MEASURING THE LEVEL OF TECHNOLOGICAL INNOVATION

DANIEL SMIT
University of Pretoria, Department of Engineering and Technology Management, Graduate School of Technology Management, South Africa
dbtsmit@gmail.com (Corresponding)

TINUS PRETORIUS
University of Pretoria, Department of Engineering and Technology Management, Graduate School of Technology Management, South Africa
tinus.pretorius@up.ac.za

ABSTRACT

Innovation is the foundation that helps to ensure a competitive edge, both economical and in the military. Several types of innovation are defined in order to provide a better understanding of what innovation really entails and what drives it.

The main drivers are internal and external to an organisation where the level of collaboration with other organisations and institutions plays an important role. The internal drivers refer to the strategy of the organisation, the innovation climate and the leadership, the entrepreneurship and the resources of the organisation. The external drivers are more related to government's role.

Innovation itself is not measureable and must therefore be linked to a pre-determined set of criteria.

In using specific frameworks, one has to determine the level of innovation as well as which drivers are applied in order to make it possible to measure the feasibility of innovation efforts. The resources that need to be allocated in terms of funding and personnel with reference to the effort must also be determined.

For this paper 27 projects, from a typical defence related industry, were used and evaluated to measure the level of innovation that is taking place per project and in the specific organisation. Three aspects were measured; namely ideas, processes and products. A second framework was drafted to measure the drivers or environment in which the innovation took place in terms of internal drivers, external drivers and the level of collaboration.

The research results provided a sound basis for the identification and measurement of the elements and drivers of innovation. It was found that the two frameworks are practical instruments that can be used to validate the innovation capability of an organisation, providing a deep insight into the level of innovation and the environment of innovation in the defence research organisation.

Keywords: innovation; types of innovation; drivers of innovation; measurement of innovation.

INTRODUCTION

Innovation is the foundation of not only economic development but also provides a competitive edge to defence forces worldwide. The competitive edge is mainly determined by the level of innovation employed in the technology development, being incremental or radical. Although the more radical the innovation transpire, the higher the risk might be. The technology innovation also relates to the level of the competitive edge that one defence force will have over another. This was

clearly demonstrated during the battles fought in Afghanistan, Iran and Iraq by means of the technological advantage the United States of America (USA) had over these countries. The deduction is made that the more radical the technology (which is employed in battle), the greater the chance of success on the battlefield. Governments invest large amounts of money in technology development which in itself requires feedback in terms of their investment. Different approaches can be followed to measure the Return on Investment. In measuring the level of innovation and determining the drivers of innovation, a sound foundation and the status of innovation are established for future investment and enhancing innovation efforts. This study focussed on measuring the level of innovation and determining the main drivers for innovation in the Council for Scientific and Industrial Research (CSIR).

The Council for Scientific and Industrial Research (CSIR)

The CSIR, being the official industrial research and scientific organisation in South Africa, deals with several organisations as clients of the CSIR to perform technology development on the client's behalf. The main focus areas are in the domains of research impact areas such as energy, natural environment, industry, built environment, defence and security and health. The greatest asset of the CSIR is the people working for the CSIR. They apply their intellectual energy in specific areas of scientific research and development throughout the CSIR, including the Defence and Security research impact area. The CSIR receives a parliamentary grant from the DST to perform research and development, according to its mandate. The CSIR report to the DST against a number of KPIs which are agreed upon between the DST and the CSIR. The CSIR's KPIs also hold and are cascaded down to the respective organisational units in the CSIR.

Defence and Security

The research impact area, Defence and Security, deals mainly with the requirements of the defence force and also supporting other organisations such as the police service and banks. Within Defence and Security, competence areas and research groups are grouped in Command and Control; Optronic Sensor Systems; Radar and Electronic Warfare systems; Aeronautic Systems; Landwards Sciences; Technologies for Special Operations and lastly national research facilities. According to Nepgen (2013:2): *"The role of a national defence science, engineering and technology capability is integral to a country's defence agility"*, underlines the importance of the CSIR in supporting the South African National Defence Force (SANDF) in technology development. The CSIR (DPSS) unit also receives research and development funding from the Department of Defence (DOD), in order to obtain and build research and development capability and capacity in the defined areas. The research areas do not have a common KPI structure.

Innovation outputs have not been formalised in either of the abovementioned funder's KPIs. However, there is an expectation that the CSIR (DPSS) will deliver innovative products and/or processes.

OBJECTIVES OF THIS PAPER

Technological innovation in many companies is the backbone of their very existence, but is seen as being part of the design and development process (as far as product innovation is concerned). The CSIR is fundamentally a scientific and industrial research organisation with its main focus on the

improvement of the quality of life of South Africa's citizens, although some of the business units are primarily involved with technology development. The performance of employees is measured by using Key Performance Indicators (KPIs). As such, the KPIs measurement tends to lean more to the scientific research than to technological innovation measurement. The initial investigation suggests that there are shortcomings in measuring the level of technology innovation at the CSIR. The associated research questions within the environment of the CSIR, specifically the Defence, Peace, Safety and Security department, are as follow:

i. What are the identifiable drivers of technological innovation concerning the technology related projects in the CSIR (DPSS)?

ii. What are the measured levels of technological innovation concerning the technology projects in the CSIR (DPSS)?

iii. What is an identifiable technology framework to measure the level of innovation concerning technology projects in the CSIR (DPSS)?

iv. What are the identifiable elements for a framework concerning innovation strategy in technology projects?

The objective of this paper is to determine the key elements for technology measurement in the defence research industry by using the CSIR as an example. The answers of these research questions will lead to a framework that can be applied to other defence related industries thereby providing useful management information in technology management.

CONCEPTUAL METHOD

The scope of work performed at the CSIR (DPSS) are measured against the types of innovation where the CSIR (DPSS) is most likely to be involved in. As adapted from Keely *et al* (2013:17) the different types of innovation are network, process, product performance, product system, service and customer engagement. The type of innovation that was researched ties in with the definition of innovation as being: "***The creation of a new product, service, methodology or exploitation of new ideas to ensure a competitive advantage, both for the industry but also to the clients of the industry"*** (Gamal 2011:7). The main focus and priorities of the CSIR are building and transforming of human capital, strengthening the science, engineering and technology base including performing relevant research and development, transferring technology and skilled human capital, thereby ensuring financial sustainability and good governance.

Internal processes in the CSIR

The current system of measuring KPIs deals with aspects that are not relevant to innovation or the innovation process. The KPIs that are measured are indicated in the table below, adopted from the CSIR (2013:109).

