Assessing the innovation capability of a research institution

by
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I Declaration

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II Abstract

The evolution of the university's role in national innovation systems has lately received increasing attention in international academic circles, with emphasis on its role in stimulating and sustaining national and regional economic growth. Universities in leading economies have adopted economic development as a third mission, along with the traditional objectives of teaching and research, directly leading to the inception of a technology transfer facilitator as an institutional unit.

Translating this mission shift into the context of the Innovation Life Cycle, it seems that universities are involved in a larger part of the innovation process, rather than simply supplying inputs for the innovation funnel of industry. The subsequent need to gain maximum value from research has led innovation management practitioners to consider ways in which the innovation capability of universities can be improved.

Several approaches have been documented to improve the performance of a university's technology transfer office as an isolated entity. Most of these studies, however, have neglected to consider the technology transfer office in the context of the organisation-wide innovation process. The aim of this research is therefore to evaluate the innovation capability of a research institution to enable the improvement of their research commercialisation system.

As a foundation the state of research commercialisation, innovation, and the relationship between the two are investigated. This process resulted in the validation that research commercialisation can be modelled by utilising an innovation model.

The Innovation Capability Maturity Model version 2 (ICMMv2) of Essmann (1) is subsequently investigated with the aim of applying the model. This in turn leads to the application of the Innovation Capability Improvement Methodology accompanying the ICMMv2 in case study format on Stellenbosch University.

The results obtained from the case study are presented in terms of the strengths and weaknesses of the innovation capability of the University. The results were found to be an accurate description of the current issues in the commercialisation system at Stellenbosch University. The latter was validated by individuals tasked with the execution of the research commercialisation process at the University.

This, in turn, validates the use of the Innovation Capability Maturity Model for the identification of any aspects that need improvement in order to streamline a university's research commercialisation efforts.

III Opsomming

Die evolusie van die universiteit se rol in nasionale innovasie stelsels kry toenemend aandag in internasionale akademiese kringe. Dit beklemtoon universiteite se rol in die stimulering en handhawing van nasionale en plaaslike ekonomiese groei. Universiteite in voorste ekonomieë het ekonomiese ontwikkeling aangeneem as 'n derde missie, saam met die tradisionele missies van onderrig en navorsing. Dit het direk gelei tot die inlywing van ‘n tegnologie-oordrag fasiliteerder as 'n institusionele eenheid.

Die verskuiwing van missie in die konteks van die Innovasie lewensiklus, dui daarop dat universiteite betrokke raak in 'n groter deel van die innovasie proses, eerder as om net die verskaffer van insette vir die innovasie tregter van die industrie te wees. Die daaropvolgende vereiste om maksimum waarde te verkry uit navorsing, het veroorsaak dat innovasie bestuur praktisyns verskeie maniere ondersoek waarop die innovasie vermoë van universiteite verbeter kan word.

Verskeie benaderings om die prestasie van 'n universiteit se tegnologie-oordrag eenheid as 'n geïsoleerde entiteit te verbeter, is gedokumenteer. Die meeste van hierdie studies het egter nagelaat om die tegnologie-oordrag eenheid te oorweeg in die konteks van die organisasie-wye innovasie proses. Die doel van hierdie navorsing is dus om die innovasie vermoë van 'n navorsingsinrigting te evalueer om die verbetering van hul navorsing kommersialisering stelsel moontlik te maak.

As 'n basis word die stand van navorsing kommersialisering, innovasie en die verhouding tussen die twee ondersoek. Hierdie proses het gelei tot die validasie dat navorsing kommersialisering gemodelleer kan word deur middel van 'n innovasie model.

Daarna is die Innovation Capability Maturity Model weergawe 2 (ICMMv2) van Essmann(1) ondersoek om ten einde die model toe te pas. Dit word gevolg deur die uitvoering van die Innovation Capability Improvement metodologie, as deel van die ICMMv2, op die Universiteit van Stellenbosch, in ‘n gevallestudie-formaat.

Die resultate wat verkry is uit die gevallestudie word in terme van sterk en swak punte met betrekking tot die innovasie vermoë van die Universiteit bespreek. Die resultate is bevind om 'n akkurate beskrywing van die huidige kwessies in die kommersialiseringstelsel by die Universiteit van Stellenbosch te wees. Dit is dan ook bevestig deur sekere individue gemoeid met die uitvoering van die navorsing kommersialiseringproses by die Universiteit.

Dit op sy beurt, bekragtig die gebruik van die ICMMv2 vir die identifisering van die aspekte wat verbeter moet word om 'n universiteit se navorsing kommersialiseringpoging vaartbelyn te maak.

IV Acknowledgements

First and foremost, many thanks to Prof Schutte for your guidance and support throughout this research. Although it was a busy year you always made time to guide us through the tough issues.

Heinz Essmann, thank you for always making time, without your always timely assistance this research would not have been possible.

Eric Lutters, thank you for your insights and constructive criticism.

Someday perhaps the inner light will shine forth from us, and then we'll need no other light.

Johann Wolfgang von Goethe

Indutech (Pty) Ltd and all its staff, thank you for providing the resources that enabled the completion of the research.

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I also want to thank my colleagues, Henno, Denéle, Tanye and Jaco, who made the journey much more enjoyable than one could have ever thought possible.

Associate with men of good quality if you esteem your own reputation; for it is better to be alone than in bad company.

George Washington

Elsje, thank you for working so hard with me this final year, without your understanding and support I would have never made it this far.

Lastly I want to acknowledge my family members and other loved ones for the emotional and financial support that allowed me to complete my studies at Stellenbosch University.

It has been a fantastic seven years that shaped me personally, professionally while creating memories that will outlive us all.

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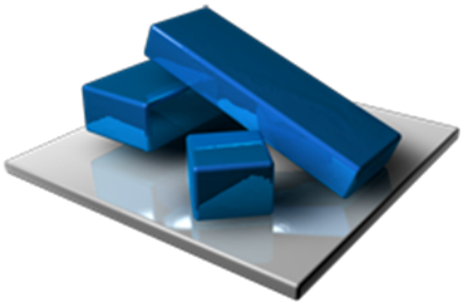
VIII List of Acronyms and Abbreviations

CMM	Capability Maturity Model
CI	Continuous Improvement
FuGIe	Innovation Model
IBM	International Business Machines Corporation
ICIM	Innovation Capability Improvement Methodology
ICMM	Innovation Capability Maturity Model
ICMMv2	Innovation Capability Maturity Model version 2
ICA	Innovation Capability Assessment
IP	Intellectual Property
ISL	Industry Science Link
NSI	National System of Innovation
OECD	Organisation for Economic Co-operation and Development
R&D	Research and Development
SEI	Software Engineering Institute of Carnegie Mellon University
SMME	Small, Medium and Micro Enterprises
SU	Stellenbosch University
TTO	Technology Transfer Office
US	United States of America

1

Introduction

This chapter provides the introduction to the research. It includes the problem statement, the research questions, methodology and scope.
Thereafter it concludes with a description of the layout and logical flow of the document.



1.1 Introduction

Over the past decades, the University's role in the innovation systems has been changing. This change has brought to light the need to increase the transfer of the knowledge accumulated in the universities to the industry. This fact, together with the shrinking budgets of tertiary education institutions internationally has prompted universities to evaluate commercial activity as a possible solution.

The commercialisation of research was identified as a mechanism to promote technology transfer while also generating an additional revenue stream for universities. Soon it became evident that successful commercialisation programmes at universities was the privilege of only a select few, which prompted international scholars to attempt to identify the critical success factors for research commercialisation.

As Etzkowitz(2) states:

"*The University of the future is one that can successfully align the traditional academic missions of teaching and research with the third mission of economic development*."

The University's role as a factory of knowledge that could lead to innovations has been re-emphasised.

This research effort was undertaken to determine if a university's research commercialisation efforts could benefit from an evaluation of its innovation capability.

1.2 Problem Definition

This section will discuss the research problem and the consequent hypothesis. Thereafter an assumption will be discussed that will influence the hypothesis and in conclusion the objectives and research questions derived from the hypothesis will be stated.

1.2.1 Problem and Hypothesis

Universities are struggling to implement successful research commercialisation as demanded by international markets and governments. This problem does not occur across the board but the distribution of successful instantiations is heavily skewed, with only a handful of universities reaping the bulk of the rewards.

If the successful institutions were emulated without consideration of the difference in context, it will lead to underachievement and ultimately unsuccessful efforts(3). A specific institution is not only affected by internal elements, but also by external factors such as government

laws and policies, the surrounding industry and regional conditions. Consequently, the identification of and adherence to critical success factors gained from an analysis of leading institutions would be a very dynamic and (in all probability) fruitless exercise.

Universities want to ensure that they get the appropriate returns from their research commercialisation efforts, but there is little consensus on which indicators are appropriate for quantifying success.

In an effort to solve this problem, the author aspires to used an innovation maturity model, to evaluate and improve a specific instantiation of a research commercialisation effort, while considering the context of the effort. The Hypothesis states:

It is possible to use an Innovation Capability Maturity model to assess the system through which a university commercialises its research and identify the aspects that need to be improved.

1.2.2 Assumption

For the purpose of this research the Innovation Capability Maturity Model version 2 (ICMMv2) of Essmann (1) will be used as the innovation maturity model referred to in the hypothesis. This model has been chosen for several reasons.

Essmann's (1) model was developed based on sound academic research into the fundamental aspects that an organisation requires in order to innovate in a consistent fashion. The model was validated using a number of case studies, documented by Essmann (1) in his dissertation on the development of the ICMMv2. Therefore, the theoretical foundation of the model is academically valid, well-documented and accessible.

This is not the case with other similar models (shown in the Appendix I), because they are typically developed and used by consulting companies, who use these models as part of their value offering. Accordingly, information about the models is not readily available and often protected as Intellectual Property (IP). Those models that do provide information do not convey enough to validate the use of the particular model.

The ICMMv2 and some of its components are also protected in the same manner, but through a research agreement with Indutech (Pty) Ltd., owners of the ICMM and related IP, the relevant IP of the model was made available for the purposes of this research project. This implies that the research may use the Innovation Capability Questionnaire and Data Analysis tools that accompany the ICMMv2 for academic purposes.

Because the execution of the evaluation process (in this case the Innovation Capability Improvement Methodology) that typically accompanies innovation maturity models is essentially a consulting process, the continuous assistance of a consulting expert would be very valuable to ensure that the assessment procedure is executed correctly. Dr. Essmann offered his assistance in this regard and this was a major contributing factor to the selection of the ICMMv2.

The last reason for choosing the ICMMv2 is the fact that the model is accompanied by an Innovation Capability Improvement Methodology (ICIM) and an Innovation Capability Assessment (ICA). The methodology guides the maturity improvement process of the capabilities specified in the model. The ICA is used to assess the current state of the capabilities' maturity, and this assessment forms part of the ICIM.

The author believes that attaining the same level of access to related IP and general assistance to execute one of the other innovation maturity models would have required resources beyond the means of this research. On a related note, it is very likely that that the additional value gained from sourcing another model and obtaining the same level of support in the consultation process would not have justified the resource expenditure.

For the sake of clarity, the Hypothesis of the research can be restated as follows:

It is possible to use the Innovation Capability Maturity Model version 2 to assess the system through which a university commercialises its research and identify the aspects that need to be improved.

1.2.3 Research Objectives and Questions

In the process of evaluating this hypothesis, the research will have two objectives, namely:

1 Determine whether it is appropriate to measure a research commercialisation system with an innovation maturity model.
2 Determine whether it is possible to measure a research commercialisation system with Innovation Capability Maturity Model version 2.

In order to guide the research and give structure to the approach, the following four research questions have been devised to support the process and reach the objectives. In addition to the objectives, these questions will guide the methodology used to execute the research. By answering these questions in sequence, the research will arrive at an appropriate and well-researched solution.

1. What is the relationship between research commercialisation and Innovation?
2. Does the Innovation Process sufficiently model research commercialisation?
3. Does the ICMMv2 identify areas of strength and weakness?
4. How might the ICMMv2 be improved?

The research (and this document) was structured so as to answer these questions in sequence, and this approach provides a logical flow which will assist in the effective communication of the research that was undertaken.

1.3 Research Objectives, Questions and Methodology

In this section the methodology will be discussed while also showing how the research objectives and research questions relate to the methodology. Figure 1 shows the relationship between the elements.

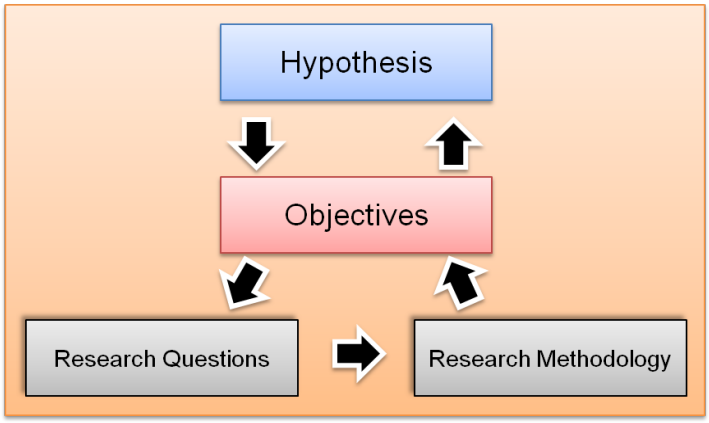


Figure 1 – Relationship between hypothesis, objectives, research questions and methodology.

In light of the objectives and the resulting research questions, a discussion on the research methodology follows below.

To evaluate the relationship between research commercialisation and innovation, it is necessary to determine the current state of research commercialisation. Accordingly, a comprehensive literature study on international technology transfer and subsequently research commercialisation is carried out.

This is followed by a review of the field of innovation, in order to assess whether innovation models can be used to model the research commercialisation process. The FuGle innovation model is described and used to model the research commercialisation process. ICMMv2, chosen for the reasons discussed in Section 1.2.2, is selected as a relevant innovation maturity model to measure and improve the system.

Maturity models are subsequently discussed and the inner workings of the ICMMv2 is investigated. This leads to the execution of the Innovation Capability Assessment (ICA) as part of the Evaluate stage of the Innovation Capability Improvement Methodology. This is done in a case study on a University.

The results from the case study are evaluated and validated, and this process is depicted below in Figure 2.

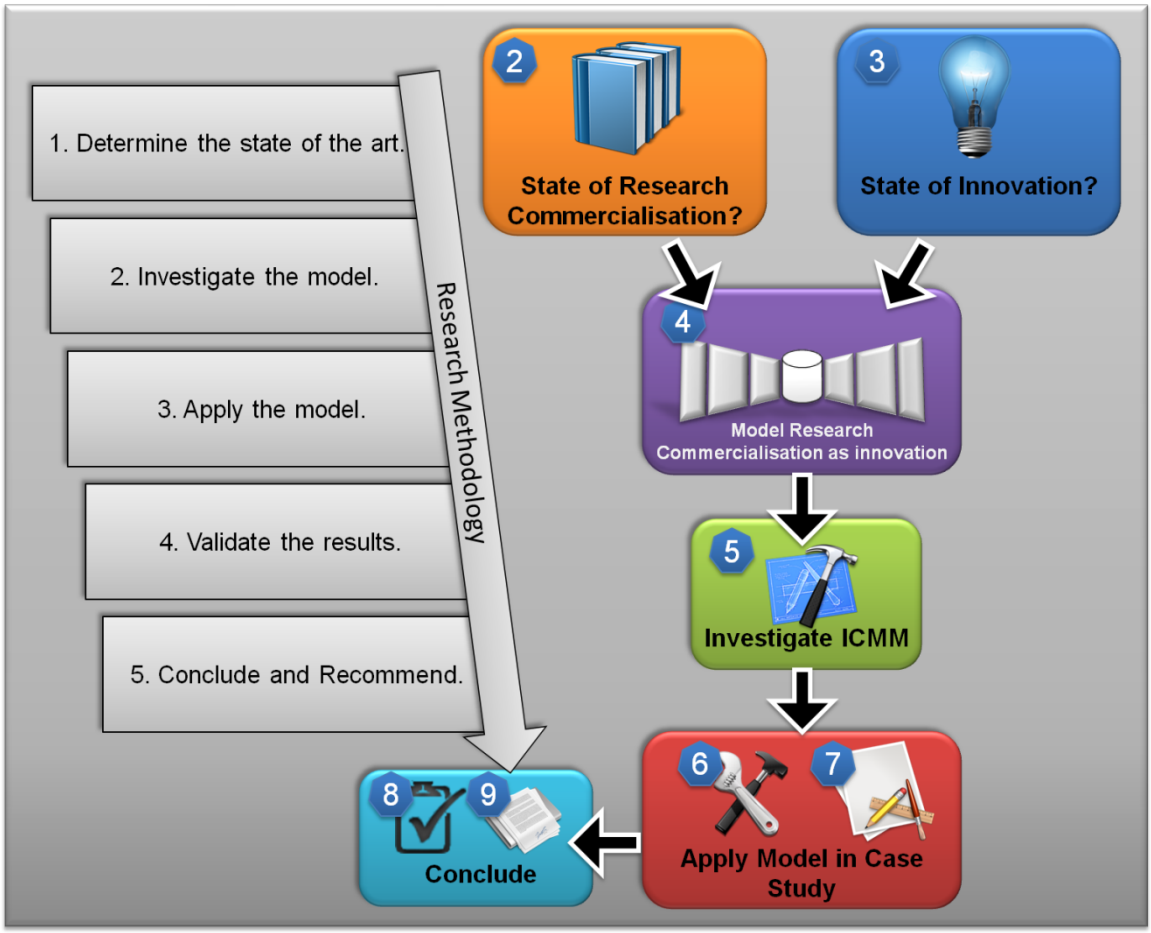


Figure 2 - Research methodology

1.4 Research Scope

For this research, the scope is divided into two parts. The first part that needs to be defined is the boundaries with regards to the application of the Innovation Capability Assessment or, rather, the unit of analysis. The second part will regard the extent to which the Improvement Methodology will be applied in the assessment.

1.4.1 Unit of Analysis

Many studies in literature have isolated the technology transfer office as the unit of analysis when attempts have been made to improve the research commercialisation process. Since this research acknowledges the influence of environmental factors from the outset, the University as a whole will be evaluated. This means that all the relevant role-players in the university system will be included, and their selection will be based on their particular influence on the process.

1.4.2 Application of Improvement Methodology

This process entails the execution of the Innovation Capability Improvement Methodology as presented by Essmann(1). The complete methodology is depicted in Figure 3 below.

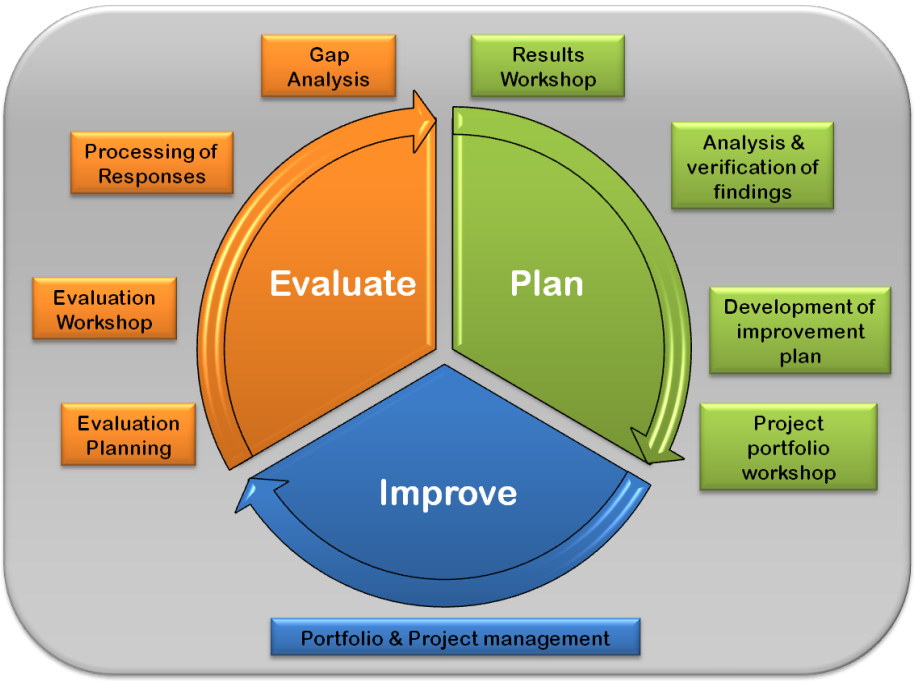


Figure 3 - Improvement methodology adapted from Essmann(1)

The first five activities will be completed – starting with *Evaluation Planning* and concluding with *Results* Workshop. The reason for this is that, up to this stage the procedure would be

generic for application to any organisations. The step entitled *Analysis and verification of findings* is a thorough, very resource-intensive activity, albeit it was decided that the value it could add to the results of the study would not be significant enough to justify the time and resources needed to carry it out.

Consequently, *Analysis and verification of findings* and all the subsequent activities are not deemed necessary to achieve the objectives of this study and would therefore be suggested as future research.

1.5 Expected Outcome

As stated previously, this research aims to determine, firstly, whether it is appropriate to measure a research commercialisation system with an innovation maturity model, and secondly, whether it is possible to measure a research commercialisation system with the Innovation Capability Maturity Model version 2.

It is expected that the ICMMv2 would be appropriate for measuring the research commercialisation system and that the ICMMv2 would also identify the shortcomings in the process with reasonable accuracy; the latter will be validated by the individuals involved in the execution of the process.

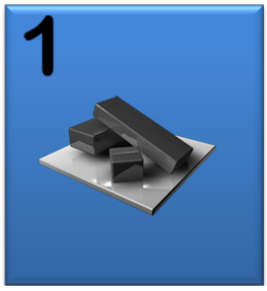
It is, however, not expected that an improvement initiative would be executed, as this would typically require resources beyond the means of this research. Another consideration is the typically protracted timeframe required to implement and track the effectiveness of improvement plans in the field of innovation. Given the timeframe allowed for this research, such an undertaking would be unfeasible.

1.6 Document Layout

To conclude the introductory section the layout of the document is discussed below. The layout and order of this research are presented in such as fashion as to provide the most logical flow. This is done in order to assist the reader throughout the document to understand the context of the specific section that is being read at any one time.

The logical flow is described by the figure below and more specifically the changes in the figure.

The following illustrations can be associated with each chapter and brief descriptions of the chapters follow below.



Chapter 1 - Introduction

This chapter provides the introduction to the research. It includes the problem statement, the research questions, methodology and scope.

The chapter concludes with a description of the layout and logical flow of the document.

Chapter 2 – Technology Transfer and Research Commercialisation Landscape.

The main objective of this chapter is to familiarise the reader with Research Commercialisation. To create the context, the first section introduces systems of innovation and the evolution of the university's role in them. This introductory section is followed by a discussion of the Research Commercialisation history, process and the factors that impact on the successful execution of the process.

Chapter 3 – Innovation Landscape

The aim of this chapter is to give a broad description of the innovation landscape. The understanding of the field of innovation will be essential when the fields of research commercialisation and innovation are brought together in Chapter 4.

The chapter starts with a definition of innovation, and continues with a discussion of some common drivers for innovation and the different categorisations of innovation. From there, the importance of research and consequently knowledge, for innovation, is discussed. The chapter concludes with an introduction to the different models of innovation.

Chapter 4 – Modelling Research Commercialisation

Chapter 4 will introduce the reader to the innovation models that are considered for modelling the research commercialisation process. Through deductive reasoning, the FuGle model is chosen and described in detail, while it is shown how research commercialisation can be modelled with this innovation model.

Chapter 5 – Innovation Capability: A Means

This chapter introduces the concept of maturity models and then explains their merit for process improvement.

In the latter part, Essmann's(1) Innovation Capability Maturity Model version 2 is introduced and comprehensively explained. This is done to give the reader insight into how the model works and is important as a foundation as it will be used in the subsequent chapters.

As the objective of the research is the application of the model, the Innovation Capability Improvement Methodology is also discussed in this chapter.

Chapter 6 – Preparing for evaluation

Chapter 6 considers the preparation for the evaluation of the innovation capability of a research institute. This preparation is performed in addition to the *Evaluation Planning* activity that Essmann(1) suggests as part of the Improvement Methodology.

Potential areas and causes of conflicts are discussed, before the chapter moves on to adapt the evaluation's methodology in order to eliminate these potential conflicts, or at least shape the context to accommodate them.

Chapter 7 – Case Study

In Chapter 7 the case study executed to test the ICMMv2 is discussed. This case study was undertaken as prescribed by the Innovation Capability Improvement Methodology provided with the ICMMv2, both developed by Essmann(1). All the activities in the evaluation phase are performed, as well as the *Results Workshop* in the planning stage. The goal is to provide a platform from which the university can improve the capabilities prioritised after the evaluation.

Chapter 8 – Suggested Enhancements to the ICA

In this chapter, some of the general observations that were made during the case study are summarised. Some of the issues that cause the low level of consensus are presented and recommendations are made to improve or illuminate these issues in future research.

Chapter 9 - Conclusions

Chapter 9 will conclude the research by means of a methodological conclusion and suggestions for future work.

2

Technology transfer and Research Commercialisation landscape

The main objective of this chapter is to familiarise the reader with Research Commercialisation. To create the context the first section will introduce systems of innovation and the evolution of the university's role in them. This will be followed by a discussion of the Research Commercialisation history, process and the factors that impact on the successful execution of the process.

2.1 National Innovation Models

Long before the emergence of the 21st century's "knowledge-based economy", knowledge was identified as a prerequisite to ensure a competitive advantage for companies and (to a larger extent) countries, because of raging global conflicts. The focus was not only on creating knowledge, but the real issue of *using* that knowledge to innovate and add value.

Facilitating the successful creation, transfer and use of knowledge was – and still is – high on the agenda of international governments. Governments realised that the higher education system can be a strategic asset in this regard, if linkages with industry can be strengthened and the process of technology transfer from universities accelerated (4) A systems approach was deemed appropriate to describe, understand and manage the environment that would facilitate this process from the government's perspective.

Boulding (5) states that, in its broadest sense, a system is "anything that is not chaos". A system can be described more specifically as a number of elements and the relationship between these elements. From this definition it seems appropriate to use systems thinking to model and understand a national innovation effort, because it can be characterised as a system. Accordingly, National Systems of Innovation were introduced in order to increase a country's global competitiveness, the objective being the organisation of innovation on a national level.

Many governments have tried to facilitate the creation of interactions between the entities needed to foster innovation by means of policy adjustments. Over the years, scholars have tried to describe these systems by focusing on the interactions between the three major role-players (or institutional spheres): government, industry and academia.

Etzkowitz et al. (6) describe the evolution of the policy models employed by different governments to facilitate interactions between the three spheres. The following sections will discuss this evolution of models used in an effort to manage innovation on a national level.

2.1.1 Linear model of innovation

After the Second World War (WWII), Bush (7) stated in a report to the President of the US that universities are key in generating basic knowledge that will eventually spur innovation. This linear model of the innovation process suggested that the funding of basic research was both necessary and sufficient to promote innovation (4).

A similar model was employed under socialism. The crux is that governments direct interaction between industry and universities in these models. A simplified illustration of the structure of these models is presented in Figure 4 below.

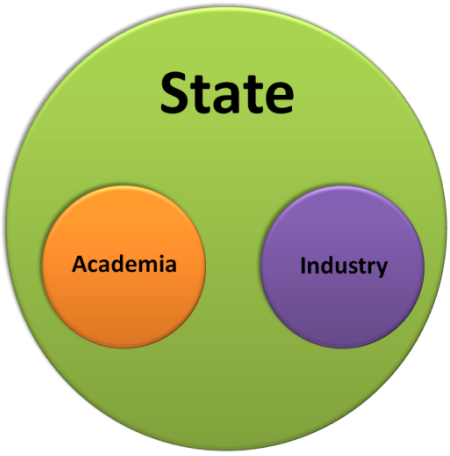


Figure 4 - Model of innovation under socialism, adapted from Etzkowitz and Leydesdorff (6)

2.1.2 National System of Innovation

The second generation of models emerged as a result of increased governmental focus on industrial competitiveness. In the 1980s heightened competition from developing economies such as China and Japan forced the US government to rethink its economic strategies (6). The need to build economies that produce jobs and wealth for a country's inhabitants became paramount and increased collaboration between industry and academia was identified as a requirement for this much-needed economic growth.

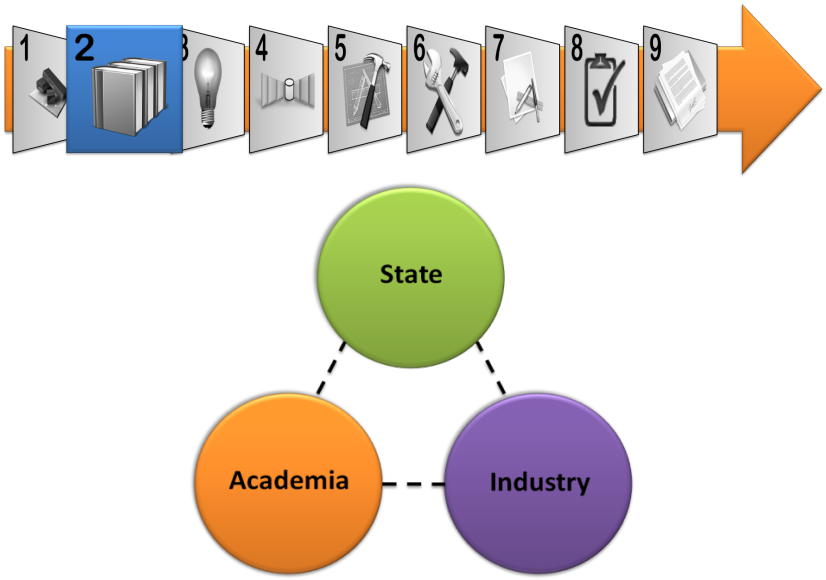


Figure 5 - "Laissez-faire" model, adapted from Etzkowitz and Leydesdorff (6)

In regard to structure, this model consists of the same three institutional spheres but government has taken a step back and instead of controlling and managing the interactions, it encourages them. This is illustrated in Figure 5 above, which shows all the institutional spheres in partnership rather than one governing the other.

A more descriptive model was developed in the 1980s to supplement this view. The aim was to try to explain the interactions more accurately and find indicators which can support the creation of policy to encourage the formation of partnerships between the spheres of government, industry and academia. Subsequently, the National System of Innovation (NSI) approach was conceived.

The term NSI was coined by Freeman and Lundvall in the 1980s and further groundbreaking research in this field was carried out by Nelson in 1993 (8). These researchers defined NSI as:

- “the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.” (9)
- “the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge.... and [are] either located within or rooted inside the borders of a nation state.” (10)
- “a set of institutions whose interactions determine the innovative performance of national firms.” (11)

In general, national systems of innovation can be seen as a network of interacting public and private organisations and institutions within a specific country’s boundaries, whose actions nurture the creation and diffusion of new technologies within the country. The innovative performance of a country depends on the dynamics of the interactions between the

components and the components' relation to each other as a collective system. This interaction is represented in Figure 6.

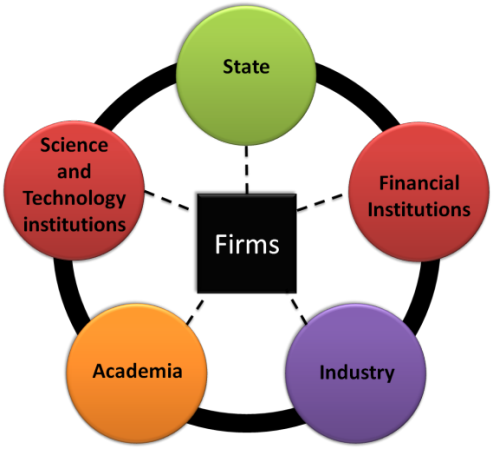


Figure 6 - National System of Innovation, adapted from Smith(12)

One quickly realises that the NSI systems approach to describing relationships between organisations and institutions within national boundaries gives the firm a central role in the system. The NSI essentially focuses on improving the competitiveness of firms and, consequently, economies. Universities and other entities are seen to perform a supporting role in fostering national innovation.

2.1.3 Triple Helix Model

Etzkowitz and Leydesdorff (6) concluded that, today, in the knowledge-based economies that are a hallmark of the 21st century, the connections and networks between the three spheres have become so complex that simple linear models of innovation have become too simplistic to explain the new knowledge exchange landscape. Therefore, they propose that the international knowledge community shifts its attention away from the National Systems of Innovation approach, where industry is privileged, and the triangle model, where government is the driver, towards a triple helix of interaction between the spheres of university, industry and government. In this triple helix the three spheres are in a true partnership and any one of the spheres can take the initiative, drive a project and involve the other two.

In this model, all three institutional spheres are tightly interwoven with a spiral pattern of linkages emerging at various stages of the innovation life cycle.

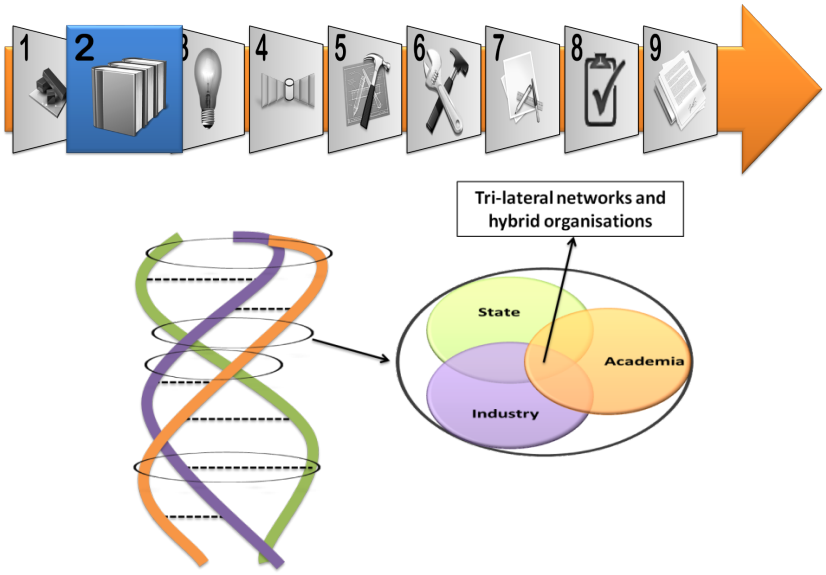


Figure 7 - Triple helix model showing tri-lateral connections, adapted from Etzkowitz and Leydesdorff(6)

Figure 7 illustrates this triple helix model and the complex nature of the interactions and relationships.

Etzkowitz (2) states that this triple helix model has identified four processes related to major changes in the production, exchange and use of knowledge. These processes are:

- The internal transformation in each of the helixes (formerly spheres);
- The transformation that the helixes initiate amongst each other;
- The trilateral linkages that are occurring (Figure 7);
- The recursive effect of these inter-institutional networks representing academia, government and industry, both on their originating spheres and on the larger society.

Central to this section is the understanding that the role of universities is changing from the traditional ivory tower to a more entrepreneurial entity that is an essential part of a national system of Innovation or Triple Helix, however it may be portrayed. The frequency of interactions with industry and government is increasing on different levels and in different modes. The objective of this interaction is to transfer the knowledge that is created through research to the industry in order to increase national competence, grow the economy and solve social problems.

To fulfil this need effectively and stay relevant in the modern global economy, universities have to evaluate their mechanisms of transferring knowledge and improve them to effect successful innovations that can contribute to economic growth and social upliftment.

2.2 Origins of Research Commercialisation

Technology Transfer between University and Industry specifically, has been around for many decades. In its traditional form, it includes interactions or the sharing of knowledge from academia to industry on platforms such as:

- publications;
- conferences;
- co-operation in graduate education;
- advanced training for organisational staff;
- periodic exchange of research staff between research institutes and companies;
- consulting;
- graduate exchange programmes;
- and a host of other informal technology exchange modes (13).

It is important to realise that technology transfer is not a unidirectional flow of information from universities to industry as conventional wisdom suggests. The feedback loop from industry allows university scientists to evolve their thinking by sparking new ideas or refining their experiments (14).

Research commercialisation emerged as a sub-division of technology transfer purely as a result of legislative changes in the US during the 1980s, which encouraged universities to evaluate how they can more effectively transfer technology to industry. It would not be the first time universities had to do some introspection.

"*The University of the future is one that can successfully align the traditional academic missions of teaching and research with the third mission of economic development*" (2). This transition is known as the second academic revolution, the first being the introduction of research as a university mission in the late 19th century. The third mission implies that universities must play an active part in the innovation systems of a country, whether the system is explicitly defined, as in leading first world countries, or not, as in some developing countries (6).

As stated earlier, the innovation gap in the US industry became apparent due to the rise of competition in the industrial crises of 1960s and 1970s. This highlighted the need to commercialise or diffuse to the industry the research results and practical outcomes accumulated in academic institutions over the years as a result of a focus on basic research.

This revelation led to the creation of a new legal framework known as the Bayh-Dole Act of 1980, which standardised patenting rules for universities and small businesses. It assigns intellectual property rights arising from publicly-funded research to the parent universities.

The institution of Bayh-Dole spurred the creation of technology transfer offices (TTOs) at universities to transfer technology and knowledge to industry (2), in order to generate financial gain for the parent university and promote economic development. The creation of these TTOs was not the explicit purpose of the legislation but rather an unanticipated consequence (15). The TTO is the vehicle in the university assigned the job of transferring technology to industry.

The success of the Bayh-Dole legislation has since been widely debated and researched, and some observers have stated that it has had no determinative effect on patenting and technology transfer in America, and that the technology would have been transferred even in the absence of such legislation (16). Others argue that the Bayh-Dole Act had a definitive effect, but that a host of other factors also played a major role in the success experienced by American universities in commercialising research (17). Literature also warns that the overstated success of the legislation could leave developing countries with higher expectations regarding monetary returns than they would likely receive (18).

Nonetheless, many universities in various cultures are forced by their new environment to create or change internal and external structures to maximise their innovation capability (2).

The United Kingdom was the first other country to emulate the American shift towards commercialisation, with a change in its public research funding policy. Funds for research would be distributed based on the effect of the research results on the economy, rather than purely on the publication output of universities. This change in policy has forced universities to undertake more research that would be likely to generate income or attract industrial funding. In 1985, universities were given the right and responsibility to commercialise research to supplement their coffers and contribute to national wealth. This process necessitated the creation of liaison offices, similar to technology transfer offices, and incubator firms.

On continental Europe and in Latin America, universities were traditionally controlled by the governments (triangle model). This control caused a delay in the need for these institutions to become more entrepreneurial, because they were sufficiently funded by their governments. As the universities gradually started gaining independence and government

funding decreased, a need for change was identified. In Europe, the European Union initiated a support fund for the establishment of liaison offices, which prompted universities to create such intermediate institutions. In Latin American, the government is currently stimulating university-industry collaboration through a range of monetary incentives for organisations engaging in such collaboration (2).

Post-WWII economies in the Far East, for example in Japan, have also been trying to re-establish university-industry collaboration. In the pre-war era, these linkages were mainly between researchers and the military industry. During the post-war occupation by the US, these linkages were cut, but recently Japanese universities have started to re-emphasise connecting with industry to grow the general economy. While the universities are trying to build a more highly skilled workforce than was required before the Second World War, because companies had their own internal education programmes, they currently also need to focus their research on areas with industrial relevance. This is not a painless task, but it is easy to imagine that the Japanese academic sphere will return to its pre-war prominence as an international source of economic development (2).

Lastly, South Africa, a developing economy and the leader on the economic front in Southern Africa, is a late joiner to the international trend of research commercialisation, with changes in government policy in 2008. Commercialisation efforts have been implemented in several universities (such as Stellenbosch University and the University of Cape Town) some years prior to the act, but without government support progress has been slow. This again emphasises the fact that participation and the alignment of objectives of all the spheres are necessary to transfer technology in a successful manner.

The fact remains that the effective creation and application of knowledge is a prerequisite for sustained economic growth and social upliftment in developing countries, and the higher education system is a key role-player in the modern knowledge-based economy. This has underscored the importance of creating ability at South African universities to transfer their research and capabilities to industry in a way that adds value for all partners involved.

While many other countries not mentioned have also implemented policies inspired by the Bayh-Dole Act, experience has shown that the so-called ‘blockbuster innovations’, such as the use of Taxol as a cancer therapeutic (50), that has brought in millions of dollars for Florida university, are few and far between (19). The distribution of wealth from patenting is heavily skewed internationally with only a few universities reaping the bulk of the returns (3).

When further studying the international evolution of research commercialisation and the ways in which universities, government and industry adapted to the changes and requirements of this dynamic process, one can conclude that creating a system that works efficiently in a specific environment is a co-evolutionary and iterative process (20). This statement will be sufficiently substantiated in later discussions.

2.3 The Research Commercialisation Process

"*Leading international universities are not only characterised by the amount of A grade researchers they employ or by the number of graduates they produce, but also by the contribution that they make to society and the broader economic environment. What distinguishes these universities from their peers is their ability to provide effective solutions to real world problems, whilst reaping the benefits associated with this approach.*" (21)

This statement by a manager of the TTO at Stellenbosch University emphasises the fact that leading South African universities are embracing the third mission of social economic development by putting structures in place to commercialise their research.

The process of research commercialisation is not clear-cut. There are numerous factors that will have a considerable influence on the success of transferring technology to industry efficiently. One should note that success is ultimately defined by the goals of the institution that is undertaking a mission such as research commercialisation, and this will be discussed later.

Ultimately, the technology transfer office, liaison office (Europe) or technology licensing office (US) is at the heart of the classical commercialisation effort in a university. The other two major role-players in the university are the university management, as they influence the environment in which the TTO operates, and the university researchers, because they provide the research.

Research commercialisation in its most basic form can be depicted as a linear process, but the reality is quite different. The processes that lead to the successful commercialisation of research are much more intricate than the simple linear process model presented in Figure 8, but this model will suffice as a introduction to the topic.

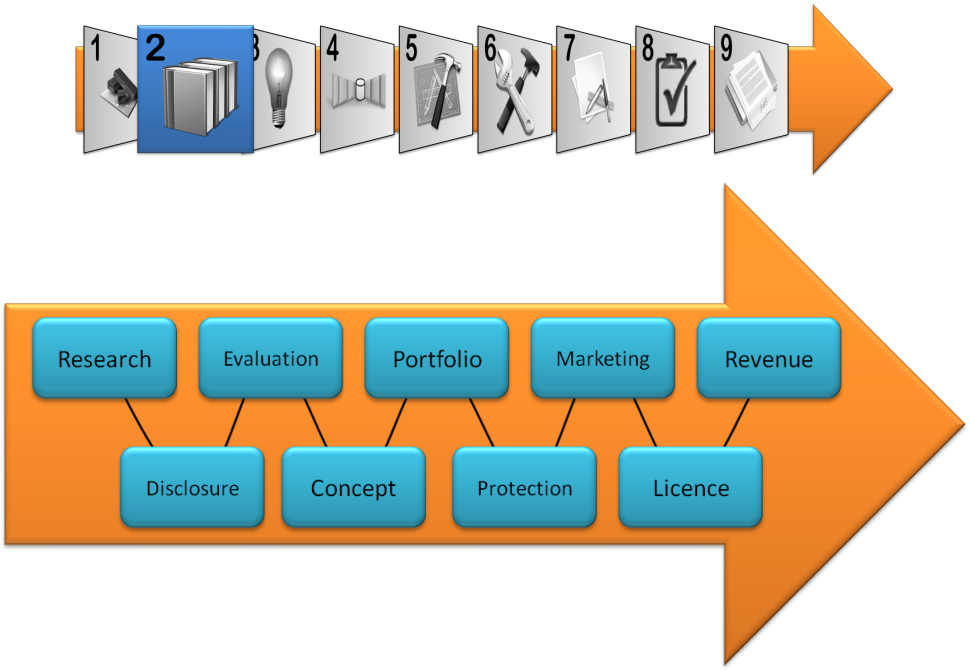


Figure 8 - The University/Industry technology transfer process

The research commercialisation process, its activities, inputs and outputs will be discussed in the light of a literature study on the matter. It should be noted that a substantial amount of additional insight into the process of structuring the activities in each stage was obtained by evaluating a generic business process model of the university research commercialisation process, developed by Johnston et al. (20).

Each step in the process will be discussed below, starting with research and continuing through to the eventual generation of revenue.

Research

Research is done by the scientist in a specific research field. The research topic can be selected based on pure interest or a presumption that economic value may be derived from it. Literature often splits research into basic/fundamental and applied research. “Basic/fundamental research” can be defined as research that is done to advance the knowledge frontiers and “applied research” as research that is more closely related to market need. At this stage, it will be assumed that both these research types have equal commercial potential, but the issue will be discussed later in more detail.

Disclosure

In the absence of a TTO function that scans the university’s research portfolio, the output from the research stage is a disclosure to the TTO by the researcher. The disclosure is typically a standard form which the researcher needs to complete and submit to the TTO. A researcher would additionally be able to convey tacit knowledge of possible commercial opportunities and this would also be captured in documentation. The disclosure contains

information about the discovery made or research being done by the researcher. This document is the main source of information for the TTO to make a decision on whether to continue towards the assessment stage or reject the idea.

Evaluation

In this stage, the TTO evaluates the research presented for patentability while also doing patent database searches. The decision to patent is also dependent on the stage of the research development process itself. It has been found that research in embryonic stage of development is rarely commercialised without Intellectual Property (IP) protection (22), while research that has made greater progress with respect to maturity could be successfully commercialised without protecting the IP. Provisional patenting can be done at this stage. Seed capital can also be made available to fund proof of concept activities at this stage before the process resumes.

Concept

In the concept stage, the researcher and TTO staff work together to create a concept. A concept is defined by the New Oxford American dictionary as an idea or invention to help sell or publicise a commodity that was developed or produced as an experimental model to test the viability of new design features.

In this context, a concept is a physical conceptualisation of an idea that enables the execution of various feasibility and other relevant analyses. This includes physical prototypes, models and pilot plants.

Activities include:

- Concept design
- Business plan development
- Feasibility (Technical, Financial, etc.)
- Risk assessments
- Market research
- Preliminary industry partner identification

A final concept will integrate all these elements to constitute an output that is ready to be used or sold and thus ready to be included in a portfolio earmarked for further capital investment.

Portfolio/Option selection

In this stage, the TTO evaluates the concept against other concepts and against its own investment criteria. It is important to note that the reason this stage is presented in the sequential process flow is to emphasise the fact that typically there are huge financial investment implications when moving on to the following stages. Portfolio management is actually used throughout the whole process, especially in the selection of ideas, but also in all the other instances where decisions are made about some form of resource commitment.

Protection

In the protection stage, the intellectual property is fully protected by IP lawyers if it is deemed necessary for the successful commercialisation of the idea. A significant amount of financial resources is often needed in this stage for legal costs and to pay patenting fees.

Marketing

Marketing the technology to the industry is a very important function of the TTO. In this regard, the TTO requires extensive marketing experience and good industry networks. The knowledge researchers have about their research and its market potential is very important, especially in the absence of a large network, which is typically the issue with small or young TTOs. The researcher is a very important source of information on possible “buyers” for the research. This is not hard to imagine since one would expect researchers working in a certain research field to have grown a network of industry contacts that would prove invaluable to the commercialisation process. Lastly, marketing can be done to existing companies, or a start-up company can be conceived if the research or innovation is deemed sufficient.

Licensing

Thus, commercialisation can either entail licensing technology to existing companies in return for royalties, or starting up a new venture. Firstly, there are many licensing options which include exclusive and non-exclusive licences and it is left to the discretion of the TTO to determine which option would be the most appropriate. In the case of a start-up company, TTOs also typically provide access to their venture capital networks and incubator services. Incubator services may include, financial, legal, administrative and even managerial support. The creation of spin-off companies additionally entails activities such as entrepreneurial skills training and business plan development which the TTO usually provides, depending on

their specific mandate. If the researcher lacks the entrepreneurial skill set or the drive to leave academia, an external entrepreneur can be approached to build a company around the research/technology.

Revenue

The last stage is the generation of revenue from the process and this can either take the form of royalties from licences, or assets such as equity in the newly-created start-up companies. An obvious question arises: "Who gets the money?" This issue is handled by royalty/equity distribution formulas stipulated by the parent university. These formulas are generally regarded as important tools for incentivising researchers to commercialise their research.

Summary

It is important to note that this is a very simplified illustration; there can be – and typically there are – many extra tasks involved in the execution of the commercialisation process. The TTOs often depict the process as a series of steps with decision gates to explain it to the researchers.

In summary the main outputs of the research commercialisation process as undertaken by universities are:

- Licensing agreements – an authorisation by a university for the use of its Intellectual Property by a specific or multiple industry partners, in return for compensation. There can be an expiry date on the licence.

- Spin-off/Start-up companies – companies established by a university; companies that have an equity investment from a university; companies created by university employee or as a result of licensing technology from a university (23).

- Research contracts – a formal agreement between a university and a company which stipulates that the university will perform research for that company in return for compensation.

2.4 Role Players

There are four major role-players in the research commercialisation process. Three of these are in the university, and industry is defined as an external recipient in the process. The structure, responsibilities and requirements of these four role-players will be discussed in

this section. Firstly, it would be valuable to evaluate an illustration of the internal role-players in the value chain of research commercialisation from a generic perspective.

