Sonntag, V. 2010. Designing sustainability indicator frameworks for information flow: A case study of B-Sustainable. *Applied Research in Quality of Life* 5 (4): 325-339.
Spielman, D.J. and Birner, R. 2008. *How innovative is your agriculture? Using innovation indicators and benchmarks to strengthen national agricultural innovation systems*. Agriculture and Rural Development Discussion Papers # 41.
Su, H. and Lee, P. 2010. Mapping knowledge structure by keyword co-occurrence: A first look at journal papers in Technology Foresight. *Scientometrics* 85 (1): 65-79.
Stoeglehner, G. and Narodoslawsky, M. 2008. Implementing ecological footprinting in decision-making processes. *Land Use Policy,* 25: 421-431
Tijssen, R. and Hollanders, H. 2006. *Using science and technology indicators to support knowledge-based economies.* UNU-MERIT Policy Brief 11.
UNAIDS. 2010. *Monitoring and evaluating fundamentals: An introduction to indicators*. Geneva: Switzerland
UNDESA (United Nations Department of Economic and Social Affairs). 2007. *Indicators of sustainable development: Guidelines and methodologies* (3rd edition). New York: UNDESA.
UNDP (United Nations Development Programme). 2001. *Human development report 2001: Making new technologies work for human development*. New York: Oxford University Press
Van Bochove, C.A. 2013. Economic statistics and scientometrics. *Scientometrics* 1-20.
Warren, M.D, Slikkerveer, L.J. and Brokesha, D. 1995. *The cultural dimension of development: Indigenous knowledge*. London: Intermediate Technology Publications.

Waters-Bayer, A., Wettasinha, C. and Van Veldhuizen, L. 2007. *Building partnerships to promote local innovation process*. Prolinnova Working Paper #16.

Wettasinha, C., Wongtschowski, M. and Waters-Bayer, A. 2008. *Recognising local innovation: Experience of Prolinnova partners*. A publication in the series on Promoting Local Innovation. Silang, Cavite: The Philippines.