Table 1: KPI measurement in the CSIR adopted from CSIR (2013:109)

KPI	Measurement
Human resource management	Total size of science, engineering and technology (SET) staff in the organisation (number). Increase in the number is positive.
	% of SET base who are black
	% of SET base who are female
	Number of staff with doctoral level qualifications
Research and development outputs	Publication equivalents (scientific journals)
	New technology demonstrators
	Value of investment in property, plant and equipment
R&D outcomes	New patents granted
	Royalty and license income
Contract R&D	Contract R&D income
	Private sector R&D income
Financial sustainability	Total income
	Net profit
Corporate governance	BBBEE rating
	Energy efficiency
	Disabling injury frequency rate (DIFR)

In using the KPIs, it will be possible to acknowledge innovation efforts from the journals presented, new technology demonstrators produced, new patents granted, royalty and licence income, contract R&D income and private sector R&D income although it does not measure the level of innovation that took place. In order to formulate a model and/or framework to measure innovation, relevant theories of innovation will be applied in this study.

Theoretical background

The CSIR (DPSS) depend mostly on the SANDF to finance and determine the technology development requirements. This limits new ideas where people can present their own ideas for evaluation and further development. The direction of technology development is already pre-determined by the SANDF through the requirements presented via Armscor to the defence industry, unless parliamentary grants (PG) (with respect to the CSIR) are used for research and development purposes. This reason has a fundamental impact on how innovation takes place in the defence industry, including the CSIR (DPSS).

There are several theories that may be applied when measuring innovation, however all are not applicable although it may be relevant. Metcalfe and Miles (2000:108) argue that the best method to measure innovation centres on the grouping of innovation types clarifying the concept that not all types of innovation are applicable to one organisation. This is further confirmed by Wallin *et al* (2011:2) who stated that the wording of the definition of innovation ultimately determines the way and method how to measure the innovation. The Oslo manual defines innovation very close to the adopted definition of innovation applicable to the CSIR and defence related industry. The definition, "***The creation of a new product, service, methodology or exploitation of new ideas to ensure a competitive advantage, both for the industry, but also to clients of the industry"*** is very relevant to measure innovation. It is fundamental to understand what innovation and its impact on an organisation is. Figure 1 provides an overview and flow of innovation.

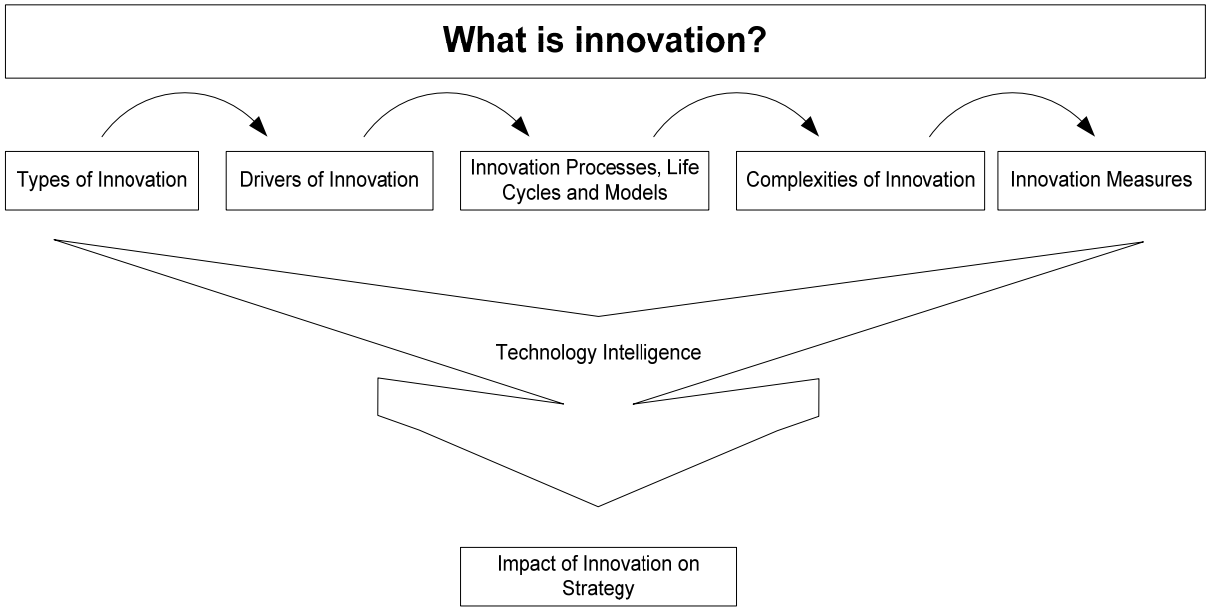


Figure 1: Overview of innovation

What is innovation

In order to understand the different meanings, innovation is defined for specific purposes. The most commonly used definitions are listed in Table 2.

Table 2: Some definitions of innovation

Author	Definition
Scumpeter, J.A. (1943)	An innovation was something that changed the market place in a profound way. The innovating organisation was, thus, likely to become the new market leader and to gain an immense advantage over its competitors.
Drucker, P.F. (1993)	Innovation is the specific tool of entrepreneurs, the means by which they exploit change as an opportunity for a different business or service.

Author	Definition
Freeman, C. (1997)	Industrial innovation includes the technical, design, manufacturing, management and commercial activities involved in the marketing of a new (or improved) product or the first commercial use of a new (or improved) process or equipment.
Albury, D. (2005)	Successful innovation is the creation and implementation of new processes, products, services and methods of delivery which result in significant improvements in outcomes, efficiency, effectiveness or quality.
Oslo Manual (2005)	An innovation is the implementation of a new or significantly improved product (goods or service), or process of a new marketing method, or a new organisational method in business practices, workplace organisation or external organisations.
Microsoft (2007)	Innovation is the conversion of knowledge and ideas into new or improved products, processes, or services to gain a competitive advantage.
UK DTI (2007)	Innovation is the successful exploitation of new ideas.
Gamal, D. (2011)	Innovation is the introduction of a new product, service, or process through a certain business model into the marketplace, either by utilization or by commercialization.

The definitions indicate that innovation comprises of **new ideas**, **processes**, **products**, **methods**, **services** or the **exploitation of new ideas**. Fundamental to most definitions is that **technology** is central to most of the innovation that takes place. This research will make use of the definition of innovation as stated by Gamal (2011:7), but amended to the specific focus of the defence research organisations. For this research, innovation is defined as follows: ***The creation of a new product, service, methodology or exploitation of new ideas to ensure a competitive advantage, both for the industry, but also for clients of the industry***. Each innovation effort relates to a type of innovation and will be discussed in the next paragraph. This research focussed mainly on **ideas**, **processes** and **products**.