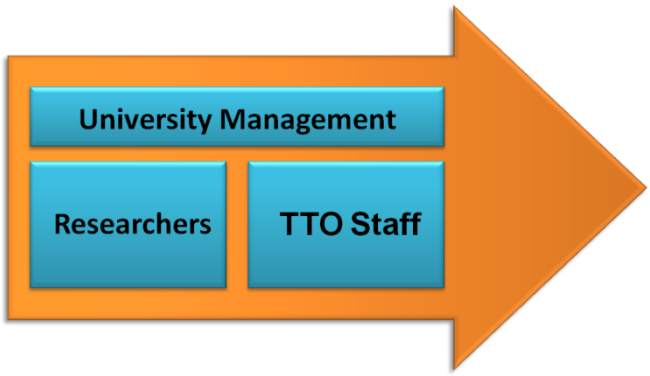


Figure 9 - Research commercialisation role-players

Figure 9 demonstrates that the Researchers and the TTO are central to the process, while university management plays a supporting role. Industry is a customer to the process and its role will also be discussed, because it plays a defining role in the successful commercialisation of research. Other supporting role-players will be identified later in a case study.

2.4.1 Technology Transfer Office

The TTO acts as a dual agent for university management and faculty (researchers); both play a major role in shaping the strategy of the TTO as far as the mode of output (24) is concerned. To satisfy all the stakeholders, it is clear that the staff of a TTO must possess a unique interfacing skill set.

2.4.1.1 Structure of the TTO

Firstly, the positioning of the TTO within the university will be discussed. Secondly, Bercovitz et al. (25) found that the structuring of the technology commercialisation effort affects the performance of the technology transfer effort in a predictable manner, a discussion will follow on the different types of organisational structures.

The technology transfer office is at the centre of the international research commercialisation industry and according to Markman et al. (26), the common TTO can be housed in the university in three different ways, also defined as the TTOs mode of operation.

a. Traditional University Structure

In the traditional way of structuring the commercialisation processes, the TTO is run as a department of the university. This department usually falls under the jurisdiction of the vice-

chancellor of research and the budgetary obligations are fulfilled by the university's research division. The staff is made up of untenured university staff. Their main objective is to pursue conventional licensing opportunities for royalty income. This form of organisation is tightly monitored by university administration, which limits the decision-making ability of TTO managers.

b. Non-Profit Research Foundation

In this structure, the TTO is a separate entity outside the university structures. These TTOs have their own Board of Directors which is often chaired by a university vice-chancellor. This limits a university's liability towards intellectual property infringements, lawsuits from licensing disputes and future liabilities with regard to products or services developed from the university's licensed technology. The TTO also enjoys full budgetary autonomy and this structure provides for more flexibility regarding incentive structures and licensing strategies.

c. For-Profit Private Extension

This form of organisation has an independent CEO and a Board. It is staffed by personnel with extensive experience in IP law, business plan development and venture capital acquisition. The TTO can have a strong focus on economic development and the creation of start-up companies. These TTOs also enjoy full budgetary autonomy and have the most flexible incentive structures, distribution formulas and licensing strategies. The university enjoys limited legal liability, as with non-profit research foundations. This form of organisation is by far the most conducive to the generation of spin-off companies.

The most important structural considerations can be summarised as follows:

- The reporting relationships
- The degree of functional autonomy

As stated earlier, Bercovitz et al. (25) suggested that there exist an additional four ways of structuring the technology transfer effort itself after it has been decided how to position the TTO within the university. Four types of structural configurations are identified based on Chandler's (1962, 1977, 1990) characterisation of different types of organisational structure identified during his research on the evolution of modern business enterprises. The four types are:

- U-Form (Unitary form) – This is a very hierarchical structure which places the decision-making authority with university administration. Top management sets the goals and strategy, and oversees and coordinates the efforts of individual units.

- M-Form (Multi divisional form) – This form decomposes the organisation into semi-autonomous operating divisions along functional lines, such as customer, product or geographical functions. A central office monitors and coordinates the individual divisions.
- H-Form (Holding company form) – This form also has a divisional structure but relies on a weaker central office than the M-Form.
- MX-Form (Matrix form) – This form of organisation operates with a functional and product hierarchy simultaneously. In this form, a subunit is responsible for multidimensional functions.

These different structuring options have a predictable effect on (25):

- Coordination Capability
- Information Processing capacity
- Incentive alignment

Accordingly, one must align the type of structure chosen with the strategy and objectives of the commercialisation programme within a university to execute the activities required to perform the process efficiently. One can also evaluate retrospectively whether the prevalent structure is sufficient to achieve the designated strategy.

2.4.1.2 Responsibility and Requirements of the TTO

TTOs should act as a boundary spanner or interface specialist between the different role-players in the commercialisation process. Within a specific university internal boundaries exist between role-players such as the researchers and university management. External boundaries separate industry, government and the university.

Polt et al. (27) found that most TTOs in Europe are rather small and as a result, they struggle to create industry science links (ISLs). He noted that some of them still manage to outperform the rest, despite the challenges they face in this regard. Factors that typically distinguish them from other less successful TTOs are:

- their focus on combining basic and applied research within research teams, and regularly auditing the research strategy of the group in order to cope with changes in economy and society;
- their day-to-day proximity to the researchers themselves;

- their emphasis on building the complementary assets needed for the research groups to be effective in their ISLs (contract law, intellectual property management, spin-off development, access to venture capital, etc.);
- the design of sufficiently attractive individual remuneration packages that reward successful transfer activities.

These factors can be translated into the role a TTO should play – in other words, the critical functions a TTO should perform and the services it should provide. Typically, the most important and fundamental functions are the complementary services they provide, which support researchers through the commercialisation process. In addition to those stated above, there are services such as business plan development, entrepreneurial training for researchers and expertise in the technology marketing field.

It is evident that the personnel in a TTO should possess the relevant interfacing capabilities to successfully integrate the needs and requirements of all the role-players, and a host of other skills to close deals with industry successfully. These requirements can all be hugely influential in the successful execution of the commercialisation process and will be discussed more extensively in Section 2.5.3.

2.4.2 Researchers/Scientists/Faculty

This section will explain the structure in which the researchers reside and their responsibilities concerning research commercialisation.

2.4.2.1 Structure

The structure in which researchers finds themselves is essentially determined by the university management. In the late 19th century, at the time of the first academic revolution, research was introduced as an additional mission of the university, which had traditionally focused on teaching alone. Accordingly, the German university model of one professor representing a single discipline broke down, and it was replaced by departments with relative autonomy and professors taking on research responsibilities rather than just teaching (28). Over time, this structure has evolved further to a stage where professors are running research groups assisted by graduate students and taking on large research projects.

This research group orientation can be – and nowadays *is* – gradually implemented in universities which have traditionally opted for an organisational structure that some may call professional bureaucracy, marked by faculty and departmental boundaries or silos (13). This traditional structure can be a barrier to commercial initiatives.

The research groups have essentially become firm-like entities. The only thing that distinguishes them from companies is the lack of direct profit motivation. The shift is most obvious in the sciences, where the research groups have superseded the professor-student dyads as the primary organisational mode (28). The shift towards a matrix structure, as explained in section 2.4.1.1, is the next step in the evolution towards a more entrepreneurial culture within the university. This MX-form allows research groups to be actively involved in the commercial exploitation of their research. This implies that accountability with respect to revenue and expense generation resides at group level. This could be an added incentive to partake in commercial activities.

Another advantage of a group orientation is that it can incorporate research of a multidisciplinary nature, since most solutions to modern industrial problems demand input from multiple research fields. This is what essentially gives university research as a product, the competitive edge as opposed to the research of other research institutions and the internal R&D activities of companies. This sentiment is echoed by the Organisation for Economic Co-operation and Development (OECD), who noted that, because science-based innovations increasingly have a multidisciplinary character and are built on “difficult to codify” people-centred interactions, university-based research initiatives combining basic and applied research with the broader education mission are enjoying a competitive advantage over other research institutes (13).

Researchers themselves admit that there seems to be a conflict in modern universities, where researchers often seem to operate more autonomously where entrepreneurial activity is concerned, while still being confined to some extent by the hierarchical university structures and restricted by the shrinking research budgets. This statement is supported by Kenny and Goe (29), who found that institutional history, culture, and regulations of the larger university in which researchers find themselves, influence professorial entrepreneurship and involvement with industry. Their research suggests that an individual embedded in a department that supports the formation of industry links and the pursuit of entrepreneurial activities can counteract, to some extent, the disincentive or lack of support of the larger university for pursuing such activity.

2.4.2.2 Responsibility and Requirements

A high-quality faculty, which achieves a balanced mix of basic and applied research, is very important to any university’s research commercialisation efforts. Reaching scientific excellence is an important first condition for a successful commercialisation programme and

for university research to appeal to the industry (13). Mansfield (30) also found that the reputation of a university's quality of research directly correlates with the likelihood that the industry would approach and collaborate with that university.

Traditional thinking argues that universities, especially in developing countries, need to focus increasingly on, and on a larger amount of applied research in order to increase the opportunities for commercialisation and provide solutions for current problems. This relates to the "skewing problem" which states that corporations will corrupt university research agendas in the long term if commercialisation remains a mission. This sentiment is supported by some literature which found that universities that embrace the third mission of economic development through research commercialisation tend to focus more on applied research than on basic research (31). This also suggests that there is a trade-off between the amount of basic and applied research that can be done by an institution, and universities should split their labour to pursue both forms of research efficiently (32).

A host of studies have found that pursuing commercialisation activities and more applied research actually enhances basic research output or at least does not influence basic research output negatively (33) (34) (35) – a fact that illustrates the first of many contradictions in research commercialisation literature. Some authors even suggest that researchers who participate in commercialisation activities (academic entrepreneurs) typically have a higher publication output than their peers (36). Many similar ambiguities in international literature will be discussed in the next section.

In addition to research, another important responsibility of researchers is to disclose their research to the technology transfer office. This obligation is enforced by law in many countries that have adopted Bayh-Dole type legislation, but it is also incentivised in most cases. Robert et al. (37) found that, although many researchers generate ideas with commercial value, not all of them will act to commercialise these ideas. He argues that commercial behaviour is related to the background and experience of the individual. In a sense, this finding is echoed by research that shows older faculty has a higher propensity to patent research, indicating that experience plays a part (38).

Researchers are often required to team up with the companies that license their outputs to provide expertise and support, as the technology often needs to be developed further by the companies themselves to reap the benefits in the market (39).

Literature agrees that researchers need to be incentivised to elicit disclosures and have them engage in entrepreneurial activity. To this end, royalty and equity distribution formulas play a major role (40); individual incentives to become an entrepreneur, such as attractive tax rates (41) and recognition of commercial activities in promotion paths, as well as tenure decisions within the university structure (42), are also critical issues.

2.4.3 University Management and Administrators

In this section, the influence that university managers can have on the structures of the university and their consequent influence on the commercialisation process will be discussed. Many issues that are relevant in this section have already been touched upon in previous sections, but here they will be discussed in more detail.

Modern research commercialisation is essentially an evolving phenomenon, and governments regularly initiate policies that encourage universities to take on an increasingly entrepreneurial role. This implies that the landscape is dynamic and consequently accompanied by change. For universities to be successful they need to adapt to changes in their new environment and this will influence their structure and culture. Strong leadership is often the most important factor for implementing change successfully. The subject of change management is beyond the scope of this research, but the need for it will be emphasised. Visionary leadership is crucial in order to remove the hurdles that may appear on the path to restructuring for successful commercialisation, but Thomas Kuhn's words are as true today as they were in 1962: "There is no smooth path for any paradigm change" (43).

Leadership shapes the internal landscape(within the university) in which the TTO and researchers operate. They have a significant influence over the structure and culture of the university and their actions can promote or impede research commercialisation.

Some scholars have identified the structure of the traditional university as a huge barrier to research commercialisation. Professional bureaucracies should make way for divisional structures with a mission to exploit the university's "know-how" (13). The changes in international government policy have also created some confusion regarding the role of the university. Merely changing a university's organisational structures will not be sufficient to transform a university into a more entrepreneurial version of itself. The proverbial elephant in the room is the adaptation of the mission and the culture of the university (44).

Entrepreneurial activity should be an explicit mission of a university in conjunction with its traditional missions of teaching and research. If universities get the balance of these missions right the missions may actually reinforce each other (45).

Culture is the last potential barrier on which management can have a distinct impact. There are two issues regarding the culture. The first issue is the internal university culture concerning commercialisation. According to literature, this issue can be resolved with appropriate incentive structures (39). The second issue, which relates to the next section, is the differing cultures of academia and industry. Cultural barriers will be extensively discussed later in this document, but at this stage it would be worthwhile to mention that a proactive exploration of and attempts to understand all the stakeholders' cultures can prevent serious issues from occurring (42).

2.4.4 Industry

One of the core competencies of a TTO should be the marketing of its patent portfolio and unpatented research to industry partners and, they should focus both on local companies to promote regional economic development and international organisations. To do this efficiently, it would be useful to evaluate the reasons why firms would source technologies or collaborate with universities.

Markman (46) states that external sourcing of basic and applied research is important to firms for three reasons. Firstly, it improves a firm's absorptive capacity; secondly, it lowers search cost; and lastly, it reduces the risk of technological and market exclusion. These and similar drivers for collaborations, such as lowering research costs and staying abreast of recent technology, are cited throughout literature. When looking at developing countries specifically, firms should recognise that they can use research commercialisation as a vehicle to improve their technological capabilities, which should eventually enable them to compete at the cutting edge (47). They can often find the technologies they need to spur innovation within local universities.

An important observation made by Powel et al. (48) illustrates that the locus of innovation is shifting. With the knowledge base of industry becoming ever more complex and the sources of expertise more dispersed, the locus of innovation will move to networks of learning rather than being contained within the boundaries of individual firms. This shift underscores the need for firms to collaborate both locally and internationally.

A critical issue that seems to persist, especially when trying to transfer technology to local industry, is the “absorptive capacity” of firms or rather the capacity of firms to learn (49). Literature has therefore suggested that government not only focus resources on the university side of technology transfer, but also try to empower Small, Medium and Micro Enterprises (SMMEs) to enable them to use technology from universities (50). These SMMEs should be enabled to formally search for the technology they need or build networks through which they can gain access to the required technology.

Harmon el al. (51) found that industry rarely does formal searches for new technology. Researchers in firms with in-house R&D capability seem to be the only ones doing formal searches and usually their only motivation is a desire to keep abreast of the latest technological developments in their own fields. This suggests that marketing from TTOs might be insufficient and personal relationships or networks with firms are the way to move forward, a fact supported by results from Harmon et al. (51), who found that 80% of technology transfer activities in their study were initiated by longstanding relationships between the parent university and the industry partner.

Another problem facing industry is the fact that university technologies are often too immature to create immediate value in the market place, thus extensive further development is often necessary (52). This obviously involves a great deal of risk for industry partners and universities need to understand this.

The last, but probably the most important, barrier to successful technology transfer can be the immense difference in academic and corporate culture (53). University culture is a grossly under-researched area compared to the amount of research done to understand corporate culture (43), but it is not hard to imagine that tensions may arise when merging two spheres where the perception about the importance of the bottom-line is so different. This will be discussed further in section 2.5.2.4.

2.5 The Research Commercialisation Landscape

This section provides an explanation of the research commercialisation landscape. All the factors found by international literature to influence the research commercialisation process will be discussed from a broad perspective.

It will be helpful to mention upfront that this field of research is still very much in an embryonic stage, compared to more established research areas such as Economics and Strategic Management, and therefore many contradicting views and results can be found in the literature (43). These contradictions also stem from the fact that as of yet, much of the research has been carried out in developed countries with a very localised view. The maturity of the research commercialisation phenomenon in each of these countries also plays a defining role in shaping the results of the various research studies. Firstly, a short discussion will follow on how the section is structured.

2.5.1 Organisation of Literature

To guide the reader through the research commercialisation landscape, structure will be drawn from the amalgamation of a framework created for the synthesis of research commercialisation literature and a model for managing innovation. These two elements will first be discussed, and the synthesised framework used in this chapter is illustrated later by Figure 11.

2.5.1.1 Framework of Impacting Factors

The first framework was developed by Rothaermel et al.(43) and is used in this research as a guideline to identify and structure all the factors that impact on the commercialisation process. Rothaermel et al. (43) developed a taxonomy of literature in an attempt to organise the current international literature on the research commercialisation process. Their objective was to produce better suggestions for future research and provide guideposts for international policy makers.

The research of Rothaermel et al.(43) showed that there are four emerging streams of research in the research commercialisation area:

- Entrepreneurial research university
- Productivity of technology transfer offices
- New firm creation
- Environmental context, including networks of innovation

These research streams will be incorporated in the discussion while considering their relevance to the scope of this research. In addition, the researcher will also add topics as deemed appropriate by means of insights obtained during the research. Insights gained from literature published after the framework of Rothaermel et al. (43) was completed will also complement the discussion. Lastly, some of the topics were already discussed in the preceding section on role-players and will therefore only be mentioned in this section.

2.5.1.2 Model for Managing Innovation

In the section, structure will be drawn from a model for managing innovation. The discussion of the impacting factors will be structured in such a way so as to enable the reader to recognise the relationship between research commercialisation and innovation. This relationship will be formally discussed in Chapter 4.

The model was developed by Galanakis (54) and is termed the Creative Factory model. The model is presented in Figure 10 below.

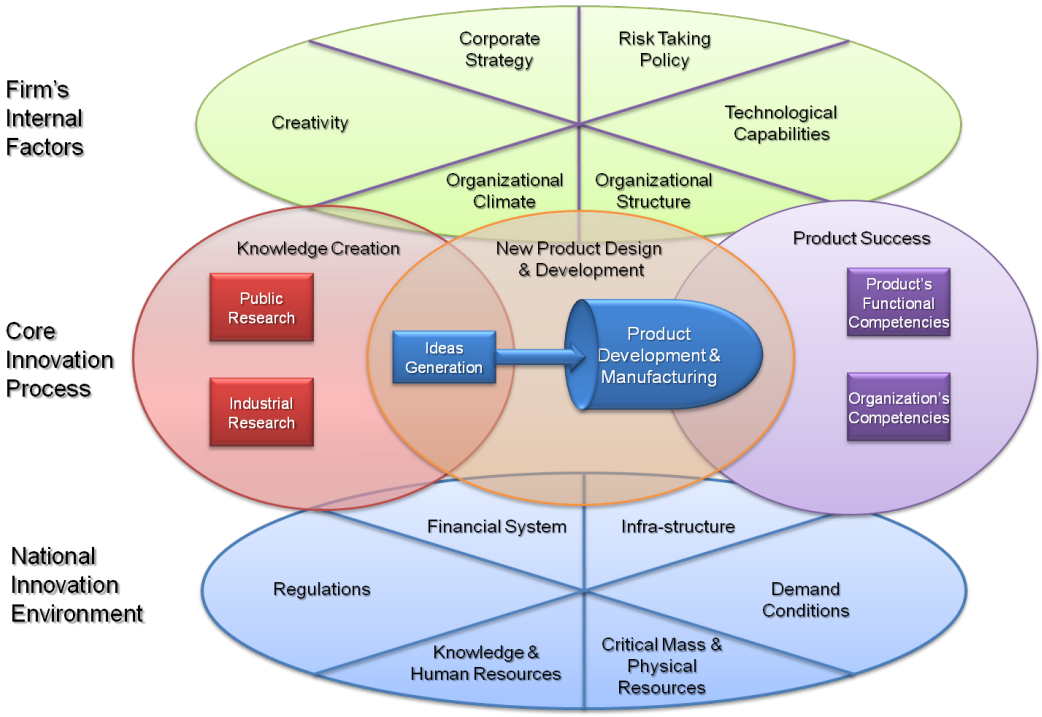


Figure 10 - Creative Factory Model by Galanakis(54)**, adapted from Schutte**(55)

Similar to innovation, research commercialisation is a process that is influenced by a host of internal and external stakeholders. It is also characterised by the interactions of various subsystems. These, along with other similarities that will be formally discussed in Chapter 4,

are the reasons why this model was deemed appropriate to gain insight in order to appropriately structure the discussion of the factors affecting research commercialisation.

The model was developed using a systems thinking approach to managing innovation. Figure 10 depicts the process at the core of the model that is affected by internal factors of the organisation (e.g. corporate strategy, organisational structure) as well as external factors in the National Innovation System (e.g. government policy, national infrastructure) (54).

2.5.1.3 Resulting Framework

Figure 11 is a visual representation of how the landscape of research commercialisation is categorised in this research, with references to sections where these points are discussed in more detail.

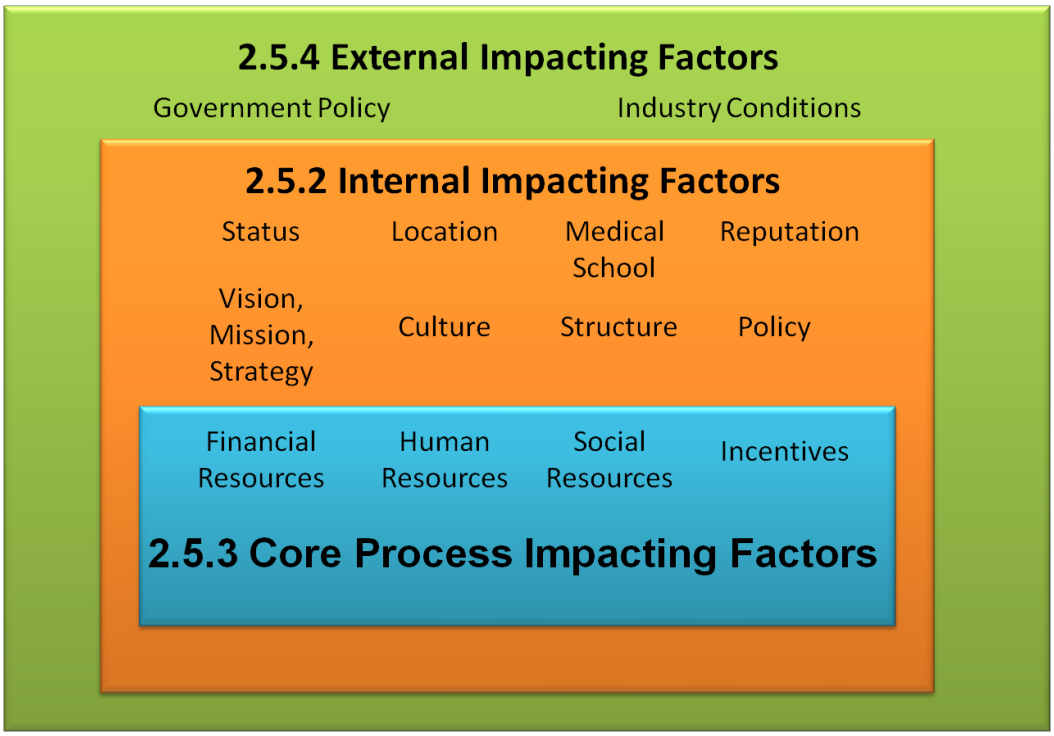


Figure 11 - Framework for presenting impacting factors on research commercialisation

The progression through the literature will be indicated using this illustration of the framework as shown below in Figure 12.

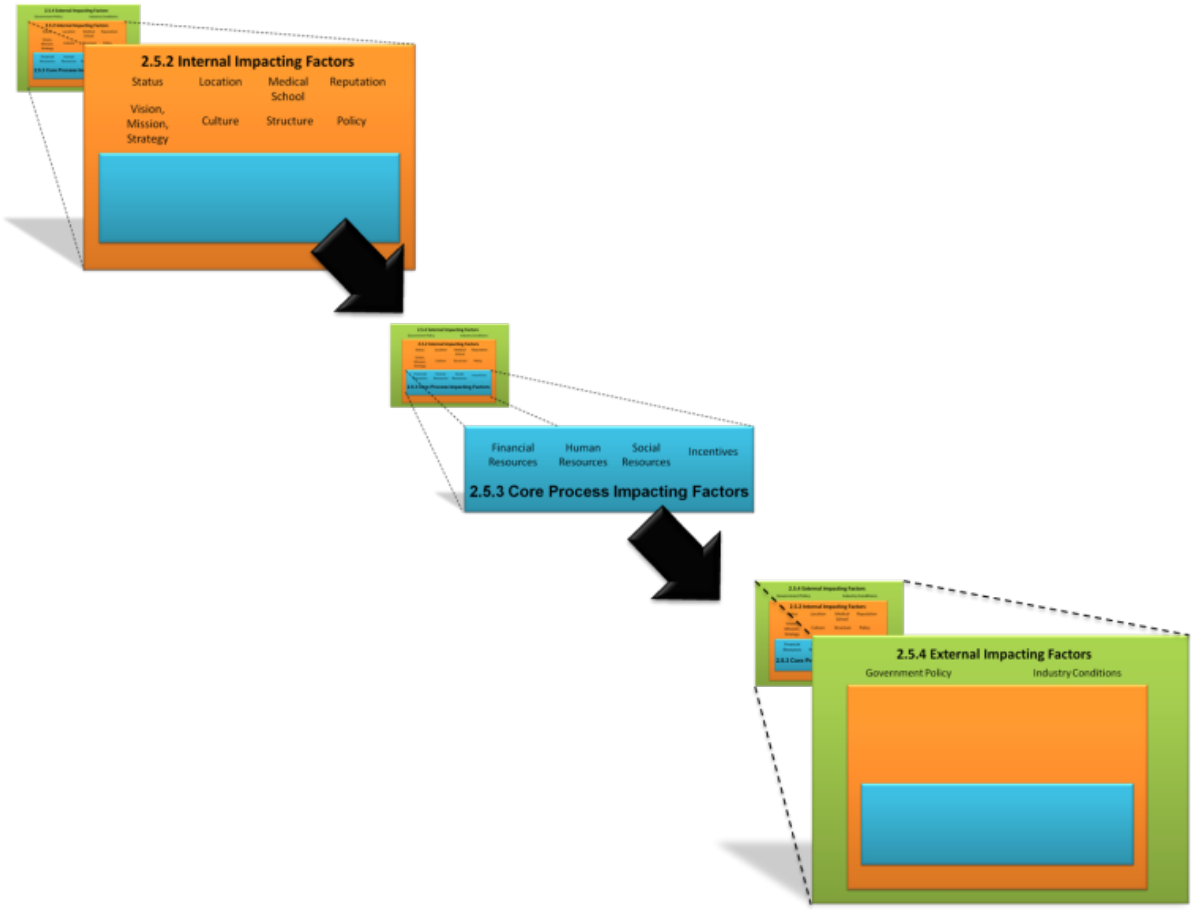


Figure 12 - Progression through impacting factors

As stated earlier, the discussion will start with the internal factors, move to the core process factors, and conclude with the external factors.

2.5.2 Internal Impacting Factors

This section will deal with the Internal Impacting factors as shown in Figure 13.

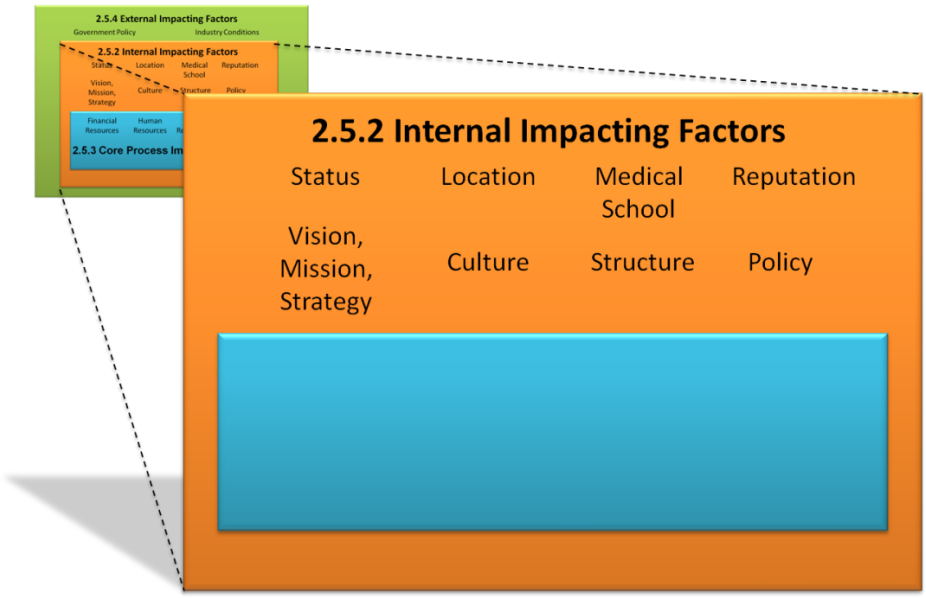


Figure 13 - Discussion progression towards internal impacting factors

In an attempt to improve the understanding of factors that impact on the efficiency of research commercialisation, literature has focused on the comparisons of different university technology transfer efforts. This was done by means of empirical evaluations of the relationship between the inputs and outputs of the system. This method has been used to isolate those factors that differentiate the successful efforts from the unsuccessful ones, thereby identifying critical success factors for technology transfer.

The ancillary factors will be discussed first, as they are categorised as elements that a university cannot change in the medium to short term. This discussion will be followed by an examination of the factors that may be significantly influenced by a university and the last factors that will be discussed are those external to the university and again not much can be done by the university itself to change them.

2.5.2.1 Ancillary Factors

a. University Status

Powers (19) investigated the difference in performance between public and private universities in the US. He found that there was no significant difference in the technology transfer activity of the two; the minor differences could be attributed to other factors such as the downturn in the economic climate that forced students to enrol in public universities

rather that private schools. As a result, private universities were compelled to engage more with industry to gain additional funding, as their main source of income had traditionally been student fees.

Thursby and Kemp (56) found that private universities are more efficient in research commercialisation than their public counterparts. The reason for this is that industry partnerships historically contribute a large share of private universities' revenue and these relationships seem to benefit technology transfer. Markman et al. (57) confirmed this claim when they found that private universities generate more licences and consequently more licensing income.

Another area where the status of the universities seems to play a role was brought to light by Lach et al. (58), who found that incentives have a greater effect on entrepreneurial behaviour in private universities than in public ones.

b. University Location

A study by Mansfield (30) found that firms do not care about proximity when they are looking for basic research collaborations. Here, faculty quality and reputation is a much more important factor. When firms collaborate for research with a more applied nature, they tend to value proximity.

Friedman et al. (40) found that universities located in areas with a high concentration of technology firms perform much better than their counterparts when it comes to signing licensing agreements and generating licensing income. Nonetheless, the firm's own R&D activity is more important in supporting its ability to collaborate with universities compared to locality with regards to high technology firms (59).

c. Universities with a Medical School

Many studies have found that universities with medical schools tend to be less efficient in the research commercialisation arena that those without medical schools (60). The reason for this may be that the commercialisation of research in the human sciences requires much more time and effort from TTOs than the average for other sciences (56). Bekkers and Freitas (61) found that the largest part of biomedical knowledge that is transferred is done through collaborative research and contract research agreements rather than patents and licences. This may be another reason why universities with medical schools appear less efficient in commercialising research.

d. University Reputation and Scientific Prestige

Through empirical research, Sine et al. (62) found that institutional prestige increases a university's licensing rate over and above the rate that can be extrapolated from past licensing performance. This emphasises the importance of institutional prestige, which in turn can be correlated directly with scientific excellence.

In the relevant literature, there is no ambiguity concerning the importance of a good base of research at universities for them to be successful at research commercialisation. Hicks (63) stresses the fact that governments that want research to cultivate innovation should ensure that scientific excellence is the order of the day. Mediocre research is unlikely to contribute to science nor to innovation. Rasmussen et al. (64) support this statement by finding through an empirical analysis of university commercialisation data that quality research is a prerequisite for successful commercialisation. Lastly, findings in a study by Debackere et al. (13) should drive home this point, as he also states that a high-quality faculty, excelling at a balanced mix of basic and applied research is very important to any university's research commercialisation efforts.

2.5.2.2 Vision, Mission and Strategy

The management community has stated unequivocally that a clear vision, mission and values are prerequisites for any organisation that seeks to achieve its strategic objectives and goals. One should expect that universities would be no different. Johns Hopkins University is one of the world's most prestigious academic institutions with a well-documented history of academic excellence, including 26 Nobel Prize winners. Contrary to expectations that such an institution should have no problem commercialising technology, Feldman et al. (65) found that they have been quite unsuccessful in this area.

He finds that the reason for this is Johns Hopkins's historically conservative view on reaping financial rewards from research, at least compared to its American counterparts such as Stanford and MIT. This proves that, without a clear university mission regarding research commercialisation, it is highly unlikely that notable success may be achieved (65). This statement has been confirmed by Friedman et al. (40), who found that a university that has a clear mission will perform significantly better than universities without clear focus.

This brings to light the fact that there a various missions a university can pursue. The vision and mission of universities related to research commercialisation differ across countries and institutions. The vision is largely affected by factors such as government involvement, their vision and the universities' historical context. Common visions include national and regional

economic development, contributions to society and financial security for the parent university (66). This can translate into missions such as freely distributing patents, focusing on licensing to generate revenue or being more aggressive to create start-up or spin-out companies.

The vision, mission and strategies will inevitably evolve as the process of research commercialisation matures in countries and universities. One could hypothesise that developing nations would initially focus on economic development as a central vision, while this can shift over time to an emphasis on the additional revenue stream that supplements university coffers. In the long run, this vision can transform back to economic development at a stage where universities are so well-funded that they do not need the money anymore; evidence of this tendency may be found at some US universities.

There are three main strategies to achieve the independent visions and missions (46):

- Drawing up research contracts that give licensees access to future IP resulting from a specific programme, in exchange for research funds
- Licensing intellectual property for cash
- Trading the expected value of intellectual property for equity (creating a start-up)

The most common research commercialisation strategy among universities in developed countries is the maximisation of income resulting from licensing agreements (26). This is not hard to imagine, if one takes into account the reduced risk of such a strategy relative to the risk and effort involved in the creation of spin-off companies, and the often protracted delay in monetary return from research contracts.

Having said that, international scholars warn that a university's strategy should not only focus on a pursuit of licensing for cash, as the appropriate strategy is very closely linked to the maturity and the characteristics of the technology or research under consideration. Thus, a one-dimensional strategic approach to commercialisation will lead to the eventual downfall of a technology commercialisation programme (46). Del Campo et al. (67) state that the university TTO needs to take a more businesslike approach when identifying the appropriate strategy that to match the technology (type and maturity), market and commercialisation potential.

2.5.2.3 Culture

Culture in this study is defined as a combination of assumptions, values, norms, and beliefs, commonly shared by members of a social group, that shapes the perceptions and

behaviours of members of that group (68). Establishing an entrepreneurial culture within a university is one of the core problems of international research commercialisation efforts. Klofsten et al. (69) suggested, as part of three basic activities for stimulating entrepreneurship in universities, that an enterprising culture should be created and maintained. This sentiment is echoed throughout literature and the responsibility for creating such a culture is put at the door of university management, typically the university president or provost (45).

Various tools are suggested for the creation of a culture that is more suitable for entrepreneurial endeavours within a university. Among others, these tools include:

- The promotion of and connection with other colleagues by researchers both inside and outside the university (15);
- The strengthening of individual incentives for entrepreneurial behaviour within universities (41).

Still, there is an even bigger challenge than establishing a culture within a university and that is establishing mutual understanding of the different stakeholders' cultures across the whole research commercialisation process. In this regard, two challenges are evident. The first is the cultural barrier between industry and universities, dubbed "the two cultures problem" (44). The second challenge was identified by Siegel et al. (45), who found that the traditional university, as an organisation, actually has two sub-cultures: scientists and administrators. In order to gain insight into this subject, Siegel et al. (45) proposed and evaluated three distinct cultures in the research commercialisation process.

Table 1 - Key stakeholders in the transfer of technology from universities to the private sector (45)

Stakeholder	Actions	Primary motive(s)	Secondary motive(s)	Organizational culture
University scientist	Discovery of new knowledge	Recognition within the scientific community—publications, grants (especially if untenured)	Financial gain and a desire to secure additional research funding (mainly for graduate students and lab equipment)	Scientific
Technology transfer office	Works with faculty members and firms/entrepreneurs to structure deals	Protect and market the university's intellectual property	Facilitate technological diffusion and secure additional research funding	Bureaucratic
Firm/entrepreneur	Commercializes new technology	Financial gain	Maintain control of proprietary technologies	Organic/entrepreneurial

In Table 1, one can see the differing motives and culture of the stakeholders as perceived by Siegel et al. (45). An example of a cultural clash also echoed in other scholarly work is the

traditional academic propensity to publish in the public domain while industry prefers secrecy to maintain a competitive edge (70). Siegel et al. (45) classify this difference in Table 1 as a clash of motives rather than culture, but in this context motive is often shaped by the prevailing culture.

To be able to commercialise research over these cultural barriers, TTO staff need exceptional boundary-spanning skills, including the expertise to bridge the gap between the "customer" (industry/entrepreneur) and the "supplier" (scientists) who essentially operate in very different environments (45).

2.5.2.4 Structure

The impact of structure has been discussed in the role-player section and therefore this section will only highlight the most important issues. The debate around the appropriate university organisational structure for research commercialisation has centred around studies by Bercovitz et al. (25) and Debackere et al. (13) In addition, Markman et al. (26) identified specific TTO structures or rather modes of operation as discussed in section 2.4.1.1. There is general consensus that structure plays a role, but opponents to the recent findings of the first two authors suggest that the university should simply define its role, rather than changing its structure, and set appropriate boundaries separating non-core activities such as development from core-activities such as research and teaching (32). This implies a division of the labour in order for industry to focus on development and the problems closer to the market while universities focus on basic research.

Bercovitz et al. (25) insist that the structures within a university will affect technology transfer performance in a predictable manner. As discussed in section 2.4.1.1, they identified four organisational arrangements that are often found in universities and evaluated their efficiency for facilitating research commercialisation individually. Debackere et al. (13) state that there should be an shift in university structures away from its traditional bureaucratic history, which leaves little room for entrepreneurial activity, to a more flexible and adaptable matrix structure. This matrix structure is characterised by a divisional structure, which implies increased autonomy for research groups and the centralised commercialisation unit.

2.5.2.5 Policy

By altering research funding structures and changing legislation concerning the ownership of publicly funded research, policymakers have tried to create closer relationships between universities and industry. In the following subsections, public policy changes will be discussed as interventions on a government level. Trends in university policy regarding IP

creation and funding, in other words policy instituted by university management, will also be elaborated on.

a. Public Policy

The shift in public policy in the US initiated modern research commercialisation. This fact should support the notion that policy is at the heart of the shift towards a more entrepreneurial university. Current literature on public policy provides policymakers with guidelines on the formulation of modern policy for the improvement of university-industry relations. Some scholars oppose such policy, while others argue that there should rather be a degree of public input on the matter, because such an approach might better align the interests of universities, industry and the general society (71).

Some authors dispute the university's role in the national innovation system and suggest that government policy is forcing universities to operate outside the areas in which their core capabilities reside (72). They argue that the government should not push universities to engage in development, as this is an area in which industry has been much more successful. Universities should uphold their objectives of teaching and research, and policies should protect the academic interest and avoid an excessive shift to commercialisation concerns, which could threaten the university's institutional integrity (73).

The fact remains that many countries have implemented policies that incentivise universities to embrace research commercialisation and make an effort to move research into industry through patents, licences and spin-out companies. Many researchers have found evidence that should ease the concerns of the nay-sayers, proving that university researchers who are closely involved with industry are in fact also significantly contributing with traditional academic outputs, such as publications (74).

Scholars will continue to try to provide legislators with guidelines on how to better shape public policy, in a way that will support university-industry collaboration effectively within the boundaries of the requirements, resources and objectives of the environment in which it operates.

b. University Policy

University policy, as discussed in research commercialisation literature, is largely concerned with the university's funding priorities and intellectual property management. Policies with regard to licensing, royalty sharing, and equity stake in spin-offs are also frequently used as predictor variables to find the source of entrepreneurial activity in universities (75).

Siegel et al. (42) suggest that universities adopt a more flexible stance when negotiating licensing agreements and streamline their technology transfer policies and procedures. Companies often feel that universities are too aggressive in exercising their IP rights.

Roberts et al. (76) examined whether active spin-off policies have an effect on the number of companies created by a university, and what the appropriate policy should be in the light of university's entrepreneurial infrastructure and culture. In conclusion, they suggest that universities with a weak entrepreneurial culture and infrastructure give substantial support to a selection of ventures, rather than, for instance, giving minimal support to a large number of ventures. The latter approach may lead to underinvestment in a large portfolio. These recommendations, along with findings from Powers et al. (77) regarding the appropriate policy within a specific environment, could have important policy implications for developing countries such as South Africa.

2.5.3 Core Process Impacting Factors

This section will be used to explain the factors that have an impact on the operational level of research commercialisation.

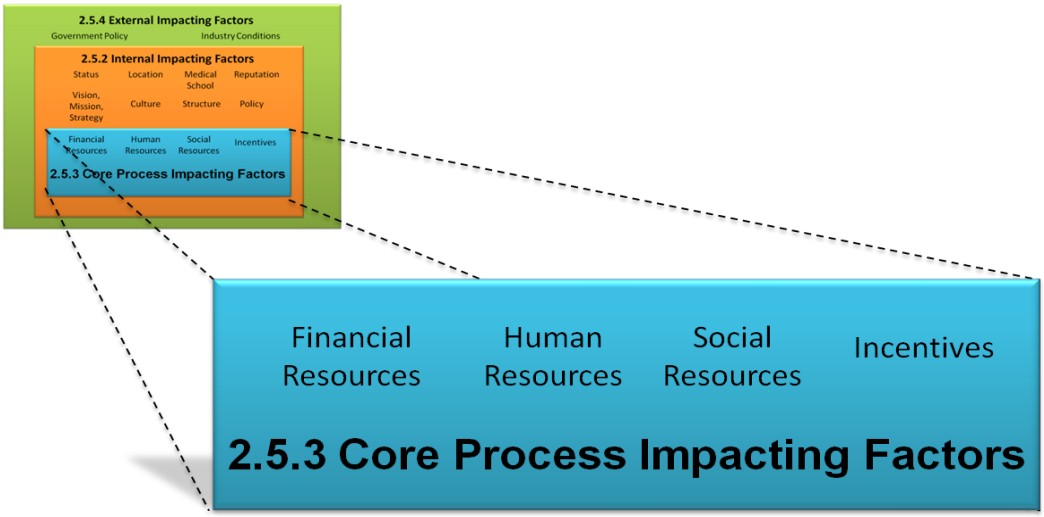


Figure 14 - Discussion progression toward core process impacting factors

In an attempt to organise the literature, certain elements will be borrowed from a framework developed by Degroof et al. (78). They constructed a framework which illustrates the resources needed in the different phases along the life cycle of a commercialisation process. They categorise these resources into technical, financial, human and social resources. Although the framework is intended to focus on only one output of the commercialisation process, namely spinning out companies, it is still considered appropriate because the same

resources will be needed to generate a licensing agreement. Figure 15 shows an adapted version of the framework by Degroof et al. (78)

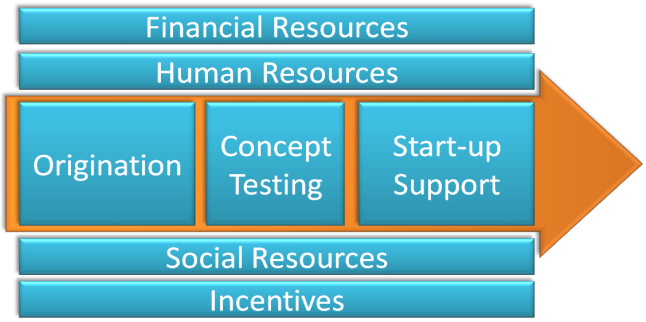


Figure 15 - Stages of the spin-off process and necessary resources, adapted from Degroof et al. (78)

Figure 15 shows the life cycle in the middle, consisting of three phases, namely Origination, Concept testing and Start-up Support. These life cycle activities are supported by specific resources in each phase. The resources are categorised into Financial, Human and Social resources. Incentives also play a supporting role and are therefore included in the adapted version of the framework.

Although Degroof et al. (78) only show three phases, the lower-level activities they describe in each of these phases are the same activities as those discussed in the description of the research commercialisation process in Section 2.3.

2.5.3.1 Financial Resources

Many studies have tried to correlate the amount of money a university spends on research with the number of commercialisation outputs achieved as a measure of TTO efficiency. These outputs range from disclosures and patents filed to patents issued and licensing income. In one of these studies, Anderson et al. (79) found that only 7 out of the 54 universities measured were perceived as efficient. No single study directly correlates research expenditure with licensing revenues, but Carlsson et al. (49) found that an increase in research expenditure increases the rate of disclosures. Kirchhoff et al. (80) found that R&D expenditure has a significant influence on economic growth in terms of new firm creation.

Concerning the returns on investment, universities should understand that these technology transfer programmes typically have a very long pay-off period. That is why a well thought-out, long-term financial plan for building a TTO is a fundamental requirement. The plan

should be based on both financial and especially nonfinancial returns, and on what the university is able to afford (81).

The next very important financial resource implication regards funding for patent registrations, seed capital funding for development of concepts, and eventually multiple venture capital requisitions for starting up companies. In this regard, the sourcing of external capital should be preferred above the reallocation of funds originally earmarked for teaching and research (64).

According to Wright et al. (82), there seems to be a mismatch between the demand and supply sides of venture capital funds. Universities want capital in the early stages of development, when the risk of failure is high, but venture capital firms usually only provide funds after the seed stage. This means that bridge funding may be needed from the university, government agencies or other external sources to close this gap.

The last point is the location of the university in relation to the venture capital firms. The university's proximity to areas with a high level of venture capital has not been found to significantly affect the success in terms of commercialisation (75) (19). This may highlight the need for exceptional sourcing networks of TTOs, since venture capital is the single largest contributor to the likelihood that a start-up firm will undergo an initial public offering (IPO) (83).

The bottom-line is that universities and their respective governments should take responsibility for the financial burden to promote technology transfer. They should ensure that these intermediary institutions are well funded, staffed and deployed (84).

2.5.3.2 Human Resources

a. Researchers

The role of the researchers has been extensively discussed in previous sections, but it should be obvious that, since academic excellence is a prerequisite of successful research commercialisation, the presence of good-quality and highly rated faculty will have a positive impact on a university's commercialisation programme. This is confirmed by Zucker et al. (85), who found that the presence of "star scientists" is positively correlated to commercialisation success in the biotechnology industry.

b. TTO Staff

Regarding TTO staff, three main points are debated in literature: the skill set required within the TTO, the number of employees a TTO should have, and the age of the TTO.

Chapple et al. (86) stress the fact that universities should recruit TTO staff with the right skills and capabilities or make it a priority to train and develop them. In a study by Siegel et al. (45), the researchers identified some of the requirements of TTO staff from the perspective of industrial managers and university scientists. Managers insist that deal-makers rather than academics work in TTOs. The staff needs to be marketing facilitators rather than lawyers, and they need to be able to take a view from the customer's perspective. Scientists feel that the staff of the TTO needs to be specialists in the fields in which they want to commercialise. They need to know where the technology is going before they can make informed decisions about patenting. TTO staff themselves also stress the importance of possessing marketing skills.

In summary, the following skills are required:

- General Business skills
- Legal expertise
- Marketing
- Boundary Spanning
- Technical knowledge
- Networking

It is hard to imagine that the whole spectrum of capabilities would reside in one person, but it is emphasised that all these areas are covered by the staff complement of a TTO. Carlsson et al. (49) found that the bigger the TTO is, the wider their range of in-house expertise typically is.

The size of the staff component in the TTO is frequently correlated with research commercialisation efficiency in order to evaluate its impact. Siegel et al. (87) found that hiring more staff in a TTO correlates positively with more licensing agreements, but does not imply increased licensing revenue. Clarysse et al. (88) also suggest that the size of the staff component has an influence on the ability of the intermediary to provide support services.

The age of the TTO is also a factor that is cited quite frequently: the technology transfer process is a cumulative learning one and accordingly the older a TTO is, the better it ought to perform, especially as far as risk management is concerned (20). Other authors found that

age *per se* may not be the issue, but rather the accumulated experience gained by the staff, implying that learning by doing might have an effect on the efficiency of TTO staff in executing the research commercialisation process (89) (90). On the contrary, Chapple et al. (86) found in a study of UK research commercialisation that older TTOs are less efficient, indicating the absence of learning by doing effects.

2.5.3.3 Social Resources

Social resources relate to the scientific networks of scientists and the industrial networks of technology transfer officials, as well as the networks that TTO officers have with its own researchers at the university. TTO staff should be well-connected with researchers to have a better idea of how their work is progressing and whether their research may have commercial potential. The visibility of TTO staff in the university may also help to create a culture where researchers are more willing to disclose their inventions and collaborate with the TTO to exploit their research.

Researchers are often an important source of information about commercialisation opportunities for their research. They frequently have networks with other scientists and industry built up over many years of research, which is of immeasurable value in the commercial exploitation of their research. Universities in general should also try to foster these formal and informal relationships, because knowledge transfer is essentially a social process to exchange codified and tacit knowledge (70).

In the absence of sufficient networks on the part of the scientist, the industrial connections and networks of the technology transfer office become very important. These networks are essential to the marketing of university research (45).

2.5.3.4 Incentives

Incentives and the structure of incentive schemes are cited throughout literature as one of the main tools to facilitate a shift to a more entrepreneurial academic community, with some scholars suggesting that inappropriate incentive structures are the single biggest barrier to technology transfer (27).

Various authors argue that providing incentives directly to faculty has the biggest positive effect on disclosure rates from faculty and general entrepreneurial activity within the university ((41), (40), (13), (91), (58)). In essence, incentives are one of the methods used to create the culture needed for commercialisation. Culture is very important if faculty is to persist with their involvement throughout the whole commercialisation process from

disclosing, through licensing, to eventual development, if participation in the latter is required by the licensee (39).

There is an opposing view on the matter, which states that providing financial incentives to faculty does not encourage them sufficiently to partake in commercialisation activity (22) (90); some authors even found a negative correlation between direct financial incentives for faculty and licensing output (92). Instead of financial incentives, Siegel et al. (42) suggest that universities evaluate incentive compensation for TTO staff as a better option for increasing commercial output.

