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Full Report

Implementation and Impact Evaluation of the Technology and Human Resources for Industry Programme (THRIP)

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Business Enterprises at University of Pretoria (Pty) Ltd

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This report has been independently prepared by Business Enterprises at University of Pretoria (Pty) Ltd, in collaboration with the University of Pretoria. The Evaluation Steering Committee comprised: the Department of Planning Monitoring and Evaluation (DPME) in the Presidency; The Department of Trade and Industry **(the dti)**; and other co-opted members. The Steering Committee oversaw the operation of the evaluation, commented on and approved the reports.

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Glossary

12I TAI	Section 12I Tax Allowance Incentive
AIS	Automotive Investment Scheme
AMTS	Advanced Manufacturing Technology Strategy
ARC	Agricultural Research Council
ATP	Advanced Technology Programme
BBSDP	Black Business Supplier Development Programme
B-BBEE	Broad-based Black Economic Empowerment
BRICS	Brazil. Russia, India, China, South Africa
BRICs	Biotechnology Regional Innovation Centres
BUSA	Business Unity South Africa
CEO	Chief Executive Officer
CRD	Collaborative Research Development
CREATE	Collaborative Research and Training Experience
CSIR	Council for Scientific and Industrial Research
DPME	Department of Performance Monitoring and Evaluation
DST	Department of Science and Technology
ECSA	Engineering Council of South Africa
EU	European Union
FP	Framework Programme
FTE	Full-Time Equivalent
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research and Development
GMSA	Grants Management and Systems Administration
HESA	Higher Education South Africa
HEI	Higher Education Institution
IoT	Internet of Things
IDC	Industrial Development Corporation
ICT	Information and Communication Technology
IP	Intellectual Property
IPR	Intellectual Property Rights
M&E	Monitoring and Evaluation
MANCO	Management Committee
MCDM	Multi-criteria Decision Model
MCEP	Manufacturing Competitiveness Enhancement Programme
MIP	Manufacturing Investment Programme
MSc	Master of Science
MVA	Manufacturing Value Addition
NACI	National Advisory Council on Innovation
NAM	National Association of Manufacturers
NBBC	National Black Business Caucus
NECSA	Nuclear Energy Corporation of South Africa
NEPF	National Evaluation Policy Framework

NIC	Nanotechnology Innovation Centres
NIST	National Institute of Standards and Technology
NRF	National Research Foundation
NSERC	Natural Sciences and Engineering Research Council
NSI	National System of Innovation
OECD	Organisation for Economic Cooperation and Development
PFMA	Public Finance Management Act
PhDs	Doctor of Philosophy
PI	Production Incentive
PPP	Partnerships between public and private partners
R&D	Research and development
RoI	Return on Investment
RTD	Research Technology Development
S&T	Science and Technology
SA	South Africa
SANSA	South African National Space Agency
SCC	Science Councils Cohort
Seda	Small Enterprise Development Agency
SETIs	Science, Engineering and Technology Institutions
SIF	Sector Innovation Funds
SIP	Strategic Industrial Projects
SMEs	Small and Medium Enterprises
SMMEs	Small, Medium and Micro Enterprises
SPII	Support Programme for Industrial Innovations
SRP	Strategic Research Partnerships
STP	Seda Technology Programme
the dti	The Department of Trade and Industry
TFP	Total Factor Productivity
THRIP	Technology and Human Resources for Industry Programme
TIA	Technology Innovation Agency
TIP	Technology Innovation Programme
TIPTOP	Technology Innovation Promotion through the Transfer of People
ToC	Theory of change
ToR	Terms of reference
TPC	Technology Partnerships Canada
UK	United Kingdom
UNIDO	United Nations Industrial Development Corporation
USA	United States of America
USPTO	United States Patent and Trademark Office
UWC	University of W Cape
VAT	Value-added Tax

Policy summary: findings and recommendations

The Department of Trade and Industry **(the dti)** and the Department of Performance Monitoring and Evaluation (DPME) commissioned Business Enterprises at University of Pretoria (Pty) Ltd in October 2013 to undertake an implementation and impact assessment of the Technology and Human Resources for Industry Programme (THRIP), which is a **dti** research and innovation support programme administered by the National Research Foundation (NRF).

To allow cross validation, a mixed/multi-methods design was used including gathering evidence and statistics from relevant official documents; a literature review; international analyses of overseas programmes; surveys of participating researchers from universities, science councils and industry; personal interviews; and a workshop with representatives of **the dti**, DPME and the NRF. The evaluation design did not make provision for any case studies.

The three important parameters that guided the compilation of the final reports should be listed at the start. First, the initial *Policy* and *Executive Summaries* are high level summaries of the evaluation and consequently cannot cover detail such as source citations that are discussed in the main report. Secondly, the fieldwork and analyses took place between January and April 2014 and the report consequently does not cover subsequent dynamic changes to relevant strategies. Thirdly, it should be noted that the terms of reference of the evaluation project did not include the drafting of plans for implementing the findings and recommendations of the assessment and this aspect was therefore deemed to form part of subsequent departmental implementation plans.

Key findings, recommendations and policy implications

1. It is recommended that THRIP should be continued and be further strengthened.

2. THRIP is an established, valid and important element of the South African government's portfolio of research and innovation support measures. It is efficient (e.g., demonstrating substantially lower overheads than comparable overseas programmes) and offers considerable value for money both in terms of technology development (with and estimated revenue of R24 million five years after conclusion of a project) and in terms of developing human resources with industry related skills (by engaging 1 450 postgraduate students per financial year).

3. Its core principles of collaboration between research institutions and industry on the one hand and quality of research and development, on the other, are well aligned to international best practise.

4. The total funding of THRIP should be increased according to industrial absorptive capacity and needs (in real terms it is currently about half of what it was 10 years ago; it could productively absorb more than twice its current allocation).

5. While the Programme is efficient and achieves its objectives (new technologies and knowledge and human resources for industry), it has to satisfy a broader spectrum of needs than its typical counterpart programmes in countries such a Canada, the United States of America (USA) and some European countries. The impact of THRIP can be enhanced by reducing the number of objectives it has to serve.

6. THRIP plays a unique role in the country's system of innovation. However, its domain is designed to support all types of research necessary to resolve the industrial challenge. Following international best practise it is important for **the dti** and the country to develop additional programmatic instruments supporting industry to commercialise the THRIP produced know-how, including the tracking of THRIP project outcomes beyond project conclusion.