Types of innovation

Keely, L., *et al*, (2013:17) refers to ten types of innovation namely a profit model, network, structure, process, product performance, product system, service, channel, brand and customer engagement. In the profit model, companies will focus on ideas or processes to improve the profit margin of the company. In the network model, companies focus on being connected to other companies for collaboration, meaning that external organisations can benefit own efforts in innovation by making use of other organisation's processes, technologies, offerings, channels and brands. The third type, structure, refers to how an organisation is structured and organised in order to create value; structure focus on the company assets such as the facilities, human capital and the intangible assets (knowledge base). The fourth type, process, involves the activities needed to produce the goods or service in order to create value. The fifth type of innovation refers to product performance such as the value of the product, the features of the product and the quality of the product offering. The

sixth type, product service, refers to how individual products and services are connected or bundled in order to create valuable offerings. The seventh type of innovation, service, ensure and enhance the utility, performance and apparent value of an offering. The eighth innovation type, channel, deals with the ways and means by which a company is connected to its customers and users. The ninth innovation type, brand, refers to how an offering is recognised in the market, how it is remembered and distinguished. The last type of innovation, customer engagement, refers to understanding the customer and the customer's aspirations and needs and connects it meaningful to the company.

Although ten types are reflected, on a higher level it boils down to the definition of innovation and the life cycle of innovation. Some elements are useful and applicable for this research. The Oslo Manual (2005: 16), reflects on four types of innovation, which are product innovation, process innovation, organisation innovation and marketing innovation. The scope of the types of innovation in the Oslo Manual is directing this research study because of the international recognition. Some of the elements were useful as reflected in my own definition above. A summary of Keely is displayed in Table 3.

Table 3: Summary of Keely

Type of innovation	Description
Profit model	The essence of profit model innovation is the methods being applied to remain profitable. This may be achieved by exploiting pricing opportunities in relation to the needs of the customer.
Network	Network innovation refers to what the core business is of the business and what aspects should be produced by other closely linked organisations, benefitting from risk sharing and not having to maintain/create specific capabilities.
Structure	Structure innovation focus on the resources that cost money such as personnel, facilities and intangible resources to optimise the productivity levels that cannot be matched by its competitors.
Process	Process innovation revisits the manner how things are done, optimising it in a creative manner to produce more profits.
Product performance	Product innovation focuses on new products and on the improvement of existing products to increase the profit margin and/or to gain the market share.
Product system	Product system innovation refers to the combination of several products to form a greater system and therefore offer an improved product to the customer.

Type of innovation	Description
Service	In short, service innovation focuses on the experience of the customer and how to improve it with through the ease of use of products and the promotion of the products what it can do for the customer.
Channel	Channel innovation is mainly responsible for the method how the offerings of an organisation are brought to the customer and to make it easier for the customer to gain access to the offering.
Brand	Branding an offering of an organisation is not an easy task, especially when it is a new product and organisation, however, branding innovation ensures that customers are confident with the specific supplier and manufacturer, even if the product only carries the name, but is manufactured elsewhere. The trust of customers in a brand determines the price they are willing to pay for it.
Customer engagement	Customer engagement innovation refers to how an organisation connects with its customers and the experience they have from this interaction and engagement. Although this type of innovation might be routed in other types of innovation such as the service provided or brand, it remains valuable that the customer's experience of the offering is such that the customer wants to return for more.

Another approach of innovation reflected by Katz *et al* (2011:63) suggests that innovation can be placed into three main categories. The **categories** are the different types of innovation with the first category as new products, new services, new methods of production, opening new markets, new sources of supply and new ways of organising. The second category is the newness of the innovation, which is explained as the continuum between radical innovations versus incremental innovation. The third category is the impact of the innovation, which is explained on a continuum from sustaining to disruptive. The explanation of Katz *et al* (2011:63) by categorising innovation provides a better understanding of innovation and can be illustrated in Table 2.3.

Table 4: Innovation per definition and category matrix adapted from Katz et al (2011:63)

Innovation Elements per Definition	Innovation Category		
	Types of Innovation	**Newness of the Innovation**	**Impact of the Innovation**
New products	New products	Radical	Sustaining
New services	New services	Incremental	Disruptive
New processes	New methods of production		

New ideas	Opening new markets		
	New sources of supply		
	New ways of organising		

The understanding of innovation in terms of the elements and categories of innovation, ultimately leads to the question: what is driving innovation? This aspect will be discussed in the next paragraph.

Relevant processes, life cycles and models

The description processes, life cycles and models are interrelated and used in the same context as displayed by various publications. The more common known illustration of the innovation life cycle is found in Figure 2. This figure illustrates that innovation has a growth component, but retract after maturity is reached, clearly indicating that any innovation is limited to its relevancy to the end user. The relevancy to the end user is one of the most important characteristic of innovation because there is no indication of how long innovation should take. In some instances, incremental innovation makes all the difference such as cell phones and tablets; however, there are two main reasons for innovation to drag on even over years where incremental innovation only takes place in terms of knowledge creation. These instances are firstly where research over many years takes place, and a breakthrough is not yet achieved for example Acquired Immunodeficiency Syndrome (AIDS) research. The second instance would be (very much related to the defence industry) where some technologies do exist in some countries, but are not available and accessible to a particular country for various reasons, political being one of many.

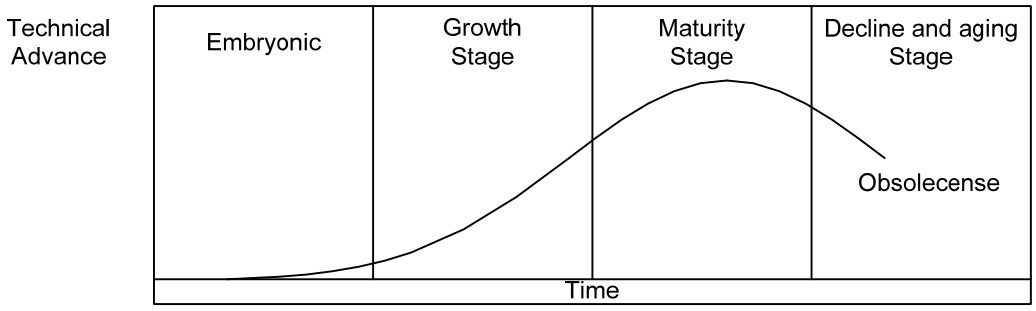


Figure 2: Technology innovation life cycle adapted from Steele L.W.