Although there seems to be ambiguity about specific incentive structuring, it will be valuable to evaluate the different options that are available, since incentives evidently remain an important factor in the commercialisation process . Lach and Schankerman (58) identified two main trends regarding incentives that are important for promoting researcher participation:

- Royalty and equity sharing for faculty
- Financial research support

In addition to these trends, Siegel et al. (42) emphasise the fact that patents and licences should be accounted for in promotion and tenure decisions, and universities should not focus on publications alone.

2.5.4 External Impacting Factors

External impacting factors can be aggregated into two major categories, namely Government Policy and Industry conditions. Many of the issues have been discussed in the literature up to this point and will only be mentioned briefly in this chapter.

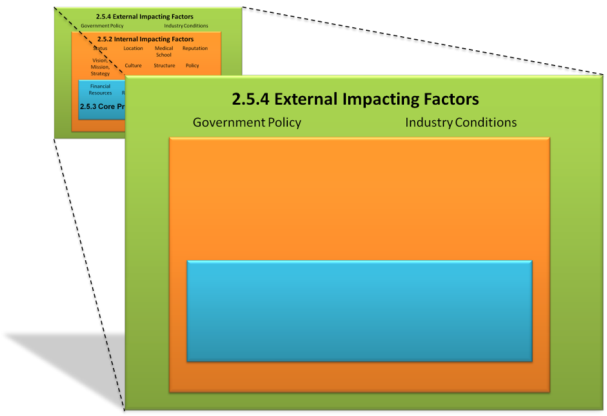


Figure 16 - Discussion progression toward external impacting factors

2.5.4.1 Government Policy

By now, it should be obvious that the objective of governments is to get universities and industry to collaborate for the good of society. Accordingly, they try to shape policies to encourage this collaboration. The fact remains that mere duplication of US policy can be detrimental to research commercialisation in other countries. Governments trying to emulate Bayh-Dole should understand the underlying structural differences in the higher education system of the different nations (93).

The objective of policy is to elicit change in the targeted institutions or organisations. This means that government policy should be evaluated and considered by universities when they formulate their strategies. If different governments have different policies, which they surely do, then obviously there will be no "one size fits all" commercialisation programme for universities (84). This should be considered when establishing commercialisation programmes and also when evaluating the performance of specific programmes.

2.5.4.2 Industry Conditions

There are numerous factors on the "industrial side" that influence the success of research commercialisation. The main factors that appear in literature are:

- Availability of venture capital
- Locality in terms of high technology firms
- Absorptive capacity of local industry
- Structures and culture of corporations

All of these factors have been discussed in previous sections. The goal of this current section is to emphasise that these are all external factors that influence the research commercialisation process. These factors, in conjunction with government policy, shape the landscape in which universities operate with respect to research commercialisation.

2.6 Chapter Summary

The landscape in which universities have to commercialise their research is a dynamic one. This chapter introduced the reader to the history of research commercialisation and showed how its progression into the university mission has affected the role universities are required to play in the innovation systems of different countries.

The research commercialisation process was described, and this was followed by a section on the central role-players tasked with performing it successfully. The landscape of research commercialisation was discussed and supplemented by a systematic breakdown of many of

the impacting factors that were identified, investigated and discussed by international scholars. All of these factors influence the process in some way and they are categorised as internal, core process and external impacting factors.

It is clear from the discussion that various factors are under debate in international circles and consensus about critical success factors is still lacking. Many universities, such as Stanford (US), MIT (US), Cambridge (UK) and Oxford (UK), have been identified as efficient, but emulating their strategies across the board will inevitably lead to insurmountable obstacles in the process. The environment in which a university operates has a profound influence on how the process should be supported and configured to be successful.

Rothaermel et al. (43) state that "*it is difficult for any technology transfer function or office to do all things well. Each of the approaches has its own operational idiosyncrasies and craft knowledge. Each may also be more pertinent to one university context, mission, or strategy than another. It is incumbent upon universities and their industrial partners to choose those linkages and approaches that are most suitable for their environment*."

The specific elements and organisation of these elements that create successful commercialisation programmes in the US will not work in other countries because the contexts are not identical. This is the main reason why voices in international literature are at odds with each other about so many of the so-called "critical success factors" for research commercialisation.

An integrated approach is needed to manage this process efficiently and effectively. The local process needs to be optimised and the context of that process must be taken into account. Those factors that international scholars deem critical to the success of a process can be evaluated and considered in the optimisation process purely as possible causes of inefficiencies.

There is obviously a need to come up with a model that can be used to optimise a local research commercialisation process. But before such a model is devised, the related research field of innovation will first be discussed in the next section.

3

Innovation Landscape

The aim of this chapter is to give a broad description of the innovation landscape. The understanding of the field of innovation will be essential when the fields of research commercialisation and innovation are brought together in the next chapter.
The chapter starts by defining innovation, followed by a discussion of some common drivers for innovation and the different categorisations of innovation. From there the importance of research and consequently knowledge is discussed for innovation and the chapter concludes with an introduction into the different models of innovation.

3.1 Defining Innovation

In recent years, innovation has become a buzzword used by organisations in marketing campaigns to distinguish themselves from their competition. Although it is now a widely adopted view that innovation is the only way a company can stay ahead of its competition, a company would hardly realise this ambition by putting the term on its slogan. According to Tidd et al. (94), innovation is a generic enterprise activity that focuses on the long-term survival of the enterprise.

This is only one of many definitions for innovation in modern literature, and it does not seem to convey much of what the innovation process entails. A more recent definition by Katz (95), which seems to get closer to the issue, states that innovation is:

The successful generation, development and implementation of new and novel ideas, WHICH introduce new products, processes and/or strategies to a company OR enhance current products, processes and/or strategies LEADING TO commercial success and possible market leadership AND creating value for stakeholders, driving economic growth and improving standards of living.

This definition highlights a crucial element that is missing from so many applications of the term. Innovation should lead to value creation, economic growth and improved standards of living. In turn, these elements can be correlated directly with the common objectives of research commercialisation, as stated earlier. It follows that innovation is not only applicable to for-profit organisations, but innovation theory can be applied inside the government, as well as public and social services, to allow these organisations to perform to the ever-changing expectations of society (96).

According to Tidd (94), the innovation process consists of four key activities:

- Search – Identify and/or create new ideas or opportunities to exploit
- Select – Filter potentially viable opportunities
- Implement – Exploit the opportunity
- Learn – Learn from the process

A depiction of this process described by Tidd (94) appears below as Figure 17.

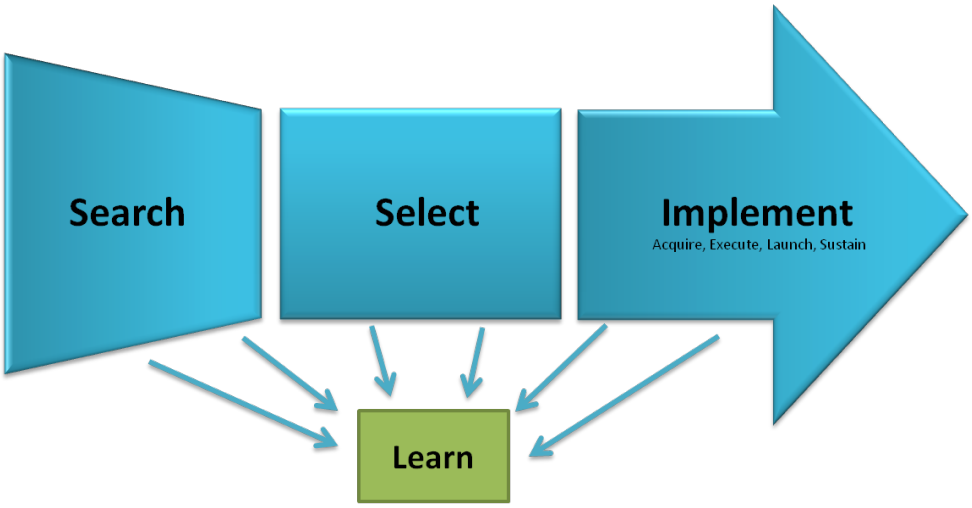


Figure 17 - The basic innovation process, adapted from Tidd (94)

This description and illustration do not cover the whole life cycle of innovation as it excludes operation and disposal. The complete life cycle of innovation will be discussed in Section 3.6.

3.2 Drivers for Innovation

As stated earlier, the main driver for a company to be innovative is the need to sustain a competitive advantage. Innovation theory highlights two drivers for innovation: market-pull and technology-push. Market-pull suggests that the market initiates the need for the technology to be developed, while technology-push implies that companies develop the product or service in the absence of an identified need and accordingly push the technology into the market, creating and fulfilling a need (96).

These are two very high-level triggers for innovation and Du Preez et al. (96) identify a number of more detailed factors that can drive the need for an organisation to innovate. These drivers can be categorised into internal and external drivers. The drivers for each category are presented in Figure 18.

3.2.1 Internal

- *Time* – reduce lead times to bring new offerings to the market in less time and before competitors.
- *Cost* – reduce costs to offer products and services at a lower cost or increase margins.
- *Quality* – improve quality of offering to distinguish from competitors and reduce defect rates.

- *Revenue* – create new revenue streams through new or existing markets due to a dated value offering, declining revenue streams or to grow as an organisation.

3.2.2 External

- *Customer needs* – ever-changing and more demanding customers
- *Technological change* – driven by continuous research and development
- *Socio-economic environment* – continuous drive to improve living standards
- *Legislation or regulation* – as required by governments and regulating bodies

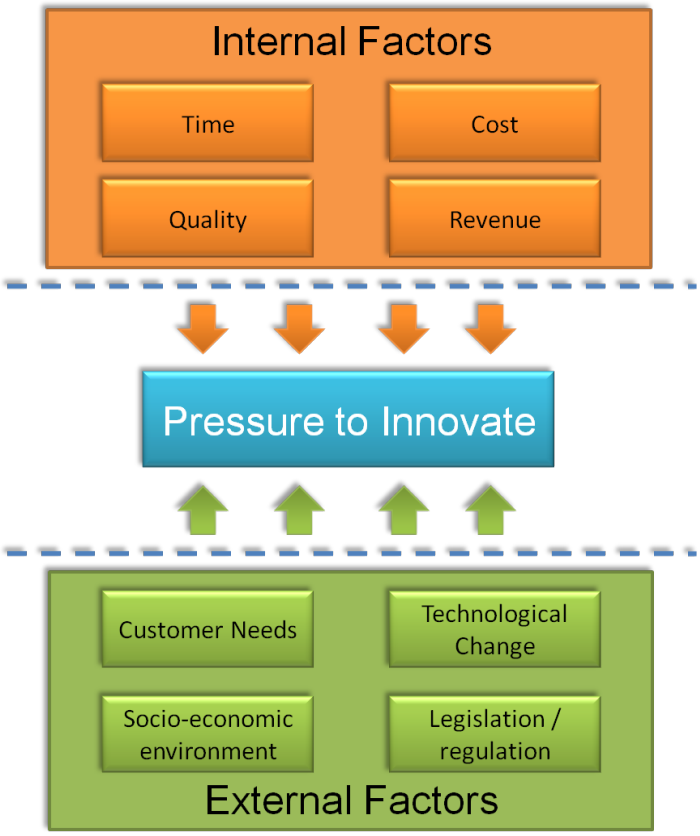


Figure 18 - Internal and external drivers for innovation, adapted from Du Preez (96)

3.3 Categorisation of Innovation

Literature suggests that there are various types of innovation. The most commonly cited types are product, process, strategy and marketing innovation.

Tidd and Bessant (97) use the 4 P's of marketing to create a framework that illustrates the innovation space available for any organisation. This space is characterised by the types of innovation that are possible and also incorporates the newness dimension of innovation. A depiction of this model is presented in Figure 19 below.

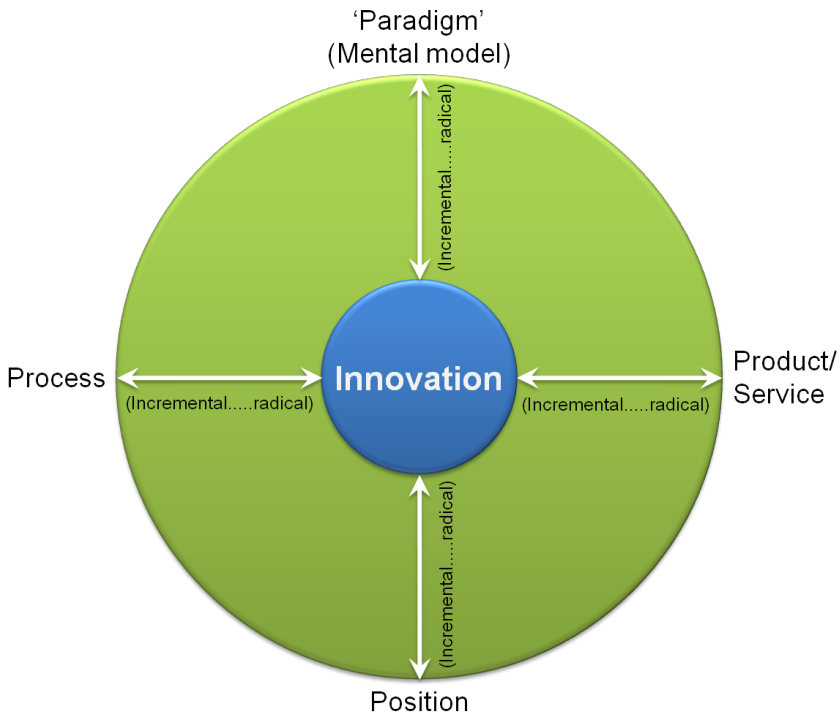


Figure 19 - The 4P's of innovation space, adapted from Tidd and Bessant (97)

The difference between the two extremes of newness which are *incremental* and *radical*, will be discussed in 3.3.4.

Similarly, Du Preez et al. (96) argue that one can aggregate all innovations into three basic types. These are product, process and strategy innovation. The relationship between these types is illustrated in Figure 20.

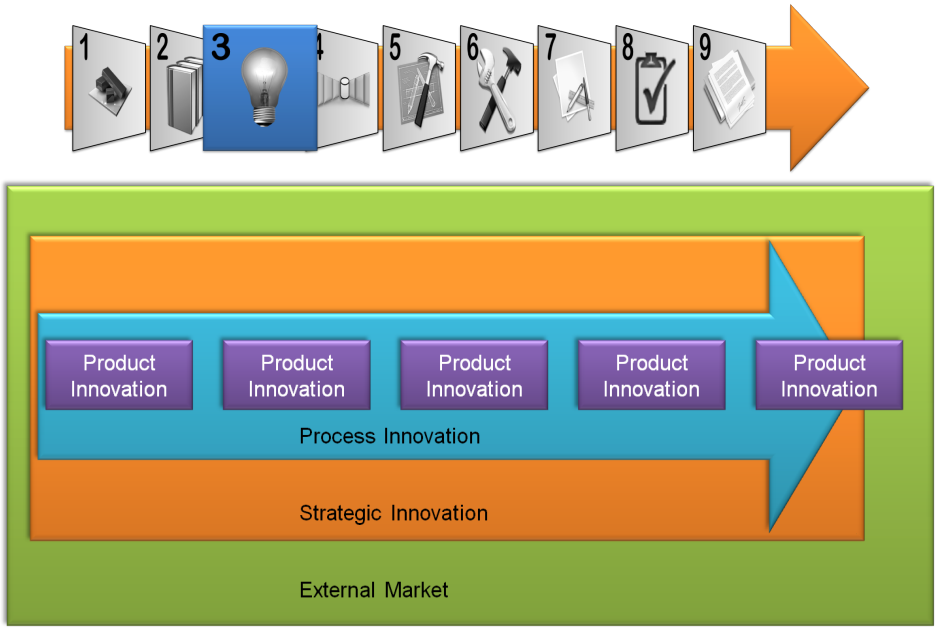


Figure 20 - Types of innovation, adapted from Marais(98)

These three types are discussed below.

3.3.1 Product Innovation

Du Preez et al. (96) describe a product as the output generated from an organisation and delivered to the consumer, accompanied by the exchange of value to both parties. Value from a for-profit organisation's perspective will typically be compensation. Organisations, such as government or social services, do not receive compensation directly from the consumer, but they do receive some form of compensation for delivering the product or service. Services are not excluded from this type of innovation, as the output may be either tangible or intangible in nature. From the perspective of the organisation, a product innovation is a "change in, or an addition to the entities that comprise its product line" (99).

3.3.2 Process Innovation

A process can be defined as any set of procedures or a sequence of actions that is utilised in the transformation of an organisation's resources (98). Such a process can be manual, automated or of a higher level management nature, such as "Management Innovation" (100).

Process innovation can be seen as any change or addition to an organisations process that gives the organisation a competitive edge in terms of the time it takes to produce an output from that process or the quality of the output.

3.3.3 Strategy Innovation

Strategy refers to the positioning and direction of an organisation. According to Du Preez (96), it includes the vision, mission and values of an organisation.

Strategy innovation will provide the organisation with differentiation in terms of its direction or positioning that will ensure a sustained competitive advantage.

Utterback et al. (101) argue that the characteristics of a firm's innovation activities (product and process) or options in terms of innovation are closely entwined with its strategy. Consequently, it is not hard to imagine that strategy innovation will eventually lead to innovation in both the firm's offering and the processes to deliver that offering.

3.3.4 Other Dimensions

Over the years, scholars have attempted to categorise innovation in numerous ways, usually along the dimensions of newness and impact.

One of these categorisations was made by Christensen (102). He proposes that innovations be plotted in two dimensions: differentiation in the newness of a product is made on the horizontal axis between the two extremes of incremental and radical, while impact is measured on the vertical axis, within the extremes of sustaining and disruptive. Figure 21 illustrates how one would plot an innovation in this framework.

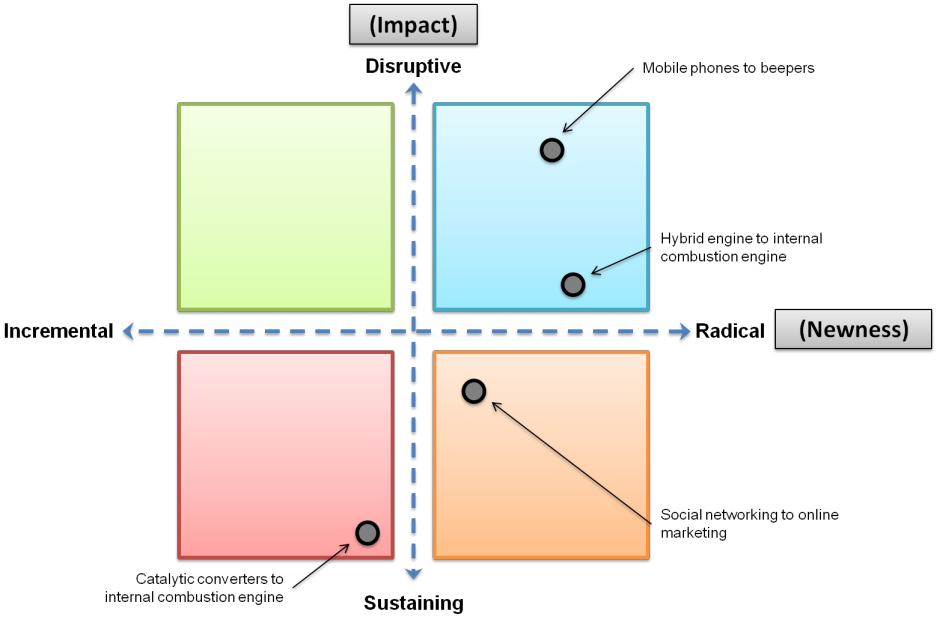


Figure 21 - Newness vs. impact, adapted from Du Preez (96)

3.4 Research and Innovation

To understand the dynamics of innovation better, Du Preez et al. (96) suggest that one investigates and distinguishes between competitive and pre-competitive research and the role-players responsible for these types.

Research can be classified into two types or modes: "mode 1", research stemming purely from the interests of the researcher, and "mode 2", a more applied type of research that is more in touch

with market need. Gibbons et al. (103) argue that these two modes are distinctly different in almost every respect.

Before these two modes are described in more detail, it would be valuable to note that mode 2 research, although perceived as following mode 1, in fact precedes mode 1 research. Mode2 was the original format of science before its academic institutionalisation in the 19th century (6), but in the 19th and 20th century, science has gradually detached from the interests of society and allowed scientists to operate more autonomously.

In the late 19th century in the US, large sums of money were donated to build new universities and expand old ones. This money came from industrialists and academics who were concerned that industry would subsequently try to influence the research priorities of scientists and want to hire and fire professors(104). To ensure that science would not be controlled by economic interests, Henry Rowland, the president of the American Association for the Advancement of Science, allegedly advocated the doctrine that if external interests tried to intervene, it would harm the conduct of science (6). Consequently, the two modes have existed in parallel ever since.

These two modes will now be discussed in terms of definition, objectives and their implications for innovation.

3.4.1 Mode 1 Research

Mode 1 research is essentially basic research, or research undertaken to advance the knowledge frontier. This mode of research is primarily funded by governments and funded as an end in itself, with only long-term practical results expected (105).

Dooley et al. (70) summarised the net effect of this type of research as follows:

- Academics have freedom as regards their research trajectories
- The sustainability of research is reliant on creative proposal writing
- The changing strategies of government funding agencies result in universities that are scattered in their focus and lacking in depth
- There is a time lag for publication into public domain
- Process of discovery is slow, due to lengthy verification and validation exercises
- Interaction between industry and universities is one-directional and industries essentially wait for knowledge spill-over

Industry obtains knowledge in the public domain, primarily in a very immature form. They can select which of these spill-overs are relevant to their innovation processes. Significant R&D expenditure on their part is then needed to realise the profits from these innovations in the market.

3.4.2 Mode 2 Research

The increasing importance of the university in economic development, together with the realisation that it could be a potential engine for innovation, has brought mode 2 knowledge creation to the forefront. This mode operates within the context of application and problems are not seen as bound to a single discipline (103).

In the knowledge-based economy, universities are expected to interact and align themselves with industry to promote knowledge creation. Funding and other resources needed to perform this mode of research are typically jointly provided by universities, industry and government.

Some of the characteristics of this mode are:

- Close interaction of many parties throughout the process of knowledge creation
- The multidisciplinary nature of research
- Research is also becoming more socially accountable

This form of research is not institutionalised primarily within the structures of the university (103). The fundamental characteristic is the creation of partnerships between different role-players to generate excellent trans-disciplinary knowledge and, in the process, it can potentially save industry some R&D costs and generate some extra research funds for universities.

3.5 Knowledge and Innovation

It is not within the scope of this research to go into a theoretical discussion of knowledge management; as a result, this section will describe the link between innovation and knowledge by introducing the reader to a perspective of how knowledge is created and translated through the so-called Knowledge Supply Chain.

The basis of modern companies' competitive advantage is knowledge (106). Knowledge has become an important – if not *the* most important – asset of organisations in the 21st century's knowledge-based economy (107). Accordingly, it becomes a business imperative to use existing knowledge more effectively and constantly obtain new knowledge (108).

McAdam (109) concluded that managing knowledge is essential to foster innovation. His sentiments are echoed by various authors who argue that the creation of knowledge is a key input for managing the innovation process (110,111). But it is not only creation that is important. In Drucker's (112) definition of innovation, he states that "[i]nnovation is the application of knowledge to produce new knowledge". Consequently, the use of knowledge is equally important, which reiterates that the critical issue is the management of knowledge that integrates creation, exploitation and all other important elements.

There are various views of knowledge and these obviously lead to differing perspectives of knowledge management (113). For the purposes of this research, knowledge management will be defined from a process perspective. It entails the processes of creation, sharing and distribution (114).

Knowledge can be created through research and stored in explicit form, such as documents, processes and tools. It can also reside in the minds of people, in which case it is better known as tacit knowledge (115).

This knowledge can be leveraged in decision-making throughout the innovation process, setting the platform for successful innovation and the resulting competitive advantage (96).

Figure 22 below, adapted from Du Preez et al. (116), shows how the concepts of research (discussed in the previous section), Knowledge domain, Knowledge Supply Chain, Role-players and Integrated knowledge networks are interrelated.

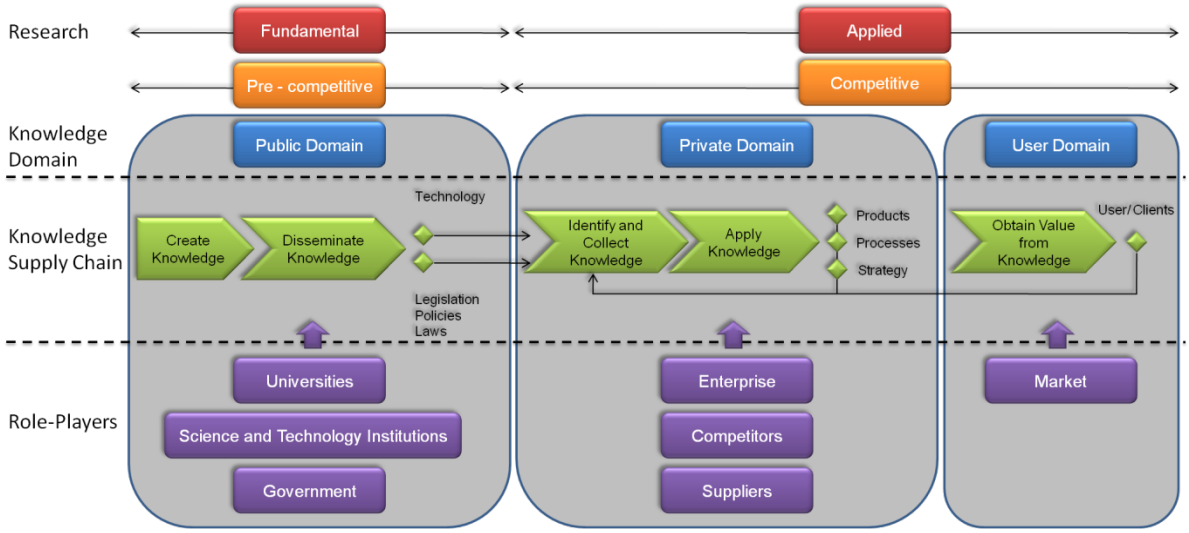


Figure 22 - Knowledge supply chain, adapted from Du Preez (96)

With triple helix theory becoming more prominent, it seems that the boundaries of the "pre-competitive" and "competitive" domains are becoming entwined particularly with regard to knowledge creation and dissemination. Accordingly, the relevance of this illustration may be limited, but it should be noted that research is constantly pushing the boundaries of innovation and knowledge management forwards and there are obviously limitations when trying to illustrate such dynamic processes in a timeless manner.

3.6 Innovation Life Cycle

There are certain fundamental activities that should be performed in order to constitute an innovation. Inputs to the process have to be considered and defined outputs need to be created. This means that there is a defined sequence of phases or steps that has to be performed. The following illustration shows an innovation life cycle with five generic phases.

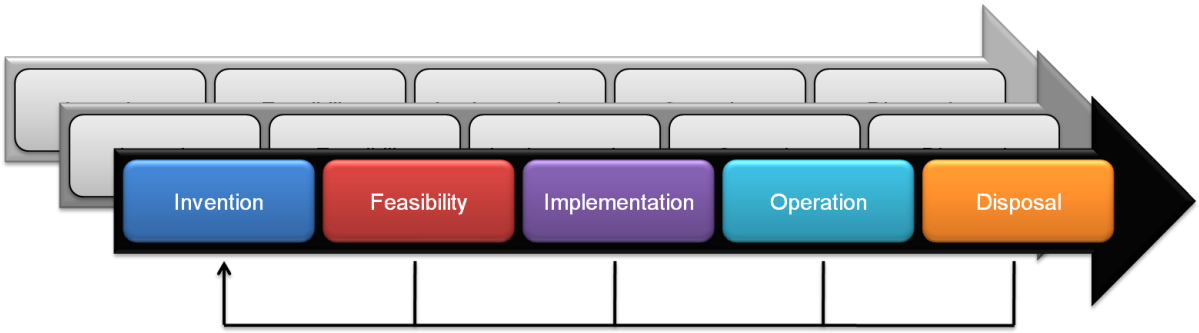


Figure 23 - The Basic innovation life cycle, adapted from Marais (98)

The process is similar to the life cycle of a product or service. The activities and deliverables will be discussed in more detail in a later section on the FuGle innovation model and thus only a short description of each of the phases will follow:

- **Invention**

  This phase relates to identifying opportunities and generating ideas. Generating “feeds” to the process usually necessitates creativity.

- **Feasibility**

  The ideas need to be evaluated in terms of their feasibility. This is done by rigorously testing and screening them. Du Preez et al. (96) also state that the specification, functional analysis and initial design should be executed in this phase.

- **Implementation**

  The ideas that passed through the previous stage are now designed in more detail and then implemented in the organisation or delivered to the market.

- **Operation**

  Once the process has delivered a commercially viable output, the operation starts. The operation phase includes activities such as production, quality control, monitoring and optimisation of processes and deployment of strategy.

- **Disposal**

  The output is terminated when it reaches its feasible lifetime, while fulfilling all environmental and legal obligations. This phase it not only for disposal of the outputs but also an opportunity to reflect and learn from the whole process.

Although these phases are portrayed as a linear process, there may be feedback loops which can enable an organisation to refine the outputs of preceding phases. The main objective of this diagram is to emphasise the fact that innovation projects need substantial structure to increase the chances of successful execution.

3.7 Role-Players in Innovation

The role-players in the innovation process can be aggregated at national and organisational level. This section will only briefly discuss the role-players on the national front and the organisational role-players will be discussed in Section 5.2.1.3.

The role-players on a national level are:

- Government – sets policies to incentivise collaboration for improving a country's global competitiveness.
- Industry – performs research and development to create outputs that add value for national and international consumers.
- Academia – universities whose main focus is research, both basic and applied.

Innovation, knowledge management and research commercialisation scholars agree that efficient and effective interaction (and collaboration) between these actors is crucial to sustain innovation on an organisational, regional and national level.

3.8 Innovation models

Although many firms have long realised the importance of innovation and are investing large sums of money into innovation projects, not many of these firms have witnessed the realisation of satisfactory returns on the bottom-line (117). Booz Allen Hamilton's (118) annual study points out that the one constant among successful innovators is "a rigorous process for managing innovation, including a disciplined, stage-by-stage approval process combined with regular measurement of every critical factors, ranging from time and money spent, to the success of new products in the market."

International literature has suggested numerous models for managing the innovation process, from the idea generation stage to the eventual exploitation of the ideas. According to Rothwell (119),

these models have evolved from describing innovation as a simple linear process to the modern, more complex networked models, which aim to describe the process over the entire innovation life cycle.

Figure 24 below shows this evolution from the technology push models of the 1930s to the modern extended innovation models.

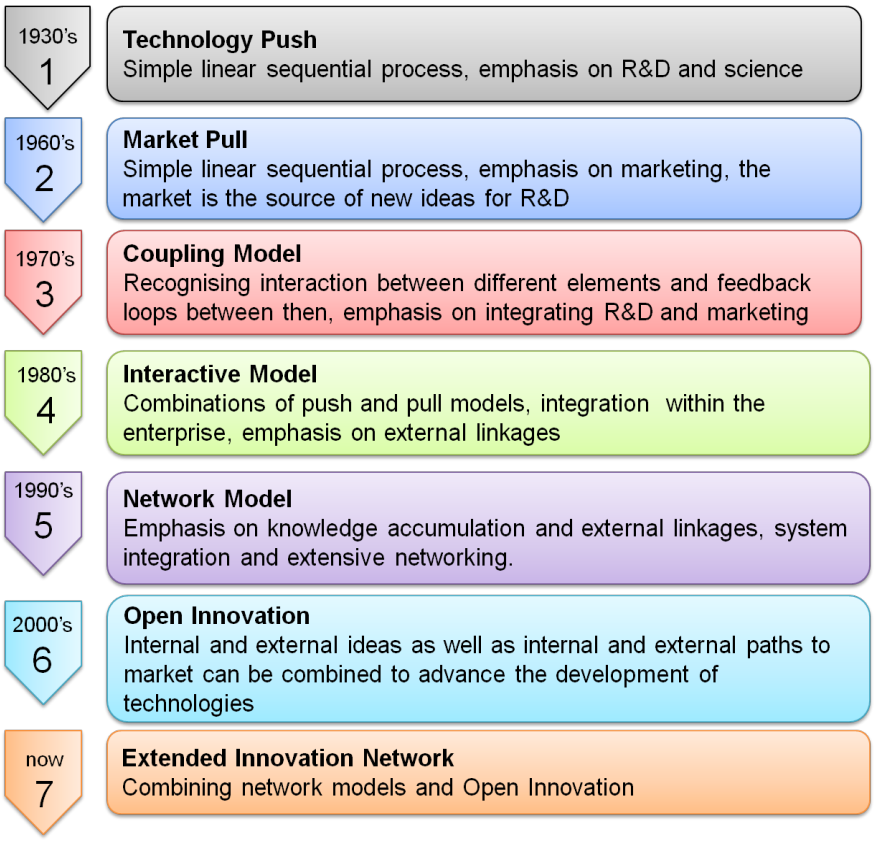


Figure 24 - Evolution of innovation models, adapted from Du Preez and Louw (117)

One of the latest editions to the evolution of innovation models is the FuGle innovation model by Du Preez et al. (117). It is suspected that this might be the seventh generation of innovation models but only time will tell. FuGle was developed by combining the concepts from various new product development and innovation process models published in literature with experience gained by industrial applications.

This FuGle model combines network models, which are essentially internally orientated within the organisation, with the concept of open innovation, which acknowledges the influence of the external environment. It also aims to cover the phases of the innovation life cycle (as discussed above) more comprehensively. It should be noted that the FuGle model is by no means regarded by its creators as the last innovation model. Du Preez et al. (96) state that these models will continue to evolve as the knowledge and understanding of the subject matter progresses.

Chesbrough (120) argues that the R&D process, which is primarily undertaken as a internal activity, has lost its effectiveness and cannot be used as an asset to sustain a competitive advantage. Marais (98) echoes this sentiment and suggests that open innovation tools and methodologies can be used to improve the comprehensiveness of innovation models.

This again emphasises the fact that collaboration in the R&D process has gained paramount importance in modern economies.

3.9 Chapter Summary

The aim of this chapter was to familiarise the reader with the landscape of innovation. Accordingly, innovation was defined, followed by a discussion of the drivers of innovation and the different categorisations of innovation.

The importance of research for the stimulation of innovation was discussed and subsequently knowledge and the knowledge supply chain were related to innovation. The chapter concluded with a discussion of the evolution of innovation models.

It is important that the reader be cognisant of the fundamentals of innovation as the following chapter will argue that the research commercialisation process can be modelled with an innovation model in order to allow for the eventual evaluation and improvement of the process.

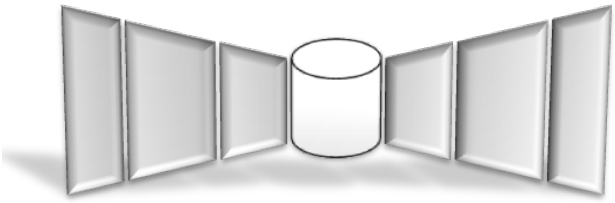
4

Modelling Research Commercialisation

One of the objectives of this research is to determine if it is appropriate to measure research commercialisation with an innovation maturity model and this chapter confirms that it is.

This research lays the foundation towards eventually improving a specific research commercialisation effort. The first step to improving a process is to investigate that process until the fundamentals of it is clearly understood. Then the process can be modelled to solidify that understanding and provide a platform for improvement.

This chapter will introduce the reader to the innovation models that are considered for modelling the research commercialisation process. Through deductive reasoning the FuGIe model was chosen. Accordingly the FuGIe innovation model will be described in detail while simultaneously showing how research commercialisation can be modelled with this innovation model.



4.1 Introduction

In order to measure and improve the research commercialisation process, it needs to be understood and modelled as a process, considering the external and internal environments in which it is positioned. The latest Innovation models, as discussed in Chapter 3, have the appropriate characteristics to be used as a reference model.

There are various innovation models that can be used as a reference and the next section will evaluate these models. The model that is most appropriate to be used for modelling the research commercialisation process is then selected.

If research commercialisation can be successfully modelled with an innovation model it will enable the use of innovation improvement methodologies to improve the research commercialisation process.

4.2 Selecting a Model

Throughout the evolution of the body of knowledge on innovation, many scholars have suggested models to manage the innovation process, whether they were aimed at product innovations or innovations needed to sustain the relevance of an organisation with reference to its processes and strategy.

Research done by Van Zyl (121) and Van Zyl et al. (122) identified various innovation process frameworks and categorised them according to their domain of application and the number of innovation life cycle phases they cover. Du Preez et al. (96) summarised these models in a convenient graphical illustration, presented on the next page.

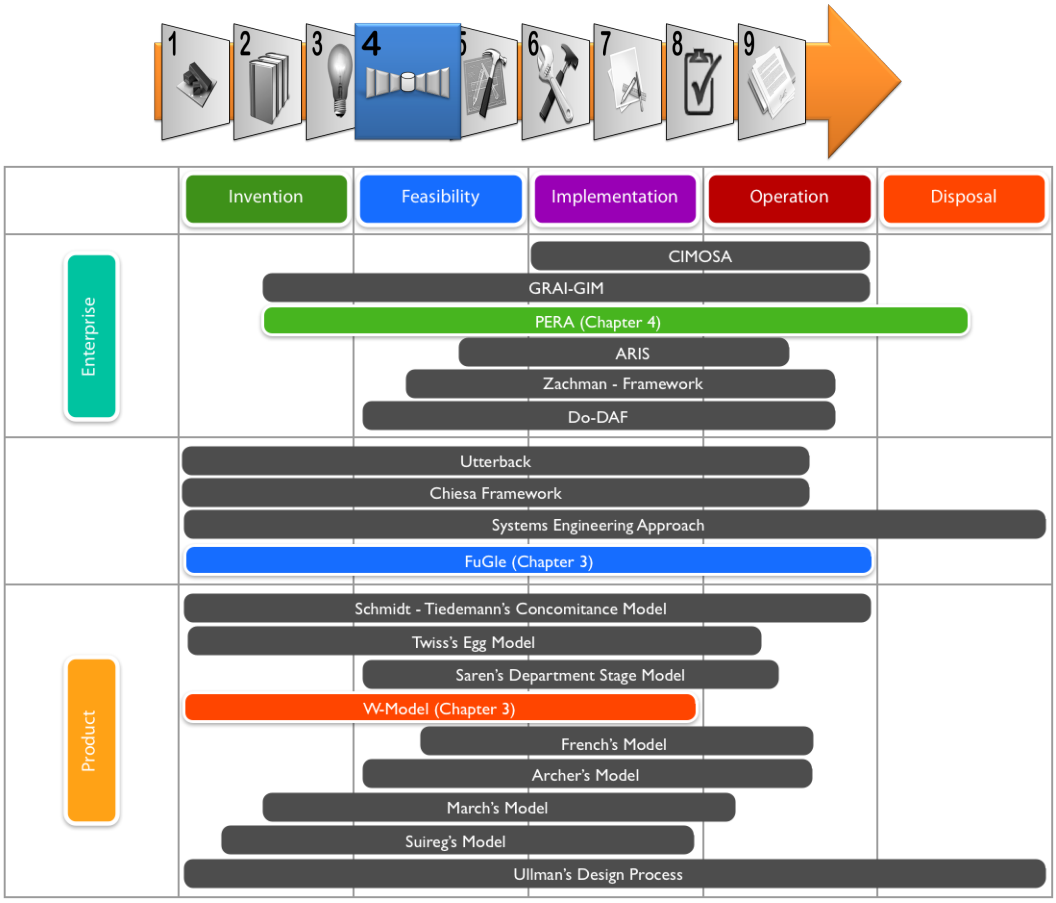


Figure 25 - Categorisation of innovation models by Du Preez et al. (96)

The models referenced in the middle section of Figure 25 are deemed appropriate for innovations in both the product and enterprise domains. With regard to their presence in the innovation life cycle, one can deduct that the Systems Engineering Approach, FuGle and Ullman's models are the most comprehensive. The latter was specifically developed for products and will thus not be deemed generic enough. Accordingly, the first two models are considered for use as a reference model.

The Systems Engineering Approach aims to assist with the effective realisation of complex and successful systems (98). Galanakis (54) used systems thinking to develop the Creative Factory innovation model, which is a fifth generation innovation model. In his model, the importance of knowledge creation is illustrated as a feed to the innovation funnel. It plays a central role and is part of the core innovation process.

Although these system approach models are also appropriate to model the research commercialisation process, they are deemed overly complex for the purpose of this section, which aims primarily to provide a simple illustration of how research commercialisation can be modelled using an innovation model.

The FuGle model, like the Systems Engineering Approach, comprehensively covers all the life cycle phases of innovation, except for disposal, but is specifically aimed at guiding and managing innovation projects. Literature on this model is freely available and the model is generally

described on a level that is sufficiently generic to be directly related to the research commercialisation process. Therefore, the FuGle model will be used to model the research commercialisation process.

A description of the FuGle model will follow in order to sensitise the reader to the structure and content that will eventually be needed to understand how the commercialisation process can be modelled into this structure.

4.3 FuGle Innovation Model

4.3.1 Background

The FuGle Innovation Process Model, first published in 2008 by Du Preez and Louw(117), was developed as a joint research project between Stellenbosch University, an Innovation consulting organisation called Indutech (Pty) Ltd., and various European research organisations.

Figure 26 serves as an illustration of the FuGle innovation model.

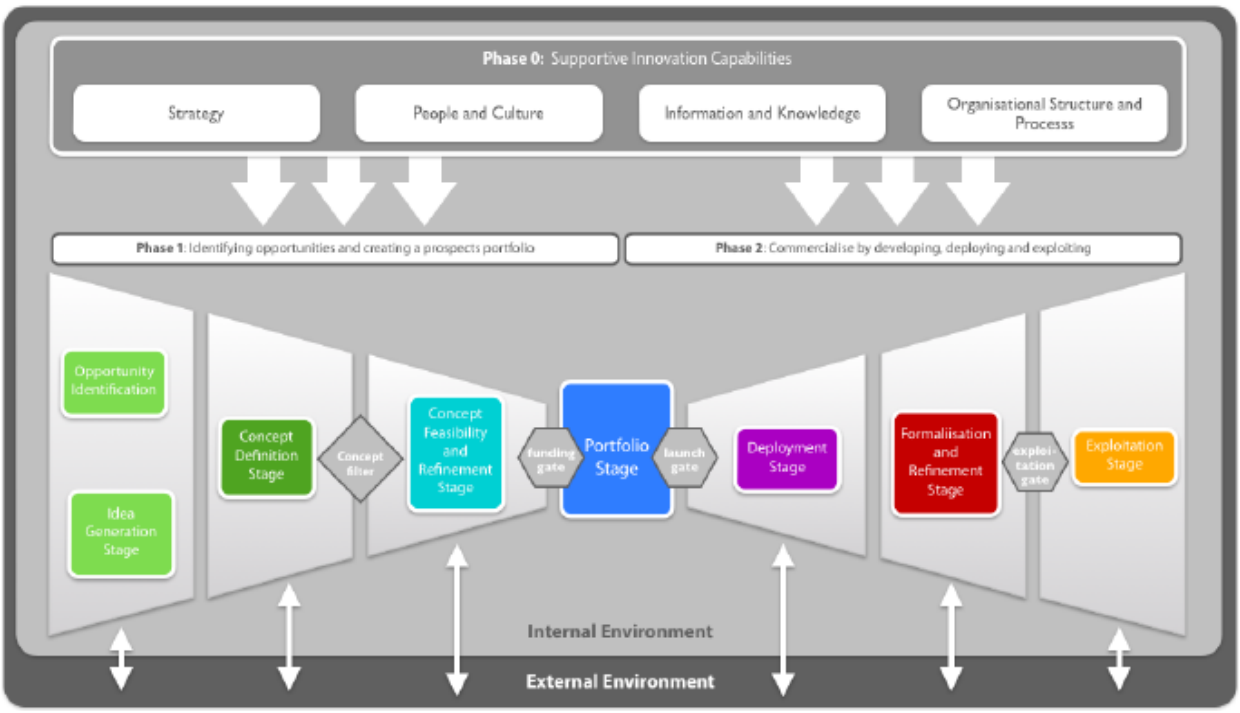


Figure 26 - The FuGle innovation model by Du Preez

The word “FuGle” stems from a amalgamation of the words “Funnel” and “Bugle”, terms typically used in discussions around the processes of innovation and exploitation.

The model is centred around the generic innovation process that combines the innovation funnel, consisting of activities such as idea generation, identification and concept definition with the divergent deployment and exploitation of innovations (117). It is presented in sequential stages,

each containing various activities that are prescribed to be enacted in each specific stage. The stages are separated by gates and filters that act as decision points. Furthermore, it should be emphasised that each of these stages is connected to the external environment; this means that they can be influenced or outsourced externally.

The innovation process is an iterative and repetitive process, and FuGle has incorporated these properties into its design. Although FuGle is portrayed as a sequential process, the stages may be revisited in an attempt to refine their outputs before they are subjected to the activities of the subsequent phase. Lastly, the core innovation process is guided and supported by an organisation's strategy, people and culture, information and knowledge, organisational structure and process.

Du Preez et al. (96) describe the FuGle model as a realistic life cycle process, as opposed to a theoretical process.

The different stages of FuGle will now be discussed individually with reference to the activities they contain, followed by the ways in which the stage and activities relate to the research commercialisation process. The relation is categorised along with the responsibilities of the different role-players within the process.

Not all the research commercialisation activities that would happen in each stage of FuGle are discussed, since the goal is not to provide a model of research commercialisation that is 100% accurate, but rather to show that it would be possible to model the process using an innovation model.

In summary, the main objective is to provide a sufficient level of detail when describing the research commercialisation activities in each stage of FuGle to allow the reader to recognise how the research commercialisation activities correlate with the generic activities prescribed in the FuGle innovation model and subsequently prove that research commercialisation can be modelled as an innovation process.

4.3.2 Idea Generation / Identification Stage

4.3.2.1 Description

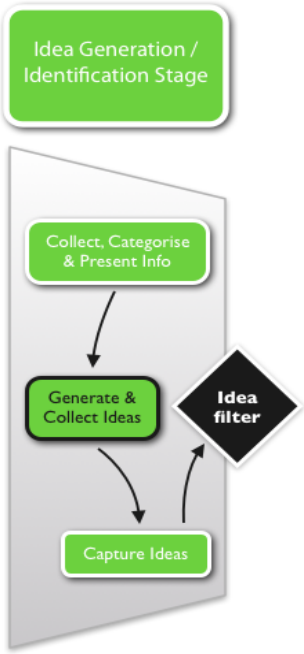


Figure 27 - FuGle idea generation stage by Marais (98)

The FuGle model commences with what is essentially a creative exercise. This initial stage is supported by activities that stimulate the generation of innovative ideas. It consists of three activities:

- Collection, categorisation and presentation of information
- Generation and collection of ideas
- Capturing of ideas

These ideas are usually sought to satisfy opportunities that have been identified by an organisation's searching and exploring activities. Ideas can also be generated with the aim of creating new opportunities for the organisation.

Du Preez and Louw (117) argue that it is possible for new innovative ideas to be triggered if the right information is provided to the right people at the right time. This claim highlights the importance of managing information effectively within an organisation.

The ideas can originate from the spontaneous creativity of individuals or be generated through the use of focused workshops and brainstorming sessions to stimulate creativity. In addition to internal idea generation, ideas can also be sourced from outside the organisation. The latter approach, known as Open Innovation, has become the focus of many organisations through the realisation that external sources can provide a cost-effective way of generating innovative ideas.

Capturing ideas in a manner that would make it easy to communicate them to others is a crucial activity in this stage. Ideas can also be shelved for later use if the current circumstances in the organisation do not warrant further investigation.

This stage is concluded with an Idea filter. A company's strategy should be a central consideration when deciding which ideas are to be put forward for development the next stage. The filtering criteria should be intelligently defined so as to select the ideas that can be developed with the resources that are available, while decreasing the probability of rejecting good ideas (117). The risk profile of ideas will also be an important consideration when filtering ideas.

4.3.2.2 Relating Research Commercialisation to Idea Generation/Identification

a. Researcher/Scientist

Researchers would often see an opportunity or dream up an idea that they wish to pursue in their research. This process of idea generation, as stated earlier, can happen as a result of pure interest or the pursuit of a foreseen commercial opportunity. Research is essentially nothing else than a very structured process of generating ideas. These ideas are developed, documented and presented in order to be evaluated by the technology transfer office.

b. Technology Transfer Office

The staff of the TTO evaluates the disclosures containing information on the discovery against predetermined criteria. More mature TTOs might have a search function in which they formally search for innovative ideas within the university's research base. As with the FuGle model, in addition to other predefined criteria, the strategy of the parent university should be a central focus when the criteria for promoting ideas through the idea filter are considered.

4.3.3 Concept Definition Stage

4.3.3.1 Description

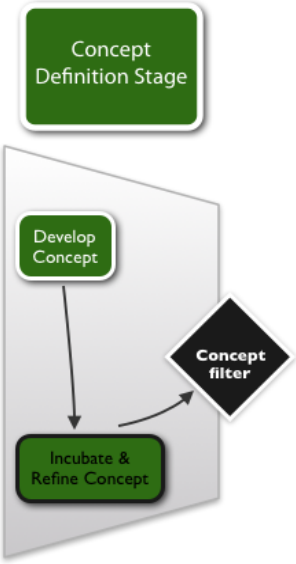


Figure 28 - FuGle concept definition stage by Marais (98)

At this stage, the ideas that passed through the idea filter are developed into workable concepts. The activities are:

- Develop concept
- Incubate & refine concept

Concepts can be developed from a single idea or a combination of ideas (117). The concepts should be well-defined and documented. These documented concepts should then be shared with various role-players to evaluate the necessity of refinements, in what is termed a concept incubation period or process.