7. Stakeholders identified the intellectual property (IP) regime surrounding THRIP as a major challenge for improving the Programme's performance. It is suggested that THRIP's IP regulations should be reconsidered by **the dti** and the Department of Science and Technology (DST).

8. THRIP is one of the oldest dedicated research and innovation support programmes in the country and whilst having retained its core mission of facilitating the training of human resources for industry, it has also adjusted its foci over time to contribute to the needs emerging from the policy eco-system, e.g., attending to the Small Medium and Micro Enterprise (SMME) sector. Awareness of the national policy context should remain high on the agenda of THRIP in future too, without neglecting its core mission.

9. THRIP contributes to job creation by producing a flow of highly skilled researchers and technology managers for industry and by improving the competitiveness of the participating business organisations. Furthermore, an analysis of THRIP's impact on the economy through the higher education and economic interface shows that, based on 2009 data, the Programme supported 2 290 jobs since inception.

Executive Summary

1. Introduction

The Technology and Human Resources for Industry Programme (THRIP) is a research and development programme established during 1992 with the objective of accelerating economic growth, creating wealth on a sustainable basis and improving the quality of life of all South Africans.

On a cost-sharing basis with industry, THRIP supports science, engineering and technology research collaborations focused on addressing the technology needs of participating firms and encouraging the development and mobility of research personnel and students among participating organisations. It is funded by the Department of Trade and Industry (**the dti)** and managed by the National Research Foundation (NRF). THRIP aims to improve the competitiveness of South African industry by supporting research and technology development. In addition, the Programme addresses one of the most critical issues related to the country's international competitiveness, i.e., to increase the number and quality of people with appropriate skills to develop and manage technology for industry. The issue has been of importance when the Programme was initiated and remains a main focus of the Programme.

As part of its mandate under the National Evaluation Policy Framework (NEPF) and in partnership with **the dti**, the Department of Performance Monitoring and Evaluation (DPME) issued the terms of reference (ToR) for the evaluation of THRIP.

Originally, the ToR, indicated that the objective of the evaluation was to "assess the impact of THRIP in the context of its objectives and priorities over the period to be reviewed and to determine how the beneficial impacts can be strengthened". However, after the literature review, the methodological challenges of the impact review in the domain of science, technology and innovation were recognised and the Steering Committee suggested that the implementation assessment should rather be emphasised.

2. Aims and objectives of the evaluation

This assessment aims to identify THRIP's relevance in the country's national system of innovation; the effects of processes (such as structure and administration) on THRIP's performance; as well as the cost-effectiveness of THRIP in comparison with other approaches.

The assessment also aims to compare THRIP with similar efforts abroad (benchmarking).

Similarly a number of impact issues are investigated – impact on technology development; impact on small, medium and micro enterprises (SMMEs); impact on skills development; impact on economic development; competitiveness; tax revenue; and intellectual property (IP).

3. Evaluation approach and methodology

To allow cross validation, a multi-method approach was followed that included literature and archive reviews; a survey of university administrators and professors; a survey of industrial participants; data collection from the THRIP databases; a comparative review positioning THRIP nationally and internationally; and interviews with key informants/stakeholders (including **the dti** and NRF officials). The report reflects the opinions and suggestions of more than 125 stakeholders who participated. However, the methodological design and approach of this evaluation were subject to limitations, such as giving priority to the implementation of THRIP rather its impacts; internal validity being moderate; incomplete statistical information; and the anticipation among some stakeholders that the administration of grants might be moved away from the NRF.

4. Key findings

The analysis shows that THRIP's design is based on second-generation innovation policy (the so-called chain-linked model of innovation).

THRIP's design allows collaboration that enables partners to share research and development (R&D) costs, to pool risks and enjoy access to institution-specific know-how and commercialisation resources. Collaboration, furthermore, guarantees that support is going to projects to across industries.

This collaboration is characterised by high social rates of return – the basic tenet of government interference in the market. Similarly, collaboration prevents the support of projects that confer proprietary advantages to individuals.

The key findings of the investigation follow below.

4.1 Implementation findings

4.1.1 Relevance

> *Is THRIP still relevant when considering other instruments in the innovation landscape? What factors in the South African context enable or constrain THRIP's positive impact, including the long term sustainability of those impacts?*

The analysis of THRIP within the context of the National System of Innovation (NSI) showed it to be a unique instrument for capacity building in the NSI. The unique characteristics of the Programme are that it:

- Provides incentives for technology development locally;
- Promotes collaboration among government, academia, science councils and industry;
- Is versatile and can support different size challenges (small or big grants);
- Focusses on industry-based priorities;
- Is open to all qualifying organisations (a number of incentives are structured to benefit particular institutions and technologies); and it
- Addresses the government priority of increasing the country's R&D expenditure.

It should be noted that, while **the dti** has a number of instruments promoting the acquisition of technology embodied in equipment and facilities technology, (e.g., the Manufacturing Competitiveness Enhancement Programme (MCEP), the Manufacturing Investment Programme (MIP) and others), THRIP is unique in promoting technology development locally.

Similarly, through the international benchmarking exercise and by applying the theory of change it was found that THRIP complies with international best practice and follows a sound approach. Almost all countries in the world develop programmes that promote the utilisation of scientific research through collaborative efforts.

The stakeholders identified that the "pre-established relationship of the universities with the industrial partners" and "relevance of university research to industry" strongly facilitate the beneficial effects of THRIP.

Relatively inhibiting factors identified are "geographic location"; "requirement to find industrial partners willing to make a cash contribution"; and "IP agreement/management issues, i.e., businesses that believe that they should own the intellectual property rights". Correspondingly, the stakeholders (both from the science base and the industrial sector) declared that the Intellectual Property Rights from Publicly Financed Research and Development Act, Act No. 51 of 2008, is an inhibiting factor.

The theory of change analysis found that THRIP is not designed to promote commercialisation of the knowledge produced beyond the applied stages of research. Further incentives across the innovation chain, such as the promotion of commercialisation, can enhance THRIP's long-term impact and sustainability.

4.1.2 Process

> *What effect do institutional mechanisms (structure, management, administration, and processes) have on the efficiency and effectiveness of delivering THRIP?*

THRIP is identified as having a commendable structure (including an Advisory Board) and it follows good practices in managing, processing and monitoring the projects. The selection criteria applied enable THRIP to meet broad national needs and help ensure that the benefits of successful awards extend across firms and industries.