Frameworks to be used in this study

Gault (2013:41) argues that rules are needed when measuring innovation and that it is rather a difficult task. Gault (2013:6-7) also relate the measurement of innovation to the Oslo Manual addressing indicators and measurement. The most important part of the innovation from the literature, gathered during this study, is to determine how to measure the ***level*** of innovation. It is valid to say that measuring innovation may have an effect on the behaviour of people and therefore needs to be objective rather than subjective. The most suitable framework to measure innovation in the defence related industry is found in the study undertaken by Ming and Kok-Soo (2010:5) mainly because of the similarity between the nature of the defence related industry and the innovation assessment framework as displayed by Ming and Kok-Soo (2010:5). The process of the innovation measurement is displayed in Figure 3.

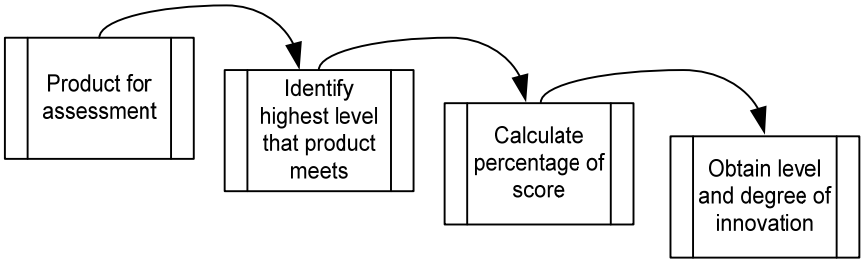


Figure 3: Innovation assessment framework adopted from Ming and Kok-Soo

RESEARCH METHODOLOGY

The case study approach, to conduct the research, is a good method according to Yin (2009:19) to explain presumed causal links in real life interventions, to describe the intervention in the real life context, to illustrate certain topics within an evaluation and lastly to provide more clarity in evaluations where the outcomes are not clear.

Although the case study method is presented with much criticism by various researchers, it remains a valid method for research and provides a sound framework to conduct the research. The case study research method is preferred as opposed to experimentation because in the case study research method, real life occurrences are analysed, and in experimentation research, variables plays a significant role in the outcome of such research which is difficult to generalise in real life (Yin, 2009:18) and measuring innovation.

Data gathering process

Yin (2009:19) states that two approaches are possible for data gatherings; these approaches are a qualitative and a quantitative approach. In some cases even a combination of qualitative and quantitative methods can be employed. For this research study a single case study approach will be applied for the analyses. A single case study approach is proposed because of the conditions, circumstances and the representation of the CSIR within the defence related industry, using the same practices in design and development related requirements, which also encompasses innovation. The primary focus will be on ***qualitative*** measurements through allocating values to quantify the assessment and due to the interaction between the research and the availability of data. The unit of analysis is based on projects.

Yin (2009:101) also states that there are six sources of evidence that can be used in the case study. The following sources were used for this study:

i. Interviews.
ii. Documentation.
iii. Records from archives.
iv. Direct observation.
v. Physical artefacts.
vi. Participant observation.

Although not listed by Yin, the internet was also used as a source of data gathering, mainly for theory building purposes.

The process that was followed in the data gathering process was done through direct contact with the CSIR, gathering of as many as possible project documentation, drafting of evaluation criteria within the proposed framework and analysis of the documentation.

Chain of evidence

The chain of evidence for the research is important to be established and demonstrated. The chain of evidence for this research is displayed in Figure 4.

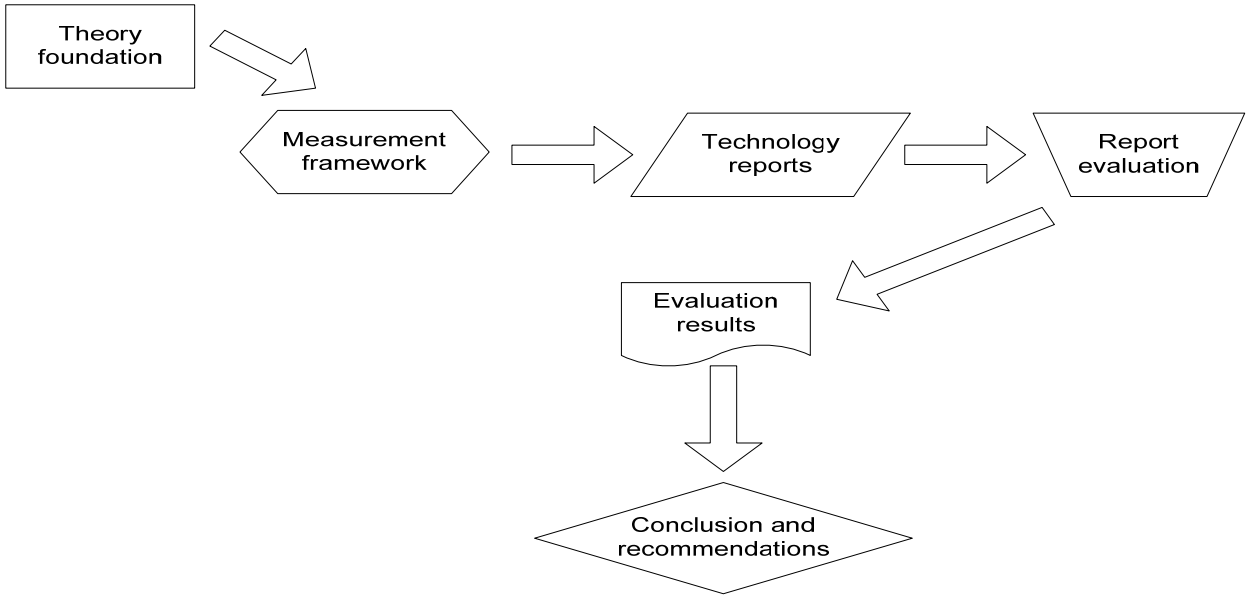


Figure 4: Chain of evidence

Innovation assessment framework and criteria

When assessing innovation it is best understood in terms of a framework. Two frameworks were used in this research study. These were a framework to measure the level of innovation and another to determine the environment in which the innovation takes place.

Measuring the level of innovation

Ming and Kok-Soo (2010:5) presented a table for measurement of innovation taking various factors into consideration, which can be applied in this research study. The table below indicates the level criteria taken from the Oslo Manual with level 1 being aspects that are defined in the Oslo Manual . Those aspects of the criteria that do not fit into the Oslo Manual's definition are placed in level 2 and 3. The detail of the measurement framework is displayed in Table 5. The elements indicated in level 3 are selected from a list of judging criteria and ranking of innovation metrics. The allocation of a score can either be zero or five in level 1, giving recognition to the Oslo Manual's requirements as being the most important contributing elements for innovation; for level 2 the score can only be zero or three as a secondary recognition to the Oslo Manual's requirements and then for the third level the allocation can only be zero or one for elements outside the Oslo's manual.