At the end of this concept incubation process, the concepts are subjected to a concept filter. The strategy of the organisation should be considered once more when a decision is made regarding the concepts that should proceed to the following stage. Other criteria would include various preliminary feasibilities, including the commercial potential of the concept.

4.3.3.2 Relating Research Commercialisation to Concept Definition

a. Researcher/Scientist

In this stage, the researcher will do proof-of-principle development. The concept will be defined, developed and refined by substantiating the idea or combination of ideas that shapes the concept.

b. Technology Transfer Office

The responsibilities of the TTO staff in this stage relate to preliminary patent searches and assisting the researcher in finding capital for financing the proof-of-principle development if the latter is required. Concepts may also be shared with experts to do a preliminary evaluation of the commercial potential of the innovation.

The last task is to evaluate the various concepts and promote those that conform to the defined criteria. Once again, it is important to consider the strategy of the parent university towards commercialising research.

4.3.4 Concept Feasibility & Refinement Stage

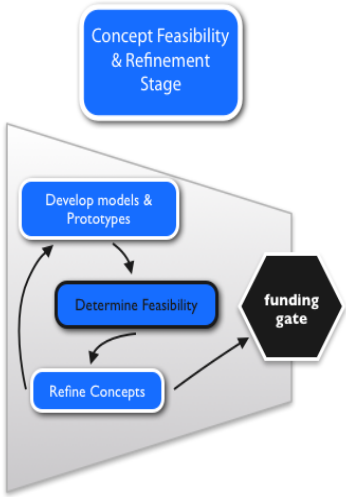


Figure 29 – FuGIe concept feasibility & refinement by Marais(98)

4.3.4.1 Description

In this stage, the concepts that passed through the concept filter are developed further and various feasibility studies are done. The activities are:

- Develop models and prototypes
- Determine feasibility
- Refine concepts

The models and prototypes are developed to make the concept tangible and enable the execution of various detailed feasibility studies. The exercise should act as a learning experience (117).

It is important that the feasibility studies be done properly, as it would be more cost-effective for the organisation to cease the development of a concept at this stage than continue spending time and resources on an unfeasible output (98).

As shown in Figure 29, the activities will typically be performed in various iterations, refining the concept and evaluating it again. The output from this stage should be a list of prospective innovation projects ready to be subjected to the funding gate. Notice that, in this instance, there is a gate rather than a filter. This emphasises the fact that there should be definite and harsh criteria

against which these prospective innovation projects are evaluated for progression as the subsequent stages involve the commitment of a large amount of time and resources. The progression of an unfeasible project through this gate could have detrimental effects on an organisation's bottom-line.

4.3.4.2 Relating Research Commercialisation to Concept Feasibility & Refinement

a. Researcher/Scientist

The researcher is tasked with developing models and prototypes for submission to various feasibility studies. Evaluating technical feasibility could also be the responsibility of the researcher.

b. Technology Transfer Office

Here, the TTO staff should be concerned with the various feasibility studies and business case development. This includes, among others, market research and the identification of possible industry partners.

At the end of this stage, the concept should be developed to a state at which it can be compared to other concepts for inclusion in the portfolio of projects which will eventually be deployed. This includes quantitative risk-return estimates and all other supporting qualitative information.

These concepts are evaluated against the funding criteria and venture capitalists may be approached for support in this regard.

4.3.5 Portfolio Stage

4.3.5.1 Description

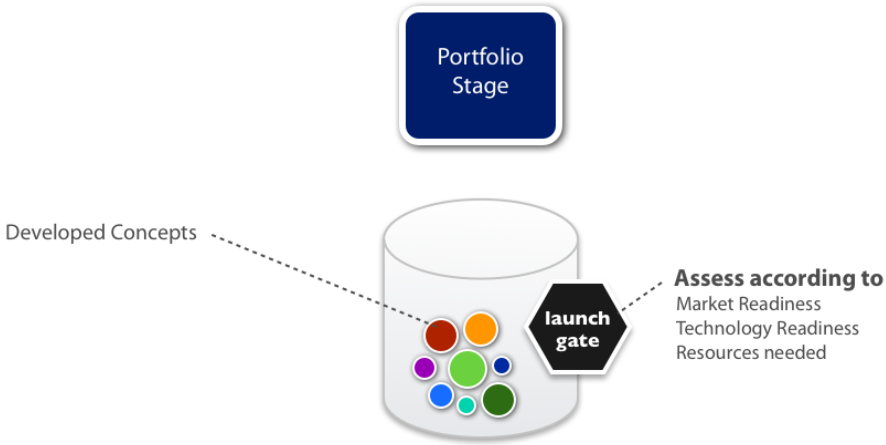


Figure 30 - FuGIe portfolio stage by Marais (98)

In this stage, the innovation projects that proceeded through the funding gate are added to the organisation's portfolio. The management of this portfolio entails the holistic management of the

organisation's innovation initiatives. The outputs from the previous stage are prioritised, scheduled and aligned in order to be exploited.

According to Du Preez and Louw (117), the management of the portfolio also includes the allocation of resources, assignment of responsibility for continuous monitoring of initiatives, understanding the aggregated affect thereof, and ensuring that the strategic objectives of the organisation are achieved. It should be noted that, although the portfolio stage is presented in a defined position in the sequential process, portfolio management is relevant throughout the innovation life cycle, and entails the management of ideas at the fuzzy front-end right through to managing all the innovations that are exploited at any point in time.

The activities in the stage end at the launch gate. The projects are deployed based on factors such as market, technology and resource readiness (98).

4.3.5.2 Relating Research Commercialisation to the Portfolio stage

a. Researcher/Scientist

The researcher has no specific task in this stage.

b. Technology Transfer Office

The TTO staff should use portfolio management tools to manage the developed concepts that have already passed through the funding gate. These concepts need to be prioritised to proceed through the launch gate. The criteria that are relevant would be issues like timing, market readiness, available resources, etc. Market readiness in this sense would be a preliminary assessment as this activity can only be fully completed when a detailed design has been realised.

Innovations can be shelved if this action would provide an opportunity to launch at a later stage and consequently ensure a larger return. TTOs would also be required to manage the licences and equity they have acquired through previous successful innovations that are currently being exploited.

4.3.6 Deployment Stage

4.3.6.1 Description

This stage entails the following activities:

- Plan project
- Detail design and test
- Implement

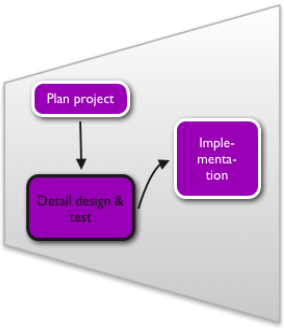


Figure 31 - Fugle deployment stage by Marais(98)

In this stage the innovation solutions, as conceptualised and decided upon in the preceding stages, are designed in detail and tested. This could include the business and marketing plans, in addition to the physical design of the output. Further activities that should be performed also include project planning, the management of these designs, and the implementation of the projects (117).

Before reaching the implementation gate, which involves the roll-out of the innovation, the design should be reviewed a final time. This will ensure that all the foreseeable aspects are addressed in order to ensure a successful implementation.

4.3.6.2 Relating Research Commercialisation to Deployment

In this stage the activities that should be performed by the different role-players and even the role-players themselves will become a function of the research commercialisation output to be generated. The output can either be a licensing agreement with an existing company or a start-up company that is created if the innovation warrants such a decision. Taking these two outputs through the second half of the FuGle stages will obviously require different activities to be performed. These activities will accordingly be related to the output from here on out.

a. Researcher/Scientist

For the researcher, the activities in this stage are consistent, whichever output is produced, and entail the detailed design of the innovation. This could include activities such as the customising the innovation for different market sectors. In the case of a licence, the researcher could join in negotiations with potential buyers to provide technical insight.

b. Technology Transfer Office

In the case of a licence, the TTO staff should finalise the IP protection progress, market the invention to companies, and negotiate the licensing agreement on behalf of the researcher.

In the case of a spin-off, business plans need to be finalised, entrepreneurial training could be provided to researchers and venture capital should be sourced if necessary. The business case and business plan should be completed and re-evaluated before implementation commences.

4.3.7 Refinement and Formalisation Stage

4.3.7.1 Description

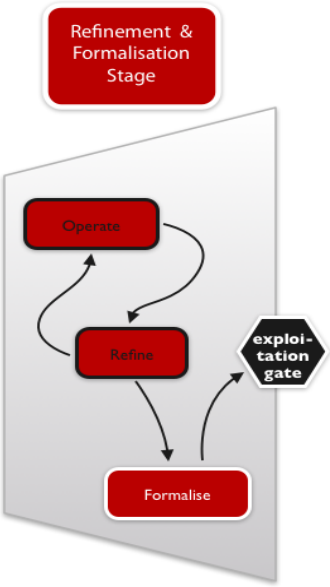


Figure 32 - Fugle refinement & formalisation stage by Marais (98)

This stage follows the roll-out of the innovation. Actions include:

- Operate
- Refine
- Formalise

Du Preez and Louw state that some implemented innovations will initially not function optimally. The objective of this stage is to monitor, measure, evaluate and refine the innovation in however many iterations until it performs satisfactorily in line with its specifications.

Once this state has been reached, the operational documentation can be formalised.

4.3.7.2 Relating Research Commercialisation to Refinements & Formalisation

a. Researcher/Scientist

When signing a licence, the researcher might be obligated to partner with the licensee to develop the innovation further, or help to implement it. In the case of a spin-off company, the researcher could be involved in the operation of the company, act as a director or divest from the company.

b. Technology Transfer Office

The negotiations should be done and the licence signed in the refinement and formalisation stage and this procedure would conclude the involvement of the TTO. In the case of a spin-off company, the TTO could provide access to incubation services and be involved in activities such as refining the business model.

4.3.8 Exploitation Stage

4.3.8.1 Description

Figure 33 - FuGle exploitation stage by Marais(98)

This stage follows the formalisation of the innovation. The innovation is exploited in the market place and the aim is to generate value from it.

4.3.8.2 Relating Research Commercialisation to Exploitation

Value, in which ever form it manifests itself, is obtained from the operation of the innovation and distributed to all role-players in accordance with either the policy of the TTO or the parent university, or the terms and conditions of the agreement reached between all the partners involved prior to implementation activity.

The TTO can still be active in this stage executing some managerial functions, but this would typically be the responsibility industry partner to whom the output was sold or licensed.

The researcher could still be involved in some optimisation activities.

4.4 Chapter Summary

Fundamentally, the funnelling paradigm can be directly applied to research commercialisation. Bridging the chasm between the creation of knowledge and the eventual exploitation of that knowledge requires time, resources, capabilities, knowledge and structures similar to the those required for the process of innovation (123).

The question remains: Why model research commercialisation as innovation? Du Preez et al.(96) state that, “[f]or the innovation process described by the FuGle to be enabled within an enterprise, various supportive capabilities need to be in place.” These innovation capability requirements will be introduced in the following Chapter on the Innovation Capability Maturity Model.

The central issue is the following: to innovate consistently, an organisation needs to possess the capabilities to do so; therefore, for an organisation to commercialise its research, the same capabilities are needed. The next chapter will examine ways to develop and improve these capabilities.

5

Innovation Capability: A means

This chapter introduces the concept of maturity models and then explains their merit for process improvement.
In the latter part Essmann's (1) Innovation Capability Maturity Model is introduced and comprehensively explained. This is done to give the reader insight into how the model works and is important as a foundation as it will be used in the chapters that follow.
As the objective of the research is to apply the model, the Innovation Capability Improvement methodology will also be discussed in this chapter.

5.1 Capability Maturity Models

The notion of using maturity models to improve the quality of products dates back to the early 1980s(124). Initially, continuous improvement (CI) seemed like the logical option for improving software products, but success with CI initiatives was sporadic. The problem was not the CI initiatives themselves, but rather their implementation.

Watts Humphrey, a world-renowned software engineer working at International Business Machines Corporation (IBM), realised that the organisation developing the software had to remove the impediments to CI in a specific order so that the quality could be improved. Subsequently, Watts Humphrey and some of his colleagues at IBM developed the concept for the Capability Maturity Model® (CMM)(124). The fully developed CMM was first published in 1993 by the Software Engineering Institute (SEI) of Carnegie Mellon University (125) (126).

The CCM created the platform from which many consequent maturity models were developed for use in different domains of practice, including, among others, project management, product development, knowledge management, software development, etc. (1)

If the objective is to manage innovation, then one should look for a maturity model that measures the innovation domain, but at the outset it would be valuable to define maturity and then discuss why the use of maturity models is appropriate for improvement in the innovation domain.

5.1.1 Defining Maturity

The definition of maturity is largely dependent on the domain in which it is used, but it generally implies that a certain plateau with a defined level of development has been reached. Concerning the development of an organisation, Cooke-Davies (127) states that maturity conveys a meaning of "[p]erfected in its application".

"[P]erfected" implies that a designer, or someone outside the system, is able to define the level to which the system under development meets its intended purpose (127).

For an organisation to reach its perfected state, someone outside the system (including employees who temporarily "step out" of the system) should be able to make changes to that organisation to move it closer to perfection. It should be noted that perfection as a state may be an unattainable goal for an organisation, since the environment in which it operates is so dynamic – in other words, 'perfection' today might be something else tomorrow. This does not, however, eliminate the need for the pursuit of perfection.

Based on Cooke-Davies's definition, Essmann (1) defined maturity in the organisational domain as: "a system assessed to be optimally fit for its purpose, as described by the designer."

5.1.2 The Purpose of Maturity Models

Since the first maturity model was presented in 1993, many designers have developed similar models to evaluate and improve their specific domains of practice. Brett Champlin, the President of The Association of Business Process Management Professionals, has identified around 150 such models (128). This number should serve as evidence that there is some merit in a maturity approach.

The real questions would be: Are these models effective in achieving their purpose? To answer this question, one must first explain what the purpose is. Essmann (1) argues that all these models have two fundamental purposes. The first purpose is to establish the capability maturity in terms of a specific domain of practice. The second purpose is based on the first: to establish a direction and course of improvement that would best suit the organisation incorporating the established best practices of the domain.

It is critical to evaluate an organisation's current capabilities by either comparing them to known best practices in the domain or evaluating them against the capabilities of similar organisations that are successful in the execution of their purpose. This is essentially a benchmarking exercise, but organisations typically operate in a competitive domain and accordingly most organisations will be reluctant to expose or share the source of their competitive edge.

However, maturity models are an effective tool to overcome this problem. The creators of these models have applied significant resources to identify the best practices for specific domains and as a result, an organisation can use maturity models to evaluate the maturity of its capabilities against these best practices.

Most maturity models prescribe improvement paths once an organisation has been benchmarked. According to Rassa, the deputy chair of the Capability Maturity Models Integration® project (CMMI®, the latest offering from the Software Engineering Institute (SEI)), a lot of research went into determining how an enterprise should look and how it should get there (1). As a result, the best practices for improving the maturity of specific capabilities are specified, while still being generic enough to be applied in many different organisations.

In conclusion, it is worth quoting Essmann (1) again, who states that the central purpose of all maturity models is "to progressively ensure the institutionalisation of domain specific best practices and facilitate process harmonisation."

5.1.3 The Success of Maturity Models

Knowing the purpose, one would now want to know whether these maturity models have been successful in meeting it. Managers want to see increased value in the form of cost reductions, improved quality, timely delivery, etc.

In a special report from the SEI, Goldenson and Gibson (129) give a comprehensive overview of the improvements that have been realised by the implementation of the software CMM® and CMMI® in a number of organisations. These organisations include Accenture, Boeing and Bosch, among others. The major improvements were realised in the areas of:

- Cost – A reduction in cost
- Schedule – Decreased time to complete tasks and higher predictability in meeting schedules
- Quality – Improvements in quality as result of reduction in defects
- Customer Satisfaction – Improved customer satisfaction
- Return on investment – Positive return on investment from CMMI-based process improvements

Essmann (1) warns that these are benefits from only two models and that they may not be representative of the returns of all maturity models; however, they do provide evidence that there is merit for the application of maturity models.

5.1.4 The Structure of Maturity Models

The basic structure of most maturity models consists of a five-level maturity scale. These levels are presented below.

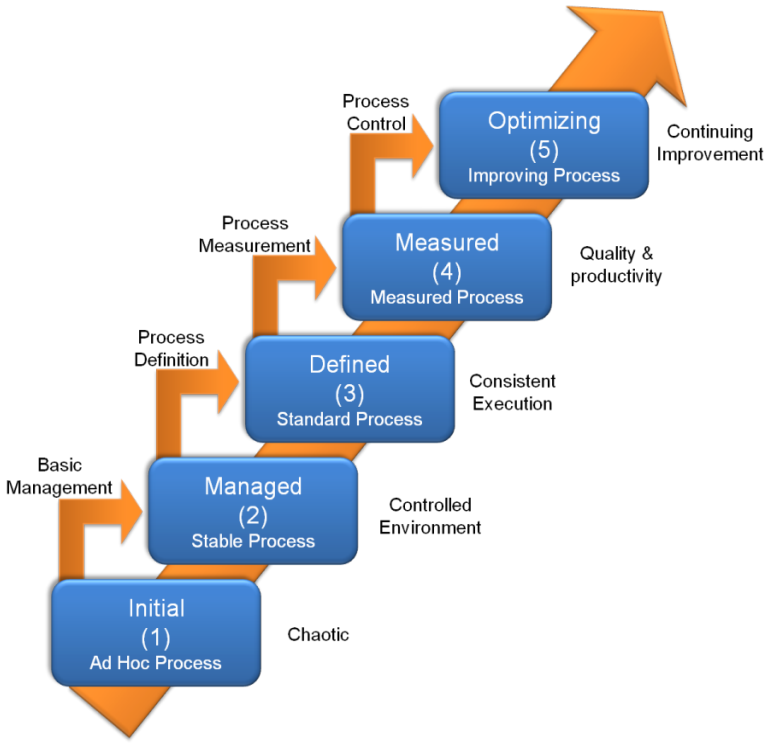


Figure 34 - Common maturity level structure, adapted from Humphrey(130)

According to Bate et al. (131), several reasons exist why the process is identified as the first dimension of organisational capability improvements. These include (1):

- The process is an integrative function of people and technology
- The process focus improves predictability of performance, and performance itself
- Research into improving process capability translates well from other fields

An organisation does not necessarily start at maturity level one. The organisation is benchmarked against the different maturity levels and the appropriate maturity level for which the organisation has fulfilled all the requirements is assigned to the organisation. An organisation can only be on a maturity level if it has fulfilled all the requirements for all the preceding levels.

The characteristics of behaviour of all five levels will now follow, as defined by Essmann (1), as his descriptions are based on the definitions of the Software Engineering Institute's Capability Maturity Model Integration®, but specifically adapted to the domain of innovation:

5.1.4.1 Maturity level 1

- The organisation is wholly consumed with day-to-day operations, maximising short-term revenue and reducing cost.
- Individual attempts at being creative or think outside the box are often dismissed.
- Innovative outputs are inconsistent and unpredictable.

5.1.4.2 Maturity level 2

- The organisation has identified the need to innovate.
- Innovation is clearly defined.
- A basic understanding of the various factors that influence innovation has been established.
- Innovative outputs are inconsistent, but traceable.

5.1.4.3 Maturity level 3

- Innovation is supported and managed with appropriate practices, procedures and tools.
- Individuals are encouraged to be innovative.
- Innovative outputs are consistent in nature and ensure sustained market share and positioning.

5.1.4.4 Maturity level 4

- Practices, procedures and tools for integrating innovation activities are used.
- A deep understanding of the internal innovation model and its relation to business requirements has been established.
- Innovative outputs are consistent, diverse and a source of differentiation.

5.1.4.5 Maturity level 5

- Innovation practices, procedures and tools are institutional.
- Individuals are empowered to innovate.
- Synergy is achieved through the alignment of business and innovation strategy and the synchronisation of activities.
- Innovative outputs provide sustained competitive advantage in existing and new markets.

5.1.5 Maturity and Innovation

In a world where change is the only constant, the capabilities of an organisation need to be dynamic (132). Innovation has been related to this evolution and revolution as a cause but also a consequent requirement. However, none of the current maturity models for the domain of innovation has sufficiently addressed this dilemma "*by assembling domain-focused process areas*

implied to be sufficiently generic that they collectively embody a depiction of organisational or domain maturity that is independent of change (1)".

The CMMI® addresses this issue to a certain extent by necessitating innovation. However, innovation is only set as a requirement to move from maturity level 4 to level 5 (1), which means that innovation is only reserved for relatively mature organisations. Kostoff et al. (133) conclude being innovative does not correlate with the size of an organisation; large organisations do not necessarily have the inherent capability to innovate persistently and small firms do not generally have a crippling lack of capability. It can be argued that smaller firms are more agile and thus have a larger capacity to innovate than large corporations.

There seems to be a lack of focus on innovation on the lower levels of the maturity models that are available and this prompted Essmann (1) to constitute a maturity model specifically focused on the domain of innovation, aptly named the Innovation Capability Maturity Model.

5.2 Innovation Capability Maturity Model version 2

In this subsection the Innovation Capability Maturity Model developed by Essmann (1) will be described to familiarise the reader with the content and structure of the model.

The model was developed in three phases. In the first phase, a thorough literature study of maturity models was undertaken to evaluate their applicability in the innovation domain. In the second phase, a detailed literature review of innovation fundamentals led to the development of the Innovation Capability Maturity Model version 1 (ICMMv1). This ICMMv1 was then applied and analysed in a case study. The results from this case study were used to refine the model.

The Innovation Capability Maturity Model version 2 (ICMMv2) was a product of this rigorous refinement exercise undertaken in phase three of the process. The ICMMv2 was subsequently validated through a number of case studies and the resulting model is presented below.

5.2.1 Model Components

The model is divided into three high-level parts. The first is a framework that provides the model's structure. The second part addresses the 42 core requirements identified by Essmann (1) as crucial for innovation in an organisation and these core requirements are dubbed the Innovation Capability Requirements. The third and last part of the model describes the different roles that are required within an organisation to innovate continually.

These three parts will be discussed in more detail below. There are also supplementary components other than these three, and they will be introduced after this discussion.

5.2.1.1 Framework

The framework provides the structure of the model. This structure is provided by a three-dimensional framework consisting of:

- Innovation capability construct
- Organisational construct
- Innovation capability maturity

These three dimensions ensure that the model comprehensively covers all the aspects needed for innovation without duplicating content within the model.

a. Innovation Capability Construct

In this construct, innovation capability is described on two levels of detail. The first level is the Innovation Capability Areas and the second is the Innovation Capability Construct Items. The Innovation Capability Areas are the three main areas of innovation capability, namely Innovation Process, Knowledge and Competency, and Organisational Support. These three areas are subdivided into the Innovation Capability Construct Items which provide a more detailed perspective on the three high-level areas.

A graphical illustration is presented below to demonstrate how the three Innovation Capability Areas support each other. Innovation process is at the core of an organisation's ability to innovate: without it, there will be little to no consistent innovation success. The Innovation Process is supported by Knowledge and Competency and the foundation of innovation lies in the Organisational Support level.

Figure 35 - Innovation capability areas hierarchy, adapted from Essmann (1)

"*These aspects all contribute in a complex and interrelated manner to an organisational support system (often referred to as culture, climate and/or environment) that enables and encourages innovation.*"(1)

Each of these Innovation Capability Areas and their subsequent Innovation Capability Construct items will now be discussed separately, and this discussion will conclude with Figure 36, which shows how this construct fits into the model as a whole.

i Innovation Process

This area refers to the innovation life cycle and consists of the practices, procedures and activities, that take an idea through the phases of concept development, implementation of the concepts and finally the generation of revenue by satisfying an opportunity with that concept. This area has four construct items (1):

- Explore & Converge – searching for opportunities and being receptive to new ideas, and translating these into concepts that could potentially be realised. It also includes developing an understanding of the market; contextualising opportunities; considering aspects such as technology timelines, regulation, societal changes, etc.
- Portfolio Management – coordinating the organisational resources, the pursued opportunities, prospective opportunities and the existing value offerings to achieve balance within the project portfolio that aligns with organisational strategy and meets objectives. It also includes the testing, screening and prioritising of opportunities and ideas.
- Consolidate & Exploit – effectively and efficiently substantiating, implementing and exploiting prioritised opportunities by using appropriate project management techniques.
- Process Control & Risk Management – guiding and controlling the innovation process through effective decision-making, and managing and mitigating the risk and uncertainty associated with innovation.

ii Knowledge & Competency

To support the innovation process, an organisation requires specific and broad-based knowledge and competency. The knowledge competencies need to be created if not present in an organisation and they need to be managed along with the technology to support them. This Innovation Construct Area consists of three construct items (1):

- Discover – continuous research, networking and collaboration in existing and new fields to improve and build on the knowledge base.

- Absorb & Consolidate – identifying, extracting and capturing relevant information and knowledge in context. Also includes the management of intellectual property.
- Core Competency & Technology – developing and/or acquiring the required competencies and technologies, and managing them.

iii Organisational Support

The last Innovation Capability Area contains the structures, resources, measures, infrastructure, strategy and policies, leadership, and so on, that are necessary to support both the innovation process and the knowledge and competency. This area is divided into four construct items (1):

- Innovation Strategy & Leadership – developing and conveying innovation-specific strategy and objectives, and championing and encouraging innovative behaviour.
- Structure & Infrastructure – ensuring that organisational structuring (teams, functional, geographical, etc.) is flexible, adaptable and conducive to innovation, and that the necessary infrastructure is available to support and facilitate innovation.
- Environment & Climate – ensuring that organisational polices, values, practices and procedures contribute to an environment that is conducive to innovation.
- Resources & Measurement – investing sufficiently in innovation, aligning resources with innovation requirements and appropriately measuring innovation-related processes and outputs.

As stated earlier, Figure 36 below illustrates how these innovation capability areas and their respective innovation capability construct items fit into the framework of the ICMMv2.

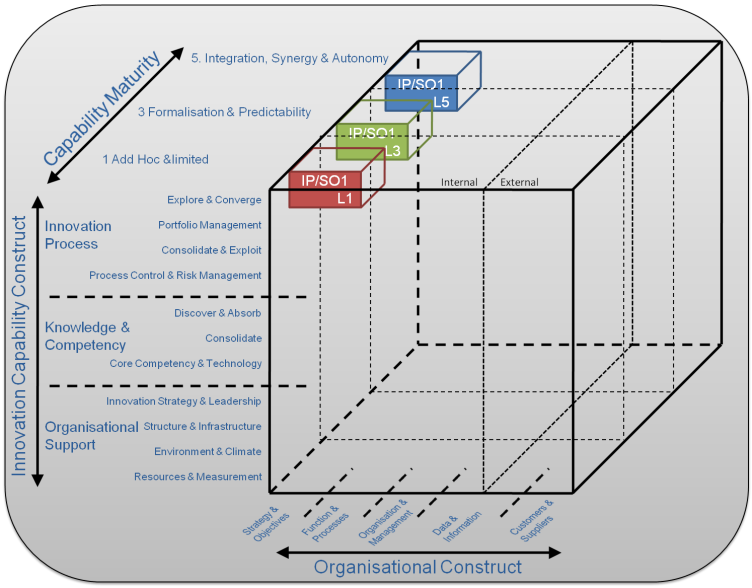


Figure 36 - Innovation capability and organisational constructs of the ICMMv2 framework, adapted from Essmann (1)

b. Organisational Construct

This construct ensures that all the fundamental aspects of an organisation are addressed. The construct adds additional value to the model by illustrating the relationship between the organisational aspects and the capability requirements. This also gives an indication of how the capability requirements affect the fundamental organisational aspects. Although these aspects may not cover all the aspects of a specific organisation, they should be considered by any organisation to conduct business effectively.

The organisational construct is subdivided into five organisational aspects:

- **Strategy & Objectives** – This aspect concerns the vision, mission, values and short- or long-term objectives of an organisation. These elements steer an organisation and will eventually determine its competitiveness.
- **Function & Processes** – This is the value added and the administrative activities that drive the organisation to fulfil its objectives.
- **Organisation & Management** – The structures and entities that are tasked with governing and/or controlling the execution of activities in order to fulfil objectives.
- **Data & Information** – This aspect relates to the basis of decision-making and communication between internal and external environments.
- **Customers & Suppliers** – The final aspect relates to the customers that pay for the value offering of the organisation and the suppliers that provide the resources used by the organisation to compile the value offering.

Figure 36 above shows how this organisational construct and its aspects fit into the model as a whole.

c. Innovation Capability Maturity

The final part of the framework represents the different levels of innovation capability maturity. As previously mentioned, these maturity levels are well-defined evolutionary plateaus for innovation capability. Figure 37 illustrates how these levels follow on each other.

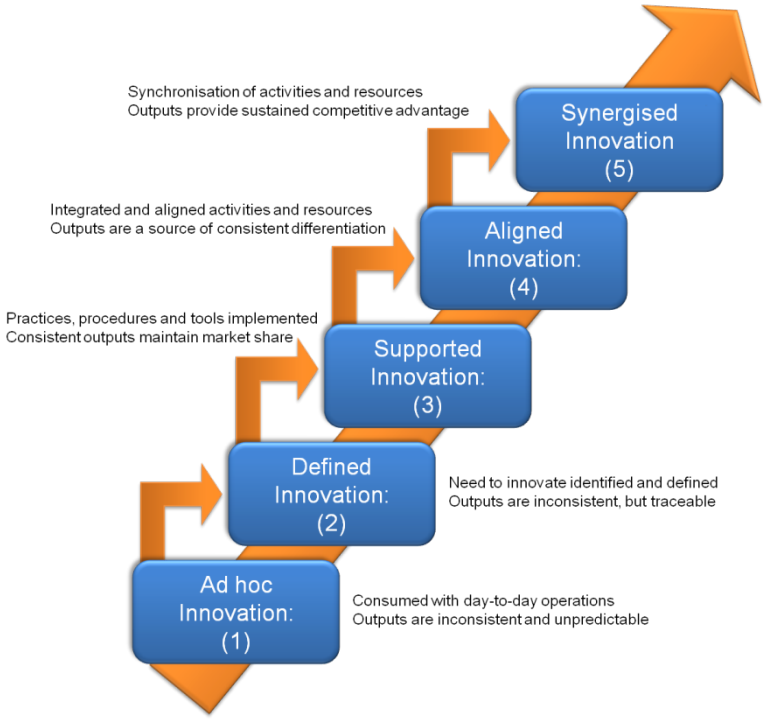


Figure 37 - ICMMv2 maturity levels, adapted from Essmann(1)

Essmann (1) provides a generic maturity description for each Innovation Capability Requirement on levels 1, 3 and 5. These generic descriptions for the individual capabilities were derived by utilising the generic description of general Innovation Capability on a maturity level of 1, 3 and 5.Levels 2 and 4 will be something between the descriptions of levels 1 and 3, and 3 and 5 respectively.

These general Innovation Capability Maturity descriptions are (1):

- **Maturity Level 1:** Ad hoc & Limited – innovation-related practices and procedures are impromptu and limited in their ability to fulfil the requirements for consistent innovation.
- **Maturity Level 3:** Formalisation & Predictability – innovation-related best practices and procedures have been indentified and deployed, enabling the consistent fulfilment of the requirements for innovation. This does not mean the deployment of rigid or stifling structures, but rather a proactive and planned approach to innovating.

- **Maturity Level 5:** Integration, Synergy & Autonomy – once formalisation has been attained, institutionalisation of practices emerges, in other words, activities become natural behaviour. This enables individual autonomy, and the freeing up of resources to concentrate on achieving alignment and synergy within and between innovation initiatives and with operational activities.

If the maturity of a capability is not formalised (level 3) but also cannot be described as ad hoc (level 1), a maturity of 2 will be appropriate for that specific capability. The maturity descriptions on levels 1, 3 and 5 for each of the 42 Innovation Capability Requirements can be found in Appendix II.

To conclude this section on the framework, a full representation of the model follows below, which demonstrates how this last part of the framework (Capability Maturity) completes the three-dimensional framework.

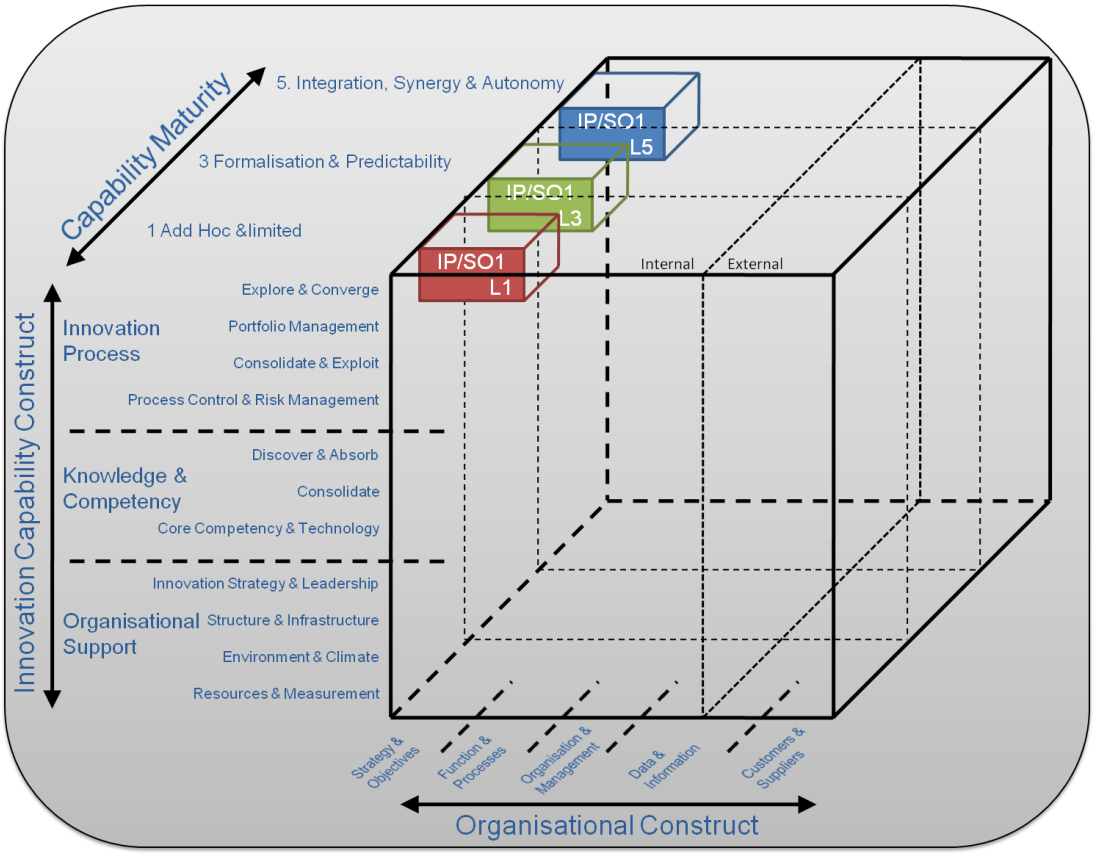


Figure 38 - Innovation capability maturity framework, adapted from Essmann(1)

5.2.1.2 Core Requirements

The Innovation Capability Requirements are the foundation on which the ICMMv2 is built. Essmann identified 42 generic organisational capabilities that an organisation has to possess in order to innovate consistently. These Innovation Capability Requirements are categorised into the

two-dimensional matrix formed by the Innovation Capability Construct and the Organisational Construct. This can be seen in Figure 39 on page 94.

The categorisation of these capabilities will be explained by way of an example. Consider the capability IP/SO1 - *Scanning and Exploring for latent opportunities,* as presented in the bottom-left corner of Figure 39 below. The representative code is a tool employed to quickly illustrate where the capability fits into the matrix. According to the representative code (IP/SO1), the capability *Scanning and Exploring for latent opportunities* is categorised into the Innovation Process Area (**IP**) on the Innovation Capability Construct and into the Strategy and Objectives area (**OP**) of the Organisational Construct. It is also the first capability in this column and corresponding row and therefore it is nr. **1**.

Essmann (1) provides three generic descriptions of the maturity on maturity levels 1, 3 and 5, as stated above. The description for this specific capability is as follows:

- **Maturity Level 1:** IP/SO1 L1 – "Opportunities" of the future are based on extrapolation of the past.
- **Maturity Level 3:** IP/SO1 L3 – Initiatives to find latent opportunities are undertaken. Procedures have been developed and implemented, and the required outputs defined.
- **Maturity Level 5:** IP/SO1 L5 – Future-orientated scanning and exploring activities provide consistent strategic input. Procedures to identify latent opportunities are institutional.

The illustration of the model in Figure 38 above shows how this capability on its different maturity levels is mapped into the model's framework. All 42 capability requirements are similarly described on these three maturity levels and mapped into the framework structure.

The two-dimensional matrix presented below provides essential information as to how a capability such as *Scanning and Exploring for latent opportunities* relates to other capabilities, both horizontally from an Innovation Capability perspective and vertically from an Organisational Aspect perspective.

To conclude this section, it would be valuable to mention that one of the most important aspects of this model for this specific research is the maturity descriptions of the Innovation Capability Requirements. These descriptions are used to create the different maturity scenarios in the Innovation Capability Assessment Questionnaire. The Questionnaire is the tool that will be used in the case study to evaluate the Innovation Capability of a research institution.

Innovation Capability Construct \ Organisational Construct		Internal				External
		Strategy & Objectives	Function & Processes	Organisation & Management	Data & Information	Customers & Suppliers
Innovation Process	Explore & Converge	IP/SO1 - Scanning & exploring for latent opportunities	IP/FP1 - Identifying opportunities IP/FP2 - Developing concepts	IP/OM1 - Contextualising opportunities & concepts	IP.KC/DI1 - Capturing, storing & retrieving data & information IP.KC/DI2 - Formal & informal internal networking & collaboration	IP/CS1 - Understanding the market
	Portfolio Management	IP/SO2 - Balancing the innovation portfolio IP/SO3 - Using fundamental principles to guide process & make decisions	IP/FP3 - Testing, screening & prioritising opportunities & concepts	IP/OM2 - Planning & coordinating the innovation portfolio IP/OM3 - Allocating resources appropriately		IP/CS2 - Involving customers & suppliers in the innovation process
	Consolidate & Exploit		IP/FP4 - Substantiating, implementing & exploiting opportunities	IP/OM4 - Using appropriate project management techniques	IP.KC/DI2 - Formal & informal external networking & collaboration	
	Process Control & Risk Management		IP/FP5 - Identifying and planning for key decision points	IP/OM5 - Reducing uncertainty & mitigating risk		
Knowledge & Competency	Discover	KC/SO1 - Establishing knowledge, competency & technology development & acquisition strategy KC/SO2 - Establishing intellectual property management & sharing policy	KC/FP1 - Continuous research	KC/OM1 - Managing tacit knowledge		KC/CS3 - Ensuring supplier competency & technology supports requirements
	Absorb & Consolidate		KC/FP2 - Identifying & extracting relevant information	KC/OM2 - Managing intellectual property		
	Core Competency & Technology		KC/FP3 - Developing & acquiring the required competencies & technologies	KC/OM3 - Managing core competency & technology		
Organisational Support	Innovation Strategy & Leadership	OS/SO1 - Developing & conveying innovation strategy & objectives	OS/FP1 - Championing & encouraging innovation	OS/OM1 - Meta-Innovation	OS/DI1 - Communication & the flow of information	
	Structure & Infrastructure	OS/SO2 - Organisational values & policies	OS/FP2 - Infrastructure, systems & tools to support process & management requirements OS/FP3 - Organisational practices & procedures	OS/OM2 - Creating cross-functional & multidisciplinary teams OS/OM3 - Developing flexible & adaptable organisational structure & infrastructure		
	Environment & Climate			OS/OM4 - Motivating, rewarding & celebrating success		
	Resources & Measurement	OS/SO3 - Investment in innovation & sourcing of capital	OS/FP4 - Providing the necessary resources *(Resource slack, focussed resources)* OS/FP5 - Measuring innovation	OS/OM5 - Hiring & aligning people's values & skills with organisation & task OS/OM6 - Benchmarking innovation		

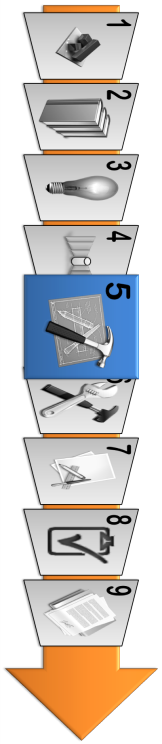


Figure 39 - Innovation capability requirements categorised into constructs by Essmann(1)

For a detailed explanation of how these 42 capability requirements were identified and their corresponding maturity descriptions were developed the reader can consult the work of Essmann (1).

5.2.1.3 Organisational Roles

The last part of the three core components of the ICMMv2 is the Organisational Roles needed in an organisation to innovate continually. Essmann (1) derived these roles by combining the roles suggested by other leading scholars in the domain of innovation (134), (135), (136), (137).

Essmann (1) describes five roles:

- **Networker** – Scan market, industry, technology, regulatory and societal trends to understand potential futures and identify latent opportunities. Create connections between internal and external individuals, teams and organisations that have common or complementary objectives.
- **Coordinator** – Balance project objectives, resources and risk. Contextualise, position and promote opportunities and concepts. Prioritise, plan, coordinate, schedule, and assure completion of projects. Overcome or outsmart obstacles faced during projects.
- **Builder** – Make tangible concepts of ideas, demonstrate concepts, obtain feedback from colleagues and customers, and refine concepts. Build, test and refine working "products" and ensure "production" readiness. Strive towards the initial vision of the concept with minimal compromise for design, production and delivery.
- **Anthropologist** – Develop understanding of how people interact physically and emotionally with products, services, one another and their environment. Transform the physical environment into a tool to influence behaviour and attitude, enabling individuals to do their best work. Anticipate and service the needs of colleagues, customers, suppliers and other stakeholders.
- **Leader** – Align activities with strategy and objectives. Build and involve teams of the "right" individuals at the "right" time. Evaluate and prioritise opportunities and ideas against a standard framework considering all business requirements. Guide progress, monitor metrics and instigate corrective action. Build synergy into projects and the organisation.

These roles provide another mechanism for relating the Innovation Capability Requirements to each other by considering the individual's responsibility and exposure to the capabilities. Further, these roles are an essential mechanism for the interpretation of the completed questionnaires as the roles will be used to provide context to the answers of the individual respondents.

5.2.1.4 Innovation Capability Questionnaire

There are three supplementary components to the model that play a crucial role in supporting the Innovation Capability Improvement Methodology:

- Innovation Capability Questionnaire
- Capability Requirement Practice lookup table
- Role-based and aggregated normalisation of responses

The most important component for this research is the Innovation Capability Questionnaire, which will be discussed in this section, while the other two components will be incorporated into the Section 5.2 on the Innovation Capability Improvement Methodology.

The Innovation Capability Questionnaire was developed by Essmann (1) to relate the situation within an organisation to the content and structure of the ICMMv2. This is done to determine the Innovation Capability Maturity of a specific organisation in reference to the 42 Innovation Capability Requirements.

The process is very much reliant on the fact that the respondents relay the situation within the organisation – or rather: their perception of the situation – to the analyst via the questionnaire. The questionnaire itself consists of four sections:

- General respondent information – In this section, the respondents are asked to provide metadata, such as their name, contact details, tenure and a basic description of daily responsibilities and activities. This data is used for the purpose of categorisation, in order to view the aggregated perceptions of some subsets, such as respondents that have been with the organisation for more than 10 years, etc.
- Role description – In this section, the respondent is required to rate his/her daily activities (in terms of a percentage) in the specific roles defined for innovation. This is done because individuals in an organisation may have limited exposure to some of the innovation requirements and this will influence the accuracy of their perception of the state of these requirements. Accordingly, this influence in their perception is accounted for in the interpretation of the results.
- Innovation status description – The respondent is asked to give a once-off overall maturity rating of the organisation's innovation capability.
- 42 Innovation Capability Requirements – Each capability is evaluated with a question. Provided with the question are the corresponding three generic descriptions of that capability's maturity on levels 1, 3 and 5. The respondents are asked to relate the situation

in their organisation to one of these generic descriptions for each of the 42 Innovation Capability Requirements, effectively rating that capability on a certain maturity level.

The first page of the questionnaire is attached as Appendix III and the remainder can be deducted from the maturity level descriptions in Appendix II.

As stated, the questionnaire is the tool used to evaluate the current Innovation Capability of an organisation. This is done in the Evaluation stage of the Innovation Capability Improvement Methodology. To give the reader further insight into the way in which the process leads to the eventual improvement of the 42 Capability Requirements, the Innovation Capability Improvement Methodology will be explained in the next section..

5.2.2 Innovation Capability Improvement Methodology

The objective of this methodology is to describe the basic activities and their inputs and outputs to take the organisation from one level of maturity to the next. The methodology is a three-stage process. Various components of the ICMMv2 are utilised in the three stages of the process, which are labelled as “Evaluate”, “Plan” and “Improve” in Figure 40:

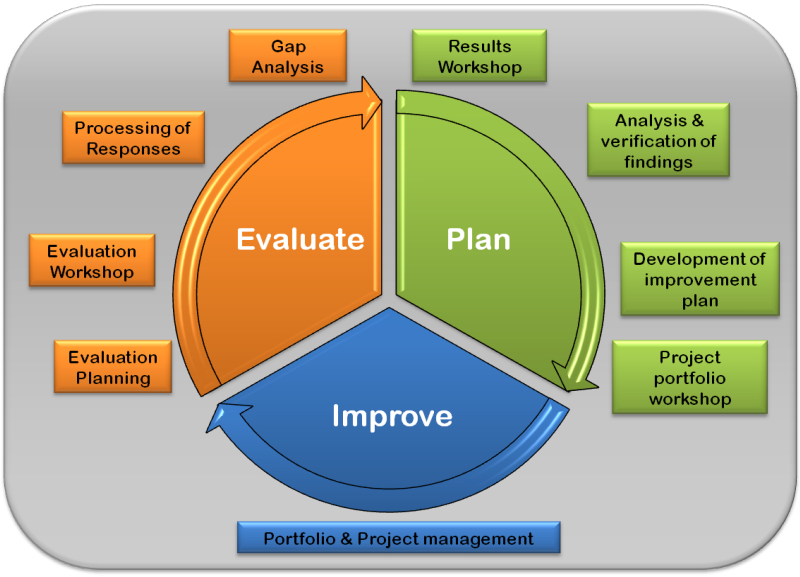


Figure 40 - Innovation capability improvement methodology, from Essmann (1)

It is important to realise that the improvement process is a continual one. This implies that the improvement of a capability in one cycle will be evaluated in the evaluation stage of the following cycle.

The three stages will now be discussed individually in more detail.

5.2.2.1 Evaluate

The improvement process starts with the evaluation stage. In this stage, the organisation's Innovation Capability Maturity is assessed with the Innovation Capability questionnaire.

Respondents from the organisation under evaluation are asked to complete the questionnaire. These responses are used to identify potential innovation capability improvement areas. The opportunities for improvement are identified during the processing of the results from the questionnaires and the consequent gap analysis.

The evaluation stage is divided into four high-level activities which include *Evaluation Planning*, *Evaluation* Workshop, the *Processing of responses* and a *Gap analysis*. These activities can be seen in Figure 41.

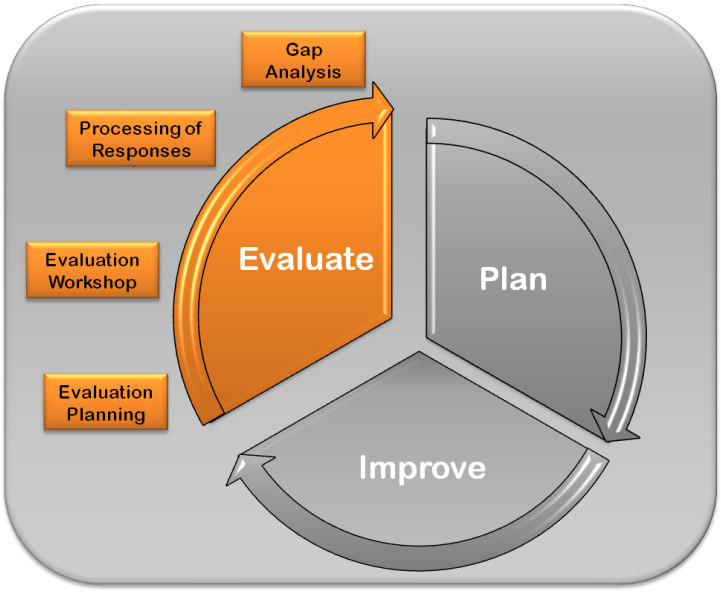


Figure 41 - Evaluate stage of improvement methodology, adapted from Essmann (1)

a. Evaluation Planning

The first step is to meet with the management or instigators of the assessment process and discuss the basic activities that will be undertaken during the evaluation. There are three important aspects that need to be addressed in this meeting, namely:

- Organisational objectives for the evaluation – this point is mentioned to bring to light the objectives management might have with assessment procedure other than the general objectives accompanying such an evaluation.

- Context – it is important to determine whether the evaluation should include the organisation as a whole or specific departments. The importance of this aspect cannot be overemphasised and will be discussed in Section 5.2.2.1. (b) under *Evaluation Workshop*.
- Perspectives on the results – various views may be taken on the responses from the questionnaire. Management can stipulate specific views they might want and the data (such as the number of years with the organisation) to isolate these views needs to be collected in the questionnaires.