THRIP produces guides/manuals for its processes, has effective digital archives and receives unqualified reports by the Auditor-General, including PFMA compliance. In assessing the administration of THRIP across ten (10) issues (effectiveness of application process, effectiveness of disbursing funds, etc*.)*, universities and science councils rated performance as above-average ratings. The lowest score was on "appropriateness of resources available".

The THRIP approach also contributes to the development of scientific and technological infrastructure. On the question: "Has THRIP created long-term collaborative activities of your university with industry?" participants were positive. Examples of responses include: "Much of the advanced genetics and genomics work at the ARC (and at UWC previously) has been funded by THRIP as industries have not been willing to fund these areas

directly. The impact is therefore on allowing the implementation of cutting-edge technology for industry without their initial commitment to the direct investment. As it becomes an effective tool, then the direct funding becomes attractive". Another response stated: "Through the combined effort of our main industry partners (Anglo American Operations, Anglo American Kumba Iron Ore and Glencore), supported by THRIP, we could establish a Centre for Pyrometallurgy in 2009, followed by the establishment of a new field of research within our centre, that of pyrometallurgical modelling in 2013."

In the survey, stakeholders identified funding ratios (industry to government) and the partial funding of projects as weaknesses in the Programme. The partial funding of projects forces the universities to renegotiate with the industrial stakeholders and revisit the scope and objectives of projects. This creates additional costs to universities, science councils and industrial partners.

The international benchmarking analyses identified that THRIP has a large number of criteria or objectives in comparison to equivalent international programmes. In South Africa the monitoring of projects comes to an end once the project is completed, while abroad project monitoring continues for a number of years after completion.

Finally, in the process of the current evaluation, it was concluded that the 10-year evaluation horizon is not optimal. One institution that was asked to mobilise its researchers to participate in the THRIP evaluation stated that "about 44% of the 2002 project leaders have left the University (mostly retired, left for Australia, one person died)". Similarly, the international efforts show that programmes similar to THRIP are assessed every five years.

4.1.3 Cost-effectiveness

> *Is the current model of delivering THRIP cost-effective in comparison to alternative models?*

THRIP operations are embedded in the NRF infrastructure, which makes the Programme efficient. During recent years the estimated operating expenses as a percentage of the programme's contributions to projects have been between 6% and 7%. As THRIP leverages resources from the industrial partners as well, the operating expenses, as a percentage of the total funds mobilised, is approximately 3%.

In comparison to other programmes, THRIP has substantially smaller overheads. The overheads are comparable with international programmes (such as the Canadian programmes), even though the programmes abroad handle substantially more resources.

4.1.4 Benchmarking

> *How does THRIP's performance compare to similar programmes nationally and internationally?"*

THRIP is unique in the country in its effort to support locally developed technologies through collaboration with the industry and scientific institutions such as universities and science councils. This collaboration facilitates an increase in the number of people with

appropriate industry-related skills and stimulates industry and government to increase their investment in R&D, innovation and technology diffusion. Internationally, most countries in the world provide incentives to their industries that are similar to THRIP's incentives. Examples include the industry-driven Collaborative Research and Development (CRD) Programme in Canada, the Advanced Technology Programme (ATP) in the USA and the Framework Programmes in the European Union.

An important difference identified is that abroad, distinct programmes/approaches are followed for separate objectives, while THRIP attempts to accommodate a wide spectrum of objectives. For example, in Canada, the Natural Sciences and Engineering Research Council (NSERC) so-called Engage grants are intended to foster the development of new research partnerships between academic researchers and companies that have never collaborated before by supporting short-term research and development projects aimed at addressing a company-specific problem. The so-called Interaction grants are intended to financially support researchers from Canadian universities to meet with Canadian-based companies with the objective of identifying a company-specific problem that they could solve by collaborating in a subsequent, newly established research partnership. The Collaborative Research and Training Experience (CREATE) Programme is designed to improve the mentoring and training environment for the Canadian researchers of tomorrow by improving areas such as communication, collaboration and professional skills, as well as by providing experience relevant to both academic and non-academic research environments.

It is noted that the ultimate objectives of Canada's programmes are separated into discrete grants, while the approach in South Africa appears to be "one size fits all".

THRIP is following international best practice by using review committees for the assessment of the project proposals and producing guides/manuals to guide its officials and reviewers in their tasks.

Differences between THRIP and programmes abroad include the low budget of THRIP in general and the small contribution of government in comparison to the contribution of the industrial partners in particular. These findings are particularly important to the competitiveness of the country's industry (both big and small enterprises).

As mentioned earlier the THRIP budget has remained at around R150 million for the last ten (10) years. This means that, in real terms, government's contribution is almost half of what it has been ten (10) years ago. NRF officials mentioned that THRIP could easily absorb twice to three times its current budget. This issue is confirmed by the fact that THRIP is currently only partially funding successful project proposals and a few successful proposals may be declined for funding due to a lack of funds. A doubling of funding will bring THRIP to its initial funding levels in terms of purchasing power parity (value of money over time).

4.3 Impact findings

As introduction, a methodological note on the perception of impact may be required. To measure impact of a policy intervention properly, a before-after evaluation design that accounts for most potentially confounding factors as well as for the systematic data of the

before-award performance is required. As in most other policy evaluations, these conditions could not be met in in this evaluation.

4.3.1 Technology development

What impact does THRIP have on technology development?

The industrial stakeholders declared that the THRIP projects are strategically important to their organisations. The industrial stakeholders mentioned that the cost-sharing, industry-driven approach has shown considerable success in advancing technologies that can contribute to important societal goals, such as improved health (e.g., controlling air pollution from domestic fires with the *Basa Magogo* project); developing tools to add value in the country's mining resources (e.g., gold-based catalysts); and improving the efficiency and competitiveness of the South African manufacturing industry. Furthermore, stakeholders emphasised that technology fields like big data and predictive analytics, breast imaging system development, metal matrix composites, grid/cloud-based mobile computing and Internet of Things for smart cities would not have been available in South Africa without THRIP.

THRIP stimulates additionality. More than a quarter of the business stakeholders declared that the project would not have been undertaken without THRIP support and the remainder of the respondents declared that without THRIP funds the project would have suffered from reduced objectives, longer time scales and a lack of partnerships.

4.3.2 Return on Investment (RoI) for industry partners

Do industry partners realise a significant return on investment (RoI)?

In response to open questions industrial stakeholders declared that they expect substantial revenues from selling goods or services that incorporate THRIP technology. The expected average revenue amounts to R24 million five (5) years after the completion of the project and R224 million ten (10) years after project completion.