Table 4: Innovation assessment criteria (adapted and altered from Ming and Kok-Soo) (refer to paragraph 4.3.1. for the legend)

Level	Score	Oslo Manual definition/effects	Judging criteria	Innovation metrics
1	5	Fundamentally new product	Degree of innovation	
	5	Improved functional characteristics	Functionality characteristics	
	5	Capability improvement	Degree of capability enhancement or establishment of a new	

Level	Score	Oslo Manual definition/effects	Judging criteria	Innovation metrics
			capability	
	5	Improved user friendliness	Ergonomics	
	5	Increased sales/market shares/ international competitiveness		Revenue growth
2	3	Improved technical specifications/efficiency		
	3	Improved components (hardware/software)/ materials		
	3	Significant innovation expenditure		
3	1		Ecological beneficial	
	1		Functionality (usefulness to the user)	
	1		Durability/ workmanship	
	1		Improved design quality	
	1		Safety	
	1			Customer satisfaction
	1			Revenue growth
	1			Percentage of sales from new offerings
Total	42			

Determining the environment in which innovation takes place

Figure 5 indicates that the internal and external drivers relates to the environment in which innovation takes place. This environment can restrict innovation or enhance innovation. The public service on its own does not have the innovation capacity and capability to deal with every demand hence the public service, besides its own capability, relies on collaboration with other entities such as universities, research institutions and specialist organisations. The result of an innovation must be

monitored and measured to ensure that the desired effect was achieved; therefore, constant feedback is needed to the environment in which the innovation takes place.

In the report, *A global study of innovation management AMA* (2006:11), it is stated that the external drivers of innovation relate to customer demands, technology, pace of change, collaboration/alliances with customers, availability and cost of talent and lastly globalisation/increased competition and is strongly related to the innovation culture of the organisation.

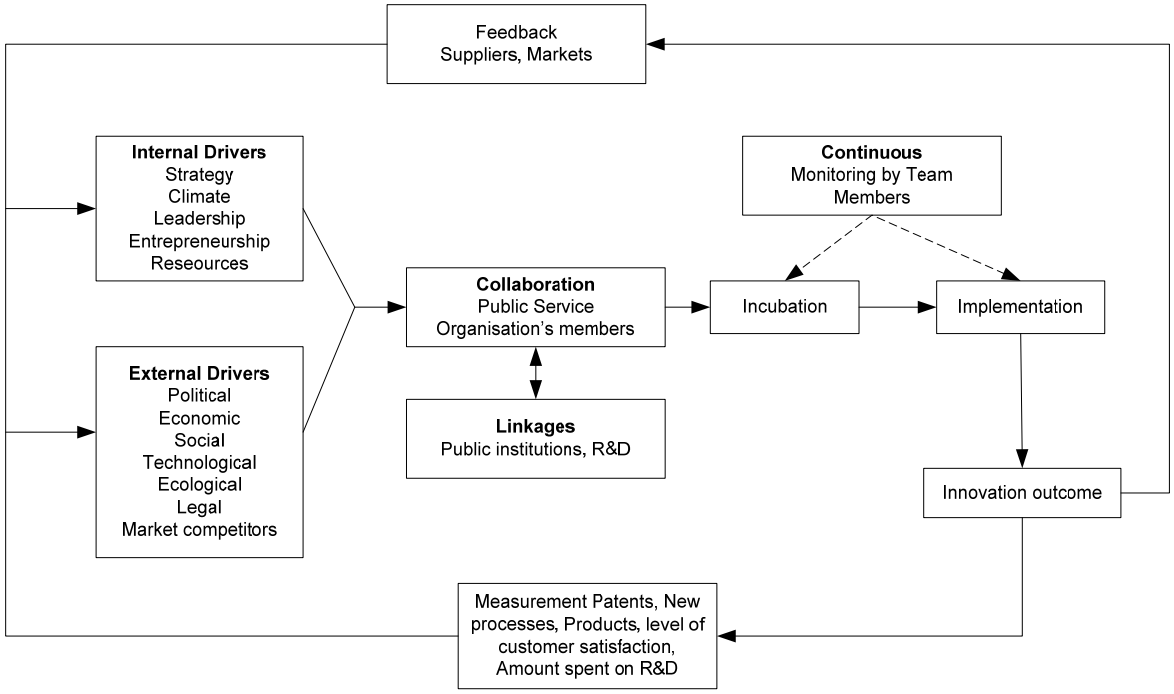


Figure 5: Conceptual framework for public sector innovation adapted from Agolla et al

The model of Agolla *et al* (2013:166) as displayed in Table 3 with minor changes was applied in a framework to measure the environment in which innovation is taking place. A framework to determine the environment for innovation was drafted where the elements identified as drivers were listed and a score of either zero or one is allocated. A zero will indicate that the element is not visible, coded for ***no*** and one will indicate that it is visible, coded for ***yes***.

Table 6: Environment for the project innovation (refer to paragraph 4.3.2. for the legend)

Driver	Score	Innovation assessment criteria	Allocated score	Justification
Internal Drivers	1	Strategy		
	1	Innovation strategy		
	1	Leadership		
	1	Entrepreneurship		
	1	Resources		
External	1	Political		

Driver	Score	Innovation assessment criteria	Allocated score	Justification
	1	Economic		
	1	Social		
	1	Technological		
	1	Ecological		
	1	Legal		
Collabo-ration	1	Public services		
	1	Organisation's members		
	1	Public institutions		
	1	Research and development		
Total	15			

RESULTS

The results are discussed in terms of the two propositions and the hypothesis as drawn from the research objectives.