The ultimate purpose of this meeting is to enlighten the analyst about the requirements that the organisation's management might have regarding the evaluation, and inform all the stakeholders of what to expect from the procedure.

b. Evaluation Workshop

This activity concerns the actual completion of the questionnaires by the respondents contained in the context specified in the planning meeting. The questionnaire is completed in an interactive workshop facilitated by a professional facilitator, the analyst or both. The agenda of this workshop is to:

- Create sensitivity for innovation capability requirements – participants are made aware of the requirements for developing an organisational innovation capability.
- Plant the seed for discussion – participants are stimulated to discuss their initial reactions to the questionnaire, while their responses are still fresh.
- Assess the innovation capability maturity – by way of the Innovation Capability Questionnaire, participants are asked to describe the actual innovation capability maturity of the organisation.
- Provide the basis for the improvement initiative – the conclusions from discussions and the assessment provide the input for the later activities of the *Evaluate* and *Plan* stages of the methodology.

The workshop starts with a short presentation to clarify some of the potentially unclear aspects of the questionnaire. It is important that no information on the ICMMv2 or the improvement methodology be shared with the respondents as this could potentially distort their answers. The respondents are told to answer spontaneously, not to over-rationalise and to avoid backtracking. Definitions of some of the important terms in the questionnaires are provided and lastly, but most importantly, the context is explained.

The context specifies how the respondents are required to relate the questions to their organisation. Answering the questions about the whole organisation would be very different from

answering within the context of a single department. The context should be specified in the planning stage and kept consistent throughout the evaluation to ensure that the results are comparable. In other words, the context can be described as that common basis from which the respondents should answer the questions.

When the initial presentation concludes and the analyst is confident that all the respondents are sure what is required of them, the participants are introduced to the questionnaire. The facilitator guides the respondents through the first three sections of the questionnaire, explains the importance of the role division and the "once-off maturity rating". Thereafter, they start to answer the capability requirement questions. Even though the questions are fairly self-explanatory, the analyst should be present to answer any questions the respondents might have.

When all the respondents have completed the questionnaire, the facilitator should engage the participants in a discussion around the questionnaire and their general perceptions of the possible strengths and weaknesses of their organisation's innovation capability. The information gathered from this exercise could prove very valuable and give the analyst additional insight when processing the results.

c. Processing of Responses

The next activity concerns the interpretation of the questionnaires and the translation of the answers into value-adding and descriptive results that would improve the respondents' understanding of the situation under evaluation.

The supplementary component of the ICMMv2, dubbed "The Role-based and aggregated normalisation of responses", is utilised to enhance the validity of the results. Since a detailed understanding of the procedure is not crucial to this research, a short discussion will be sufficient before this section continues further.

The utilisation of this component is based on the premise that there is a relationship between an individual's role in an organisation and the capability requirements. They are related via the exposure to or responsibility for the requirements. This would influence the manner in which they answered the questions related to these requirements. To account for this, a normalisation process is utilised using the role descriptions given by the respondents in the questionnaire. This process therefore intentionally biases or distorts the responses of individuals who have had more exposure to or responsibility for a specific innovation capability.

Very little can be extracted from a single maturity rating; therefore, in order to identify the strengths and weaknesses of the organisation's innovation capability, the analyst has to present the results

at various levels of aggregation and from multiple perspectives. Essmann (1) suggests the following levels of aggregation:

- Overall Innovation Capability Maturity – the highest level of detail, a single rating between 1 and 5 signifying the overall innovation capability maturity of the assessed organisation (referred to as overall, normalised average innovation capability maturity level in the case studies).
- Innovation Capability Areas – the three high-level areas of innovation capability represent the second level of detail. A single rating between 1 and 5 is provided for each, signifying the organisation's ability to fulfil the Innovation Process, Knowledge & Competency, and Organisational Support requirements.
- Innovation Capability and Organisational Construct Items –the respective construct items for innovation capability- and organisational constructs represent the third level of detail. Again, each construct item receives a single rating.
- Innovation Capability Requirements – the lowest level of detail, the 42 capability requirements each receive a maturity rating between 1 and 5 representing the level at which the organisation fulfils the requirements.

In addition to these levels of aggregation, the results can also be viewed from various perspectives, which may be:

- Participant-based – This would present the results based on the raw responses of the participants without bias or normalisation.
- Roles-based – This would present the results normalised by the roles of the respondents with the procedure mentioned above.
- Other – These views would be those specified by management in the first meeting. For example, the view of management could be compared to those of other members in the organisation to identify possible communication gaps.

d. Interpretation of Results

For the interpretation of the results and the identification of the strengths and weaknesses, Essmann (1) suggests that the analyst consider two factors:

- The actual maturity rating, and
- the difference in these ratings from the different perspectives discussed above.

A difference in the ratings is an indication of different perspectives towards the maturity of the capabilities and this discrepancy should be addressed. Similar ratings show that there is

consensus about the strength or weakness of a specific capability. These two factors can be graphically illustrated by creating a scatter plot of the average maturity of each capability requirement against the standard deviation between the answers of the different respondents:

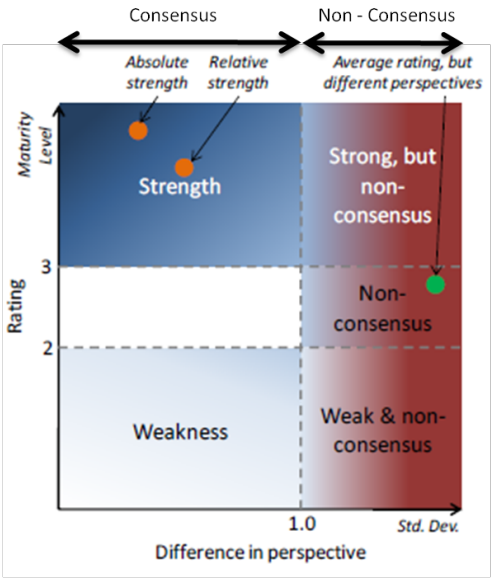


Figure 42 - Rating and difference in perspective matrix by Essmann (1)

From Figure 42, the specific boundaries for strengths and weaknesses can be deduced. A capability with a maturity of more than 3 is perceived as a strength and a maturity of less than 2 is perceived as a weakness. A capability with a standard deviation of more than one is characterised by a low level of consensus and the reason for this should be investigated.

Although organisations can have an average maturity rating of more than 3, this strength can lie with capabilities that have a low consensus rather than absolute strengths; accordingly, it is very important to evaluate the value as well as the position of the individual capability requirements.

To conclude this matter it would be important to mention that, while it is useful to stipulate these absolute values for the purpose of interpretation, the absolute values actually mean very little. The real value lies in the relative comparison of these capabilities. This implies that if an organisation had no capabilities on a maturity of less than 2, it would not mean that it has no weaknesses. In this case, the lowest capabilities relative to the others present the opportunities for improvement.

e. Gap Analysis

In this last activity of the *Evaluate* Stage, the capability requirements that the organisation should prioritise for improvement are identified based on three factors:

- The organisation's original objectives with the evaluation, identified in the first meeting with the instigators of the process.

- Other organisational aspects, including size, core business and value offering, strategy, industry and the nature of competition.
- The insights obtained from viewing the results on the different levels of aggregation and from different perspectives, as discussed in the previous two sections.

One should remember that this prioritisation is done by the analyst to provide a platform for the formal prioritisation following the *Results* Workshop, in the *Plan* stage of the Improvement Methodology. At this stage, they are only recommendations, but it important to provide them as a starting point from which the formal prioritisation can be done.

The number of capability requirements suggested for improvement should not constitute an exhaustive list. As mentioned in the factors above, the organisation's strategy should be a central consideration in this prioritisation exercise.

Only selecting the capabilities with the lowest maturity rating and the highest level of consensus for improvement is an over-simplification. Capabilities that show low consensus regarding their maturity should also be evaluated with reference to the root cause of the difference in opinion between respondents. This can be done in the *Results* Workshop, which will be discussed in the *Plan* stage of the improvement methodology.

In conclusion, the objective of the *Evaluate* stage is to identify the specific capability requirements that will be recommended for improvement in the *Plan* stage. The output is a list of the capabilities that are perceived to be strong, weak, or in need of clarification. This list is prioritised according to the identity and strategy of the specific organisation, and the insight of the analyst gained from an analysis of the responses. The completion of this activity represents the end of the *Evaluate* stage and the beginning of the *Plan* stage.

5.2.2.2 Plan

The *Plan* stage of the Innovation Capability Improvement Methodology is concerned with the eventual development of innovation capability improvement plans based on the outcomes of the previous stage. The first activity is the *Results* Workshop, in which the relevance of the capability requirements proposed for improvement is validated or alterations are made based on interaction with the respondents. This activity is followed by a more detailed analysis and verification of the findings through an in-depth analysis of the organisation. Based on the results of this analysis, actual improvement plans are developed and presented for selective adoption by the organisation. These activities are presented in Figure 43 below.

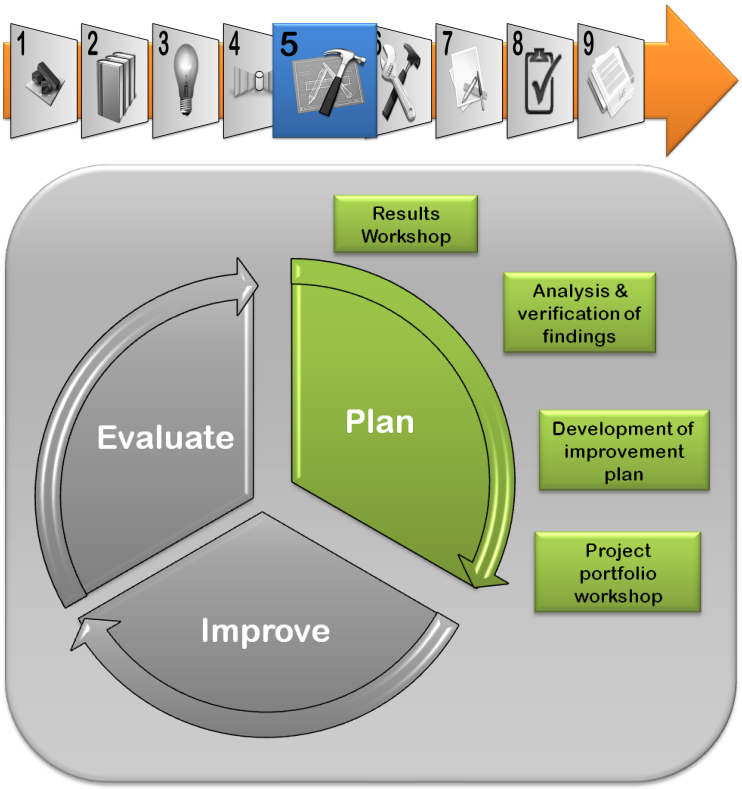


Figure 43 - *Plan* Stage of the improvement methodology, adapted from Essmann (1)

This research project is concluded with the *Results* Workshop and therefore the explanation of the following activities will be brief and to the point. For a more detailed discussion of the procedure from the Analysis & Verification activity, the reader can consult the work of Essmann (1).

a. Results Workshop

Preferably, a workshop is organised with all the individuals that participated in the *Evaluation* Workshop of the *Evaluate* stage. The objective of this second workshop is to present and discuss the findings of the *Evaluate* stage. Before the results are presented, some details on the framework, structure and content of the ICMMv2 are presented to sensitise the respondents to the relationship between the questions and the capabilities needed for innovation.

The workshop is divided into two parts: the actual presentation of the results and the final prioritisation of the capabilities for improvement.

The objective of the presentation is that the respondents should relate to the results or rather identify with what is presented. They need not know everything, as this would render the whole exercise unnecessary, but the results should stimulate a response. If this is not achieved, something has gone wrong, either with the evaluation of the results or because of a potential biasing of the initial answers, due to a variety of reasons. Consequently, the opportunity to get the respondents' buy-in to the relevance of the process will be forfeited. This buy-in is crucial to the success of the improvement initiatives that will follow.

It is important that the session be interactive, so as to allow the respondents to discuss the results. The analyst should present the results with sufficient detail in order to ensure this discussion, while

not overloading the participants with information. It could be difficult for the analyst to identify this correct level of detail on his own, but this problem can be solved by holding a small meeting at the outset with selected individuals and gaining their input on which would be the most valuable results to present to the larger group.

With regard to tactics for the presentation, Essmann (1) recommends that the analyst show the weaknesses and the strengths, not bombard the group with only negative information, and provide an overall picture of the organisation's innovation capability.

The second part of the workshop entails gaining the input of the respondents in regard to the prioritisation of capabilities for improvement. It is important to select those capabilities that will bring about the greatest level of improvement in the organisation's overall innovation capability, by means of the minimum effort and resource expenditure. Essmann (1) suggests that the following factors be considered:

- Since the Organisational Support area supports the Knowledge & Competency area, which in turn supports the Innovation Process area, capability requirements can be prioritised in a bottom-up manner to ensure that the foundation is lain before the building is constructed.
- The interrelatedness of the actual capability requirements is depicted in Figure 38.
- The organisation's distinctive characteristics, such as its industry, size, value offering, strategy, objectives, values, etc. In addition to these characteristics, the organisation's appetite for innovation is also an important consideration. These factors may render certain capabilities more relevant than others.
- The operational environment and existing innovation projects portfolio of the organisation are important. The improvement initiatives should be aligned with these activities.

The output from this workshop should be a final list of capability requirements, prioritised for improvement accounting for all the factors that influence the compilation of this list. The list should reflect the organisation's appetite for innovation and the resources it has available for the improvement initiatives.

With the conclusion of this activity, all the activities within the scope of this research will have been performed. Hence, the following three activities of this stage and the *Improve* Stage will only be discussed briefly for the sake of giving a complete explanation of the Innovation Capability Improvement Methodology.

b. Analysis and Verification of Findings

This activity is concerned with finding the root cause for the prevalent perception towards the capability requirements prioritised for improvement. It involves a detailed analysis of the actual

situation within the organisation over a period of one or two weeks. This will provide the analyst with a detailed understanding from which to develop improvement plans.

c. Development of Improvement Plan

During this activity, improvement plans are developed for the capability requirements that have been prioritised for improvement. This is the first stage where the generic nature of the ICMMv2 is substituted by a more customised approach.

The manner in which an organisation would fulfil each capability requirement is unique to that organisation (1). Therefore to improve these capability requirements will require unique improvement plans. The last supplementary component of the ICMMv2, dubbed the "*Capability Requirement Practice Lookup Table*" can still be used as a valuable tool for identifying best practices for the fulfilment of the requirements

At the conclusion of this stage, the specific improvement plans should be developed and ready for deployment.

d. Project Portfolio Workshop

In this activity, the details of the improvement plan should be discussed with all the relevant stakeholders within the organisation. According to Essmann (1), this can be done by means of a workshop that covers the following aspects:

- The findings of the analysis and verification activity, and the implications thereof in terms of the prioritised capability requirements.
- The planned solutions and how they will improve and affect the overall innovation capability of the organisation.
- The project plans to implement those solutions and their impact on the operational environment, existing innovation projects, other projects and the portfolio as a whole, and the resources available to execute those projects.

The output of this activity is the finalised portfolio of projects that will be used as a foundation for the innovation capability improvement initiative.

5.2.2.3 Improve

The *Improve* stage, as shown in Figure 44 below, is the final stage in one round of the improvement methodology and it entails implementing the developed improvement plans with the use of established portfolio and project management tools, techniques and methods. There are two additional aspects that are addressed during this stage: a generic improvement framework for the

42 Innovation Capability Requirements and the coordination of the capability improvement initiatives, with the actual execution of innovation projects.

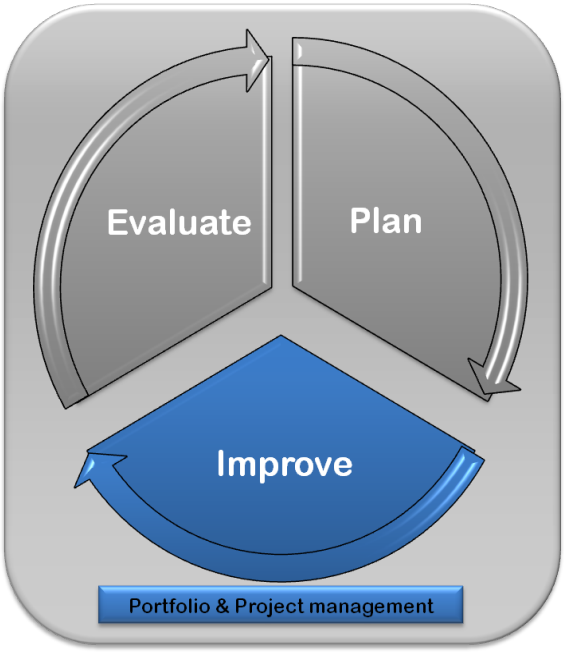


Figure 44 - Improve Stage of the improvement methodology, adapted from Essmann (1)

At the conclusion of this stage, the *Evaluate* stage will be initiated again as shown in Figure 44 above. The objective is to measure the effect of the implemented improvements. A short description of the activities within the Improve stage will follow.

a. Portfolio and Project Management

There are well-established and documented tools to successfully manage portfolios and execute projects. These tools can and should be used to the same effect on innovation capability improvement projects.

b. Generic Improvement of Capability Requirements

Essmann (1) presents a framework for improving the 42 Innovation Capability Requirements, from *ad hoc* and inconsistent, through formalised practices and procedures, to institutionalised behaviour and integrated activities.

Although the framework does not describe specific strategy, practice, system or behavioural improvement plans, it does portray in a generic manner how the organisation may improve aspects such as:

- Strategy
- Objectives and policies
- Processes
- Practices
- Procedures and tools
- Infrastructure
- Systems and resources
- Individuals and groups

These aspects all contribute to organisational innovation capability in interrelated ways. The framework is shown in Figure 45.

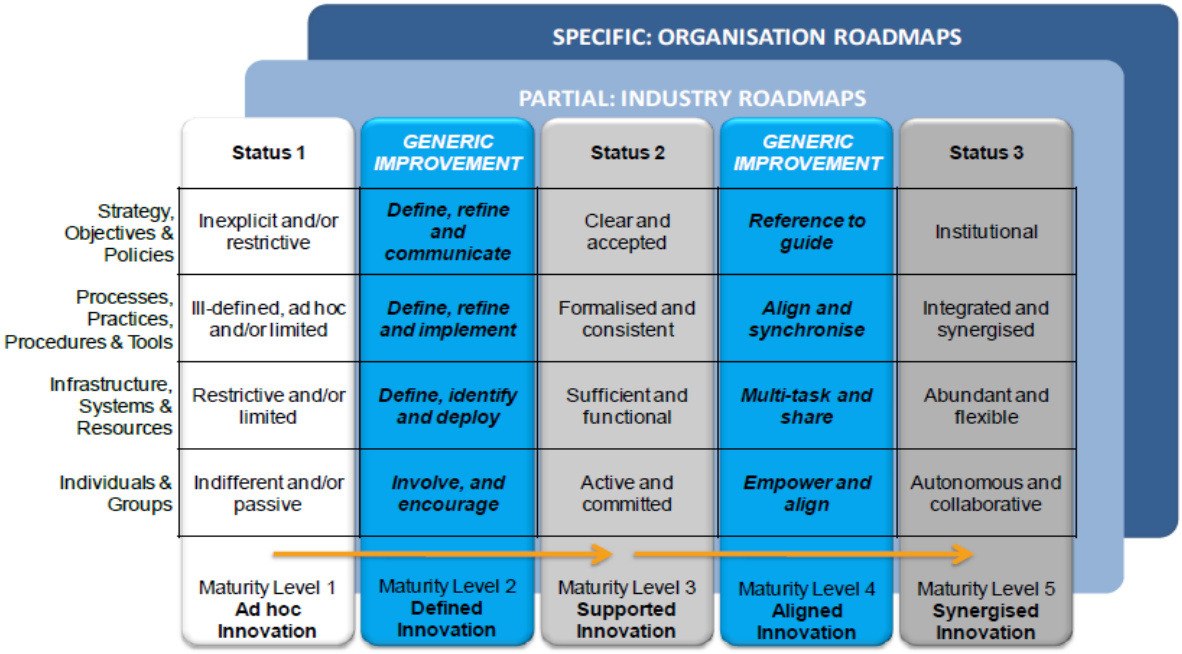


Figure 45 - Capability requirement improvement framework by Essmann(1)

c. Parallel Execution with Innovation Projects

The last aspect that is addressed by Essmann (1) is the execution of the simulation of innovation projects and innovation capability improvement initiatives. Essmann himself admits that this is not a sufficiently researched area of the ICMMv2, but he suggests that efficient coordination of these two processes would result in better innovation results.

d. Initiating the Next Cycle and Measuring Benefits

As stated earlier, the whole Innovation Capability Improvement Methodology is a cyclic process and accordingly once one round has finished the next should be instigated. Measuring and gauging the improvements against preset goals is a very important process and allows the

organisation to take corrective actions proactively if necessitated. This will ensure the effective implementation of appropriate and successful improvement initiatives.

5.3 Chapter Summary

As stated at the beginning, the first objective of this chapter was to introduce the reader to maturity models and then discuss why these models are appropriate for use in the domain of innovation.

The latter part of the chapter thoroughly discussed the Innovation Capability Maturity model developed by Essmann(1). The author will use this model to evaluate the innovation capability of a research institution in the following chapters.

The objective of this research is to set the platform for improvement and to this end, the Innovation Capability Improvement methodology has become very relevant. As a result, this methodology has been thoroughly discussed.

Innovation Capability is directly related to research commercialisation capability on the basis that research commercialisation is an innovation process as explained in chapter 4. Accordingly the same capabilities that supports innovation will also support the research commercialisation process.

The next chapter will discuss the preparation for the evaluation of the innovation capability of a university. Thereafter the 42 innovation capabilities will be evaluated with regards to their maturity and these capabilities are directly related to research commercialisation capability. In other words the assessment regarding the maturity of the capabilities is done while telling the respondents that they should relate the questions in the questionnaire to research commercialisation.

6

Preparing for evaluation

In this section the preparation for the evaluation of the innovation capability of a research institute will be discussed. This preparation is presented as a separate section because it contains discussions and activities beyond the scope of the Evaluation Planning activity that Essmann(1) suggests as part of the Improvement methodology.

The need for this "Preparation discussion" originated from the realisation that although the ICMM v2 was designed to be generic and thus applicable to all kinds of organisations regardless of the industry, value offering, strategy, etc. it has never been applied outside the industrial domain. Accordingly it should be expected that there might be some challenges for the application of the assessment in the academic sphere.

In addition to this, the mere fact that the evaluation is instigated by a party outside the system can potentially also cause some additional challenges in terms of gaining the necessary cooperation from all the relevant stakeholders.

In anticipation of these issues, the areas that might present challenges are presented followed by a discussion on how these stumbling blocks can be overcome in order to present a platform for a successful evaluation of the Innovation Capability maturity of a research institution.

6.1 Challenges

It is evident that the two spheres of industry and academia operate very differently. Since the ICMM was developed for commercial enterprises, there will be some challenges in the execution of the assessment. Some of the common differences that may affect the application of the ICA will be discussed. It should be noted that it was decided at the outset, in consultation with Dr. Essmann, that the method for applying the assessment, as well as the questionnaire would be kept in their current state, as far as possible. This is done in order to allow for a comparison of the results with results from previous applications of the assessment.

To begin with, some of the issues that may force certain adaptations to the methodology will be discussed; the boundaries between competitive and pre-competitive domains, as defined by Du Preez and Louw (116), are examined below.

6.1.1 Merging Boundaries

An altercation in the position of the competitive and pre-competitive boundaries may not affect the evaluation process in an obvious manner. A discussion on the topic is still deemed relevant because it defines the environment in which universities are required to operate.

Increasingly engaging in interactions with industry, the core of the university system expands to include activities outside the ivory tower with the goal of transforming inventions into innovations for the betterment of society and to enhance the university system's cash flow and capital endowments (43).

Du Preez and Louw (116) define the university as an entity that operates in the pre-competitive domain. While this is still true for many of the research fields in which a typical university is engaged, universities focusing on applied science have started to show different behaviour. With research commercialisation coming to the fore, universities have started to compete with other research organisations and industry to sell their outputs on the market, thus displaying competitive intent; however, universities are not alone in reaching over into the competitive domain.

Industry has long been partnering with universities in the pre-competitive domain to create knowledge, but the characteristics of these partnerships are also changing. Patenting has become more prominent as a way to protect knowledge assets, and these partnerships may create intellectual property which firms can use to gain the competitive advantage in the market. Subsequently, knowledge itself has gained status as an asset that can be bought and sold – an attribute that was traditionally home to the competitive domain.

Essentially, knowledge – especially knowledge created in the world of the applied sciences, such as engineering – is not only disseminated by publications into the public domain freely as before. If the research shows commercial potential, the intellectual property is protected, and only then can the knowledge be published.

The central implication is that universities are now incentivised with monetary returns other than grants based on publication output to distribute their knowledge. This results in the boundaries between the pre-competitive and competitive domains becoming blurred.

6.1.2 Organisational Structure & Culture

The difference between organisational structure and culture has been discussed in Section 2.5.2 in relation to the internal factors that affect research commercialisation. These differences have definite implications for the application of the Innovation Capability Assessment (ICA) and will be discussed in this section.

6.1.2.1 Organisational Structure

The difference in organisational structures between industry and academia is an issue that would have a definite impact on the execution of the assessment. The issue is related to the previous applications of the ICA. In the case studies that Essmann (1) used to validate the ICMM, the assessment was done with a relatively small number of respondents and all their responses were received by doing one *Evaluation* Workshop. Due to the dispersion of the research commercialisation role-players in the academic structure, it might prove difficult to get everyone together in one place at the same time. Many individual sessions may be required and in this case a priority would have to be made of delivering the context consistently. The issue will be addressed further in Section 6.2.3 in regard to role-players.

Another, possibly greater issue was discovered during the execution of the assessment and relates to the organisational silos that are created in a typical university structure. Respondents found it difficult to extract themselves from their local environment and give a global perspective on the Innovation Capability of the entire university. This issue can be overcome by evaluating academic departments or even research groups rather that the university as a whole. This issue will be discussed comprehensively in the case study and recommended as a future research opportunity.

6.1.2.2 Organisational Culture

In essence, the university is not a competitive organisation. This fact may have implications for getting buy-in from stakeholders needed to execute the evaluation successfully. The need for a university to innovate in terms of research commercialisation may not be obvious to university employees.

This would require some consulting skill on the part of the analyst in order to enable the participants to approach the evaluation positively and cooperate by completing the questionnaires.

6.1.3 Terminology

In the development of the questionnaire that assesses the maturity of innovation capabilities during the *Evaluation* Workshop, Essmann put certain terms into the context of the innovation domain by providing specific definitions for them. These terms were: Opportunity, Idea, Concept and Project. This was done to ensure that the questions in which these terms are used are interpreted in the same way by all the respondents.

These definitions have to change if the assessment is done in the context of the specific type of innovation such as research commercialisation. Simply put, “an opportunity” in the context of research commercialisation would imply something more specific than the same term used with the generic description provided by Essmann (1).

The objective is not to change the meaning of the words but rather to ensure that the descriptions are specifically related to the research commercialisation field and that all the respondents interpret them in the same way. This is crucial for the accurate evaluation of the four capabilities that are evaluated by using these terms.

The terms are therefore redefined, or at least put into context, in Section 6.2.4.

6.2 Planning to Avoid Obstacles

The subjects discussed above should be taken into account when applying a methodology, designed for the industry sphere, in the academic sphere. The differences between the industrial and academic spheres could present potential stumbling blocks in the assessment process.

To ensure that the questionnaire reaches its intended goal of evaluating and describing the university research commercialisation system, the original industrial methodology as prescribed by Essmann (1), should be evaluated.

To ensure that the results from the assessment are accurate, the approach to the physical evaluation process needs to be adapted. There are four issues that are influenced by the challenges discussed above. These are the Scope, Leadership Mandate, Role Players and the Terminology used in the questionnaire. These areas will be discussed in the following sections.

6.2.1 Scope

As with all survey research, it is important to define the scope of the study. There are two issues that need to be discussed with respect to the scope of the assessment. The first will be the

boundaries between which the assessment would be applied, and the second is the scope of the execution of the improvement methodology.

6.2.1.1 Assessment Boundaries

In the case studies where Essmann and Du Preez (138) validated ICMMv2, they performed the evaluation on a relatively small group of respondents within an organisation, typically in the same department.

The goal of this application is to find the capability maturity of the university as a whole. A university is a very large organisation and the role-players in the commercialisation process are dispersed throughout the university. This evaluation would be done over various departments and departmental levels with a relatively large number of respondents to get an accurate perspective of the Innovation capability of the organisation as a whole. This approach will make it different from all the previous applications of the assessment in terms of scope.

However, the evaluation will remain within the managerial boundaries of the university.

6.2.1.2 Improvement Methodology

The objective is to provide a basis for improvement. This entails assessing the AS-IS state of operations and identifying areas for improvement. This scope was determined by considering the timeframe and the resources available to execute the evaluation. The stages and activities that are excluded from this research were considered to be too resource-intensive and ultimately unnecessary in the light of the research objectives.

The improvement methodology will be executed up to the *Results* Workshop activity. This includes:

- Evaluation Planning
- *Evaluation* Workshop
- Processing of responses
- Gap Analysis
- *Results* Workshop

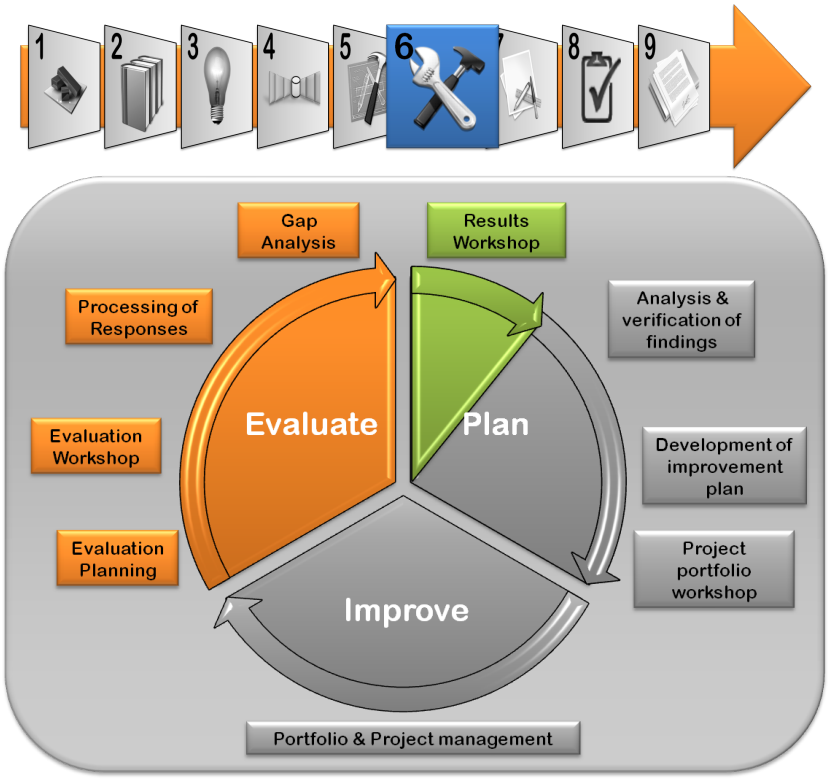


Figure 46 - Scope of the improvement methodology

Figure 46 above illustrates the scope of the improvement methodology. All the activities from *Analysis & verification of findings* will be proposed for future work. The accuracy of the results will, however, be determined in the *Results* Workshop by evaluating to what extent the respondents can relate to the results presented to them. The *Results* Workshop will be discussed in Section 7.6.

6.2.2 Leadership Mandate

Many organisations will claim that they do not need to innovate or that they are not the appropriate size to innovate, but Essmann and Du Preez (138) argue that this perception is based on unclear understanding or even complete ignorance of the long-term needs of an organisation.

Managers who argue that "you don't tamper with a system that works" certainly cannot regard long-term prosperity and growth of the organisation under their control as a high priority. Being innovative is of paramount importance to the continued prosperity of an organisation.

Although these sentiments may be dismissed as only being relevant to for-profit organisations, doing so will surely show a substantial lack of insight into the modern economy.

The world is changing and the organisations that want to stay relevant need to change with it. One can argue that a certain degree of innovation is necessary to overcome the obstacles that even the slightest amount of change presents (138). The challenge remains that some organisations need to be convinced of the need to innovate. If this realisation is manifested, the relevance of the Innovation Capability Maturity Model should become apparent.

University management should also be convinced of the ICMM's relevance, or at least buy in before the evaluation can proceed. This could prove to be harder than with industrial applications.

Sustained competitiveness is one of the most commonly perceived value additions of innovation. It would be safe to say that traditional universities, especially those that fail to consider the commercialisation of research as a priority, would not categorise themselves as organisations operating in the competitive domain. Therefore it is crucial to engage with the management of the university. Convincing the university management of the relevance and getting their approval would greatly assist the analyst in getting other stakeholders to cooperate in the evaluation.

6.2.3 Role Players

As this is an evaluation of people's perspectives, one should identify the respondents whose perspectives ought to be obtained, prior to the evaluation. This issue is brought up here because, in a typical application in industry, the instigators of the assessment will have identified the unit of assessment prior to instigating the process. Consequently, this unit of assessment would contain individuals who join the workshops to complete the questionnaires and give their perspectives on the organisation's innovation capability.

In this instance, the Evaluation procedure is instigated by the research and this means that the researcher has to identify the perspectives within the organisation that will be necessary to gain an adequate global perspective of the maturity of the system under evaluation. Accordingly, this section deals with the identification of the relevant role-players and stipulates by what means the analyst would obtain their perspectives.

A university is typically a very large organisation and it would be an enormous undertaking to gain every employee's perspective. The researcher needs the perspectives of the individuals that play a direct role (or, at least, an indirect role) in executing the process that is being evaluated. This means that one can identify a number of individuals whose combined perspectives should give a good indication of what the general perspective is.

The essential role-players can be identified with the collective input of literature on research commercialisation and the roles needed for innovation as identified by Essmann and Du Preez (138). These two sources can then be combined with the specific university's structure as typically depicted in an organogram and the role-descriptions of the employees of the university.

6.2.3.1 Literature on Research Commercialisation

As discussed previously, there are four major role-players in the process: the TTO, Researchers, University Management (vice-chancellor level) and Industry. As this evaluation will only be

performed in the university, industry will be excluded as a role-player. However, some role-players will be added to the assessment through insights gained into the inner workings of the process.

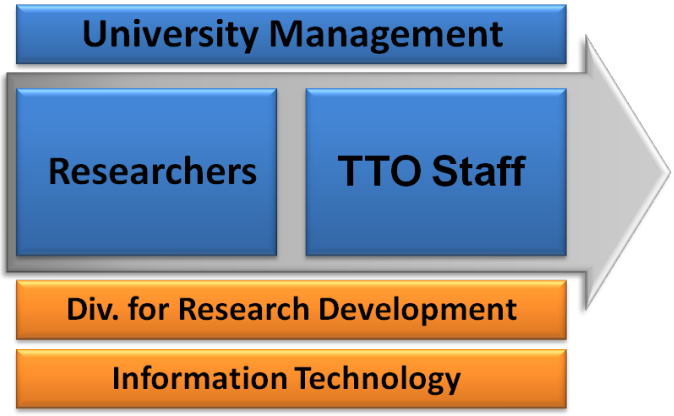


Figure 47 - Case study role-players

Figure 47 shows the relevant role-players identified in the university structure. These role-players are aggregated either by department or function. The researchers and TTO staff are primary role-players and the secondary or support functions are performed by University Management, the Division for Research and the Information Technology department.

a. TTO staff

The technology transfer office staff will typically be located in a central office and so a group workshop could be held with all of them at one specific time.

b. Researchers/Scientists/Faculty

Individual sessions would probably be more appropriate to get the researchers' perspectives, because it would be very difficult to get all of them in one place at one time to perform a workshop. In the case where a researcher has a research group it would be possible to hold a workshop with the whole group.

c. University Management (executive level)

The individuals in the University Management (deputy/pro vice-chancellor level) that are relevant to the evaluation would be determined by the specific university's reporting channels. As research is a fundamental requirement to execute the process, it would be valuable to get the perspective of the individual that manages the research portfolio of a university. In most universities, there should be a provost or vice-chancellor of research. His/her perspective will obviously be very valuable.

The other manager whose perspective will be very important is the vice-chancellor to whom the technology transfer office reports. It should be noted that the director of a TTO does not always report directly to the executive management of the particular university. Whatever the case may

be, the TTO should be the direct or indirect responsibility of one of the executives and his/her perspective on the system should be obtained.

Individual sessions will probably be more appropriate for obtaining these role-players' perspectives as they will typically have very busy schedules.

d. Division for Research

In a typical European university structure, the Division for Research will reside under the management of the Deputy/Pro Vice-chancellor for Research. Many of the important lower-level managers will be in this division. Among these could be the Manager of Research Contracts and the University Innovation Manager, if a positions such as the latter exist at the particular university.

It should also be possible to hold a workshop with the employees of this division, as they will typically occupy offices adjacent to one another.

e. Information Technology Department

This department is deemed important because it provides the ICT with infrastructure that supports the researchers and technology transfer offices in carrying out their jobs effectively.

6.2.3.2 Innovation Roles

As stated earlier, Essmann and Du Preez (138) identified five roles that need to be fulfilled for an organisation to innovate successfully. It would be important to consider these roles when selecting the individuals that need to be interviewed. This is very important in order to obtain a collective perspective that is sufficiently representative. The five roles, as defined in Section 5.2.1.3, are presented below.

- Leader
- Builder
- Networker
- Anthropologist
- Coordinator

6.2.3.3 University Organogram

A generic university organisational chart such as the one below in Figure 48 can be a valuable tool in the role-player identification process.

Figure 48 - Generic university organogram

The outlined boxes in Figure 48 show some of the important departments within the university.

6.2.4 Terminology

As explained in Section 6.1.3 in a discussion about terminology, some of the definitions in the questionnaire should be redefined or at least put into the context of research commercialisation.

These terms defined in the development of the ICMMv2 by Essmann and Du Preez (138) are Opportunity, Idea, Concept and Project. The definitions of these stages are presented with the questionnaire. These terms can be directly related to Figure 26 in section 4.3.1. The “idea” and “opportunity” are at the front end (Idea generation/identification) of the FuGIe model while “concept” is relevant in the next two couple of stages. The “project” becomes relevant in the final stages of the model where the concept is taken to market.

Figure 49 below illustrates these terms in the logical flow stipulated by their relevance in the innovation life cycle. They are essentially outputs from defined stages in the innovation process.

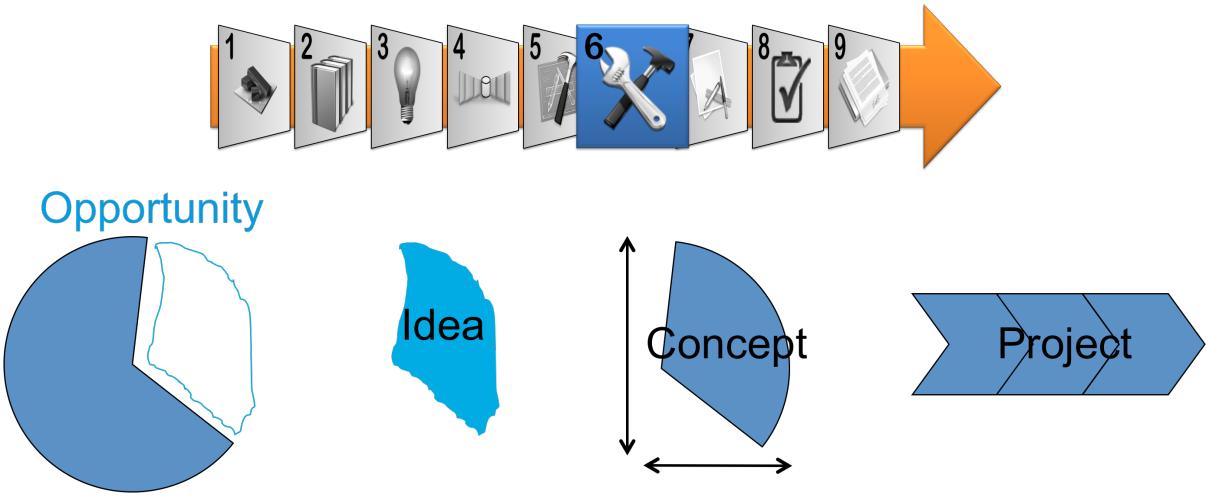


Figure 49 - Definitions by Essmann (1)

The idea and opportunity "outputs" are interchangeable. It is perfectly reasonable for an idea to be generated prior to the identification of an opportunity in which the idea can be exploited.

Essmann (1) defines these terms as follows:

- Opportunity – *Areas of market, business, process, etc. (internal or external) that are under-exploited and/or have significant room for improvement and which have the potential to significantly benefit those that pursue them.*
- Idea – *Solutions defined in simple terms, that address problems or opportunities (see definition above) within the organisation or externally.*
- Concept – *An idea (see definition above) that has been "fleshed out" with various characteristics (such as market size, physical properties, performance, competition, etc.) and is sometimes combined with other ideas, becomes a concept.*
- Project – This phase leads to the exploitation of the concept and involves activities such as marketing and sales.

There are four questions in the questionnaire that incorporate these definitions to define the four related capabilities. As can be seen above, the definitions are very generic and the objective of this exercise is to redefine them specifically for the research commercialisation domain. This was done and the adapted definitions are given below.

Opportunity – Research field in which a researcher might search for ideas to pursue.

Idea – Specific research topic in the research field that a researcher may pursue.

Concept – An idea becomes a concept when all the relevant feasibility studies (financial, technical etc.) and other tasks such as market research are completed. The researcher and the technology transfer office work together to produce the concept.

Project – A project will be selling the concept to the customer, which in this instance will be the industry recipient but can also be other universities, research organisations, governments, ect..

These definitions will be explained to the respondents as part of a short presentation in the *Evaluation* Workshop before they are asked to complete the questionnaire.

6.3 Chapter Summary

The aim of this chapter was to describe all the factors considered prior to employing the improvement methodology. As stated above, this was done separately from the Evaluation planning activity because the discussion included issues beyond the scope of that activity.

Initially the challenges posed by using this Innovation Capability Maturity model in the academic sphere, with accompanying improvement methodology, was discussed. This was done to identify potential stumbling blocks.

From Section 6.2 onwards, the plan for overcoming these challenges was drawn up. Areas that were touched upon were scope definition, role-player identification and selection, and finally the leadership mandate.

The next chapter will explain the actual application in a case study format that follows the logical flow of the Improvement Methodology developed by Essmann(1).

7

Case Study

In this chapter execution of the ICMM will be discussed. This case study was undertaken as prescribed by the Innovation Capability Improvement Methodology provided with the ICMM, both developed by Essmann (1). Al the activities in the evaluation phase were performed as well as the Results Workshop in the planning stage. Accordingly these activities will each be discussed individually after the provision of some general information on the evaluated university's research commercialisation process.

The main objective of this chapter is to guide the reader through the evaluation process, provide the results of the assessment and discuss how the respondents related to these results.

.

7.1 University Specific Background

Stellenbosch University (SU) was established in 1918 and has been recognised as one of the top academic institutions in South Africa. The university's technology transfer office, InnovUS, was established in 1999 to protect and manage the intellectual property created by university staff and students (21).

The following three sub-sections will give a quick overview of where the TTO is situated, how it operates within the university structure, what their vision, mission and strategy entail, and finally, who the major stakeholders are in the research commercialisation effort at Stellenbosch University.

7.1.1 Structure

InnovUS Technology Transfer (Pty) Ltd is a subsidiary company of Stellenbosch University and the office reports to the executive director of operations and finance. It has a board of directors which includes, together with six other members, the company's CEO, the Vice-Rector of research and the Vice-Rector of Operations and Finance.

The technology transfer team consists of seven members(139):

- CEO
- Intellectual Property and financial assistant
- Copyright officer
- Business Developer
- Part-Time business developer
- Project manager
- Administrative officer

7.1.2 Vision, Mission and Strategy

The CEO of InnovUS (Pty) Ltd. stated their vision as follows: "*Stellenbosch University establishes itself, through InnovUS Technology Transfer (Pty) Ltd as an important contributing vehicle, as the most successful university in Africa and to become the benchmark of excellence on the continent in terms of innovation, technology transfer and actively contributing interventions that will benefit society and business alike and will raise the profile of SU as a leading international player in this field.*" (21)

The mission: "*In essence InnovUS Technology Transfer (Pty) Ltd should become the primary innovation and commercialisation vehicle of SU and should be able to act as an independent company, with strong links to research and development, and directed by an independent and empowered board comprising of both SU management and business leaders.*"(21)

Strategy: *Enhance value added services to the researchers and inventors who are making use of intellectual property management services*.

The vision, mission and strategy, as described in the quotations above, demonstrate that Stellenbosch University has pledged a strong commitment towards research commercialisation.

7.1.3 Stakeholders

This section discusses the stakeholders in the Stellenbosch University process as defined by InnovUS Technology Transfer (Pty) Ltd. The life cycle and associated stakeholders in the Stellenbosch University research commercialisation process are presented below in Figure 50.

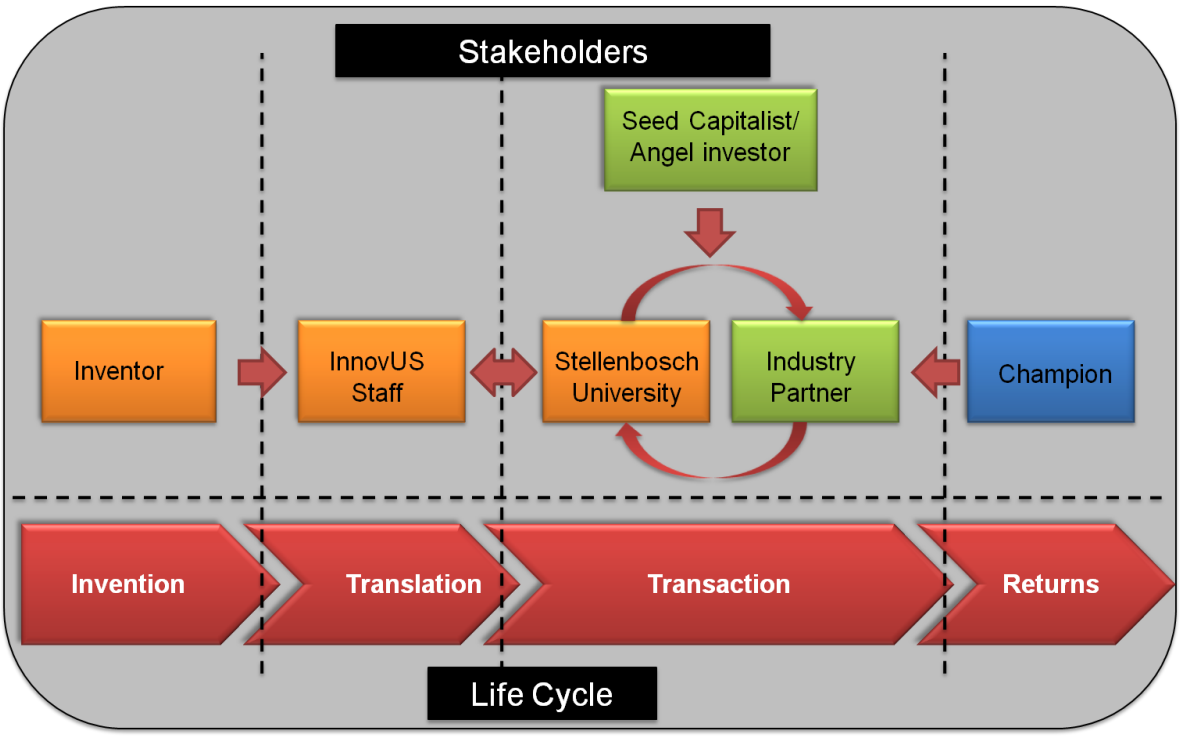


Figure 50 - Stakeholders in life cycle phases at Stellenbosch University, adapted from Nel (21)

This is a typical commercialisation process. The stakeholders also have certain responsibilities in each phase, stated below as described by Nel (21).

7.1.3.1 Inventor

- Creates idea
- Discloses to InnovUS
- Identifies people
- Is a technical expert

7.1.3.2 InnovUS Staff

- Professional project management

- Evaluation and assessment
- Market Research
- Due Diligence
- Search for new clients
- Negotiation and facilitation of deals
- Management of relationships

7.1.3.3 Seed Capitalist/Angel Investor

- Seed Capitalist
- Angel Investor

7.1.3.4 Champion in the University

- Understands value of technology
- Convinces management
- Facilitates processes within the company

7.2 Evaluation Planning

The bulk of the evaluation planning exercise was discussed in the previous section. In order to give a clear, complete picture and a logical flow through the steps of the improvement methodology, the main activities in the stage will be discussed, while unnecessary repetition is avoided.

The evaluation planning involves three major subjects that need to be addressed with the management of the organisation prior to the evaluation. These are the organisational objectives with the assessment, the context of the assessment, and specific perspectives on the results that the university may require. There are also some additional requirements related to ethical clearance that will be discussed in relation to the Evaluation planning activity.

Following the suggestion by Essmann (1), a meeting was held with the university executive management. The objective of this meeting was firstly to obtain the university's approval to perform the assessment and then discuss the other issues that were relevant at that stage. The content of this meeting is included in the discussions below.