4.3.3 Impact on Small Medium and Micro Enterprises (SMME's)

What impact does THRIP have on SMMEs?

THRIP pays particular attention to SMMEs and, during the recent years, there were twice as many SMMEs participating in the Programme than large corporations. In addition, SMME's declared that high benefits arise from their participation in THRIP. Comparisons of the SMME responses with those across all industries show that SMMEs receive commercial returns and economic impacts well above those in the average participating industry. SMMEs gave full marks on the statements that their participation in THRIP: "increased competitiveness", "improved turnover", "improved financial viability" and "increased productivity". Furthermore, the SMMEs declared that the projects are strategically important to their organisations.

Public/private partnership arrangements targeting Small and Medium Enterprises (SMEs) are an international phenomenon. There are two reasons for this. The first is that

successful innovation in firms will increase the number of competitors, leading to improved performance in product markets and consequently facilitating job creation. The second is that there is a general perception that SMEs face higher risk and uncertainty in technological innovation because of their more limited R&D portfolios and lack of resources, such as information and human and financial capital. Market failures may also arise in product markets when the dominant position of large firms or the oligopolistic structure of a given market impedes innovations by SMEs.

However, the above does not mean that large corporations do not need innovation support. Asia's emergence was based to a large extent on the ability of large corporations to enter international export markets. For example, the government of General Park Chung Hee (1962–1979) came to the conclusion quite early on that Korea needed big companies if it were to compete in the international markets. To achieve that goal, they promoted a series of national champions called *chaebols*. (Yergin & Stanislaw, 1998). These firms were nurtured with low-interest government loans, tax advantages and other incentives to enable them to become large and strong industrial groups. Thus were born companies of which the names are now globally known, such as Hyundai, Samsung and Daewoo. Similarly, the Organisation for Economic Co-operation and Development (OECD) suggests that "blindly promoting partnerships between SMEs and universities could divert resources away from projects with larger firms that may have potentially higher social and private returns" (OECD, 1998).

4.3.4 Skills development

What is the impact of THRIP on skills development?

THRIP's mission states that it aims to "produce a flow of highly skilled researchers and technology managers for industry". Engaging students in graduate studies and their obtaining of degrees are internationally accepted as valid indicators of skills development.

The investigation identified that THRIP engages just under 300 honours graduates, more than 750 master's students and over 400 PhD candidates per financial year (also see Section 5.1.4, **Table 11** p. 60, for THRIP outputs). Of critical importance however is the fact that the postgraduates participating are involved in research topics chosen and relevant to industrial partners. In addition, the industrial partners declared that part of the benefits of the THRIP project in their respective organisations were "qualifications earned by their staff". The average organisation declared that, during the period of the THRIP project, eight (8) members of staff earned additional qualifications, and during the three (3) years following the end of the project, ten (10) members of staff earned additional qualifications.

Taking into account that approximately 300 projects are initiated annually, the number of staff members earning qualifications after the end of a project becomes significant. THRIP makes a substantial contribution to the development of human resources for industry.

4.3.5 Return on investment (RoI) for South Africa as a country

Does South Africa realise a significant RoI from THRIP against the cost of delivering the programme in term of economic growth and empowerment; skills development and job creation (rate) ; taxable revenue ; and competitiveness.

THRIP supports economic growth through a variety of channels. Through universities, THRIP makes a contribution to the growth in the South African economy. The Higher Education Institutions (HEIs) in the country produce, except for knowledge and skilled graduates, their own economic output, as shown in the main report. They also employ numerous employees of different professions and at various qualification and skills levels. In addition to their own output and employment, universities generate additional output and employment in other economic sectors through secondary or "knock-on" multiplier effects.

It is estimated that the total Gross Domestic Product (GDP) generated from THRIP (through the HEI interface) is R508 million. The importance of the figure becomes profound when one takes into account that government contributes approximately only R150 million to THRIP while industry, on the other hand, provides approximately R300 million. Furthermore, by applying the modelling approach referred to in Box 1 (Section 5.2.1), it is estimated that THRIP contributed to the creation of 2 290 jobs in the economy (through direct and indirect effects). It should be emphasised that the figures above do not take into account economic growth and employment effects that can be attributed to e.g., new knowledge, skills development, industrial competitiveness, etc.

The industrial stakeholders were asked to rate from 1 to 10 the contribution of THRIP with regard to a number of policy objectives. The policy objectives of "improved economic development and growth"; "improved employment situation"; "improved preservation of the environment"; "improved standards of living in rural and semi-rural communities"; and "improved competitiveness" scored a median rating of 8. This means that at least 50% of the respondents rated the contribution of THRIP to policy objectives at 8 or higher.

Industrial stakeholders were requested to provide estimates of the expected revenue and tax income from THRIP projects. Estimates of the expected taxable revenue created by each THRIP project shows that from the 5th to the 10th year after completion, each project is expected to generate R7.2 million taxable revenue, and after the 10th year, the tax revenues increase substantially. These amounts are considerable, taking into account that THRIP contributes less than R1 million to the average project. THRIP not only provides a substantive return to the industrial participants, but it also provides through tax, a return of investment to the country.

Industrial stakeholders ranked THRIP's impact on competitiveness highly. They were asked to rank the ways in which THRIP enhances competitiveness in industry. The indicators of or routes to industrial competitiveness that were rated highest included "higher quality goods, services, etc."; "expanded reputation for THRIP and leading-edge technology"; and "improved innovation performance". The long-term expected impacts of THRIP on competitiveness are rated more important than the impacts during the undertaking of the project.

THRIP-supported research is producing, on average, 30 patents per year, as well as copyrights, trademarks and designs. The industry partners mentioned that a number of

technologies are commercialised, even though THRIP does not provide incentives for further development after the prototype stage. In the question: "Since the end of THRIP project funding, how much has your company spent on continued R&D and commercialisation of your THRIP project?" the mean reported by the respondents was R3.84 million. It is apparent that THRIP projects are often supported by the industrial partners after the termination of THRIP funding for the relevant project.

4.3.6 Intellectual property (IP) and commercialisation

> *What happens to the IP from completed THRIP projects? To what extent are completed projects commercialised, and if not, why not? To what extent are benefits of THRIP realised in South Africa, and if not, why not?*

The stakeholders (both from the science base and the industrial sector) declared that the Intellectual Property Rights from Publicly Financed Research and Development Act, Act No. 51 of 2008, is a challenge.