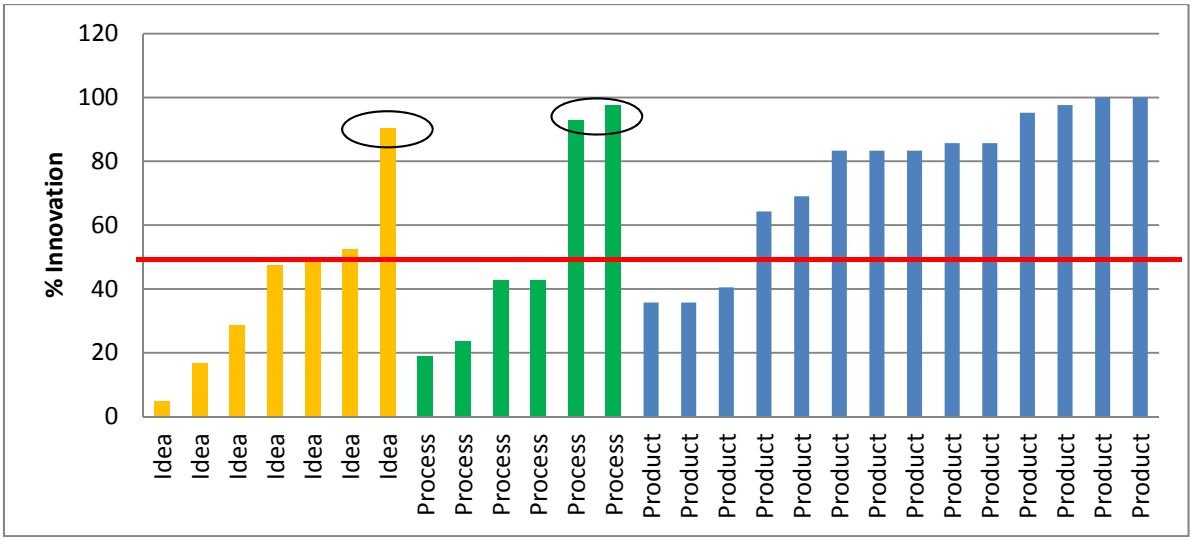
Measuring the level of innovation of 27 projects

Table 7: Order per innovation type

Project no	Total	Possible	% Innovation	Type of Innovation
12	2	42	4.8	Idea
14	7	42	16.7	Idea
18	12	42	28.6	Idea
11	20	42	47.6	Idea
10	21	42	50.0	Idea
27	22	42	52.4	Idea
13	38	42	90.5	Idea
3	8	42	19.0	Process
24	10	42	23.8	Process
8	18	42	42.9	Process
9	18	42	42.9	Process
4	39	42	92.9	Process
22	41	42	97.6	Process

Project no	Total	Possible	% Innovation	Type of Innovation
1	15	42	35.7	Product
21	15	42	35.7	Product
2	17	42	40.5	Product
25	27	42	64.3	Product
17	29	42	69.0	Product
5	35	42	83.3	Product
6	35	42	83.3	Product
7	35	42	83.3	Product
19	36	42	85.7	Product
23	36	42	85.7	Product
26	40	42	95.2	Product
20	41	42	97.6	Product
15	42	42	100.0	Product
16	42	42	100.0	Product

It is clear from table 7 that the projects that were surveyed, falls within the basic research domain (mostly the ideas) and the research and development domain. The average level of innovation that is taking place is **61,8%**. There is no standard that one can compare the level of innovation that is taking place in an organisation, except to say that the higher the percentage, the more innovation is taking place. If **50%** is seen as the average of an acceptable level of innovation that is taking place in the organisation, then **61,8%** would be above average, although there is no proof in this research study to support the claim. The measurement of acceptable innovation being **50%** also provides a very clear distinction between the different projects which may be funded in the future and which to terminate. Based on the analysis it is clear that a high level of innovation is taking place but it also indicates the low level of innovation taking place in some projects which may be considered to be stopped. The range of innovation per type is indicated in graph 3.



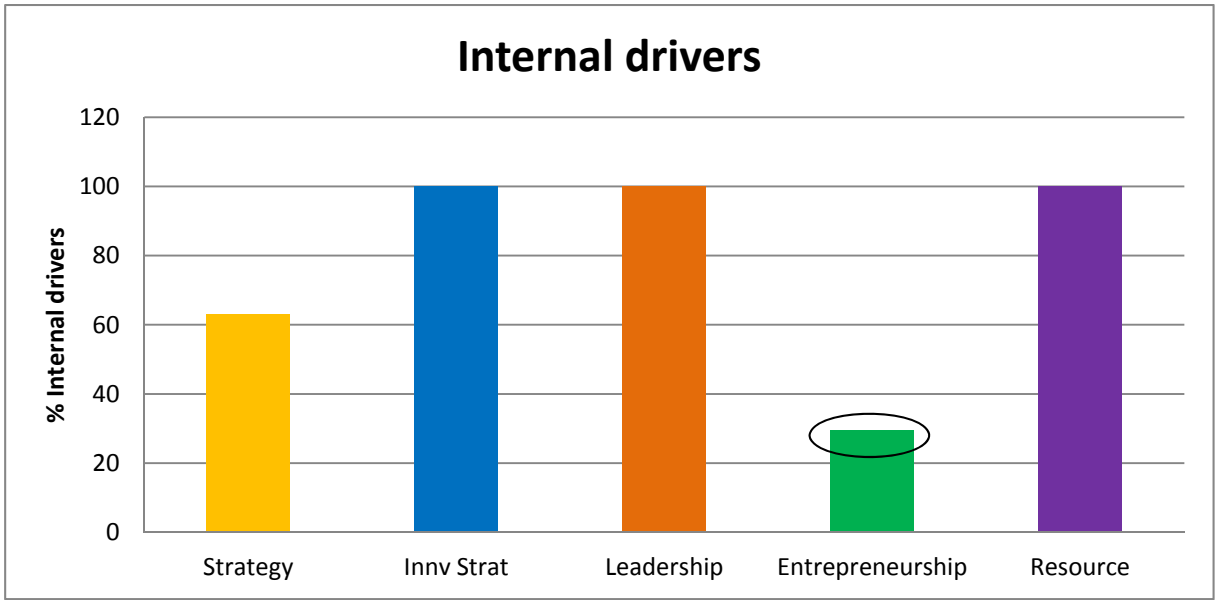
Graph 3: Distribution of innovation per type

The graph above shows that most innovation is taking place mainly in the **products** with **process** ranging second and **ideas** thirdly. Only one idea of seven was significantly enough to be regarded as an innovation, two of six process reports can be regarded as an innovation and eleven of fourteen products can be regarded as innovation. Product innovation featured significantly higher than any other innovation process.