7.2.1 Organisational Objectives

As stated previously, it was the researcher's initiative to start the evaluation procedure. In the meeting with the university management mentioned above, the researcher enquired whether they had any additional objectives with the execution of the assessment. Management made no specific additions to the objectives and accordingly the evaluation's objectives are limited to the general objectives of performing such an evaluation.

7.2.2 Context

Shaping the context and conveying it to the respondents consistently is crucial for a successful evaluation, especially to ensure that the results from the individual respondents are comparable. The context in this evaluation is fixed by the researcher rather than the organisation, because the objective of the research is to address the whole organisation's innovation capability maturity rather than only addressing certain of its sub-units. In Section 9.4 (which deals with future work), the possibility of different contexts will be discussed.

In summary, the respondents were asked to relate the questions to the capability maturity of the university as a whole. They should also keep in mind that the assessment specifically pertains to the research commercialisation process within the university.

7.2.3 Perspectives on the Results

In the meeting with management, it was agreed that the researcher decide which perspectives are important. It was decided that the aggregated perspectives of the researchers, management and TTO staff will be the most important as they are central to the process. The metadata captured in the standard questionnaire was deemed sufficient to obtain these perspectives and therefore no changes were made to the questionnaire.

7.2.4 Additional Requirements

An additional stipulation made by the university was that ethical clearance for the research was required. This is a standard procedure that has to be adhered to in order to be granted permission to perform an assessment or survey on the personnel and students of the university.

The procedure included the submission of a short research proposal and the completion of a standard form containing additional information about the research and how the interests of the university and its personnel would be protected. Additionally, the questionnaire had to be submitted for approval, along with a list of the individuals that were to be interviewed.

The last document that was needed to finalise the procedure was the "Informed consent form", which also had to be completed by the researcher. This form was presented to each respondent during the assessment workshop. Its purpose is to inform each respondent of the purpose of the assessment and assure them that it would not be used in any way that could negatively affect their employment security.

The application process took two months and this delay should be included in the planning of future assessments of this nature.

With management's approval and ethical clearance obtained, the evaluation workshops could commence.

7.3 Evaluation Workshops

To start the process, a meeting was held with the CEO and one project manager of InnovUS Technology Transfer (Pty) Ltd, at which time a basic introduction to the process was provided. This was done to expose them to the research and its implications without giving them too much information about the model, as this might have biased the answers they would provide during the completion of the questionnaire.

Each workshop was conducted according to the method prescribed by Essmann(1) in the development of the ICMM. Dr. Essmann also joined the first two workshops to ensure that the session was conducted in the correct manner and to give the researcher first-hand exposure to the consultation process.

7.3.1 Workshop 1 with InnovUS Technology Transfer (Pty) Ltd

The first evaluation workshop was held with the whole staff component of InnovUS Technology Transfer (Pty) Ltd. At this session, the context was provided and the definitions of the terms – opportunity, idea, concept and project – were explained as defined above. After this introduction, the questionnaires were completed with some guidance in the first few sections.

When the questionnaires had been completed by all the respondents, a discussion on the content of the questionnaire commenced. As a starting point for the discussion, two questions were asked.

- Are there questions in the questionnaire that seemed irrelevant?
- Are there any specific capabilities in which they presume Stellenbosch University to have a high and low maturity?

The subsequent discussion brought to light the difficulty to understand some of the questions, specifically question number 17 which relates to continuous research. Some respondents did not know whether this capability was related to the university's research base as such or the research being done to identify better ways of commercialising research. In other words, they struggle to differentiate between research done for product innovations and research done for process innovations. This implies that the question can be interpreted in two different ways.

The second very interesting point was made regarding their feeling that the assessment is assessing a non-core activity of a university, since the traditional core activities of the university are teaching and research.

Some of the barriers to the research commercialisation process that were pertinently mentioned were:

- Lack of incentives
- Marketing of technology transfer services
- Intellectual property leaking from universities

Although IP leakage was mentioned as a barrier, the management and securing of intellectual property was still stated as a definite strength of the university.

7.3.2 Workshop 2 with Division for Research development

This session was held with a selection of individuals from the Division of Research Development. Once again, the context was sketched and the various appropriate definitions explained. After the questionnaires were completed, the same two questions were asked as in the first workshop to stimulate discussion.

Some of the respondents remarked that it is difficult to relate to some of the questions because they do not regard innovation as part of their responsibility. One of the respondents remarked that while the department does promote innovative research, its focus is not innovation as such. This sentiment hints at the fact that they regard innovation as a process that includes development activities and, according to them, development is not part of the university's core activities and subsequently also not part of their specific responsibilities.

Some of the barriers to commercialisation mentioned in the discussion following the completion of the questionnaires were:

- There is a perceived trade-off between publishing and patenting
- Insufficient incentives are provided by government for universities
- Universities are expected to do basic research
- Commercialisation is not a core competence for the university

One of the biggest value additions of this assessment process was highlighted by one respondent who remarked that he found it very valuable to be made aware again and think critically about the innovation life cycle from the research end to the eventual generation of rewards from that research.

7.3.3 Individual Sessions

In addition to the two workshops, fifteen individual sessions were held with respondents from various departments in the university, including the two vice-rectors, two deans and eight researchers.

These sessions were presented in the same manner as the workshops with a short introductory presentation shaping the context and explaining the definitions before the respondent was asked to fill out the questionnaire. Whenever time was available, a discussion about the questionnaire was facilitated and some of the general comments are discussed below.

Some of the respondents remarked that they found it difficult to extract themselves from their local environment and give a global perspective of the university's maturity with regard to some of the capabilities. This could be the downside of trying to assess the organisation-wide innovation capability in an organisation which has so many managerial silos.

The lack of incentives to engage in commercial activity was also mentioned in many instances.

A general deduction from all the discussions pertains to the lack of an entrepreneurial culture in the university and little effort on the part of the university to create such a culture. The need for such a culture is also a point for debate.

7.4 Processing of Responses

The purpose of this activity, as described by Essmann (1), is to interpret the questionnaires and translate the answers to value-adding and descriptive results that would improve the respondents' understanding of the current situation in the organisation.

7.4.1 Prioritise Capabilities for Research Commercialisation

It is unlikely that one organisation would ever possess the resources to engage in the improvement of all 42 capabilities at one time, and it is very unlikely that any one organisation would insist on a maturity level of 5 in all 42 capabilities.

This implies that one has to prioritise the capabilities in order of importance for any single organisation, while considering their strategy with regards to innovation. In a first round of prioritisation, Essmann (1) considered 13 capabilities fundamentally important for innovation in any organisation. The rest of the capabilities were categorised as "base" and "progressive". When the results have been evaluated, certain capabilities are chosen again as more relevant to the specific organisation in a second round of prioritisation. These capabilities would be the capabilities either prioritised for improvement if they have a low capability maturity, or leveraged if they are perceived as strengths.

For this specific application, the first 13 fundamental capabilities were revisited to evaluate their applicability in the academic sphere. For the academic sphere, all but two of these capabilities were judged to be fundamental for a research commercialisation programme to be successful. Six more were promoted to be fundamental, based on the critical success factors for research commercialisation found in the literature review.

These seventeen capabilities are:

1. Understanding the market
2. Identifying opportunities
3. **Developing concepts**
4. Testing, screening & prioritising opportunities & concepts
5. Reducing uncertainty & mitigating risk
6. Continuous research
7. **Establishing intellectual property management & sharing policy**
8. **Managing intellectual property**
9. Formal & informal internal networking & collaboration
10. **Formal & informal external networking & collaboration**
11. Developing & conveying innovation strategy & objectives
12. Providing the necessary resources
13. Creating cross-functional & multidisciplinary teams
14. Communication & the flow of information
15. **Motivating, rewarding & celebrating success**
16. **Hiring & aligning people's values & skills with organisation & task**
17. Measuring innovation

The six capabilities that were promoted to fundamental status are shown in bold in the list above. The reasons for their promotion will become apparent in the next section on the contextualisation of the capabilities. This then implies that these seventeen innovation capabilities are from here on out also deemed research commercialisation capabilities and the two phrases will be used interchangeably when referring to the these capabilities.

This is justified because none of these capabilities can be incorrectly interpreted from the questionnaire to imply something other than the intended question. For example in the context of innovation or research commercialisation a question about the maturity of managing intellectual property would be answered the same.

The capabilities that were selected for improvement in the second round of prioritisation will be discussed in the summarised results section.

7.4.2 Summarised Results

This section will present the results of the assessment up to the stage where certain capabilities are prioritised for improvement. This prioritisation will be done in the subsequent section. Many of the figures presented in this section are derived from those used by Indutech (Pty) Ltd in the formal presentation of the results of the questionnaires to their clients. These figures were obtained and are published here with the permission of Dr. Essmann.

Stellenbosch University achieved the highest average maturity rating of any organisation that had previously been evaluated with the ICA. The results are summarised in Table 2 below.

Table 2 - Summarised results: Overall results

Average Maturity Rating	**2.90**
Standard Deviation	**0.61**
90% Confidence interval	**0.18 (α = 0.1)**

The standard deviation was also the largest ever achieved. This can be speculatively attributed to several factors which will be discussed in Chapter 8. The confidence interval implies that if one redid this assessment, 9 out of 10 times the average maturity rating would be between the limits 2.81 and 2.99.

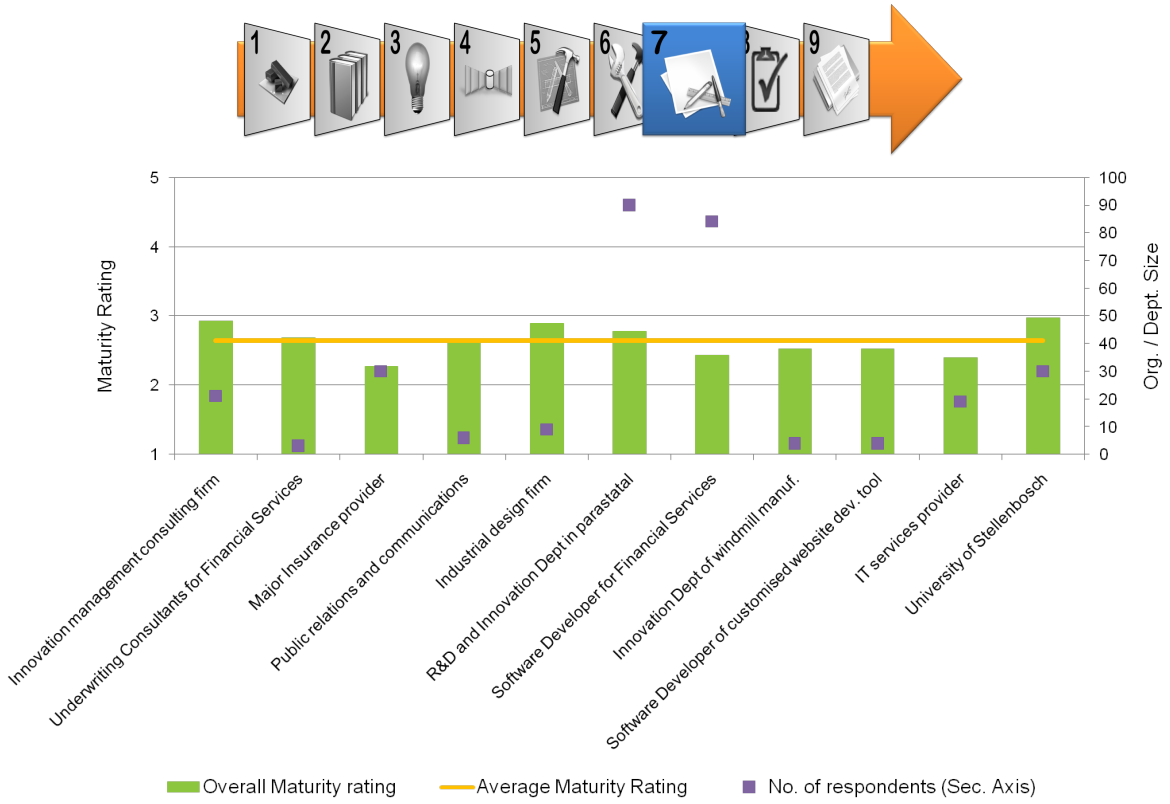


Figure 51 - Comparison against previous assessments

From Figure 51, one can see that the university achieved the highest rating and is well above the average of 2.64. The number of respondents that participated compares well with the other instances excluding the two outliers.

Although these statistics in isolation do not mean very much, it is still important to show them to the respondents in the process of obtaining buy-in for their participation in the improvement process. As will be reiterated throughout this procedure, the real value of the assessment can be derived from evaluating the relationships between the results obtained, rather than their absolute values.

The average maturity ratings of the three most important stakeholders in the SU rating are shown in Table 3 below:

Table 3 - Summarised results: Major role-players' perspective

TTO	**3.11**
US Management	**3.29**
Researchers	**2.69**

From Table 3 it can be deduced that the researchers perceive the overall innovation capability of the university to be the lowest. This difference in perception is an important one as literature often suggests that such a negative perception from the researchers' point of view can present huge barriers in the research commercialisation process.

As for the individual capabilities, *Establishing intellectual property management & sharing policy* achieved the highest rating of 4.2, while *Investment in innovation & sourcing of capital* was the capability with the lowest maturity rating of 2.16.

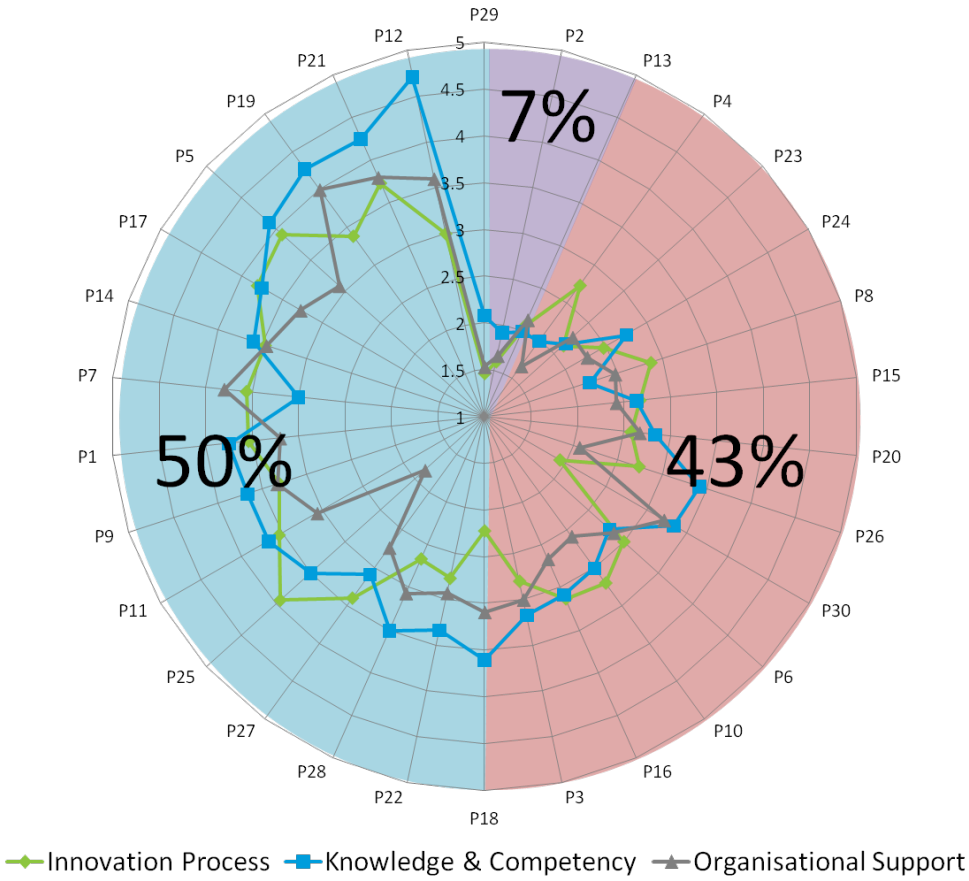


Figure 52 - Categorisation of ratings from respondents

The wheel chart presented in Figure 52 shows that 7% of the respondents (represented by P* in the chart) rated the overall maturity of the university lower than 2, 43% rated the overall maturity on a level between 2 and 3, and 50% on a maturity level of more than 3.

Another observation that can be made from Figure 52 is that the area of *Knowledge & Competency* is perceived as a strength by most respondents (the blue line is mostly on the outside), while *Organisational Support* is generally rated as the weakest of the three Innovation Capability Areas.

This is confirmed when evaluating the Innovation Capability landscape view presented in Figure 53 below. This depiction is used to identify the high-level strengths and weaknesses of the organisation. The strong areas are outlined by the green line to highlight it and correspondingly the weak areas are framed by a red border.

The second column from the right gives the average maturities of the Innovation capability areas. The fourth column gives the average maturity of the Innovation capability construct items. Remember that each of these construct items can consist of more than one capability. The same goes for the second row from the top which is the average maturities of each of the organisational areas. There are only thus 32 values in the matrix because some of the maturities of the individual capabilities are averaged together.

				Strategy & Objectives	Function & Processes	Organisation & Management	Internal - Data & Information	External - Data & Information	Customers & Suppliers
				2.75	2.70	2.59	2.83	3.43	2.53
Innovation Process	2.69	Explore & Converge	2.86	2.31	3.14	2.60	2.89	3.43	3.02
		Portfolio Management	2.46	2.52	2.17	2.38			2.88
		Consolidate & Exploit	2.72		2.75	2.63			
		Process Control & Risk Management	2.67		2.57				
Knowledge & Competency	2.94	Discover & Absorb	3.06	3.38	3.49	2.87			1.67
		Consolidate	3.19		3.20	3.60			
		Core Competency & Technology	2.58		2.29	2.43			
Organisational Support	2.52	Innovation Strategy & Leadership	2.63	2.87	2.56	2.45	2.71		
		Structure & Infrastructure	2.69	3.09	2.73	2.57			
		Environment & Climate	2.70			2.46			
		Resources & Measurement	2.23	1.94	2.18	2.36			

Figure 53 - Innovation capability landscape, adapted from Essmann(1)

In Figure 53, it can be seen that the area of *Organisational Support* is generally perceived to be at a lower maturity relative to the other two areas. This is consistent with the overall picture up to this stage. It is important, however, that these results be evaluated in the context of what is strategically relevant to the organisation.

For example, the red (low relative maturity) capability at the intersection of the *Knowledge & Competency* and the *Customers and suppliers* area is not as important as the rest, because it evaluates the competency of suppliers and in this case, there is no defined supplier in the research

commercialisation process. In this depiction it also seems to be the lowest-rated capability, as opposed to *Investment in innovation & sourcing of capital* that was mentioned earlier, but this is only because the response-normalisation and aggregation process influences the values projected in this landscape view.

To evaluate the individual capabilities, the so-called Innovation Capability Portfolio is used (1). This is the scatter plot described in Section 5.2.2.1, Figure 42. The figure plots a point for each of the 42 capabilities, based on the average rating from the respondents (there is no normalisation) and the standard deviation between their answers.

For clarity purposes, only the 17 capabilities that were deemed fundamental to research commercialisation are displayed in Figure 54. For the plot with all 42 capabilities, see Appendix IV.

It should be noted that the horizontal axis in this plot, is displaying the standard deviation between the responses for each capability starts at 0.6 rather than 0. This is done to improve the visual presentation of the results and deemed appropriate because none of the capabilities had a standard deviation of less than 0.8.

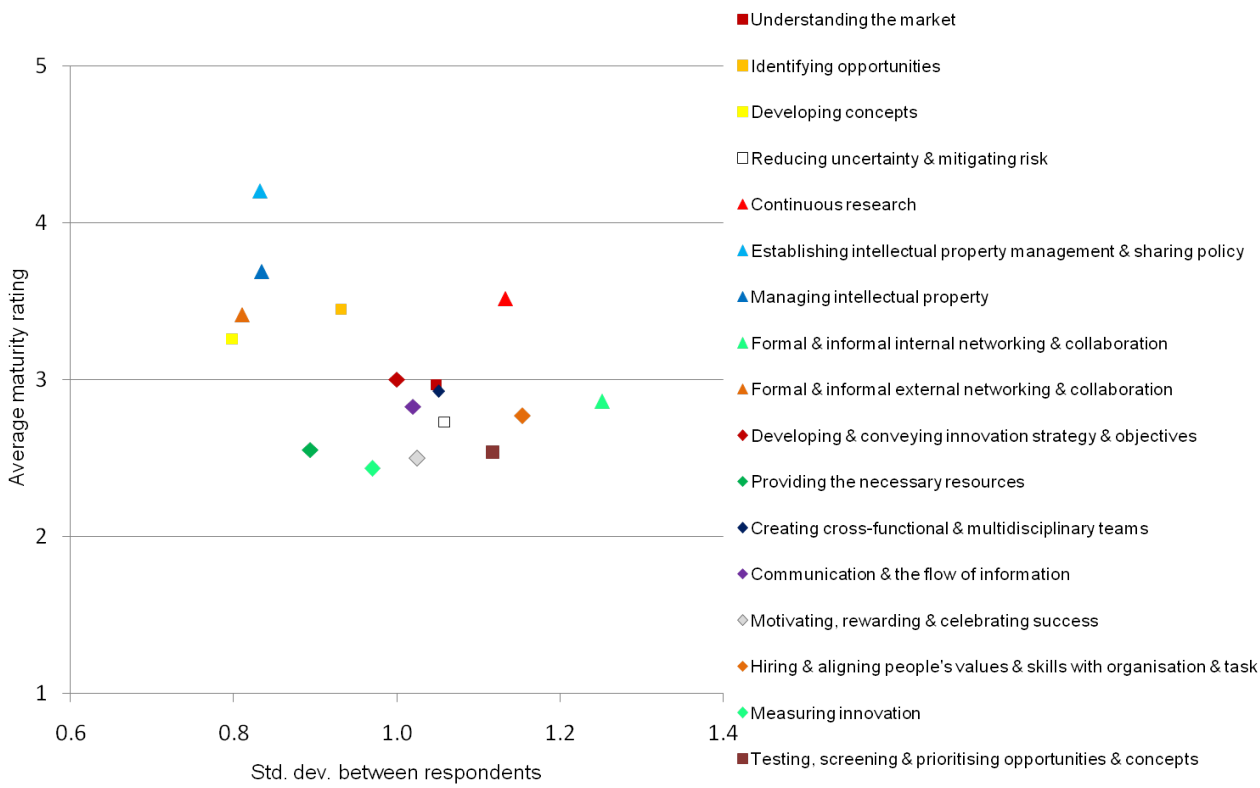


Figure 54 - Scatter plot of 17 fundamental capabilities

This depiction enables the analyst to quickly identify the strengths, opportunities for improvement and areas of non-consensus. From Figure 54 it can again be deduced that *Establishing intellectual property management an sharing policy* is the highest-rated capability with relatively good consensus among the respondents. Among others, the capability entitled *Formal and Informal internal networking* needs to be clarified.

An important issue to mention at this stage relates to the "rule of thumb" boundaries used to define the strengths, weaknesses and areas of non-consensus. As explained in Section 5.2.2.1, the boundary for defining strengths is set at 3 and similarly the boundary for defining weaknesses is set at 2.

In Figure 54, it can be seen that none of the capabilities displays a maturity of less than 2. This does not, however, imply that the organisation has no weakness. As stated earlier, an important aspect of the interpretation is the evaluation of the results relative to each other. Accordingly, the boundary for defining weaknesses will be moved to 2.8. While this may seem technically inappropriate, it has no effect on the actual results. It is only a mechanism to improve the presentation of the results with respect to the identification of opportunities for improvement.

By making this change it can be deduced from Figure 54 that *Providing the necessary resources* and *Measuring innovation* are perceived as weaknesses or rather possible opportunities for improvement, considering that they still need to be discussed in relation to strategic relevance. The actual prioritisation of the capabilities for improvement will be done during the next activity, which is the *Gap analysis*.

Another way to view the results is by making use of a stack chart. Again, only the 17 fundamental capabilities are displayed (Figure 55). For the stack chart with all 42 capabilities, see Appendix IV.

On the left vertical axis is the capability names and on the horizontal axis is the percentage of respondents that rated the capability on a maturity as illustrated by the key on the right. For example ±27% of people rated the first capability on level 3, ±25% rated the maturity on level 4 and about 48% rated it on maturity level 5. The orange bar displays the percentage of respondents that answered "not sure" on the maturity of the specific capability and the light purple would mean that respondents said that the capability is "not applicable". Not one respondent rated any of the 17 fundamental capability requirements "not applicable".

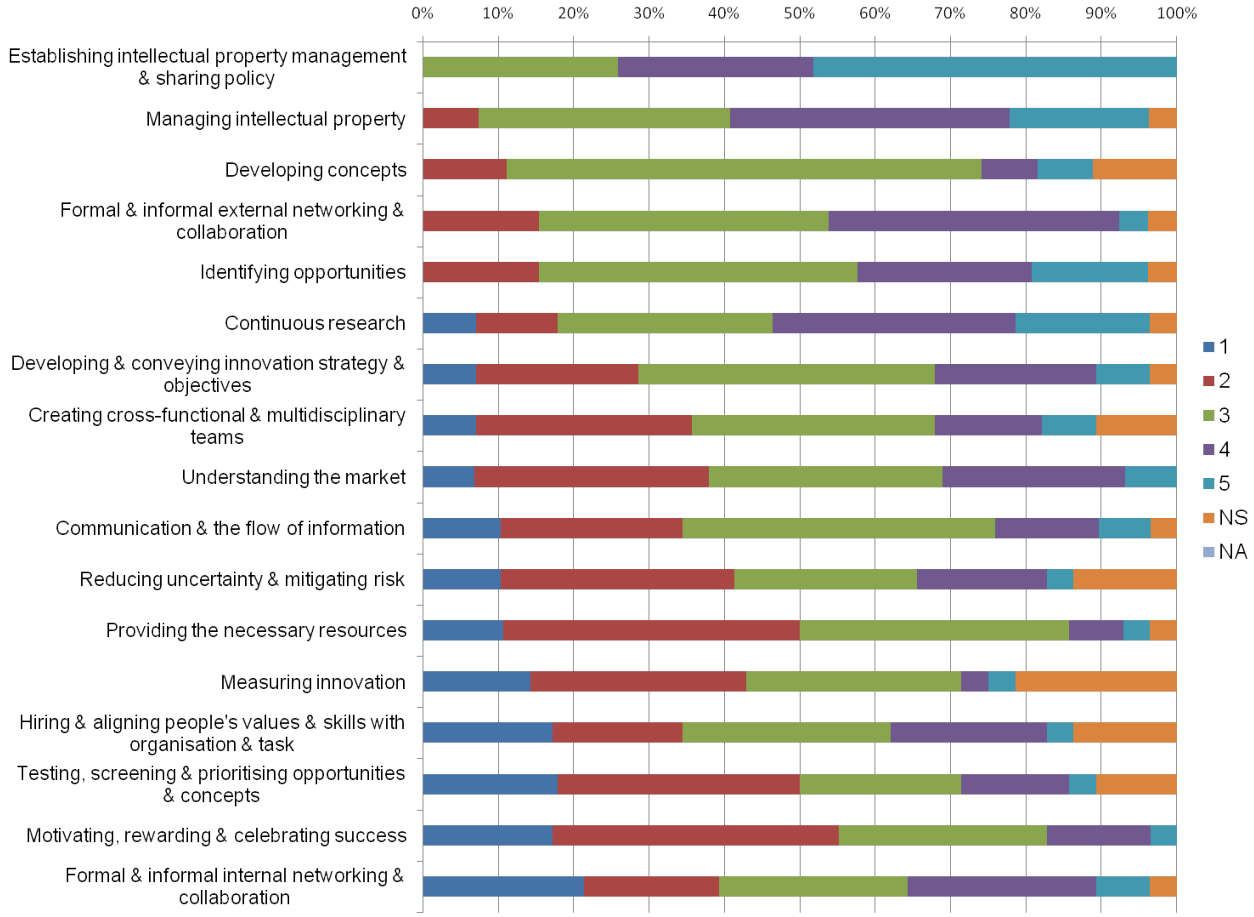


Figure 55 - Stack chart depiction of results

Other summarised interpretations that can be made from this chart is the following. More than 80% of respondents feel that:

- The IP policy protects the interests of all involved while enabling external collaboration
- Practices for external networking and collaboration are deployed successfully
- IP is sufficiently managed and infringements are dealt with
- Concepts are developed to meet defined outputs and fill opportunities
- Opportunities are identified and individuals are provided guidelines to substantiate ideas

Similarly, more that 40% of the respondents feel that:

- The necessary resources are not provided for innovation
- There are not sufficient metrics for measuring innovation
- Insufficient incentive is provided to motivate and reward innovative behaviour

This will also be considered in the prioritisation of the capabilities for improvement in the gap analysis. Through an evaluation of Figure 54 and a consideration of the overall standard deviation,

it can be deduced that some of the respondents are at odds about the maturity of specific capabilities. To evaluate this difference in perception, the respondents' answers can be aggregated based on the department/division in which they work, and these cumulative perceptions can be compared.

Before this can be done, the capabilities that display a relatively low level of consensus or high standard deviation should be identified, as it would be tedious and unnecessary to compare all 42 or even 17 capabilities in this manner. Figure 56 shows a table where the capabilities with a low level of consensus can easily be identified as those with the largest standard deviation. From Figure 56, five capabilities will be chosen to evaluate at this stage. They are:

- Testing, screening & prioritising opportunities & concepts
- Reducing uncertainty & mitigating risk
- Continuous research
- Formal & informal internal networking & collaboration
- Hiring & aligning people's values & skills with organisation & task

			Consensus	
			Unweighted Std Dev	Clarify
Innovation Proces	Understanding the market	Fundamental	1.05	
	Identifying opportunities	Fundamental	0.93	
	Developing concepts	Fundamental	0.80	
	Testing, screening & prioritising opportunities & concepts	Fundamental	1.12	X
	Reducing uncertainty & mitigating risk	Fundamental	1.06	X
Knowledge & Comi	Continuous research	Fundamental	1.13	X
	Establishing intellectual property management & sharing policy	Fundamental	0.83	
	Managing intellectual property	Fundamental	0.83	
	Formal & informal internal networking & collaboration	Fundamental	1.25	X
	Formal & informal external networking & collaboration	Fundamental	0.81	
Organisational Support	Developing & conveying innovation strategy & objectives	Fundamental	1.00	
	Providing the necessary resources	Fundamental	0.89	
	Creating cross-functional & multidisciplinary teams	Fundamental	1.05	
	Communication & the flow of information	Fundamental	1.02	
	Motivating, rewarding & celebrating success	Fundamental	1.02	
	Hiring & aligning people's values & skills with organisation & task	Fundamental	1.15	X
	Measuring innovation	Fundamental	0.97	

Figure 56 - Table for identifying non-consensus capabilities

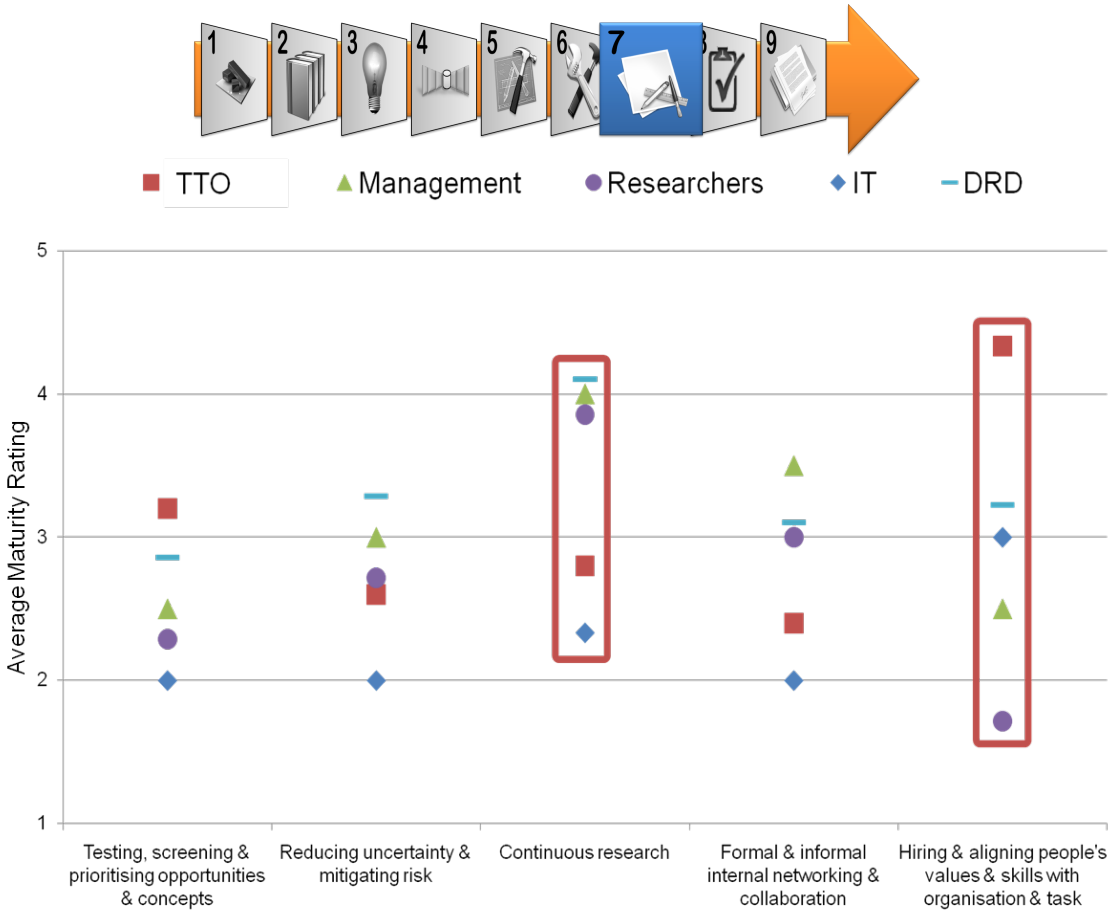


Figure 57 - Scatter plot showing departmental difference in perception

From Figure 57 it is clear that there are large interdepartemental differences in perception regarding the maturity of these five capabilities. An interesting observation is that the departments that are, to a large extent, responsible for the execution of a specific capability seem to rate that capability quite high and the opposite is also true.

Consider the capability *Continous Research.* It can be assumed with relative confidence that the researchers and Division for Research Development (DRD) would deem themselves either responsible for the physical execution of this capability or its management; the TTO would not typically consider itself responsible for this capability. Accordingly, the researchers and DRD rate it on a high maturity and the TTO rates it on a low maturity.

The cause of this phenomenon, as well as the general differences in perception, should be entirely or at least partially clarified in the *Results* Workshop. If one of these capabilities is deemed strategically relevant and consequently needs to be improved it is suggested that a more formal method be used to clarify the matter, such as root cause analysis. This analysis will only be formally executed in the “Analysis and verification of findings” activity in the planning stage of the improvement methodology, which is outside the scope of this research.

This concludes the initial processing and interpretation of the results. The next activity concerns the prioritisation of the capabilities that should be improved and is dubbed the Gap Analysis.

7.5 Gap Analysis

With the completion of the processing and interpretation of the results, the prioritisation of the strengths and opportunities for improvement can commence. The objective is to determine which of the 42 Innovation Capability Requirements the organisation should improve. It is important to remember that these innovation capability requirements are directly related to research commercialisation requirements because research commercialisation is a type of innovation as explained in Chapter 4.

For the sake of completeness, the factors that need to be considered during this prioritisation according to Essmann(1) will be reiterated:

- The organisation's objectives for the evaluation, as agreed upon in the evaluation planning
- Various organisational specific aspects, such as strategy, core business, value offering, industry, etc.
- The results as analysed in the previous section.

As stated earlier, there were no additional objectives with the evaluation and thus only the typical objective for doing such an evaluation will be considered. The objective is to provide a platform for improvement of the organisation's Innovation capability. The other organisational aspects such as strategy and core business will be incorporated.

It is important to note that the prioritisation will be done with the experience and insights gained by the analyst/researcher during the execution of the evaluation. As a result, this prioritisation might be modified during the results presentation if the organisation finds either the order of the prioritisation incorrect or suggests other capabilities that are strategically more relevant. It is important, however, that the analyst at least provide a starting point for the formal effort through this prioritisation exercise.

As explained in section 7.4.1, Essmann(1) prioritised the 42 innovation capabilities into three categories according to their individual importance to the general innovation effort. These categories are fundamental, base and progressive. Although this research focus on the 17 innovation capability requirements that were deemed fundamental to research commercialisation the other capabilities (base and progressive) were also evaluated and are used in the construction of Figure 58 below.

One should expect that any organisation would operate best if at least all the fundamental capabilities were at a respectable maturity. This does not mean that an organisation can ignore the base and progressive capabilities; it simply means that the capabilities in a healthy organisation

should get progressively more mature moving from progressive towards the fundamental capabilities. The blue line in Figure 58 below represents this desired trend.

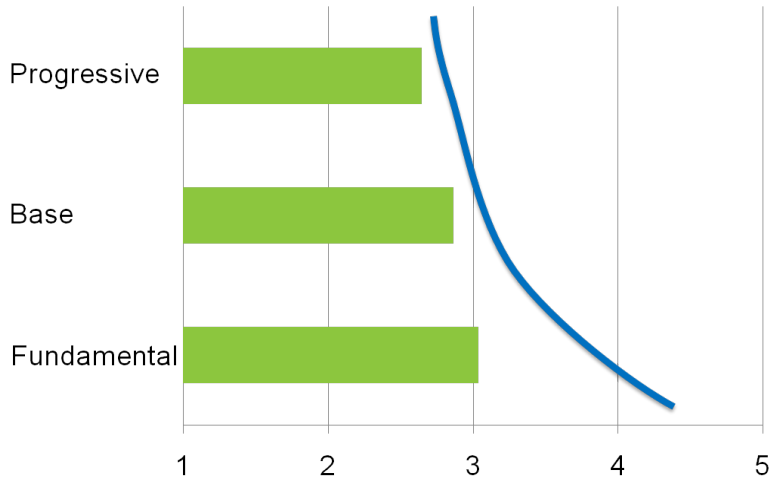


Figure 58 - Progressive maturity of the three categorisations of capabilities

In Figure 58, it is encouraging to see that the results obtained from the assessment on the university show a similar trend.

In the prioritisation activity, only the 17 fundamental capabilities would be evaluated for possible improvement opportunities to further extend the cumulative maturity of the fundamental capabilities.

The prioritisation will be done in three phases. First the strengths to be leveraged will be prioritised; secondly, the weaknesses or opportunities for improvement will be prioritised, and lastly, the capabilities that need clarification will be discussed. In Figure 59 on the next page, all 17 fundamental capabilities can be seen plotted on a scatter plot that also shows the boundaries from which the strengths, weaknesses and unclear capabilities can be identified.

It should be noted, as stated earlier, that these boundaries were moved from 2 and 3 to 2.8 and 3.2 respectively. This is done to improve the presentation for easier detection of the strengths and weaknesses.

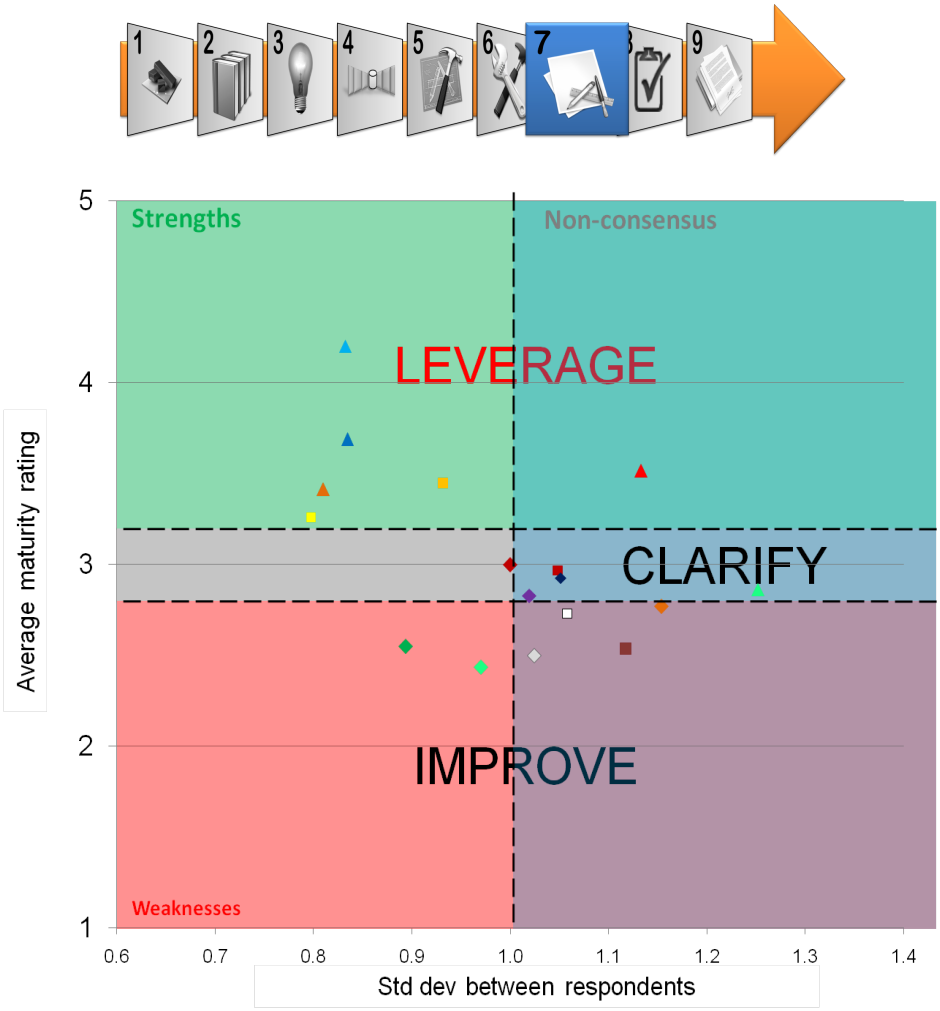


Figure 59 – Scatter plot of all 17 fundamental capabilities

7.5.1 Strengths

The actual presentation and discussion of the strengths of an organisation are both very important because these strengths would typically be the core competencies of the organisation and the respondents should be exposed to them. It is important to keep these competencies in mind when developing plans aimed at improving the weaknesses. This should be done to avoid a negative impact on the existing strengths by losing touch with what were core competencies (1). There would be no point in improving certain capabilities at the expense of others.

Another important reason to present the strengths to the respondents is to minimise the negative effect of presenting weaknesses. This is another important factor in the creation of an environment which would ensure that respondents buy into the relevance and consequent improvement initiatives of the ICMMv2.

It is worth repeating here that strengths are those innovation capabilities that are perceived to be at a high maturity (above 3.2) relative to the other capabilities, with a relatively high consensus (standard deviation of less than 1). The perceived strengths with regards to research commercialisation of Stellenbosch University are presented below in Figure 60.

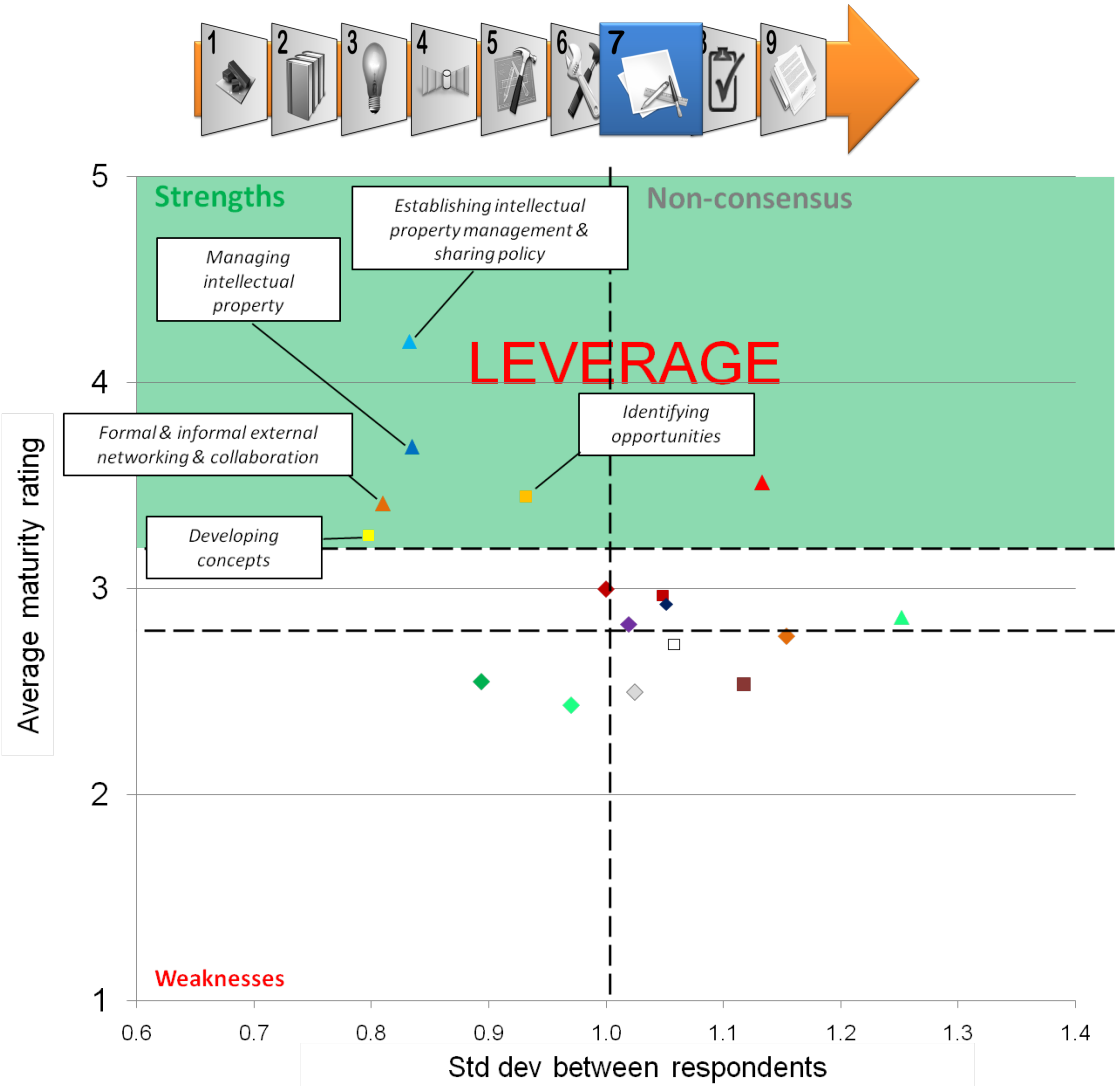


Figure 60 – Scatter plot of capabilities that are perceived as strengths of Stellenbosch University

On the basis of Figure 60, the strengths categorised into their Innovation Capability Area are:

- **Knowledge and Competency**
  - Establishing intellectual property management & sharing policy
  - Managing intellectual property
  - Formal & informal external networking & collaboration
- **Innovation Process**
  - Developing concepts
  - Identifying opportunities

The capability *Continuous research*(red triangle is left out because there is not enough consensus about the maturity of this capability.

At first glance, it is evident that there are no strengths in the *Organisational Support* area. This is consistent with the preliminary processing of responses, discussed in the previous section, which showed that *Organisational Support* was the lowest-rated Innovation Capability construct area of the three. The implications of this will be discussed in the next section.

To understand what these strengths imply, these capabilities have to be contextualised to understand what they mean for research commercialisation. This is not a gruelling exercise, because these strengths relate very well to research commercialisation.

The first two strengths highlight the fact that the university has clear, well-communicated and well-managed Intellectual Property policies and regulations – a definite prerequisite for a successful research commercialisation programme.

Formal & informal external networking implies that researchers and TTO officers network and collaborate very well with outside partners and this should be expected in a university for which research contracts contribute to roughly 20% of its total income (140).

Identifying opportunities and *Developing concepts* are both crucial to the commercialisation process as they are very important activities in the execution of the life cycle. Identifying opportunities can be interpreted in two different ways but this will be discussed in the next chapter.

This concludes the discussion of the strengths, and opportunities for improvement will follow.

7.5.2 Weaknesses & Aspects to Consider

In this section, the capabilities that are suggested for possible target areas of improvement projects will be discussed. Weaknesses in this instance are those capabilities that were rated on a relatively low maturity (less that 2.8) with relatively high consensus (standard deviation of around 1). While this criterion is used, all the fundamental capabilities that were not either classified as strengths or areas of non-consensus are presented as possible areas for improvement to maximise the points for discussion in the *Results Presentation* activity that will follow. The capabilities can be seen in Figure 61 below.