Responses to the open question probing IP issues showed that businesses need ownership of IP and consequently prefer not to participate in THRIP. It is emphasised that this is not an implementation challenge, but an inhibiting environmental factor.

The issue of IP is an interesting one in the THRIP context. The number of patents is a performance indicator reported by the National Advisory Council on Innovation (NACI) to the DST. However, the country's innovation system produces a limited number of international patents. It can be argued that this is the result of the structure of the economy (lack of high-technology industries and large multinationals) and probably a lack of appropriate government support.

THRIP statistics show that the Programme produces just over 26 patents per year (locally and abroad). As there are no detailed statistics, it is difficult to judge the quality of these patents. For example, local patents are not examined for novelty, usefulness, etc. (Pouris, 2011). No data nor case study material were available on the extent of commercialisation of the reported patents.

On the other hand, South Africa produces less than 120 patents in the United States Patent and Trademark Office (USPTO) per annum. Hence, if THRIP-supported patents are granted by the USPTO, the Programme makes a substantial contribution in the field.

It should be emphasised that THRIP does not support near-market development. Hence, from an incentive structure perspective, the Programme cannot influence the progress of IP to commercialisation. However, the industrial partners declared "licenses issued" among the outputs produced (1.6 licences during the period that the Programme was running and just over three (3) during the three (3) years after completion of the project).

On the question: "What changes in the IP regulations can improve chances of commercialisation of the THRIP projects?" the majority of respondents mentioned the adverse effects of the Publicly Financed Research Act on THRIP.

THRIP is not attractive to foreign owned companies. This is in line with the relevant Programme rules which do not encourage foreign participation.

It is also important to quote **the dti** (2008) report, which states: "In-depth analysis, however, indicates that if there are technologies that have been "lost" abroad during the period under examination – in the sense that they have been successfully commercialised and provide an income to their current owners (without benefit to original inventors) – they are not profound. The case studies that we investigated did not identify any technologies that have been transferred abroad (to the detriment of the inventors), are successfully commercialised or provide an income to their current owners." THRIP creates benefits for the South African national system of innovation and its benefits are not lost abroad.

4.3.7 Strengthening of beneficial impacts

How can the beneficial impacts of THRIP be strengthened?

Mechanisms identified in the report include extending the mandate of THRIP to include outcomes; a meaningful increase of its public funding; the improvement of communication and marketing; a review of the intellectual property regime; and the streamlining of selected aspects of its administration.

5. Recommendations

The above implementation findings and findings on the perceptions of impact lead to the following recommendations:

5.1 Recommendation 1: the dti should retain THRIP and enhance the government's financial support. A doubling of funding should be the first objective over the intermediate term.

From the evidence presented (relevance, benchmarking and impacts) it becomes apparent that THRIP is a valid and important element of the South African government's portfolio of innovation support measures. Following international best practice, it offers considerable value for money and has not yet reached the stage where it is running into diminishing returns. It is recommended that THRIP should be retained and its available funding should be increased according to industrial absorptive capacity and needs.

5.2 Recommendation 2: the dti (owner) and NRF (manager) should protect and enforce the core principles contributing to THRIP's successes over the past 12 years.

The success of THRIP in contributing to national objectives, according to evidence from benchmarking and relevant stakeholders' opinions, depends on its ability to retain a number of core principles listed below. Failure to do so will result in a dilution of THRIP and will diminish its contribution to technology transfer and innovation in the country. The recommended principles that should constitute the Programme's "hurdles" (minimum entry requirements) are as follows:

- Collaborative research involving at least two (2) partners – one (1) business and one (1) from the research base;

- Scientific quality of research;
- Pre-commercial character of research, which can be safeguarded through the participation of more than one firm; and
- The maximum funding available from government of 1:2 (government:business) for most research projects and of 1:1 for projects with particular requirements should be reconsidered by **the dti** with the objective of bringing THRIP on a par with international standards and supporting the local industry appropriately.

5.3 Recommendation 3: the dti and NRF should act to improve the operational challenges of THRIP, i.e., number of objectives; partial funding; participation of companies partially owned by HEI/Science, Engineering and Technology Institutions (SETIs); participation of universities that were unsuccessful; and programme evaluation.

Evidence from the process questions and benchmarking reveals that there is a need to continuously review the processes that underpin and support THRIP in order to ensure that users are provided with the most efficient and effective service possible. Areas where refinements are required as a matter of priority are the following:

- THRIP should reduce the number of Programme objectives following international good practice;
- The issue of partial funding of projects should be applied only when the committee has reasons to believe that the relevant costs are inflated;
- The monitoring of the projects should be expanded so that their impacts could be monitored after completion of projects;
- As suggested by stakeholders, THRIP should consider accepting contributions from companies owned wholly or partly by HEIs/SETIs up to a limit of 25% ownership;
- THRIP should consider developing separate approaches linking universities that were previously not succeeding in obtaining THRIP funds with relevant industrial establishments and successful THRIP institutions; and
- Programme evaluations (like this one) should be undertaken every five (5) years. The ten-year horizon is too long a period for evaluation as the majority of the early participants are no longer available to contribute to the evaluation.

5.4 Recommendation 4: the THRIP management and executive should create links with similar international programmes and learn from their experiences.

There are a number of programmes similar to THRIP internationally. In the review, we have identified, among others, the Canadian Collaborative Research Development (CRD) grants and the Advanced Technology Programme (ATP) in the USA. THRIP could benefit by establishing linkages with such programmes and learn from their experiences and approaches.

5.5 Recommendation 5: the dti should consider the expansion and supplementation of THRIP in support of industry for the uptake and commercialisation of generated knowledge, including the monitoring and evaluation of THRIP project outcomes beyond project conclusion.

THRIP plays a unique role in the country's system of innovation. Its domain covers all research necessary to resolve the industrial challenges of the country. Following international good practise and in line with the tenets of the theory of change it is important for **the dti** and the country to develop additional programmes and to streamline the existing ones that support industry.

Incentives should be available to industry to take THRIP funded outputs further and commercialise THRIP-produced know-how. Such an approach would have the additional advantage that existing programmes will not have to operate on the basis of the "one-size-fits-all" approach.

5.6 Recommendation 6: the dti should engage with DST in order to resolve the challenge of intellectual property ownership.

THRIP participants identify the IP regime within which the Programme operates as an obstacle to commercialisation. THRIP and **the dti** should engage with the DST to identify ways of simplifying the IP regime for THRIP projects. The IP Draft Policy that is being developed by **the dti** could also include the relevant recommendations.