Determining the environment in which innovation takes place

The following graphs were drawn from the results of the research study:

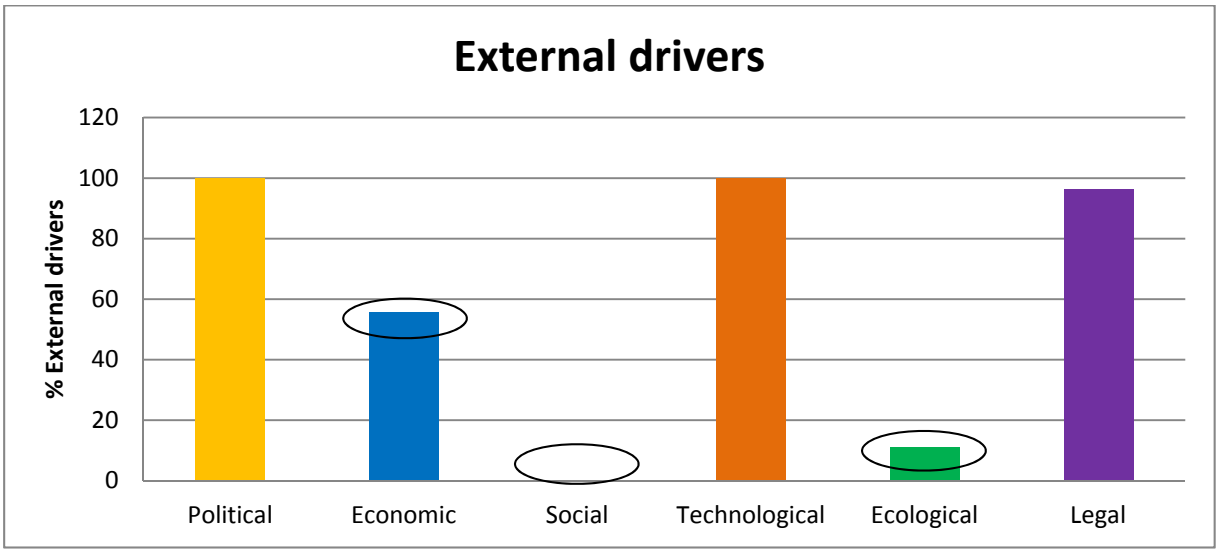
Determining the internal drivers



Graph 4: Factor distribution of the internal drivers of innovation

Graph 4 indicates that innovation strategy, leadership and resources are the strongest factors contributing to the internal drivers of innovation followed by strategy and then by entrepreneurship. Entrepreneurship is reflecting a low percentage thereby confirming that the CSIR is not a business enterprise but a research organisation

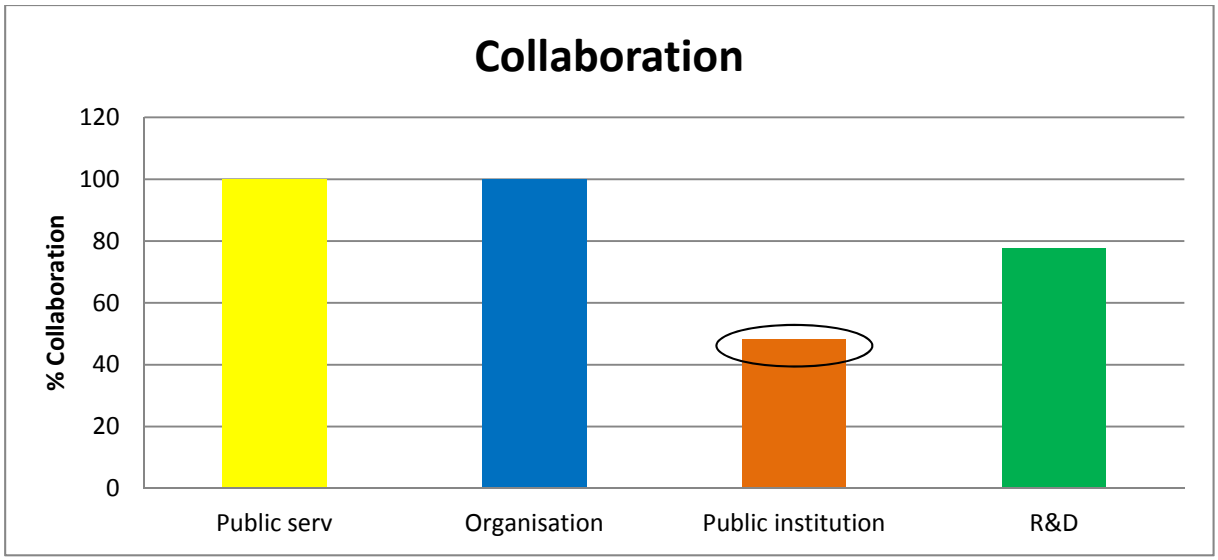
Determining the external drivers



Graph 5: Factor distribution of the external drivers of innovation

Graph 5 indicates that political and technological are the strongest external drivers for innovation followed very closely by legal, then economics and very low, ecological and social. Social shows no effect as an external driver on innovation mainly because military innovation does not necessarily consider social objectives as a driver, but mostly has the opposite negative impact due to conflict and war. Ecological is very low because of the priority the ecology is playing in the development of new weaponry and as a main objective also being regarded as low.

Determining collaboration



Graph 6: Factor distribution of collaboration

Graph 6 indicates that collaboration with the public service and other organisations are the strongest collaboration elements followed by research and development and then by public institutions to enhance innovation. The lower percentage in public institution collaboration is a reflection that the CSIR had a lesser need for collaboration with public institutions because the CSIR possessed the capability and knowledge. The graph also indicates that innovation cannot take place on its own in an organisation, in many instances support from and collaboration with other organisations are needed.

Hypothesis testing

The first research question: "*What are the identifiable drivers of technological innovation concerning the technology related projects in the CSIR (DPSS)?*" has been answered and the main drivers were identified to be the following in order of merit:

i. Internal drivers
   - Innovation strategy.
   - Leadership.
   - Resources.
   - Strategy.

ii. External drivers
   - Political.
   - Technological.
   - Legal.

iii. Collaboration with:
   - Public services.
   - Organisations.
   - Research and development.

The second research question: "*What are the measured levels of technological innovation concerning the technological projects in the CSIR (DPSS)?*" has been answered through the three types of innovation of product, process and new ideas. Each innovation type indicated the following: new ideas 41.5%, process innovation 53.2% and product innovation 75.7% respectively.

The third research question: "What is an identifiable technology framework to measure the level of innovation concerning technology projects in the CSIR (DPSS)?" is established through the application of the framework as proposed by **Ming and Kok-Soo**, but with some amendments to make it more applicable in the defence industry.

The fourth research question: "*What are the identifiable elements for a framework concerning innovation strategy in technology projects?*" can be drawn from the research into the impact of

innovation on strategy. From the study it is clear that the following fundamentals must be borne in mind when drafting an innovation strategy for an organisation:

- The mission and vision of the organisation gives direction to the enterprise strategy to distinguish the business from others. This strategy already provide a basis for future innovation, specific if an organisation such as defence industry is more involved in product development. The key here would be that innovation must be incorporated into the enterprise strategy.
- The innovation strategy of an organisation is a derivative of the main strategies of the organisation and fills a place as a functional strategy.
- The importance and priority given to the functional strategy in relation to the other functional strategies are of significance in determining the focus of the organisation. It is therefore not less important than for instance the human resources strategy.
- The drivers of innovation are fundamental to the overall functional innovation strategy and must be identified in the innovation strategy. In other words, the drivers that will be important to a specific organisation must be identified and then be the focus for future innovation to align the drivers with the innovation environment of the organisation.
- The elements measuring the level of innovation are fundamental to support innovation and must give strategic direction to innovation. These elements can be adopted to be suited for the organisation.