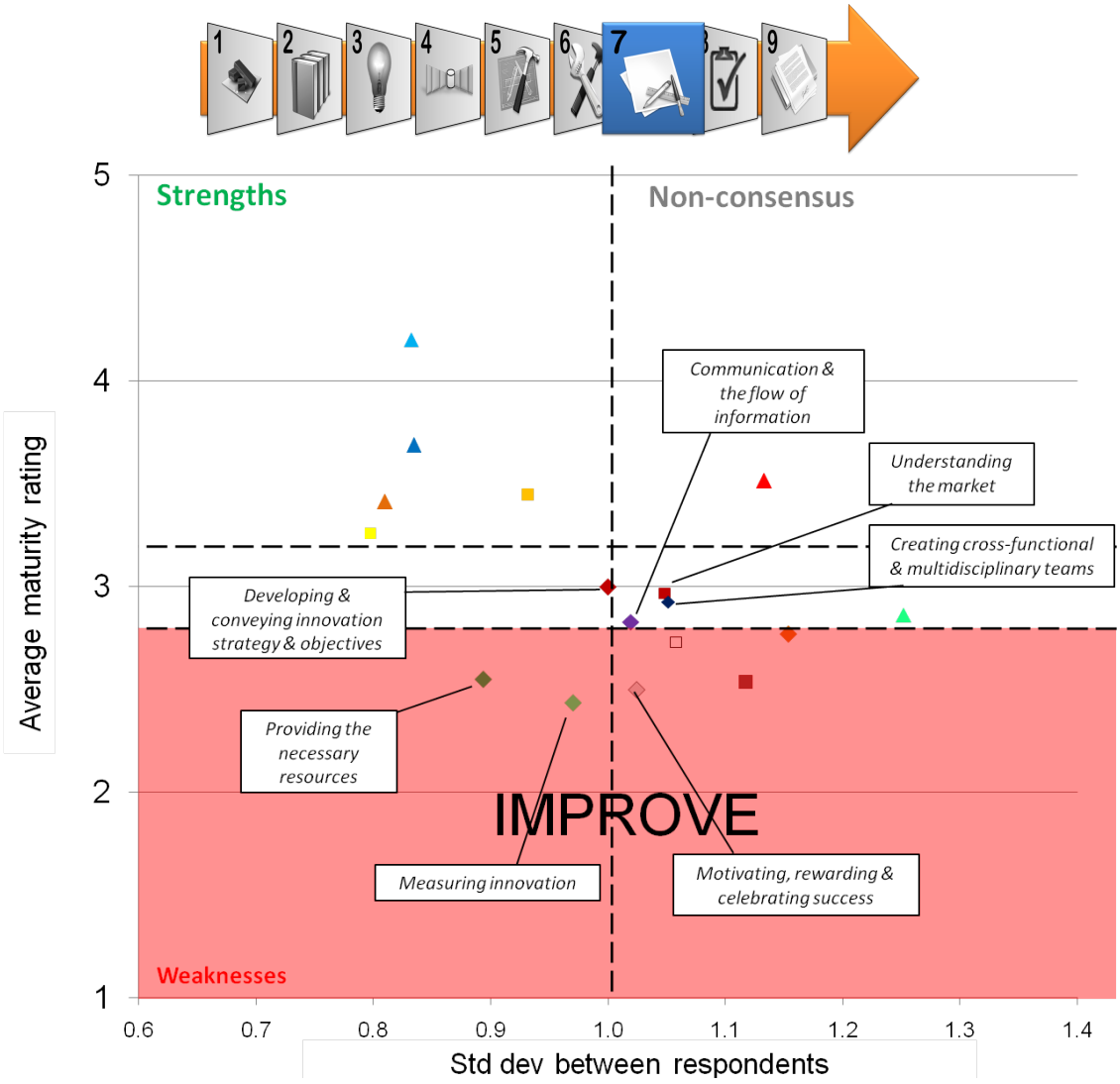


Figure 61 - Scatter plot of capabilities that are perceived weaknesses of Stellenbosch University

On the basis of Figure 61, the weaknesses categorised into their Innovation Capability Area are:

- **Organisational Support**
  - Measuring innovation
  - Motivating, rewarding & celebrating success
  - Providing the necessary resources
  - Communication & the flow of information
  - Creating cross-functional & multidisciplinary teams
  - Developing & conveying innovation strategy & objectives

- **Innovation Process**
  - Understanding the market

From these points it is again amplified that the weakest Innovation Capability area is *Organisational Support,* as almost all the perceived weaknesses are contained in this area. This is a worrying observation, because according to Essmann (1) the Organisational Support capability

requirements provide essential support structures, systems and behaviours for the capability requirements of the Knowledge & Competency and Innovation Process areas. It is essentially the foundation on which the other two areas are built, as illustrated by Figure 62.

Figure 62 - Innovation capability areas prioritisation, adapted from Essmann(1)

To understand what these capabilities mean in terms of research commercialisation, they have to be contextualised. Accordingly, a discussion of each of the weaknesses will now follow before this section is concluded.

Measuring Innovation and *Motivating, rewarding & celebrating success* are two capabilities that are very closely related. It is commonly believed that "what you measure is what you get". In order to stimulate innovative behaviour, one has to incentivise such behaviour, but for any incentive structure to be successful the appropriate performance measures should be identified. These two capabilities are of critical importance for creating an entrepreneurial culture in a university and it would relate to elements such as the royalty distribution formulas and tenure promotion policies.

Providing the necessary resources is also an important capability to consider. This can relate to all kinds of resources (financial, human, etc.) and not only the provision thereof but also the division, as any organisation would only have a specified amount available. Giving staff the resources they need is essential for supporting innovation.

Communication and the flow of information relates to how information is translated along divisional lines and over other boundaries within an organisation. This is a capability that will influence many of the others as communication is essential for any innovation effort. The capability called *Developing & conveying innovation strategy & objectives* is one that would be negatively affected

by insufficient communication in an organisation. This highlights the importance of evaluating the relationship between capabilities in addition to their perceived maturity.

Creating cross-functional & multidisciplinary teams is a capability that measures how teams are assembled. The importance of a multidisciplinary approach to solving problems and generating ideas is iterated throughout research commercialisation and innovation literature. It seems that the creation of such teams is an area that can be improved in the university.

The only capability that is not categorised in the *Organisational Support* area is *Understanding the market.* This capability relates to the maturity of the methods and tools (if any) that are used to understand the market to which the value offering is delivered. Understanding the needs of the market can help the organisation shape its value offering to attain a better match with the needs of potential customers.

The fact is that altering research agendas to fit market need is a very controversial subject in the academic sphere and this point may very well render the capability strategically irrelevant. Essmann(1) stresses the fact that each organisation will have its own unique way of fulfilling each capability and this is an important factor to consider before stating that a capability such as *Understanding the market* is not strategically relevant. Understanding the market could for instance help the TTO to better tailor concepts to the needs of their customers.

This concludes the prioritisation of the capabilities that will be presented as possible areas for improvement in the *Results Workshop*. The ideal is that the respondents relate to these basic recommendations made by the analyst. This will provide the platform from which a formal selection can be made with regard to the capabilities that need to be improved using improvement plans.

7.5.3 Non-Consensus

In this section, the capabilities that showed substantial variation (standard deviation of more than 1) in their maturity rating will be discussed. Although these capabilities might not directly present opportunities for improvement due to the low consensus about their maturity, they should be discussed to clarify the reasons for the differences in opinion.

The capabilities that will be discussed are presented in Figure 63.

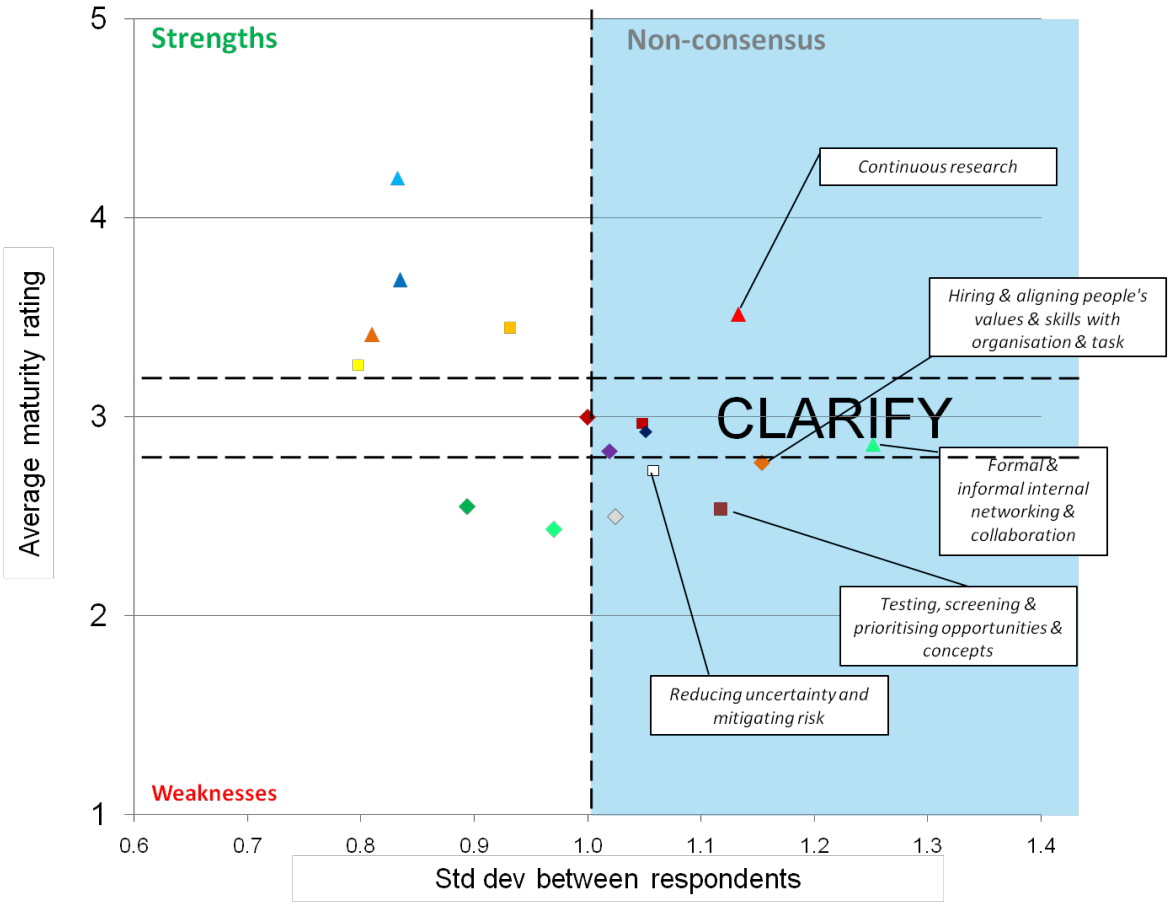


Figure 63 - Scatter plot of capabilities displaying low consensus

From Figure 63 the capabilities that show low consensus, categorised into their Innovation Capability Area are:

- **Innovation Process**
  - Testing, screening & prioritising opportunities & concepts
  - Reducing uncertainty & mitigating risk

- **Knowledge & Competency**
  - Formal & informal internal networking & collaboration
  - Continuous Research

- **Organisational Support**
  - Hiring & aligning people's values & skills with organisation & task

Although the reasons for the ambiguity in the perception of the respondents is not clear at this stage, these capabilities will also be contextualised in terms of research commercialisation. The

contextualisations discussed below can be used in the *Results Presentation* to evaluate whether interpretation of the questions in terms of research commercialisation is a possible cause for the non-consensus.

Testing, screening & prioritising opportunities & concepts relates to how opportunities and concepts are matched. It evaluates the process of testing and subsequently prioritising the development of concepts by considering the interrelation between opportunities and possible future scenarios. It also evaluates the criteria used to test and prioritise throughout the process.

Reducing uncertainty & mitigating risk relates to the procedures used for understanding and minimising the risks involved in the execution of projects. Starting up companies and negotiating licences can be a lengthy and very risky process, although the latter to a lesser degree. This implies that procedures for identifying, understanding, managing and balancing these risks in a portfolio are crucial.

Formal & informal internal networking & collaboration evaluates the practices and procedures within the organisation aimed at facilitating networking and collaboration between employees. This capability is closely related to the creation of multidisciplinary teams and also internal communication. Collaboration and networking internally is important for devising innovative solutions to problems and minimising rework or “inventing the wheel twice”.

Continuous Research is a capability that one should expect to be a core competency of a university. The capability relates to research being done to create ideas for feeding the innovation funnel. The disparity in the answers on this capability is a concern and is an area that needs to be prioritised for an investigation as to the root cause.

Finally, *Hiring & aligning people's values & skills with organisation & task* relates to the human resource procurement policy of the university. Hiring the people with the appropriate skill set to work in the TTO is a very important aspect if the goal is to successfully commercialise research on a continuous basis.

This concludes the discussion on the areas of non-consensus. These capabilities were presented for discussion in the *Results* Workshop with the objective of identifying the cause of the discrepancy in the answers.

7.6 Results Workshop

In this section, the formal presentation of the results generated in the *Evaluation* Stage were discussed. The results were presented with some additional information about the ICMMv2 that was purposefully excluded prior to the survey so as to avoid influencing the answers of the

respondents. The rationale behind the decision to give the respondents the information at this stage is to sensitise them to the relationship between the individual Innovation Capability Requirements.

As stated earlier, the objective is to get the respondents to associate with the results. As Essmann (1) states, someone has to say, “Oh yes, I understand why this has been happening! It all makes sense now.”

This will serve as the validation that the ICMM is successful in identifying the strengths and weaknesses of the University’s Research Commercialisation capability. Subsequently, the final prioritisation of results for the creation of improvement plans, as suggested by Essmann (1), will not be executed as it is beyond the scope of this research.

The results were presented in two workshops or feedback sessions. The first session was presented to the the TTO. The second was held with university officials at executive level. A discussion of the content of these two workshops follows.

7.6.1 Feedback Session 1 (InnovUS Technology Transfer (PTY) Ltd)

This is a summary of the main points motioned in a feedback presentation presented to two members of the technology transfer office at Stellenbosch University.

They were informed that the objective of the feedback session was to find out to what degree they could associate with the results from the assessment.

When discussing the weaknesses/opportunities for improvement, the following remarks were made:

Some of the weaknesses were recognised as points already under discussion at the university and that action has been taken to improve some of them. As an example, the university is currently busy working to facilitate discussions between specific research groups in order to identify areas of overlap in their research focus and this could lead to new innovative projects and research.

It was remarked that many of the weaknesses relate to communication and marketing problems, specifically the capability “Providing the necessary resources”.

Another remark was that although “Measuring innovation” is perceived as a weakness, there are indicators in place to deal with the capability; accordingly, the problem again may not be the actual capability, but rather the way in which it is communicated.

The fact that “Motivating, rewarding and celebrating success” is perceived as a weakness was deemed accurate and the issue is currently being discussed within the University.

The final comment made related to the capabilities “Establishing intellectual property management & sharing policy” and “Managing intellectual property”. The perception that these capabilities are perceived as quite mature is deemed accurate, because the issue had recently been addressed with the introduction of a new IP policy at the University. Accordingly, it should be fresh on the agenda of many of the respondents who participated in the assessment.

As a general comment, it was agreed that rephrasing some of the questions in the actual questionnaire or at least shaping the context better at the beginning would improve the accuracy/applicability of the results.

The meeting was concluded and it was agreed that the respondents could generally relate to the results of the assessment, but more value can be drawn from the exercise if the context was shaped better and the assessment redone on faculty level in addition to university level. These issues will be discussed in the following section, and in the section on future research.

7.6.2 Feedback Session 2 (Executive level officials)

This is a summary of the main points motioned in a feedback presentation presented to executive officials at Stellenbosch University.

The participant was informed that the objective of this feedback session was to find out to what degree the results of the assessment could be acknowledged as a reflection of the issues the university is facing in terms of research commercialisation.

In the discussion around the weaknesses and opportunities, it was pointed out that the issues can indeed be related to the current situation at the university. A specific capability that stood out was *Understanding the market*. The discussion evolved around the fact that the University as a whole has been broadening its focus with certain initiatives that would inevitably require a better understanding of the needs of the market, in terms of specifically technology but also other needs. This would involve a focus on applied research, especially in the research fields that are closer to the market such as engineering. Subsequently, development-related activities would inevitably become part of the responsibility of the university as it tries to solve the issues confronting humanity.

However, it was stated unequivocally that this would never imply that the University would shift its focus to applied research, but rather that it would broaden its focus. Basic research will always be a fundamental mission of the University and this should shape the foundation for the enhancement of applied research and producing research that are more closely related to the needs of society. “Applied research is basic research plus...”.

With respect to strengths, it was confirmed that the university is busy shaping and deploying new Intellectual Property policies and this would have put the issue on the agenda of many of the respondents. Nonetheless, it is a strength that can be used to leverage improvement of other capabilities.

7.7 Chapter Summary

The objective of this chapter was to discuss the execution of the Innovation Capability Maturity Assessment on Stellenbosch University. The discussion started with a general description of how the research commercialisation effort is structured within the University.

The subsequent discussion was guided by the Improvement methodology of Essmann(1). The Evaluation stage was discussed, including the preliminary evaluation of the responses, followed by the detailed results and prioritisation of the innovation capability requirements in the Gap analysis. These prioritised capabilities were then presented to the respondents to evaluate to what extent the results related to the current situation within the university.

There was consensus that it was an accurate depiction of the current strengths and issues that the University faces in terms of research commercialisation, because the innovation capabilities can be directly related to research commercialisation capabilities as explained earlier..

The next chapter will involve a critical review of some of the aspects in the evaluation procedure.

8

Case Study Review

In this chapter some of the general observations that were made during the case study will be summarised. Although the evaluation was successful in identifying the strengths and weaknesses of the innovation capability which is directly correlated to research commercialisation capability there are some areas that can be improved upon. Some of the possible reasons for the low level of consensus will be presented hinting at possibilities to improve or eliminate these issues in future research.

Although the Innovation Capability assessment was largely successful in identifying the strengths and weaknesses of a university's research commercialisation effort, this research would not be complete without discussing some of the issues that can be improved to provide better and even more accurate results in future executions.

As stated in Section 7.4.2, on the topic of the evaluation of the responses, the university achieved the highest average standard deviation (0.61) between the answers of the respondents of all the organisations that had previously undergone the assessment. The average standard deviation for the different companies on which the assessment was performed is displayed in Figure 64 below.

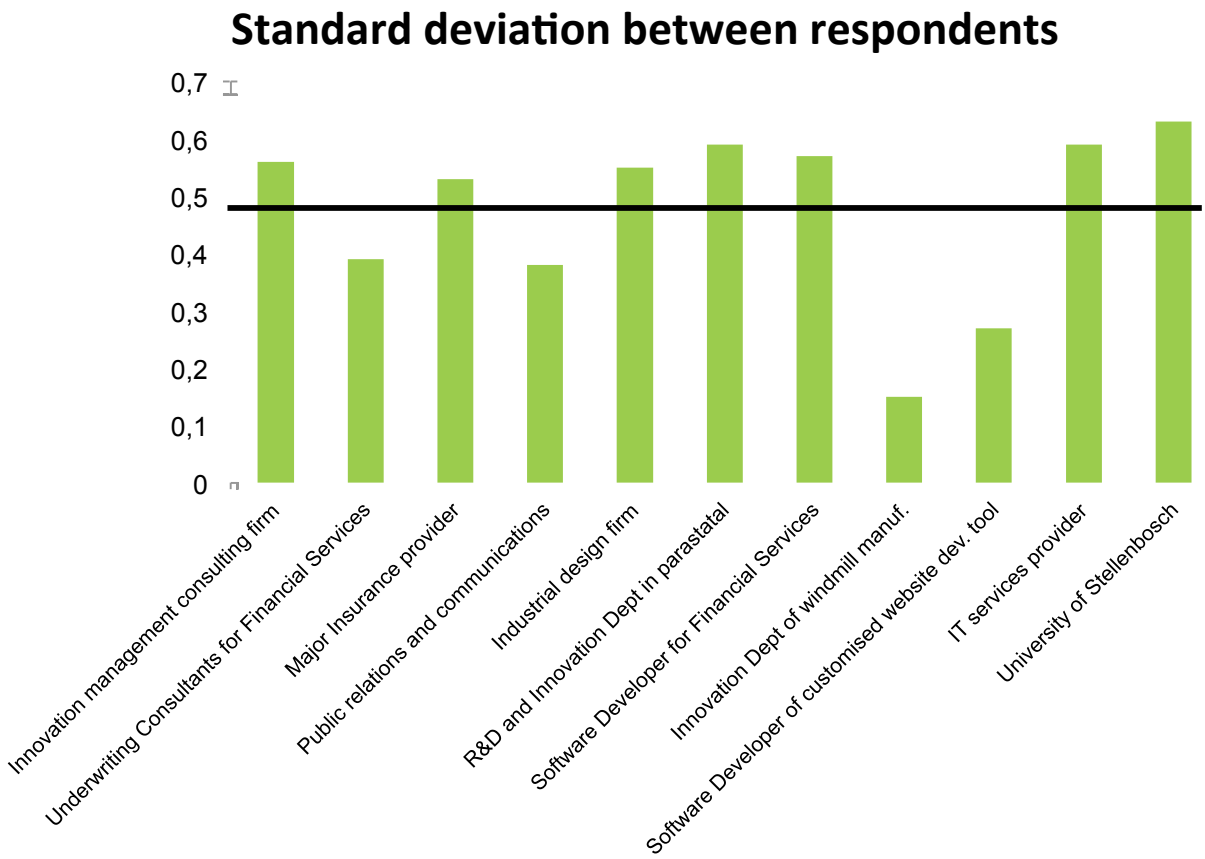


Figure 64 - Average standard deviation between respondents

The average for all the standard deviations is depicted by the black line at 0.47 in Figure 64. Although this deviation is expected due to the high-level nature of the model, which inherently causes deviation in answers, the issue is discussed here to ensure a comprehensive evaluation of the use of the ICMM in the academic sphere. The objective is to hint at possible reasons for the discrepancy and provide solutions for the issues, even if these solutions are only partial.

The issues will be discussed in the following subsections, starting with Context Confusion.

8.1 Context Confusion

Some of the respondents remarked that they had trouble extracting themselves from their local circumstances and taking a global view of the university's innovation capability. This could be a possible drawback of doing the assessment on such a large organisation, with its numerous managerial silos.

It would be valuable to do a series of assessments by fixing the context to one research field or faculty at a time. This would allow the researchers in particular to give a more accurate perception, because they are rating their local environment with which they should be very familiar.

Additionally, it would give insight into the "sub-maturities" of different research fields with regard to research commercialisation. This could possibly lead to the identification of the bottlenecks that lower the overall maturity of the university.

Such a study would be relevant to research commercialisation, as many authors suggest that TTOs should specialise in certain research areas (50) (141) (86). This assessment can be very valuable when determining the needs of different research fields in terms of resources and support.

8.2 Interpretation Problems

The ambiguity of some definitions and the interpretation of some questions in the questionnaire were identified as possible reasons for the low level of consensus. These two issues will be discussed in this section.

8.2.1 Definitions

The definitions in question are those four that were redefined during the preparation for the evaluation in Section 6.2.4. The process of redefinition was crucial for an effective evaluation. There was one issue that arose during the assessment procedure.

The term 'opportunity' was defined as a research field, which is absolutely correct from the perspective of the researcher, but, because the TTO acts as a broker in the system, effectively only selling what the researchers generate, it sees opportunity in a way that is different from the perspective of the researchers. For the TTO, an opportunity would be identified retrospectively when it has obtained an idea (left-most blue block in Figure 65 below) from the researcher, provided that the process flow of research commercialisation is followed as defined in Section 2.3.

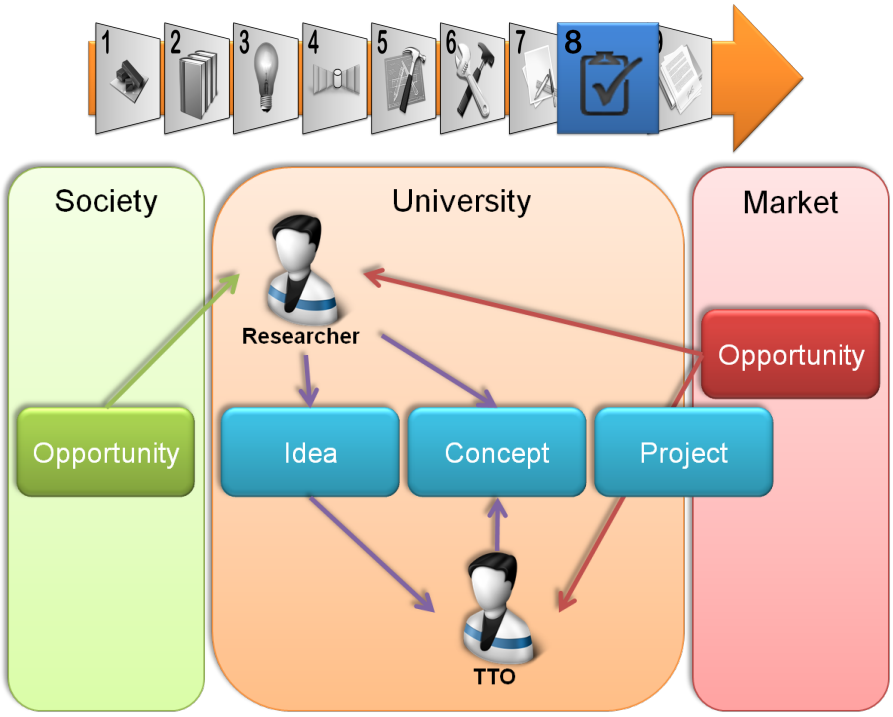


Figure 65 - Opportunity identification

As shown in Figure 65, the opportunity (red block) that the TTO identifies can be the same as the researcher's initial opportunity if the researcher had commercial intent in the identification stage and he/she expected the specific opportunity to arise from the research conducted. This would not always be the case, especially in more traditional universities where the emphasis still falls mainly on basic research and the idea of letting commercial potential influence research agendas is generally opposed.

This implies that, in some instances, the questionnaire would evaluate the capability in terms of two differing interpretations and ideally one would not have this be the case. It would be valuable to know the maturity of the researcher's capability to identify opportunities and separately the maturity of the TTO's capability to identify opportunities for the ideas created by the researchers. The latter would be specifically relevant if the goal is to assess the efficiency of the TTO in isolation.

It is encouraging to notice that "Identifying Opportunities" was one of the case study's strengths. This means that, in general, the University is good at identifying opportunities; after all, the purpose of this assessment was to find the capability of the organisation as a whole.

8.2.2 Questions

The respondents' interpretation of some of the questions in the questionnaire during the assessment procedure was a real issue. A capability such as *Ensuring Supplier competency & technology supports requirements* does not translate well to the research commercialisation process, as defined for this assessment. The reason is that there is no supplier defined in the process. This rendered the capability irrelevant for the purposes of this assessment.

There were other such capabilities, which could either be seen as irrelevant, such as the example above, or interpreted in more than one way. It is important to note that these capabilities were mostly not part of the 17 fundamental capabilities; consequently, the misinterpretations presented here did not affect the results presented in Section 7.6.

Nonetheless, in order to minimise the effect of this problem and render all the capabilities relevant, it is important to shape the context in which the questionnaire is answered very well beforehand, but this could potentially make the workshop a long and tiring experience for the respondents.

An alternative suggestion entails the contextualisation of the capabilities and consequently of the questions within the questionnaire in terms of research commercialisation. This implies that the procedure remains exactly the same, but that the wording of the questions and corresponding maturity descriptions within the questionnaire be changed.

This would simply mean that a questions such as, “How are innovation projects planned and coordinated?” would become “How are research commercialisation projects planned and coordinated?”. It is important to notice that, because an “Innovation project” and a “research commercialisation project” mean the same thing, the underlying model stays intact and all the subsequent benefits of the ICMM can still be harvested.

All the capabilities were contextualised in terms of research commercialisation during this research. This was done by first evaluating the maturity descriptions of each capability, selecting relevant research commercialisation literature and then describing what the capability implies for research commercialisation.

It should be noted that the output from this exercise was not validated and the researcher believes that considerable experience in the field of innovation will be crucial for the accurate translation of the capabilities. In spite of this lack of validation, the descriptions that were made could be valuable as a guide in the process to accurately contextualise capabilities, rephrase the questions in the questionnaire and identify best practices in literature for improving the capabilities.The contextualisation is attached as Appendix V.

8.3 Chapter Summary

The objective of this chapter was to suggest possible enhancements to the Innovation Capability Assessment. This was done to suggest ways in which to improve some aspects relating to the execution of the evaluation as well as the questionnaire. It is the researcher’s belief that focusing on these issues in future research could significantly improve the accuracy of future applications of the assessment in the academic sphere. The next chapter will provide the final conclusions of the research and suggestions for future work.

9

Conclusions and Recommendations

This chapter presents the conclusions of the research. A methodological summary is presented followed by the conclusions in the context of the objectives and Hypothesis. Hereafter the limitations of the research is briefly discussed followed by the recommendations for future work.
The chapter concludes with the value added by this research.

9.1 Research Conclusion within the Context of the Research Methodology and Research Questions

The research approach was outlined in sections 1.2 and 1.3, and Figure 66 below serves as an illustration of how the chapters in this document contributed to the research methodology. Each step in the methodology will now be discussed and it will be shown how the research questions were answered.

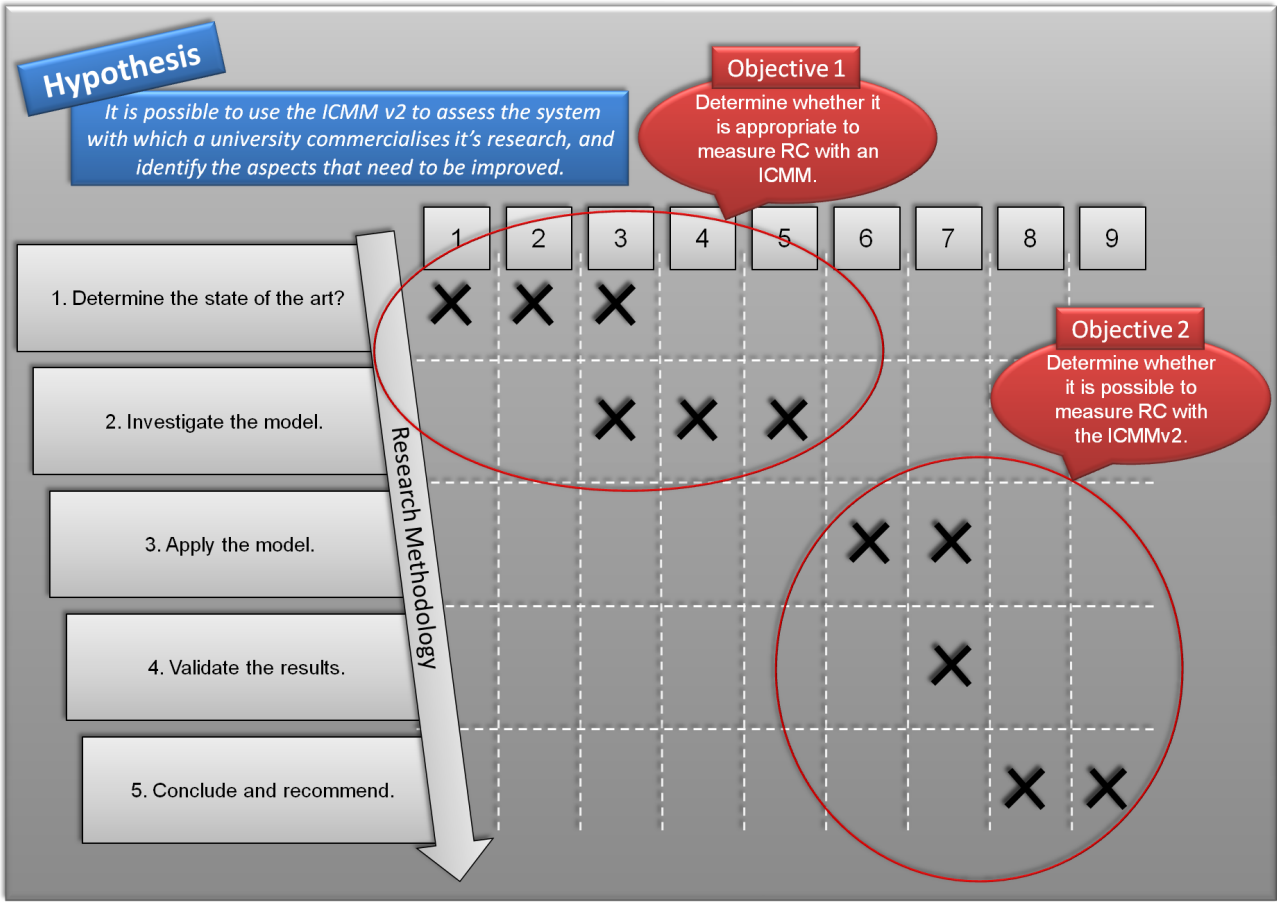


Figure 66 - Research method chapter cross-reference

Determine the state of the art: It was important to determine the current state of research commercialisation. The literature presented in Chapter 2 of this research allowed for the understanding of the research commercialisation process and how different external and internal factors impact on the process. Chapter 3 aimed to evaluate the state of innovation. Although the literature presented in this research does not begin to cover all the research done in this field, it was comprehensive enough for the purpose of this research as it allowed for an understanding of the fundamental aspects of innovation. The combination of Chapters 2 and 3 *allowed the researcher to evaluate the relationship between research commercialisation and innovation* (Research Question 1 in Section 1.2.3). Chapter 4 used this understanding to model the research

commercialisation process with the FuGIe innovation model. *This was completed to justify that the innovation process can be used to sufficiently model the research commercialisation process* (Research Question 2 in Section 1.2.3) and a ICMM was appropriate for use in the research commercialisation domain.

Investigate the model: In order to apply the ICMMv2 on a research institution, the inner workings of the model were investigated. Chapters 3 and 4 contributed to this understanding by relating the content of the ICMM to research commercialisation. In Chapter 5 maturity models in general were explored with respect to their applicability and success. The second half of Chapter 5 discussed the inner workings of the ICMMv2 and the Innovation Capability Improvement Methodology. A thorough understanding of the latter was identified as a prerequisite for the application of the model.

Apply the model: In Chapter 6 the preparations for applying the ICMMv2 were discussed. The discussion revolved around the implications that the differences between the Industrial and Academic spheres might hold for the application of the assessment. Certain alterations were made and this provided a platform from which the evaluation could start. Chapter7 investigated the evaluation of Stellenbosch University's innovation capability maturity. Initially, some information is provided in the research commercialisation effort at Stellenbosch University, after which the execution of the evaluation is discussed in detail and the results are presented.

Validate the results: In Section 7.6, the results that were presented to the major role-players in the Stellenbosch Research Commercialisation system were discussed. All the respondents confirmed that the perceived strengths and weaknesses are a true reflection of the current situation in the University. *This validates that the ICMMv2 is able to reflect the current state of the research commercialisation effort in terms of strengths and weaknesses* (Research Question 3 in Section 1.2.3).

Conclude and Recommend: Chapter 8 discussed some of the issues with the evaluation and *suggests possible improvements that can be made to illuminate these issues* (Research Question 4 in Section 1.2.3). Chapter 9 concludes the research with a discussion on how the objectives were reached, the hypothesis was proved and recommends opportunities for future research.

9.2 Research Conclusion within the Context of the Hypothesis and Research Objectives

This section will discuss the conclusions regarding the hypothesis and the objectives. Figure 66 shows how the chapters and methodology relate to the two objectives that were stated at the beginning of this research, namely:

1 Determine whether it is appropriate to measure a research commercialisation system with an innovation maturity model.
2 Determine whether it is possible to measure Research Commercialisation with Innovation Capability Maturity Model version 2.

Chapters 2, 3, 4 and 5 showed that it is appropriate to evaluate the research commercialisation process with an innovation maturity model. First, it was shown that the research commercialisation process can be modelled with an innovation model such as FuGle. Since an innovation process can be improved using innovation maturity models, the same should apply to research commercialisation. In other words, the same capabilities that support the innovation process will support the research commercialisation process. Accordingly, Objective 1 was reached.

Chapters 6 and 7 deal with the application of the ICMMv2 in the academic sphere, specifically on the research commercialisation system of Stellenbosch University. The Innovation Capability Improvement Methodology was successfully executed up to the *Results* Workshop activity. In the *Results* Workshop, the results were presented to the TTO and officials at executive level in the university. The Results were presented in the form of capabilities categorised into strengths, weaknesses and areas that needed to be clarified. Both the CEO and the Vice-Rector stated that they could confirm the results as an accurate representation of the current situation within the university system. This validates the ICMMv2's identification of the strengths and weaknesses as accurate and therefore it is possible to measure the research commercialisation system with the ICMMv2. Accordingly, Objective 2 was reached.

As a result, the hypothesis has been proved: *It is possible to use the Innovation Capability Maturity Model version 2 to assess the system with which a university commercialises it's research, and identify the aspects that need to be improved.*

9.3 Limitations of Research

This section will discuss some of the limitations of the research.

The fact that the research exclusively utilised the ICMM of Essmann (1) does limit the findings with regard to generalisation. Although Essmann's model described the current situation accurately, as stated above, it does not prove that all innovation maturity models would be appropriate for this purpose. It does, however, provide evidence that in general innovation management principles could add value to any effort to improvement the research commercialisation process.

There is also some limitation with regard to the generalisation of the approach taken to execute the evaluation. It is unlikely that any two universities would have the same structures, either in terms of the general university structure or the placement of the TTO (unit that executes commercial obligations). This implies that some aspects regarding the application of the evaluation procedure would have to be revisited if another case study is attempted.

There are no additional, foreseeable limitations, except for the general limitations of applying a model such as the ICMM.

9.4 Future Work

The research proves that the ICMMv2 shows great potential in providing a platform to improve a specific instantiation of the research commercialisation process.

Two specific opportunities that will be discussed in this section; both entail altering the scope of the research and they will be discussed individually below. The section will conclude with some thoughts on the value of the research.

9.4.1 Scope with regard to assessment boundaries

As stated earlier, the scope of the case study was to evaluate the innovation maturity of the university as a whole. The scope was justified because the technology transfer office provides commercialisation assistance to all the academic research fields within the university therefore it was deemed appropriate to measure how they serve the university system as a whole.

It would be valuable to redo the assessment and limit the sample to specific research fields or faculties, as depicted in Figure 67 below.

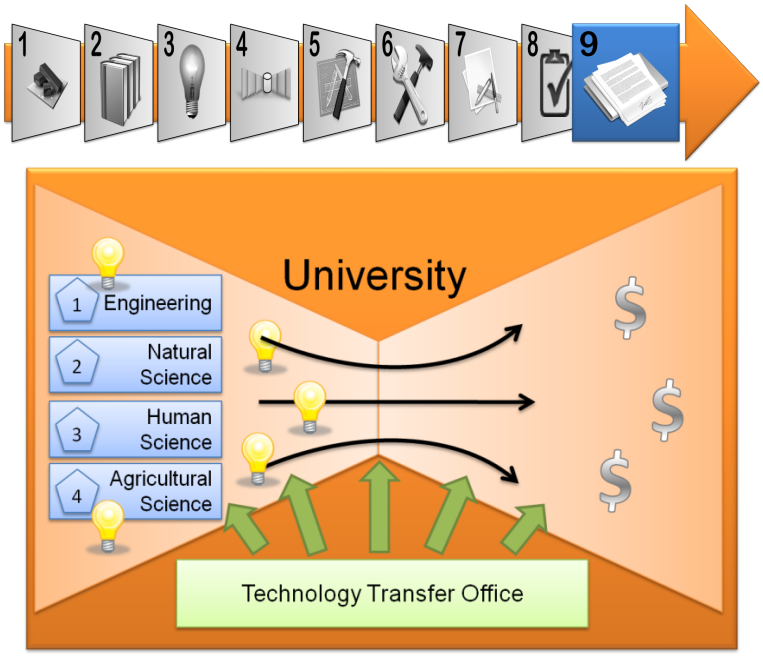


Figure 67 - Future work regarding the unit of analysis

In this way, it would be possible to find the innovation capability maturity of the subunits that the technology transfer office is mandated to serve. The real value would be the ability of the research to evaluate the needs of each specific research field. This would allow the university to focus its resources on improving priority capabilities in each specific research field or faculty, rather that improving overall capability and waste resources on research fields that might already be quite mature with respect to those specific capabilities.

9.4.2 Scope with regards to improvement methodology

As defined in Section 1.4.2, only the first five activities of the improvement methodology were executed. It would be valuable to continue the improvement process and perform the rest of the activities as depicted in Figure 68 below. This would entail doing a thorough infrastructure analysis to find the root causes of the weaknesses, prioritising the weaknesses for improvement, developing improvement plans and finally implementing these plans. The contextualised capabilities presented in Appendix V could prove to be a valuable resource for the development of the improvement plans as the literature cited typically provides international best practices.

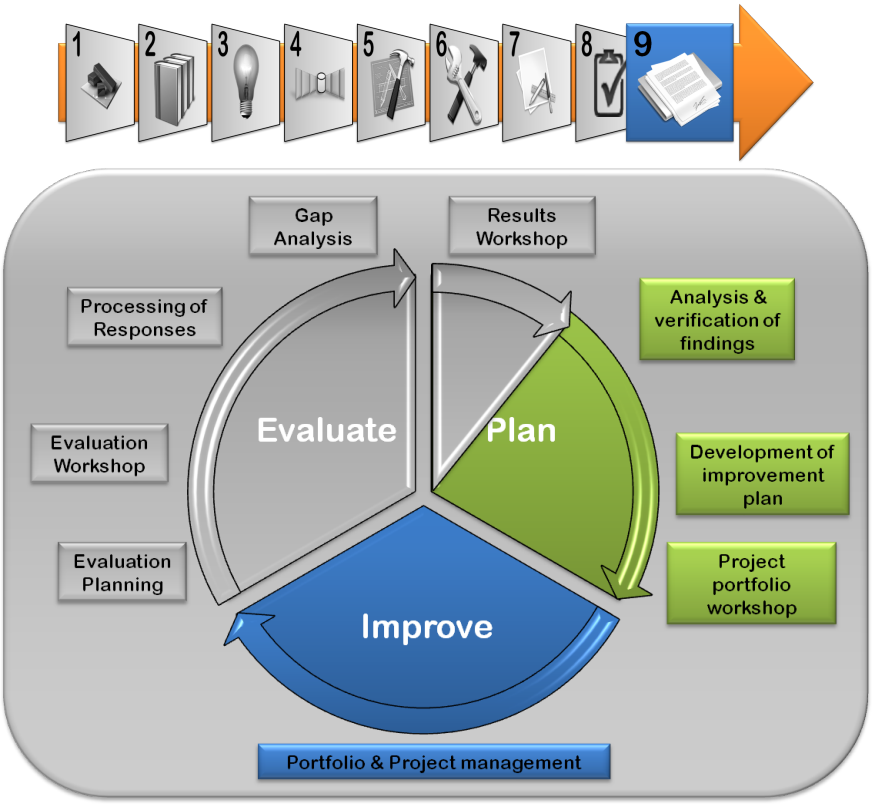


Figure 68 - Future work regarding improvement methodology

After the improvement plans are implemented, the process can be reiterated to measure whether the appropriate improvements have been realised.

9.4.3 Improvements to ICMMv2 for evaluating the Academic Sphere

As discussed in Chapter 8, there are some areas of the ICMMv2 that can be adapted to ensure that the issues that cause the low level of consensus are illuminated. This specifically relates to the questions and maturity description in the questionnaire. It would be a valuable exercise to contextualise the questions and maturity descriptions for the domain of research commercialisation and redo the assessment to evaluate the success in terms of the level of consensus. It is important that the structure of the model should not be tampered with during this exercise, as this would render the model useless. As a result, it is a valid area for further research.

9.5 Value of Research

It is the researcher's belief that this research has presented a platform for the improvement of research commercialisation efforts at public research institutions in developing countries. The value is that the ICMM considers the context of the specific instantiation and can therefore provide environment-specific solutions to the problems faced in the commercialisation process. It could also allow South African universities to be compared on the basis of capability to commercialise their research rather that resources.

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Appendices

I. Other Innovation Maturity Models

This section presents a number of innovation maturity models that are currently used to manage organisational innovation initiatives. These models were identified using Google's search engine.

- Innovation Maturity Model from Think for a change
  (http://www.thinkforachange.com)
- Innovation Maturity Model from OVO
  (http://www.slideshare.net/jdpuva)
- Business Innovation Maturity Model from Accelper Consulting by Praveen Guptha
  (http://accelper.com/)
- Innovation Maturity Model from PRTM
  (http://www.innovationtools.com/PDF/Roadmap_PRTM.pdf)
- Innovation Maturity Model from Product Development Consulting, Inc.
  (http://www.pdcinc.com/ibm-corporation)
- Innovation Maturity Model from Tata Consultancy Services Ltd. By Narayana (148)
  (http://www.tcs.com)
- INPAQT Innovation Capability Maturity Model from INPAQT
  (http://www.inpaqt.com/)
- Innovation Aptitude from the Innovation Practice
  (http://www.theinnovationpractice.com/)
- Innovation Capability Maturity Model from Indutech (Pty) by Essmann (1)

It is apparent that limited information on the inner workings of these models is available to the general scientific community, or at least free of charge. In contrast the ICMM v2 of Essmann's is thoroughly discussed in a dissertation that is available on the web. This information, with some additional assistance from Indutech (Pty) Ltd. and Dr. Essmann himself, enabled the researcher to use the model for analysing the university's innovation capability maturity.