6. Conclusions

The THRIP evaluation offers valid evidence in support of retaining and even further strengthening the Programme. It is a valid, important and efficient element of innovation support that offers considerable value for money both in terms of technology development and in terms of developing human resources with industry-related skills. By and large, its core principles of collaboration and quality of research and development are in accordance to international best practise. Its beneficial effects can be reinforced by reducing the number of objectives, streamlining its funding administration to meet stakeholders' requirements, addressing the challenges associated with the IP regime and introducing post-project monitoring and assisting non-participating science and technology institutions to participate in the Programme.

1 Introduction

This chapter offers an overview of the history of THRIP, followed by a short summary of its evaluation history. The chapter also lists the main issues that, according to the terms of reference (ToR), must be addressed through the current evaluation process and finally provides an outline of the structure of the report.

1.1 History of THRIP

The Technology and Human Resources for Industry Programme (THRIP) is a research and development programme established during 1992 with the objective of accelerating economic growth, creating wealth on a sustainable basis and improving the quality of life of all South Africans. On a cost-sharing basis with industry, THRIP supports science, engineering and technology research collaborations focused on addressing the technology needs of participating firms and encouraging the development and mobility of research personnel and students among participating organisations. THRIP addresses one of the most critical issues related to country's international competitiveness, i.e., increasing the number and quality of people with the appropriate skills to develop and manage of technology for industry. The issue has been of importance when THRIP was initiated and it still remains a main focus of the Programme.

1.2 Evaluation history

THRIP and/or specific functions related to the Programme have been assessed at least four (4) times since its establishment, namely in 1997 by Brighton, Arnold, Pistorius and Zingu; in 2001 by Brighton, Gihwala, Pather, Pillay and Van den Heever; in 2006 by Pouris; and in 2010 by Botha. This document reports the results of the fifth assessment of the implementation and impact of THRIP.

1.3 Terms of Reference (ToR)

Originally, the terms of reference (ToR) indicated that the purpose of the evaluation was to "assess the impact of THRIP in the context of its objectives and priorities over the period to be reviewed and to determine how the beneficial impacts can be strengthened". However, after the literature review, the particular challenges of impact review in the domain of science, technology and innovation were recognised and the Steering Committee suggested that the emphasis should rather be placed on implementation assessment.

1.3.1 Implementation questions

The ToR identified the following implementation questions:

Relevance
Is THRIP still relevant when considering other instruments in the innovation landscape? What factors in the South African context enable or constrain the beneficial impact of THRIP, including the long term sustainability of those impacts?

Process
What effect do institutional mechanisms (structure, management, administration, and processes) have on the efficiency and effectiveness of delivering the Programme outcomes?

Cost-effectiveness
Is the current model of delivering THRIP cost-effective in comparison to alternative models?

Benchmarking
How does the performance of the Programme compare to similar programmes nationally and internationally?"

1.3.2 Perceived impact questions

The ToR identified the following impact-related questions:

Technology development
What impact does THRIP have on technology development?

Industry's return on investment
Do industry partners realise a significant return on investment (RoI) from THRIP?

Impact on SMMEs
What impact does THRIP have on SMMEs involved in technology development?

Skills development
What is the impact of THRIP on skills development in science, engineering and technology?

National return on investment
Does South Africa realise a significant RoI from THRIP against the cost of delivering the Programme in terms of economic growth and empowerment; skills development and job creation (rate); taxable revenue; and competitiveness?

Intellectual Property Rights (IPR) and commercialisation
What happens to the intellectual property (IP) from completed THRIP projects? To what extent are the outputs of THRIP projects commercialised and are benefits realised in South Africa?

Further reinforcement
How can the beneficial impacts of THRIP be strengthened?

1.4 Structure of this report

This report first offers an overview of the history of THRIP, followed by a short summary of its evaluation history. The first chapter also lists the main issues that, according to the terms of reference (ToR), must be addressed through the current evaluation process and finally provides an outline of the structure of the report.

Chapter 2 describes the methodology and approach followed. In Chapter 3, the literature review describes THRIP and elaborates on the theoretical reasons for government involvement in the field of research, technology and innovation. The chapter also outlines the country's national system of innovation with emphasis on the various incentives offered for technology development and enhancement. Chapter 4 offers a theory of change and develops the relevant diagram for THRIP. Chapter 5 outlines the implementation and impact assessment of THRIP. The final chapter includes the findings and develop relevant recommendations.

The appendices (from A to C) contain the three (3) questionnaires that were utilised for the investigation; the background to the THRIP process; application evaluation criteria; the economic gains from THRIP R&D; and finally a summary of the outcomes of the theory of change focus group discussions.

2. Methodology and approach

While a variety of approaches (World Bank, 2004) and classifications are used internationally for Monitoring and Evaluation (M&E), such approaches can be classified methodologically into "theory-based" and "indicator-based" reviews. Theory-based reviews analyse and elaborate on the approach, structure, criteria, etc. that are used to compare and contrast a theoretical body of literature, other programmes and activities that are considered best practice.

Indicator-based reviews develop measures of inputs, processes, outputs, outcomes, and impacts for projects, programmes, or strategies. When supported by sound data collection – usually involving formal surveys – analysis and reporting of indicators enable managers, sponsors and other stakeholders to track progress, demonstrate results, and take actions to improve service delivery. Participation of key stakeholders in this process of monitoring is important, because stakeholders can provide the relevant indicator data.

2.1 Mixed-methods design

For reviewing THRIP, both the theory-based and the indicator-based approaches were used (cf. DPME, 2014). The methodological design was therefore essentially a mixed-methods one. The mixed-methods design enables cross-validation across the respective approaches and thus provides stronger validity and evidence (cf., e.g., Bryman, 2006; Marais, 2012). The theory-based assessment includes a literature review that describes THRIP and elaborates on the theoretical reasons and empirical evidence for government involvement in the field of research, technology and innovation. The review further outlines the country's national system of innovation with emphasis on the various incentives offered for technology development and enhancement. Finally, the review elaborates on the theory of change and develops the relevant diagram for THRIP based on the focus group session conducted with representatives of **the dti**, DPME and NRF (see **Figure 4,** p. 50).