The hypothesis presented for this research project was:

"Significant innovation takes place during technology development in defence research industries and can be reflected if the elements and drivers of innovation are identified and measured".

The results of the research provide a sound basis for the identification and measurement of the elements and drivers of innovation. The two frameworks, one for the measurement of the level of innovation where specific elements were identified and the other framework to evaluate the environment for innovation, are practical instruments to validate the innovation capability of an organisation, provided a deep insight into the level of innovation and the environment of innovation in the defence related industry, particularly the CSIR.

The hypothesis is supported.

The fact that innovation is captured on a high level in the KPIs of the CSIR result in the innovation that actually taking place by not being visible. It does not mean that innovation is not occurring. By applying specific measuring techniques as presented in the two frameworks, it is clear that a high level of product innovation takes place in the CSIR.

CONCLUSIONS AND RECOMMENDATIONS

Research results

The results of this research provided a sound basis for understanding of how innovation takes place, from a new idea to a process or product. The measurements taken indicate that measuring new ideas are even more difficult, mainly because of the end result not being clear or in most cases not

defined or not feasible. The framework for measuring the level of innovation pertaining to new ideas cannot be used as is and will require much more research to draw a framework for measurement. Most of the elements in the framework to measure innovation for processes and products can be used in the defence industry, but some elements in the framework may need to be replaced with applicable elements for a specific industry, for example, capability establishment was added in the framework, because of the significance of capability improvement. In the defence industry context, the innovation must contribute to the establishment or improvement of a capability; otherwise the innovation would be worthless. The results correlated with the actual process and product innovation that took place.

The framework to determine the environment for innovation provided a clear picture on the drivers for innovation.

Implications and contributions

The two frameworks, one for measuring the level of innovation and one for determining the environment for innovation are sound mechanisms to be used as a management tool to improve on the profitability of the defence related industry. The two frameworks are also intertwined with one another in the sense that knowing what the environment of innovation is of an organisation, more resources and focus can be employed to enhance it, be it internal or external. The role collaboration is playing as a driver needs to be analysed very carefully by any defence research organisation. Although there are many pitfalls in collaboration, no organisation knows everything and specialists in other organisations can contribute much to the innovation initiatives of the organisation. The levels of innovation give a clear indication to the organisation if it is a production house or an innovation organisation. The importance of knowing the difference is clear in where the organisation should be focusing on. If the organisation is an innovation organisation, more attention should be given to the drivers of the innovation process. It is the understanding of these two frameworks that makes a huge contribution in innovation management in the defence related industry.

Recommendations

It is recommended that this study be used in different defence related industries to determine the innovation capability. Both frameworks may be refined as a result of such a study to later become an international recognised instrument for measuring innovation.

It is also recommended that a future study be directed towards a framework for measuring new ideas in defence related industries.

The results of this study should be used by the CSIR to direct resources and management focus on innovation particularly. The benefits will lead to a winning combination of being more competitive and providing a leading edge to its primary customer, that is the South African National Defence Force.

REFERENCES

Books and Journals

Agolla, J.E. and Van Lill, J.B. 2013. *Public Sector Innovation Drivers: A Process Model*. J Sec Sci, 34(2): 165-176 (2013). School of management sciences, North West University, Mafikeng Kampus.

Drucker, P.F. 1993. *Innovation entrepreneurship*. New York. HarperCollins

Freeman, C. 1997. *The economics of industrial innovation*. 3rd Edition. London. Frances printer.

Handbook of innovation indicators and measurement. Edited by Gault, F. 2013. Edward Elgar Publishing Limited, UK.

Keely, L. *et al*. 2013. *Ten types of innovation: The discipline of building breakthroughs*. New Jersey. John Wiley & Sons.

Metcalfe, J.S. and Miles, I. 2000. *Innovation Systems in the Science Economy, Measurement and Case Study Analysis*. Economics of Science, Technology and Innovation. Volume 18.

Oslo Manual. 2005. *Guidelines for collecting and interpreting innovation data*. 3rd Edition. France. Organisation for Economic Co-operation and Development (OECD) and Eurostat.

Scumpeter, J.A. 1943. *Capitalism, Socialism and Democracy*. 5th Edition (1976). USA. Allen & Unwin.

Steele, L.W. 1990. Technology Maturation and Technology Substitution. *IEEE Engineering Management Review*, March 1990 (Spring Issue), Volume 18, Number 1.

Yin, R.K. 2009. *Case study research: Design and methods*. 4th Edition. Applied social research methods series. Volume 5. USA. Sage Publications, Inc.

Articles, Papers and Publications

Albury, D. 2005. Fostering innovation in Public Services. *Public Money and Management*. January 2005, Volume 25, Issue 1.

CSIR. 2013. Technology that Transforms, *CSIR Publication*. CSIR Strategic Communication.

Gamal, D. 2011. How to measure organisation innovativeness?: An overview of innovation measurement frameworks and innovation audit/management tools*. EgyptInnovate*. Egypt.

Katz, B.R., Du Preez, N.D. and Schutte, C.S.L. 2011. Definition and Role of an Innovation Strategy. *Department of Industrial Engineering Stellenbosch University*, *RSA*. Stellenbosch University, Department of Industrial Engineering, South Africa.

Ming, T.Y. and Kok-Soo, T. 2010. Development of a measurement framework for product innovation. *The 11th Asia Pacific Industrial Engineering and Management Systems Conference, Melaka, 7 – 10 December 2010.* Monash University.

Wallin, J., Larsson, A., Isaksson, O. and Larsson, T. 2011. Measuring innovation capability – assessing collaborative performance in product-service system innovation*. 3rd CIRP International Conference on Industrial Product Service Systems, Braunschweig, 2011*. Sweden.

Reports

CSIR. 2013. 2012/13 Annual Report: To contribute to the improvement of the quality of life of the people. CSIR Strategic Communication.

Internet

Microsoft. 2007. *White paper: Innovation process management*. Microsoft [Online]. Available: http://www/download.microsoft.com/.../Innovation%20Process%20Management%20 [Cited 18 November 2013].

Department of Trade and Industry (DTI) – British Council. 2007. Innovation [Online]. Available: http://www.dti.gov.uk>innovation [Cited 18 November 2013].