II. Innovation Capability Maturity Descriptions by Essmann (1)

Code	Capability Requirement	Primary Role-players	Secondary Role-players	Limited Role-players	Question	Maturity Scenarios		
						Maturity Level 1 Ad hoc & Limited -->	Maturity Level 3 <-- Formalisation & Predictability -->	Maturity Level 5 <-- Integration, Synergy & Autonomy
IP/CS1	**Understanding the market** (Existing & latent needs, maturity, size, competition, regulation, etc.)	Networker Anthropologist Leader	Builder	Coordinator	What is done to understand the market (existing and latent needs, maturity and size, competition, regulation, etc.)?	Market perspective is based on past experience.	Initiatives to probe the market are periodically undertaken. Procedures have been developed and implemented, and the required outputs defined.	Initiatives are regular and results effectively utilised for planned and in-progress projects and strategy development. Procedures are institutional.
IP/CS2	**Involving customers & suppliers in the innovation process**	Networker Anthropologist	Builder Coordinator Leader		How effectively are customers, suppliers and other stakeholders involved?	Customers play a small role early in the innovation process. Suppliers are considered and consulted in the later phases.	Customers and suppliers are consulted at various stages throughout the innovation process.	Customers and suppliers play an intrinsic role throughout the innovation process - consistent involvement in activities and at key decision points.
IP/FP1	**Identifying opportunities**	Leader Builder Anthropologist Networker Coordinator			How do opportunities and ideas surface?	Opportunities and ideas are seldom discussed or brought forward.	Individuals are encouraged to bring ideas forward and have guidelines on how to substantiate and present those ideas.	Identifying opportunities and bringing them forward is natural behaviour. Ideas are also sourced from external stakeholders. Procedures to manage and substantiate ideas are institutional.
IP/FP2	**Developing concepts**	Leader Builder Anthropologist Networker Coordinator			How are opportunities and ideas transformed into concepts?	Ideas are seldom elaborated on or put into action.	Ideas are conceptualised and basic characteristics elaborated on. Procedures have been developed and implemented, and the required outputs defined.	Concepts developed are modular and flexible, enabling multiple opportunities to be addressed. Conceptualising opportunities and ideas is institutional.
IP/SO1	**Scanning & exploring for latent opportunities**	Networker Leader	Anthropologist Builder Coordinator		How are latent, future opportunities identified?	"Opportunities" of the future are based on extrapolation of the past.	Initiatives to find latent opportunities are undertaken. Procedures have been developed and implemented, and the required outputs defined.	Future-orientated scanning and exploring activities provide consistent strategic input. Procedures to indentify latent opportunities are institutional.
IP/OM1	**Contextualising opportunities & concepts** (Future roadmapping, scenario planning, etc.)	Networker Leader	Coordinator	Anthropologist Builder	How are opportunities and concepts put into context?	Opportunities, ideas and concepts are viewed as isolated potential projects.	Opportunities and concepts are coordinated and viewed in context with required technology, competencies, processes, systems, etc.	Latent opportunities, opportunities and concepts are viewed in relation to one another considering timelines of future technologies, changing regulation and society, etc. Future scenarios are identified and used during strategic planning and portfolio planning.
IP/FP3	**Testing, screening & prioritising opportunities & concepts** (Strategic alignment, market timing, prototyping)	Leader Coordinator	Networker Builder	Anthropologist	How are opportunities and concepts tested, screened and prioritised?	Testing of concepts is superficial and ad hoc. Prioritisation is a once-off activity based on limited understanding of the opportunities and concepts.	Concepts are tested and screened using various formal techniques. Prioritisation is based on testing and screening results and other factors like strategic alignment, market timing, etc.	Concepts are quickly made tangible in the form of prototypes. Prioritisation also considers interrelations between opportunities, concepts, future scenarios, etc.
IP/FP4	**Substantiating, implementing & exploiting opportunities**	Coordinator Builder	Anthropologist Networker Leader		How effectively are concepts developed, deployed and exploited?	Concepts are slow to get taken forward, lacking both direction and focus.	Focused practices and procedures for developing and implementing concepts have been defined and implemented.	Development and implementation of modular concepts and sub-components enables concurrent exploitation of opportunities. Practices and procedures are institutional.
IP/OM2	**Planning & coordinating the innovation portfolio**	Coordinator Leader	Builder	Anthropologist Networker	How are innovation projects planned and coordinated?	Projects are planned and executed in isolation.	Project tasks and schedules are planned and coordinated as a portfolio of projects based on prioritisation.	Projects are integrated by aligning and overlapping tasks that share objectives, concurrently completing multiple project requirements.
IP/OM3	**Allocating resources appropriately**	Coordinator Leader	Builder	Anthropologist Networker	Are resources appropriately allocated?	Resources are assigned in an ad hoc.	Resources are allocated to the portfolio based on project prioritisation.	Resources are pooled through the alignment and integration of project tasks.
IP/SO2	**Balancing the innovation portfolio** (Radical vs. incremental value-add & disruptive vs. sustaining market influence)	Leader	Networker Coordinator	Builder Anthropologist	Are the effects of innovation projects understood and balanced (radical vs. incremental value-add and disruptive vs. sustaining market impact)?	The effect of pursing an opportunity is seldom understood.	Considering and balancing the potential impact (internal and external) of projects is a standard procedure.	The potential impact of latent opportunities and future scenarios is considered in combination with possible projects. The project portfolio is balanced to align with strategic objectives.
IP/OM4	**Using appropriate project management techniques**	Coordinator	Builder Anthropologist Networker Leader		Are appropriate project management techniques utilised?	Project control and management techniques are used inconsistently.	Appropriate techniques and procedures for managing schedule, cost and quality at the different stages of innovation have been defined and deployed.	Projects' schedule, cost and quality are managed as an integrated whole within the innovation portfolio. Techniques and procedures are institutional.
IP/FP5	**Identifying and planning for key decision points** (Go, no-go - fail quick, smart & cheap)	Leader	Coordinator	Builder Anthropologist Networker	Are key decision points identified within the innovation process?	Decisions regarding project direction are made primarily in times of crisis.	Key decision points are identified for each project. Planning and information needs have been defined and implemented.	Key decision points are identified, planned and executed with consideration for other projects. Procedures are institutional.
IP/SO3	**Using fundamental principles to guide process & make decisions** (Governance principles)	Leader Coordinator	Builder Anthropologist Networker		How are decisions made?	Decisions are made based on past experience and with limited understanding of progress.	Governance principles derived from strategy, objectives and values are used to guide decision making.	Fundamental principles are institutionalised, with individuals using them to guide and focus activities and make decisions autonomously.
IP/OM5	**Reducing uncertainty & mitigating risk** (Policies, causal understanding)	Coordinator Leader	Anthropologist	Builder Networker	How are uncertainties and risks managed and reduced?	Project uncertainties are seldom addressed and the risks not identified or fully understood.	Procedures to reduce project uncertainty and identify, manage and mitigate risk have been defined and implemented.	Project uncertainties and risks are identified, managed, balanced and reduced as an integrated whole within the innovation portfolio.
KC/SO1	**Establishing knowledge, competency & technology development & acquisition strategy**	Leader *(Strategic Management)*	Networker	Builder Anthropologist Coordinator	Has a knowledge, competency and technology development/ acquisition strategy been established?	Strategy is not explicit or focuses on maintaining the status quo.	Development and/or acquisition strategy to meet future requirements has been established and deployed.	Strategy provides clear objectives to align organisational learning and differentiate their ability to deliver value.
KC/FP1	**Continuous research**	Leader Builder Anthropologist Networker Coordinator			How is research conducted?	Research is limited to known fields and focused on building on existing knowledge.	The practice of exploring existing and new fields of research has been established. Sources and tools for research are readily available.	Individuals and teams explore and expand knowledge related to organisational learning objectives. Research efforts are co-ordinated and traceable and practices institutional.
KC/FP2	**Identifying & extracting relevant information**	Leader Builder Anthropologist Networker Coordinator			Is the essence of new information identified and extracted?	Information is seldom summarised or the relevant inserts highlighted.	The practice of summarising, highlighting and/or extracting relevant information is established.	Grasping and extracting the core, most relevant information is an institutional behaviour.
IP.KC/DI1	**Capturing, storing & retrieving data & information** (Opportunities, ideas, concepts, project & other information & documentation, standard procedures, relevant literature, etc.)	Leader Builder Anthropologist Networker Coordinator			How is data and information captured, stored and retrieved?	Information is "dumped" into unstructured storage. Search and retrieval is predominantly manual.	Procedures and frameworks for contextualising, categorising and capturing, and tools for storing and retrieving, data and information have been identified, defined and deployed.	Individuals and teams have adopted and exploit the deployed procedures, frameworks and tools.
KC/OM3	**Managing core competency & technology**	Leader	Coordinator	Builder Anthropologist Networker	Are competencies and technologies effectively managed?	Competencies and technologies are application specific and used in isolation.	Core competencies and technologies are identified, managed and maintained to ensure that project and operational needs are continuously fulfilled.	Core competencies and technologies are aligned and synchronised for both innovation and operational requirements.
KC/FP3	**Developing & acquiring the required competencies & technologies**	Builder Leader Networker	Coordinator	Anthropologist	How are competencies and technologies developed or acquired?	Development and acquisition occur on an "as-and-when-needed" basis.	Procedures for proactively identifying, developing and/or acquiring required competencies and technologies have been defined and deployed.	Development and acquisition focuses on adaptable and flexible core competencies and technologies to meet multiple requirements.
KC/SO2	**Establishing intellectual property management & sharing policy**	Leader *(Strategic Management)*	Networker	Builder Anthropologist Coordinator	What is the policy regarding intellectual property?	Their is no specific policy or the policy is to guard IP at all cost.	Policy prescribes appropriate protection of IP, while enabling collaboration with external parties.	Policy facilitates collaboration and mutual sharing of IP, while protecting the interests of all involved.
KC/OM2	**Managing intellectual property**	Leader Networker	Builder Anthropologist Coordinator		How is intellectual property policy deployed and managed?	IP is not protected or it is heavily protected with strict regulation limiting accessibility and exposure.	Procedures and techniques for protecting IP and managing infringement are understood and employed.	Procedures and techniques that balance protection and sharing, while minimising resource consumption, are institutional.
KC/CS3	**Ensuring supplier competency & technology supports requirements**	Coordinator Networker	Leader	Builder Anthropologist	Are supplier competencies and technologies evaluated for their ability to support requirements?	Supplier competencies are seldom considered or evaluated.	Procedures to evaluate suppliers' ability to support requirements have been defined and deployed.	The practice of supporting suppliers in competency and technology development is institutional.

KC/OM1	**Managing tacit knowledge** (Teaching and mentoring)	Leader	Builder Anthropologist Networker Coordinator		How is tacit knowledge managed?	Little effort is made to "pass-on" knowledge between individuals.	Teaching and mentorship programs have been established. Identifying, documenting and implementing best-practices is standard procedure.	Individuals readily teach and mentor others. Best-practice management and improvement is institutional.
IP.KC/DI2	**Formal & informal internal networking & collaboration** (Communities of practices, cross-project & department collaboration, social interaction)	Coordinator Networker	Builder Anthropologist Leader		What is the state of collaboration and networking internally?	Networking and collaboration within the organisation is informal and ad hoc.	Practices to network and facilitate collaboration between internal teams have been defined and deployed. Informal networking is encouraged and facilitated.	Teams and individuals naturally involve the knowledge and skills of others. Teams with complementary objectives are aligned. The nature of interaction is open and trusting. Practices have been institutionalised.
IP.KC/DI2	**Formal & informal external networking & collaboration** (Knowledge networks, NoN, Open Innovation, cross-organisation collaboration - government, academia, research institutions, conferences etc.)	Coordinator Networker	Builder Anthropologist Leader		What is the state of collaboration and networking with external parties?	There is little or no networking and collaboration with external parties.	Practices to network and facilitate collaboration with external parties have been defined and deployed. Informal networking is encouraged and facilitated.	Teams and individuals naturally involve the knowledge and skills of external parties. Groups with complementary objectives, or where mutual benefit exists, are identified and involved. Practices have been institutionalised.
OS/SO1	**Developing & conveying innovation strategy & objectives** (Linking to business strategy, objectives, focus & clarity)	Leader *(Strategic Management)*	Builder Anthropologist Networker Coordinator		Has an innovation strategy been established and communicated?	Innovation strategy and objectives are not explicit.	Innovation strategy and objectives are developed to support business objectives and clearly communicated. Aligning project objectives with innovation and business objectives is standard practice.	Strategy and objectives are developed from a holistic view of latent opportunities, future scenarios and business objectives. Strategy and objectives are regularly communicated and "owned" by all individuals.
OS/SO2	**Organisational values & policies** (Resource slack, positively influence individual behaviour, transparency & openness, relationship orientation)	Leader Anthropologist	Builder Networker Coordinator		How do values and policies contribute to the organisational environment?	Values and policies focus strongly on tradition, conformance and maintaining the status quo. Individual opinion is seldom accommodated.	Values and policies create an environment that encourages individuals to communicate openly and bring ideas forward. Time is allocated for learning, exploring, and building relationships.	People and relationships are considered fundamental drivers of innovation. Appropriate freedom fosters continuous learning, improvement and autonomy. Change and mistakes are seen as opportunities to learn.
OS/FP3	**Organisational practices & procedures** (Best-practices, change management)	Leader Anthropologist	Builder Networker Coordinator		How do organisational practices and procedures support innovation?	Innovation-specific practices and procedures are limited. General practices and procedures are seldom reviewed.	Best-practices and procedures are identified and standardised. Change management procedures have been defined and deployed.	Best-practices and procedures are continuously monitored and improved. Change management procedures are institutional.
OS/FP1	**Championing & encouraging innovation** (Consistent input & feedback, positively influence individual behaviour)	Leader Anthropologist	Builder Networker Coordinator		How is innovative behaviour encouraged and supported?	Little encouragement or support is provided for innovative behaviour.	Innovation champions are identified and tasked with leading, supporting and encouraging innovative behaviour. Leaders support and guide individuals through change initiatives.	Autonomous behaviour is encouraged. Leaders support, coordinate and ensure alignment between individuals' activities.
OS/SO3	**Investment in innovation & sourcing of capital**	Leader Networker		Builder Anthropologist Coordinator	How does capital investment support innovation?	Investment in innovation is limited and the required return structures restrict project activities.	Direct investment in innovation is consistent, ensuring that business and innovation objectives are achievable.	Investment quantity and structures, and the required returns, provide sufficient "slack" and freedom for activities to deviate when required.
OS/FP4	**Providing the necessary resources** (Resource slack, focussed resources)	Leader Coordinator	Builder Anthropologist Networker		How are resources made available to support innovation?	Resources assigned to innovation are limited or activities have low priority.	Innovation activities are appropriately prioritised and assigned the necessary resources to meet targets and objectives.	Resources dedicated to innovation are provided ensuring sufficient "slack" for activities. Needs are continuously monitored and gaps filled.
OS/FP2	**Infrastructure, systems & tools to support process & management requirements**	Leader Coordinator Builder	Anthropologist Networker		How effectively does infrastructure, systems and tools support innovation?	Infrastructure, systems and tools are insufficient to support innovation activities.	Infrastructure, systems and tools to support innovation activities and management requirements are available.	Dedicated infrastructure, systems and tools to facilitate innovation activities are available. Modularity enables multi-functionality. Needs are continuously monitored, gaps filled and improvements made.
OS/OM3	**Developing flexible & adaptable organisational structure & infrastructure** (Hierarchy, functional & project structures, decision structures, facility layout)	Leader	Builder Anthropologist Networker Coordinator		How does organisational structuring and infrastructure installation support innovation?	Structure and layout lacks flexibility to adapt to changing business requirements. Authorisation channels are complex.	Functional and project structures are designed to be as flexible as possible to meet changing business requirements.	Functional and project structures are modular and adaptable in nature. Installation and layout of infrastructure is flexible and adaptable.
OS/OM2	**Creating cross-functional & multidisciplinary teams**	Leader Networker Anthropologist	Coordinator Builder		How are teams constructed?	Teams are predominantly skills based, with limited depth of training, competency or perspective.	Innovation teams are made up of individuals from various functional divisions with diverse skills.	Teams constitute core, multidisciplinary individuals that involve the skills base across functional and organisational boundaries.
OS/DI1	**Communication & the flow of information** (Company communication, project feedback, performance feedback, etc.)	Leader Coordinator	Builder Anthropologist Networker		What is the state of communication?	Communication is poor and the vertical flow of information limited. Individuals provide and receive limited feedback.	Vertical and horizontal communication is adequate. Mechanisms and tools to facilitate the flow of information have been identified and implemented.	Communication is regular, transparent and open.
OS/OM4	**Motivating, rewarding & celebrating success**	Leader Anthropologist	Builder Networker Coordinator		How are individuals and teams motivated and rewarded?	Initiatives to motivate do not exist or lack in ability to mobilise individuals and teams.	Standardised initiatives to motivate individuals have been developed and implemented. Successes are communicated and celebrated in a consistent manner.	Motivation is linked to business and innovation targets. Individuals motivate each other. Initiatives are monitored and refined based on their impact.
OS/OM5	**Hiring & aligning people's values & skills with organisation & task**	Leader Anthropologist	Networker	Builder Coordinator	How are new people hired and roles assigned?	Hiring procedures seek to fill vacant positions. Individuals perform the tasks they were hired to do from the start.	Procedures to hire the "right" people with needed skills and align existing personnel's' skills with their role have been defined and implemented.	Initiatives to find and attract individuals with the "right" values and skills are performed. Existing personnel's' roles are adapted and/or changed to meet their skills and preferences (as much as possible).
OS/FP5	**Measuring innovation** (ROII, process throughput, individuals & teams, etc.)	Leader Coordinator Anthropologist	Networker Builder		How is innovation measured and monitored? (ROI, patents, process throughput, individuals & teams, etc.)	Innovation measurement is ad hoc with limited definition of metrics and associated inputs.	Innovation metrics have been identified, defined and implemented. Targets are aligned with innovation objectives. Metrics are monitored to identify process and management improvements.	The impact of utilised metrics on innovation performance is determined. Metrics and targets are continuously refined. Monitoring and improving processes and management practices is continuous.
OS/OM1	**Meta-Innovation** (Innovation model adaptation)	Leader	Coordinator	Builder Anthropologist Networker	How is the innovation model adapted and improved?	The innovation model is undefined and poorly understood.	The innovation model, with associated processes, practices, tools, etc., is defined. Improvement initiatives are practice, procedure or tool specific.	Improvement initiatives are holistic and integrated, considering process inputs, outputs and relations between practices, procedures, and tools. Initiatives balance incremental and radical improvement requirements.
OS/OM6	**Benchmarking innovation** (Metrics, processes, management practices, outputs, etc)	Leader Networker	Anthropologist Coordinator	Builder	How are innovation processes and management practices benchmarked?	Innovation processes and management practices are not compared to those of external entities.	Benchmarking compares innovation processes, management practices and standardised metrics with those of other organisations. Internal improvements are identified and deployed.	Benchmarking is a collaborative effort to collectively identify and define best-practice processes, management practices, metrics, etc.

III The first page of the Innovation Capability Questionnaire

INNOVATION CAPABILITY QUESTIONNAIRE

The completion of this questionnaire is the first activity of an Innovation Capability Audit. The purpose of the audit is to determine your organisation's capability to innovate. To start, we need to know a few things about you and your role within the organisation.

Name and surname:	
Date:	Office hours contact (tel. and/or email):
Your title/position:	Business unit:
No. of years in company:	No. of years in business unit:
Describe your day-to-day activities in a few words:	

ROLE DESCRIPTION

Below are descriptions of 5 organisational roles. A person does not necessarily play only one role and the roles do not cover all organisational roles. If any of these roles describe, in part, some of the activities that you perform, what percentage of your day do they consume? (E.g. Networker 20%, Coordinator 40% and Anthropologist 5% - totalling 65% of daily activities.)

		%
Net-worker	Scan market, industry, technology, regulatory and societal trends to understand potential futures and identify latent opportunities. Create connections between internal and external individuals, teams and organisations that have common or complementary objectives.	
Coordi-nator	Balance project objectives, resources and risk. Contextualise, position and promote opportunities and concepts. Prioritise, plan, coordinate, schedule, and assure completion of projects. Overcome or outsmart obstacles faced during projects.	
Builder	Make tangible concepts of ideas, demonstrate concepts, obtain feedback from colleagues and customers, and refine concepts. Build, test and refine working "products" and ensure "production" readiness. Strive towards the initial vision of the concept with minimal compromise for design, production and delivery.	
Anthro-pologist	Develop understanding of how people interact physically and emotionally with products, services, one another and their environment. Transform the physical environment into a tool to influence behaviour and attitude, enabling individuals to do their best work. Anticipate and service the needs of colleagues, customers, suppliers and other stakeholders.	
Leader	Align activities with strategy and objectives. Build and involve teams of the "right" individuals at the "right" time. Evaluate and prioritise opportunities and ideas against a standard framework considering all business requirements. Guide progress, monitor metrics and instigate corrective action. Build synergy into projects and the organisation.	

INNOVATION STATUS DESCRIPTION

Below are 5 high-level descriptions of innovation status within organisations. Read through them and mark the one that most accurately describes the overall status of innovation within your organisation.

		X
1	The organisation is wholly consumed with day-to-day operations - maximising short-term revenue and reducing cost. Individual attempts at being creative or "out-of-the-ordinary" are often dismissed. Innovative outputs are inconsistent and unpredictable.	
2	The organisation has identified the need to innovate. Innovation is clearly defined. A basic understanding has been established of the various factors that influence innovation. Innovative outputs are inconsistent, but traceable.	
3	Innovation is supported and managed with appropriate practices, procedures and tools. Individuals are encouraged to be innovative. Innovative outputs are consistent in nature and ensure sustained market share and positioning.	
4	Practices, procedures and tools for integrating innovation activities are used. A deep understanding has been established of the internal innovation model and its relation to business requirements. Innovative outputs are consistent, diverse and a source of differentiation.	
5	Innovation practices, procedures and tools are institutional. Individuals are empowered to innovate. Synergy is achieved through the alignment of business and innovation strategy and the synchronisation of activities. Innovative outputs provide sustained competitive advantage in existing and new markets.	
Not applicable	I do not think that this classification is applicable or relevant to my organisation.	
Not sure	I am not sure whether my organisation falls into any of the categories described above.	

The remainder of the questionnaire asks that you position your organisation on a scale of 1 to 5 for each of 42 Innovation Capability Requirements. Each requirement is described with 3 scenarios for each of the maturity levels 1, 3 and 5. Level 2 is represented as a mixture between levels 1 and 3, as is the case for level 4. The 42 requirements are divided into 3 Innovation Capability Areas, namely: Innovation Process, Knowledge and Competency, and Organisational Support. Make a **X** in the appropriate block.

INNOVATION PROCESS QUESTIONS

		Level 1	Level 2	Level 3	Level 4	Level 5
1	**What is done to understand the market (existing and latent needs, maturity and size, competition, regulation, etc.)?**	Market perspective is based on past experience.		Initiatives to probe the market are periodically undertaken. Procedures have been developed and implemented, and the required outputs defined.		Initiatives are regular and results effectively utilised for planned and in-progress projects and strategy development. Procedures are institutional.
	Not sure ☐ *Not applicable* ☐	☐	☐	☐	☐	☐
2	**How effectively are customers, suppliers and other stakeholders involved?**	Customers play a small role early in the innovation process. Suppliers are considered and consulted in the later phases.		Customers and suppliers are consulted at various stages throughout the innovation process.		Customers and suppliers play an intrinsic role throughout the innovation process - consistent involvement in activities and at key decision points.
	Not sure ☐ *Not applicable* ☐	☐	☐	☐	☐	☐

IV. Additional Results

This section shows the results in terms of all 42 capabilities, therefore the base and fundamental capabilities are included in the figures below.

In order to avoid information overload, only the fundamental capabilities were discussed in the case study, but to ensure the reader is able to appreciate the whole picture with regards to the capabilities, this section is deemed relevant.

The capabilities presented here are not only the fundamental ones as presented in section 7.5, but also the base and progressive capabilities. A final reason for the inclusion of these capabilities in this section is that these capabilities may become relevant in a second iteration of the evaluation and subsequently it would be valuable to present them here. The following two figures show the scatter plot and stack chart with all 42 capabilities.

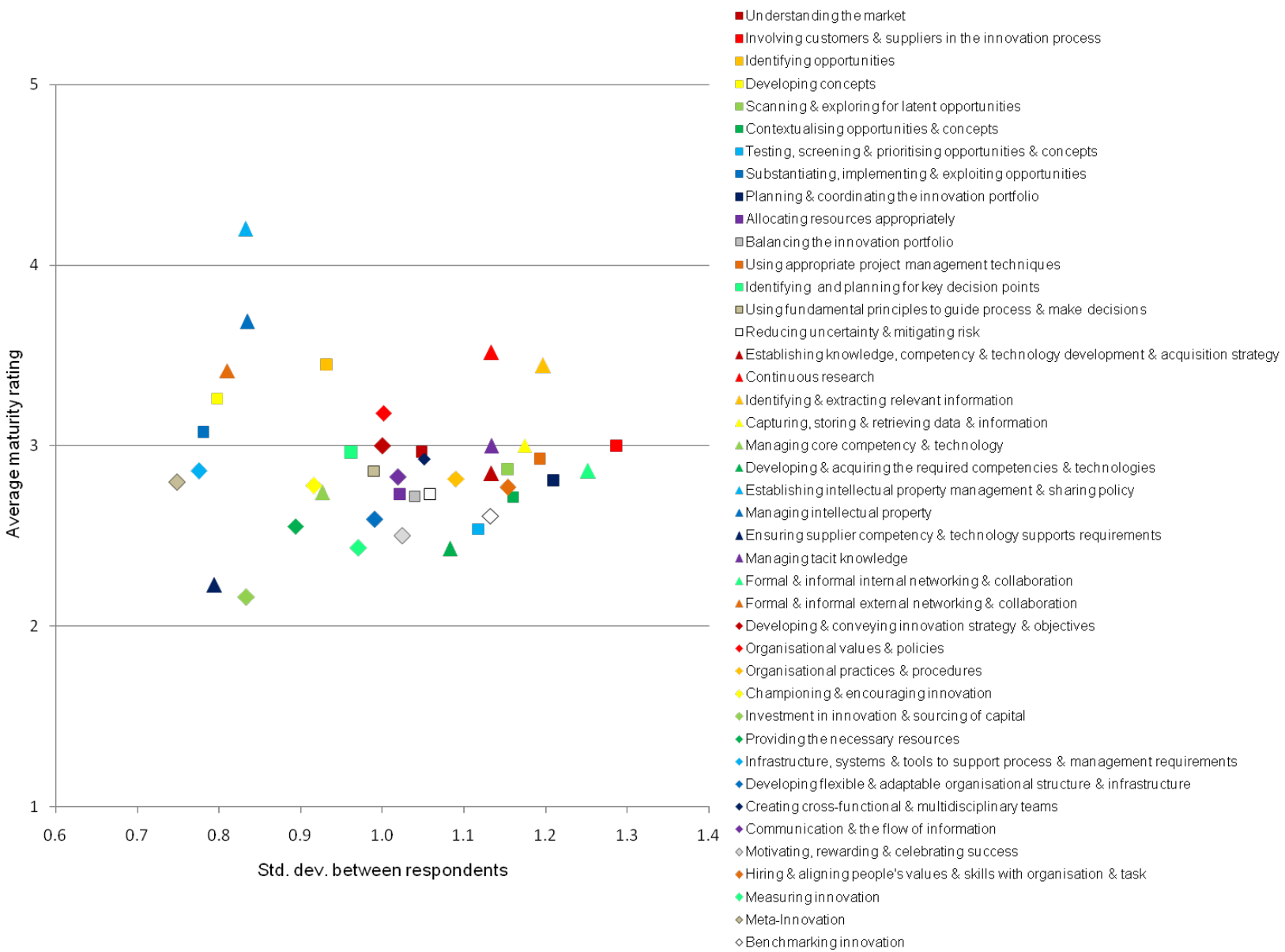
Capabilities that are of interest are:

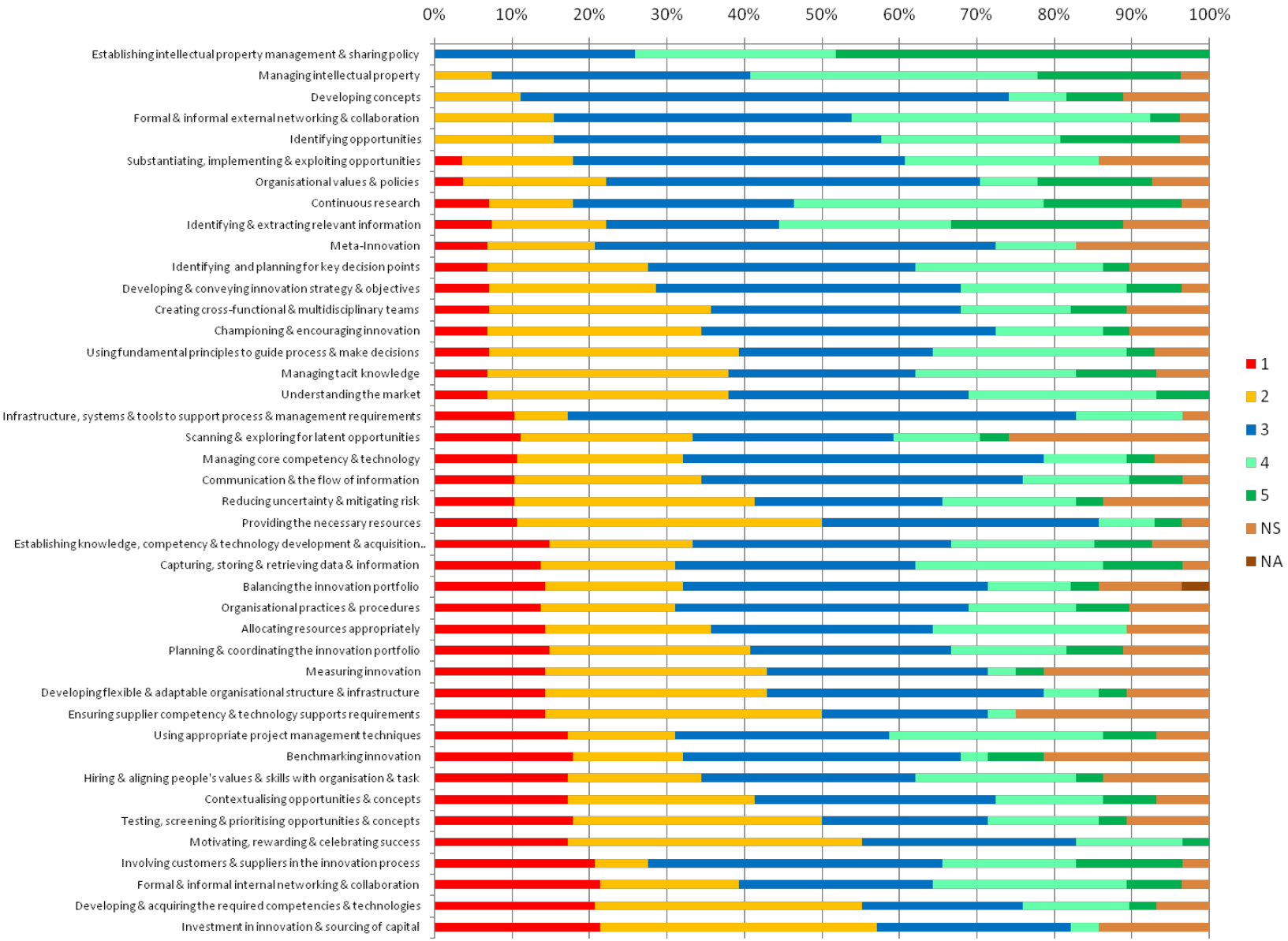
- Involving customers and suppliers in the innovation process.
- Ensuring supplier competency & technology supports requirements.

These two capabilities are of special interest because they both influence the overall standard deviation in a curious way. The problem is that there is no defined supplier in the process and this causes confusion with regard to the interpretation of the questions in the questionnaire. This is the reason why the first capability is so far to the right.

Although there seems to be consensus on the maturity of the second capability the actual reason behind this is that many of the respondents answered the question by marking the “not sure” option. This creates a false sense of consensus. This again shows the importance of thoroughly analysing the results and not only looking at maturity ratings and standard deviation.

Additionally there are some other capabilities that display interesting maturities and standard deviations. Because an infrastructure analysis is beyond the scope of this research, one can only speculate and debate the reason for their respective maturities and standard deviation. Such an exercise is not deemed appropriate considering the objectives of this research and will therefore not be included in this research.


Average maturity rating
5
4
3
2
1
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
Std. dev. between respondents
Understanding the market
Involving customers & suppliers in the innovation process
Identifying opportunities
Developing concepts
Scanning & exploring for latent opportunities
Contextualising opportunities & concepts
Testing, screening & prioritising opportunities & concepts
Substantiating, implementing & exploiting opportunities
Planning & coordinating the innovation portfolio
Allocating resources appropriately
Balancing the innovation portfolio
Using appropriate project management techniques
Identifying and planning for key decision points
Using fundamental principles to guide process & make decisions
Reducing uncertainty & mitigating risk
Establishing knowledge, competency & technology development & acquisition strategy
Continuous research
Identifying & extracting relevant information
Capturing, storing & retrieving data & information
Managing core competency & technology
Developing & acquiring the required competencies & technologies
Establishing intellectual property management & sharing policy
Managing intellectual property
Ensuring supplier competency & technology supports requirements
Managing tacit knowledge
Formal & informal internal networking & collaboration
Formal & informal external networking & collaboration
Developing & conveying innovation strategy & objectives
Organisational values & policies
Organisational practices & procedures
Championing & encouraging innovation
Investment in innovation & sourcing of capital
Providing the necessary resources
Infrastructure, systems & tools to support process & management requirements
Developing flexible & adaptable organisational structure & infrastructure
Creating cross-functional & multidisciplinary teams
Communication & the flow of information
Motivating, rewarding & celebrating success
Hiring & aligning people's values & skills with organisation & task
Measuring innovation
Meta-Innovation
Benchmarking innovation


0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Establishing intellectual property management & sharing policy
Managing intellectual property
Developing concepts
Formal & informal external networking & collaboration
Identifying opportunities
Substantiating, implementing & exploiting opportunities
Organisational values & policies
Continuous research
Identifying & extracting relevant information
Meta-Innovation
Identifying and planning for key decision points
Developing & conveying innovation strategy & objectives
Creating cross-functional & multidisciplinary teams
Championing & encouraging innovation
Using fundamental principles to guide process & make decisions
Managing tacit knowledge
Understanding the market
Infrastructure, systems & tools to support process & management requirements
Scanning & exploring for latent opportunities
Managing core competency & technology
Communication & the flow of information
Reducing uncertainty & mitigating risk
Providing the necessary resources
Establishing knowledge, competency & technology development & acquisition..
Capturing, storing & retrieving data & information
Balancing the innovation portfolio
Organisational practices & procedures
Allocating resources appropriately
Planning & coordinating the innovation portfolio
Measuring innovation
Developing flexible & adaptable organisational structure & infrastructure
Ensuring supplier competency & technology supports requirements
Using appropriate project management techniques
Benchmarking innovation
Hiring & aligning people's values & skills with organisation & task
Contextualising opportunities & concepts
Testing, screening & prioritising opportunities & concepts
Motivating, rewarding & celebrating success
Involving customers & suppliers in the innovation process
Formal & informal internal networking & collaboration
Developing & acquiring the required competencies & technologies
Investment in innovation & sourcing of capital
1
2
3
4
5
NS
NA

V. The Innovation Capability Requirement Contextualisation

As stated the innovation capability requirements were contextualised in terms of research commercialisation and categorised into the Organisational Construct. Essmann's (1) maturity definitions for each capability(presented in the figures above) is evaluated and translated into the research commercialisation domain with the insights gained from literature and the execution of the case study.

This is not a extensively researched or validated area of the research but it does serve as an introduction to what the capabilities imply in the research commercialisation domain.

Strategy and Objectives

The mission and vision, short- and long-term objectives, etc. are at the core of an organisation and steer it in a particular direction that will eventually determine the competitiveness of the organisation.

Scanning and Exploring for latent opportunities (IP/SO1_5) – Research commercialisation should be seen as the third mission of the Entrepreneurial University enabling the parent institution to take advantage of future opportunities that will inevitably be introduced through government policy. Future opportunities could also relate to gaps/shortcomings/problems/needs in society that has not even been recognised yet. TTO should actively scan the market and the research base to identify opportunities for matching a idea from the researchers to a opportunity. Very often researchers are the most important source of information to TTO officers providing them with information which will help identify possible industry partners.

Balancing the innovation portfolio (IP/SO2_11) - The most common research commercialization objective among universities in developed countries is maximization of income resulting from licensing agreements (26). Risk aversion by more traditional universities can limit its ability to form start-up companies and accommodate partner firms that needs to respond quickly to environmental changes (45). Accordingly a university or TTO's strategy with regard to commercialization should not only focus on a pursuit of licensing for cash, as the appropriate strategy is very closely linked to the maturity and the characteristics of the technology or research under consideration. Being one dimensional in strategic approach to commercialisation will lead to the eventual downfall of a TTO (46). There should be an appropriate balance between licensing and start-up activity (86). Thus a strategy facilitating this balanced approach enabling the TTO to choose the most appropriate form of commercialisation, all factors taken into account, is crucial.

Using fundamental principles to guide process & make decisions (IP/SO3_14) – Governance principles should be in line with the strategy and objectives of the organisation. The individuals

within the organisation should be able to use fundamental principles to guide and focus activities. Decisions on which opportunities should be pursued should be made by considering the strategy of the commercialisation programme at the university. Researchers should also evaluate the strategy of their university with regards to research to choose appropriate topics that might create commercial opportunities in the future.

Establishing knowledge, competency & technology development & acquisition strategy (KC/SO1_16) – A strategy for the development or acquisition of appropriate knowledge, competency and the technology to ensure the efficient operation of the process in the future, should be in place. This relates to acquiring the right personnel in the TTO and ensuring that there is a strategy to develop the competencies needed to commercialise research.

Establishing intellectual property management & sharing policy (KC/SO2_22) - The technology transfer and intellectual property policies of the university is very important and can be a huge barrier to technology transfer if they are not flexible (45). Well articulated policies and intellectual property rights regime has also been cited by Link et al. (142) as a crucial factor for smooth technology transfer. The university strategy with regards to the timing of intellectual protection in the life cycle of the technology is important. Colyvas et al. (22) found that in most cases it is unlikely that technology transfer of embryonic inventions would occur in the absence of intellectual property protection. Cohen et al.(143) suggest that patents and licences may only be the appropriate way of transferring technology in some research fields rather that across the board.

Developing & conveying innovation strategy & objectives (OS/SO1_28) – The strategy and objectives of the research commercialisation process and technology transfer as a whole should support business objectives and they should be well communicated throughout the organisation. This relates to creating a more entrepreneurial culture within the university through active championing of the cause by management.

It is important that the ultimate responsibility and decision making rights lay on the appropriate level of management to promote the technology transfer process. Vice-chancellors and university management in general play a very important role in creating a culture that fosters technology transfer in the university (45).

Organisational values & policies (OS/SO2_29) – Values and policies should create an environment where new ideas are valued and mistakes are seen as an opportunity to learn. The creation of liaison offices has not been a easy process with sceptic academics ignoring the IPR policies of the universities because of personal believes or in some cases the confusion caused by the policies (2).

Investment in innovation & sourcing of capital (OS/SO3_32) – There should be a strategy in place to source capital which enables resources slack and flexibility in the funding structure when it

is required in the execution future projects. This capability can also relate to the acquisition of venture capital by the TTO.

Function and Processes

The activities that are in place to drive the organisation closer to fulfilling its objectives, whether directly (such as valued-added processes) or indirectly (such as administrative and support processes).

Identifying opportunities (IP/FP1_3) – Researchers should be encouraged to give disclosures to the TTOs as this is a very important source of Ideas for the TTO. Chapel et al. (86) stress the fact that with or without quality disclosures great expertise is required on the part of TTO staff to ensure that licensable inventions(ideas) are identified. The quality of these disclosures are very important to TTO's, both with regards to the description of the idea and the actual potential of the idea. TTOs can only work with what they are given (24). The TTO can also promote areas of research that they identified as having good potential for commercialisation, but this implies influencing research objectives and traditional Universities may oppose such activities.

Developing concepts (IP/FP2_4) – The TTO plays a crucial part in developing the concept with the researcher from the researcher's idea. One should not confuse the concept/prototype the researchers may have developed in their research with the final concept. Concept in this context implies a fully developed (to expectations of market) research idea accompanied by all the necessary feasibility studies. For a start up the concept will also include among others a business plan and business model.

Testing, screening & prioritising opportunities & concepts (IP/FP3_7) - This relates to the criteria a TTO uses to evaluate its disclosures and concepts. Common criteria amongst other are (147):

- Market need
- Market size
- Existence of patent
- Success chances for R&D stage
- Level of innovativeness
- Degree of maturity of the idea

Substantiating, implementing & exploiting opportunities (IP/FP4_8) - The speed with which TTO's commercialise their patent protected technologies has a direct positive relation with the

amount of royalties they receive and the amount of spin-off companies they create. The commercialisation speed is a function of available resources, competency of the TTO staff in identifying licensees and the participation of faculty in the commercialisation process (57).

Identifying and planning for key decision points (IP/FP5_13) – Stage gating is often used to manage the research commercialisation process. It is a very efficient way of streamlining a essentially chaotic process. The key advantages of stage gating are realised in the areas of determining feasibility, dividing resources efficiently, limiting re-work and measuring performance.

Continuous Research (KC/FP1_17) - High quality faculty, excelling at a balanced mix of basic and applied research is very important to any university's research commercialization efforts. Reaching scientific excellence is an important first condition for forming links with industry(13). Traditional thinking suggests that commercialization negatively affects basic/spontaneous research. Contradictory to this many empirical studies have found that universities engaging in technology transfer experience and increase in basic research. This suggests that technology transfer is not a one dimensional flow of information from universities to industry as conventional wisdom suggests. The feedback loop from industry allows university scientists to evolve their thinking by sparking new ideas or refining their experiments (14). Informal technology transfer may also allow academics to obtain additional laboratory equipment and fund graduate students (45).

Identifying & extracting relevant information (KC/FP2_18) – The most important information should be identified, extracted and summarised. This could relate to the evaluation of disclosures and could also speak to the generation of disclosures by the researchers. This capability is very relevant in the research process.

Developing & acquiring the required competencies & technologies (KC/FP3_21) - Sufficient ICT support should be obtained to support the process. The operational needs of the TTO and also the researchers should be fulfilled. Beyond operational needs the competencies and technology should also support innovation.

Championing and encouraging innovation (OS/FP1_31) – This relates to people in the university tasked with championing the commercialisation cause. This is closely related to creating a culture that fosters commercialisation. Researchers should be supported and encouraged by these champions to evaluate their research for commercial opportunities.

Infrastructure, systems & tools to support process & management requirements (OS/FP2_34) – The infrastructure and tools that are available should support innovative behaviour and also the requirements of such behaviour. The TTO should be able to support the requirements of all research fields by providing modular infrastructure that enables multi-functionality. The right tools and systems should be in place to execute the commercialisation process and manage it.

Organisational practices & procedures (OS/FP3_30) – This capability relates to innovation specific-best practices and procedures. Best practices and procedures for commercialisation should also be standardised and reviewed on a regular basis.

Providing the necessary resources (OS/FP4_33) - Insufficient resource allocation to technology transfer by universities will stem the process as large amounts of capital are needed for the registration of patents. Human resources are also important because large teams are often needed to commercialize a single concept. When insufficient resources are allocated to research commercialisation efforts it could shift the actions of the TTO away from using equity to generate revenue as it will force them to sustain their operations with more short term return strategies such as licensing rather than start-up creation (144). This may clash with the prescribed university strategy and result in sub-optimal commercialisation options being pursued in some cases.

Measuring innovation (OS/FP5_40) – Developing metrics and indicators to measure the efficiency and effectiveness of the process is fundamental, not only as a measure to evaluate performance but also because measurement per se often has a significant impact on human behaviour. "What you measure is what you get" A well established input and output structure is critical to build appropriate and robust assessment model. The evaluation framework must consider the university characteristics(mission and goals) and their impact on technology transfer (60). Simply using the impact of technology transfer on the university's cash flow as a measure of administrative success can be a overly simplistic method. This method is heavily dominated by accounting treatment and essentially ignores the value new technology transferred to industry can generate which is more appropriately expressed by present value and value added in the free market (145).

Organization and Management

The structures and entities that are tasked with governing and/or controlling the execution of activities in order to fulfil objectives.

Contextualising opportunities & concepts (IP/OM1_6) – Opportunities and concepts must be put into context with the required technology, competencies, processes and systems needed to match them into a project (Opportunity being a market gap and concept is developed by the researcher and TTO together). Road mapping or scenario planning can be used. Contextualizing an concept/idea also reveres to evaluating in what stage the technology developed by the researcher finds itself in. "Is the technology at a embryonic/early stage or is it far along its development path?" The answer to this question is very important since this will influence how the final concept will be developed relating to IP protection specifically and which opportunities it will be possible to fill in the market.

Planning & coordinating the innovation portfolio (IP/OM2_9) – Projects should be integrated by aligning and overlapping tasks that share objectives (1). This will enable the concurrent completion of multiple project requirements. Tasks and schedules should be planned and coordinated as a portfolio of projects based on prioritisation. The same should be done in a commercialisation effort as this will ensure optimal use of scarce resources.

Allocating resources appropriately (IP/OM3_10) - Insufficient resource allocation to technology transfer by universities will stem the process as large amounts of capital are often needed for the registration of patents. Building a robust technology transfer programme takes sustained financial investment (81). There must also be enough people to perform the necessary tasks such as the marketing of the technology portfolio of a university. Here the importance of hiring the right people must be stressed again (45). A study also found that researchers heading research groups should be totally or partially relieved from managerial responsibilities by a centralized unit while not affecting the performance of the research group negatively. This will allow the researchers confined to managerial tasks to refocus on generating research outputs again rather that just doing day to day management tasks(28). Balancing resources over the different activities, departments, research areas etc. is crucial.

Using appropriate project management techniques (IP/OM4_12) – This relates to the tools and techniques used to manage projects and portfolios. This is very important in any organisation as it will help to limit the risk involved in the projects and accurately recognize the value of the projects to the organisation.

Reducing uncertainty & mitigating risk (IP/OM5_15) - The management of the risk exposure associated with technology transfer is a sensitive and serious issue at most universities. A common method is to accept no liability resulting from technology transfer but to require licensees to indemnify the university if liability should occur (or to obtain the necessary indemnification insurance coverage). However, this may not work in cases when the potential licensee is a small start-up (49).

Managing tacit knowledge (KC/OM1_25) - Cumulative experience greatly enhances the ability of TTO staff to manage the risks involved in technology transfer (20). Knowledge being passed on by researchers to students is a core capability of a university.

Managing intellectual property (KC/OM2_23) - Universities are perceived to be very aggressive with regard to the protection of intellectual property. This also often leads to an overvaluation of technology by TTO administrators. Managers and entrepreneurs regard informal knowledge transfer as a very important output of the technology transfer process(45).

Managing core competency & technology (KC/OM3_20) – Core competencies and technologies should be identified, aligned and synchronised for innovation and operational needs

(1). This can also be relevant to the core competencies and technology needed for successful research commercialisation.

Meta Innovation (OS/OM1_41) – This capability becomes relevant when an innovation model with its associated tools, practices and processes is defined and utilised. This model should be refined and improved regularly.

Creating cross-functional & multidisciplinary teams (OS/OM2_36) – Science-based innovations increasingly have a multidisciplinary character, build on "difficult-to-codify" people-centred interactions. A report prepared for the Organisation for Economic Co-operation and Development (OECD) suggests that university-based systems of industry science links, which combine basic and applied research with a broader education mission, will enjoy a comparative advantage relative to other research institutes (13). This, among other things, implies that the composition of the research team is very important if one wants to create outcomes that will fill future market opportunities. A multidisciplinary team does not suggest that there has to be individuals with a more entrepreneurial orientation included. The composition of the research group is seen as instrumental for improving scientific productivity rather than to contribute directly to a successful combination of research and entrepreneurial activities. (14). With regards to staffing practices within the technology transfer office literature has shown that its best to have a mix of scientists, lawyers and managers to excel in what essentially is a highly demanding and professional environment (45).

Developing flexible & adaptable organisational structure & infrastructure (OS/OM3_35) - It is very important to take into account the departmental barriers created when structuring the commercialisation process within a university with regards to organisational structure and infrastructure. Being to hierarchical can have a negative impact on internal communication and networking. The placement of the TTO and its branding is very important on a organisation and management level (26)

Managers and scientist think university procedures are too rigid, cumbersome and often not clearly specified (45). Organisational designs must be tailored to fit individual collaborations (70).

The traditional university organisational arrangement known as professional bureaucracy, marked by faculty and departmental organisational boundaries and structures severely limits the universities capability to transfer technology efficiently. The same can be said for organizational arrangements solely along disciplinary lines (13).

Researchers also often complain that the process of commercialization is made to difficult by university bureaucracy and this lets them shy away from the process and often use other avenues to engage with industry (45).

The structure of a university will influence technology transfer performance in a predictable manner. (25)

Motivating, rewarding & celebrating success (OS/OM4_38) – Polt et al. (27) concluded through a benchmarking exercises performed in the EU member states that inefficient incentive structures were one of two main barriers to technology transfer. The university's royalty and equity distribution formula is a topic which needs to be addressed in consultation with all stakeholders (45). A study by Link et al. has shown that universities having more attractive incentive structures for technology transfer to industry, i.e. universities that allocate a higher % age of royalty payments to faculty members, tend to be more efficient in technology transfer activities (91). The traditional academic reward system is based on academic outputs such as journal articles and research grants rather than patenting or citations in patents. Evaluation of researchers for promotions should not be exclusively based on research criteria, but should also take into account that excellence in research and teaching has become, at least partly, more tied to applications in industry (13). This is a very important capability enabling a organisation such as a university to ensure a organisational culture and environment were researchers are encouraged to be more entrepreneurial.

Hiring & aligning people's values & skills with organisation & task (OS/OM5_39) – Managers in industry insist that deal-makers rather than academics work in TTOs. The staff need to be marketing facilitators rather than lawyers, they need to be able to take a view from the customers perspective. Scientists feel that the staff of the TTO needs to be specialist in the fields they want to commercialize in. They need to know where the technology is going to be able to make informed decisions with regards to patenting. TTO staff also stress the importance of possessing marketing skills(45). It is clear that TTO staff must poses a host of skills to promote the efficient transfer of technology by the TTO. Many studies has highlighted the absence of the necessary skill set within a TTO as a major barrier to technology transfer. Some of the skills identified as critical are listed below (42):

- Business Experience and industry knowledge
- Strategic vision
- Legal expertise
- Marketing and negotiation skills
- Boundary spanning
- Networking
- Expert valuating knowledge

Benchmarking innovation (OS/OM6_42) – When undertaking a benchmarking exercise using appropriate data and understanding the value chain is very important in the evaluation process to avoid unrealistic expectations from research commercialisation (3).

Data & Information

Relating to the internal and external environments, the basis for all decision making (from complex strategic decisions to activity-based decisions) and the (communication) link between all internal and external entities (individuals, production lines, departments, management, suppliers, the market, etc.).

Capturing, storing & retrieving data & information (IP.KC/DI1_19) – Procedures and frameworks for contextualising, categorising and capturing, and tools for storing and retrieving, data and information should be identified, defined and deployed (1). This is important for the TTO and researchers with large research groups.

Formal & informal internal networking & collaboration (IP.KC/DI2_26) - The TTO is required to work as a dual agent in a very challenging environment balancing the needs of researchers, adhering to university intellectual property rights policy and their required return on expenditure while understanding the expectations of industry with regards to the quality and feasibility of the technology under consideration (24).

Formal and informal processes for knowledge transfer must exist between researchers within the university and industry (70). Social processes are crucial for the exchange of tacit knowledge.

The TTO acts as a boundary spanner or interface specialist between the different role-players in the commercialization process (87).

Formal & informal external networking & collaboration (IP.KC/DI2_27) – Networking to outside partners is very important in the TT business. It is crucial to constantly nurture the relationships and involve the external partners in the process. TTO managers play an important role and for this they require good boundary spanning skills. (45). Social relationships are more important than contractual agreements. Long term relationships with industry partners are also perceived to be better for research commercialization than regular scanning of the market. A study by Thune(146) indicates that collaborative R&D projects leading to commercialisation opportunities are formed by the use of previously established contacts and by the use of intermediaries such as the TTO playing a broker role. The latter is becoming increasingly important due to the internationalization of research collaboration and innovation policies focussing on University interaction with industry.

Communication & the flow of information (OS/DI1_37) - Good communication channels within the university between stakeholders such as your researchers, TTO staff and university administrators are crucial for sharing information.

Customers and Suppliers

The customers being willing to pay for the organisation's value offering and the suppliers providing crucial components towards that value offering.

Understanding the market (IP/CS1_1) - Scientists feel that the staff of the TTO needs to be specialist in the fields they want to commercialize in. They need to know where the technology is going to be able to make informed decisions with regards to patenting. TTO staff also stress the importance of possessing marketing skills (45).

Networking is perceived to be a critical ingredient in the success of any TTO. Social relationships are more important than contractual agreements (45). Long term relationships with industry partners are better for research commercialization than regular scanning of the market. Researchers do not understand corporate culture (42) and this could lead to problems when researchers and industry connect directly.

I**nvolving customers & suppliers in the innovation process (IP/CS2_2)** - Lateral connections between TTO officers through national professional associations of technology transfer officers increase the flow of information about commercialisable research to industry. Regular meetings on a national or regional stage between associations such as the Association of University technology managers, the Federal technology transfer executives and the Licensing executive society in the US plays a major role in creating new networks between University researchers, government laboratories and industry. These networks are essential to the marketing of university research(45).

Networking to outside partners is very important in the TT business. It is crucial to constantly nurture the relationships and involve the external partners in the process. TTO managers play an important role and for this they require good boundary spanning skills. (45)

Other researchers felt that the introduction of an intermediary such as a TTO will have a negative influence on their ties with industry by detaching them from already established industry relationships (2).

Ensuring supplier competency & technology supports requirements (KC/CS3_24) - There must be a champion with a combination of personal dynamic capabilities who has established social relationships with individuals in senior positions in industry whom can form the core of a strategic alliances (70).