The indicator-based review consists of data that were collected from the THRIP management (through interviews and documentation) and from the relevant stakeholders (universities/research councils and business stakeholders) by means of two surveys. The scientific stakeholders (universities and science councils) were deemed of special importance, as these organisations were closer to the Programme. Relevant information on the questionnaires appears in Chapter 5 and the questionnaires can be found in Appendices A, B and C. Descriptive statistical techniques were used for the analyses of quantitative data and content analysis for the analyses of the responses to the open questions and the interview material. **Table 1** offers a summary of the data collection tools used in this evaluation study.

Table 1: Data collection tools

Instrument	Response	Response rate
Key informant interviews	21	100%
Survey of HE participants	61 of sample of 110	58%
Survey of industry participants	45 of sample of 187	24.6%
Theory of Change (ToC) workshop	7	100%

2.2 Limitations of the evaluation

At least six (6) sets of limitations to the scope and validity of this evaluation should be emphasised, viz. the focus on implementation rather than impact of the programme; the validity of the measurement of stakeholder perceptions; incomplete statistical information; the fluid policy ecology at the time of the evaluation; the time frame of the project; and the absence of strategies for the implementation of the findings and recommendations. These important limitations can be summarised as follows:

First, originally the terms of reference indicated that the objective of the evaluation was to "assess the impact of THRIP in the context of its objectives and priorities over the period to be reviewed and to determine how the beneficial impacts can be strengthened". However, after the literature review, the particular challenges of the impact review in the domain of science, technology and innovation were recognised and the Steering Committee advised that *implementation* evaluation should rather be emphasised.

Science, technology and innovation *impacts* normally manifest themselves over a longer period of time that varies in duration and therefore require long term monitoring. The period taken for impact effects to manifest themselves and the ambiguous causal nature of impacts further complicate the demonstration – not even to mention the proving – of impacts, since many variables can interfere with or contribute to an impact. Furthermore, to measure impact of a policy intervention properly, a before-after evaluation design that accounts for most of the potentially confounding factors as well as for the systematic data of the before-award performance is required. As in most other policy evaluations, these conditions could not be met in this evaluation. The methodological complexities involved in the demonstration of impact are recognised internationally.

Secondly, this evaluation relied on qualitative evidence generated by interpretations of documents, survey information and information gathered by means of interviews – none of which in its own right could claim absolute validity, i.e., exactly measured what it was supposed to measure. The fact that a mixed methods design was deliberately used for this evaluation allowed for triangulation and optimising the validity of the findings, e.g., between the Likert and the open questions in the survey. Yet, in interpreting the findings it should be borne in mind that part of the evidence consisted of the interpretation of documents on the one hand and perceptions of stakeholders, on the other. With regard to external validity, i.e., generalisability of the findings, it should also be noted that the relatively low response rate in the industrial survey calls for caution in generalising the findings beyond the respondents.

Thirdly, the evaluation team could not access complete sets of statistical data in all cases and while it is unlikely that significant deviations would occur, the fact remains that gaps in the statistical data were encountered. This limitation also relates to the fact that because of time constraints, it was not possible to undertake before-after comparisons, e.g., to test the effect of the introduction of IP legislation on participation rates by businesses.

Fourthly, in a few interviews and related engagements the evaluation team did encounter concerns about the future 'bureaucratic home' of THRIP, more specifically whether the agency function would remain in the NRF or be transferred in all respects to **the dti.** Towards the latter stages of this evaluation, rumours were already doing the rounds that

THRIP might be relocated to **the dti**. Although the potential effect of such perceptions on the inputs to this evaluation could obviously not be determined with any degree of certainty, it should be marked as a potential confounding variable.

Fifthly, the fieldwork and analyses took place between January and April 2014 and the report consequently does not cover subsequent dynamic changes to relevant strategies.

Finally, it should be noted that the terms of reference of the evaluation project did not include the drafting of plans for implementing the findings and recommendations of the assessment and this aspect was therefore deemed to form part of subsequent departmental implementation plans.

In summary, whilst this evidence-based evaluation of the implementation of THRIP was designed to optimise the validity of the findings – and recommendations – it should be acknowledged that the validity of the findings are subject to an unspecified, albeit limited, degree of uncertainty – like most if not all programme evaluations.

3. Literature review

This chapter provides a literature review on the following issues relevant to the implementation and impact evaluation of THRIP:

- The mission, vision, objectives, structure, processes and criteria of THRIP are covered in the first section. The information is essential for answering process questions.

- The section "Government involvement in innovation" elaborates on the reasons for government involvement in innovation, discusses the various models for innovation and identifies a number of international programmes or incentives that are similar to THRIP. The section contributes to a number of the objectives of the evaluation, such as how the benefits ensuing from THRIP can be strengthened, international benchmarking and the like.

- The subsequent subdivision outlines the South African national system of innovation with emphasis on the various incentives offered for technology development and enhancement. This section addresses a number of questions, for example, "Is THRIP relevant when considering other instruments?" and "What factors enable or constrain the beneficial impacts of THRIP?"

- The next section, "Theory of change and THRIP", elaborates on the theory of change (ToC) and develops the relevant chart/diagram for THRIP, which provides insights on the thinking behind the Programme.

THRIP is set in each of the above contexts and the findings are summarised and elaborated on in the final chapter of the report.

3.1 Technology and Human Resources for Industry Programme

3.1.1 Background

THRIP was launched in August 1991 in response to representations made by the South African Engineering Association to the Economic Advisory Council of the government of the time - and supported by the then Foundation for Research Development - to address the challenges of skills development in science, engineering and technology (Marcus, 2014). As could be expected, the complex process of establishing a partnership funding programme such as this took some time and the first projects were approved in 1993 and the first grants were awarded in January 1994.

The above initiatives were taken against the background of appropriate skills having been recognised internationally as the key to industrial competitiveness and economic growth. Hence, most counties in the world provide incentives for their universities to provide human resources needed for their industries. THRIP is funded by **the dti** and managed by the National Research Foundation (NRF). THRIP aims to improve the competitiveness of South African industry by supporting research and technology development and enhancing the quality and quantity of appropriately skilled people – and thereby

increasing South Africa's competitiveness – through closer cooperation between higher education and industry.

3.1.2 Programme description

THRIP promotes partnerships in pre-commercial research between business and the public-funded research base, including universities and research institutions (NRF, 2012b). **Table 2** offers a summary of the mission, goals, objectives and priorities of the Programme.

Table 2: THRIP mission, goals, objectives and priorities[1]

Mission	• Leveraging collaborative partnerships on a cost-sharing basis for research in science, engineering and technology, in order to provide technology solutions towards a competitive industry and to produce a flow of highly skilled researchers and technology managers for industry
Strategic Goals	• To support research on technologies to develop the competitiveness of South African industry • To support research that develops skilled human resources for industry • To support research that contributes to social and economic development and upliftment of all South Africans • To facilitate collaborative applied research between industry and academia
Objectives	• To contribute to an increase in the number and of quality of people with appropriate skills in the development and management of technology for industry • To promote increased interaction among researchers and technology managers in industry, higher education institutions (HEIs) and science, engineering and technology institutions (SETIs) through the mobility of trained people among the sectors with the aim of developing skills for the commercial exploitation of science and technology • To stimulate industry and government to increase their investment in research, technology development, diffusion and the promotion of innovation • To promote increased collaboration between large and small enterprises, HEIs and SETIs by conducting research and development activities that lead to technology transfer and product or process development • To promote large (thematic) collaborative research and development projects in **the dti** priority areas
Priorities	• To support an increase in the number of black and female students that intend to pursue technological and engineering careers • To promote technological know-how in the small, medium and micro enterprise (SMME) sector through access to skills from HEIs and SETIs • To facilitate and improve the competitiveness of broad-based black economic empowerment (B-BBEE) and black-owned enterprises through technology and human resources development • To facilitate and support multi-firm projects in which industry partners collaborate and share in the project outcomes, strongly encouraging SMME participation

[1] The THRIP parameters as applicable over the period 2009-2014 and as at the time of the evaluation; however, the programme is dynamic with objectives and parameters changing annually.

3.1.3 Organisational structure

Since its inception in 1991, the NRF and **the dti** have jointly managed THRIP.

An Advisory Board, comprising of representatives from industry, government, higher education, labour and science councils guides THRIP. The Board is appointed by the Chief Executive Officer (CEO) of the NRF, and Director-General of **the dti** in consultation with relevant stakeholders for a period of three (3) years. The THRIP Advisory Board reports to the Minister of Trade and Industry through the Director-General of **the dti**. The organisational structure of THRIP is reflected in **Figure 1.**

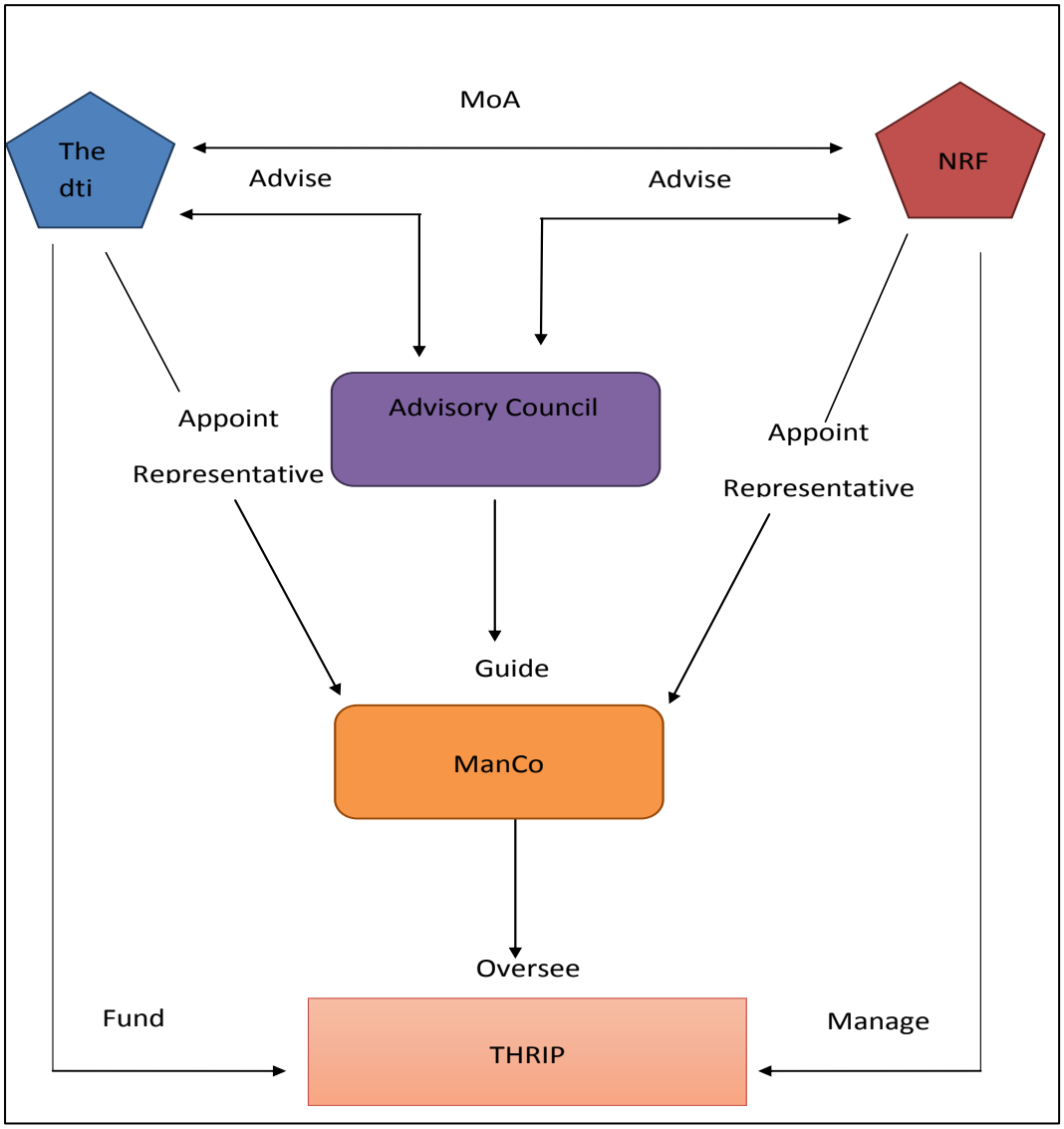

Figure 1: THRIP organisational structure

Each of the respective entities in the above-mentioned THRIP structure has its own roles and responsibilities.

Table 3 indicates the roles and responsibilities of the various governance structures of the Programme as well as the current members serving in these structures (cf. NRF, 2012b).

Table 3: Responsibility matrix

Governance structure	Role / Responsibility	Members
THRIP Advisory Board	• Recommending strategy and objectives for the Programme • Monitoring, evaluating and commenting on the performance of the Programme • Assisting in the promotion of and lobbying for support for the Programme to facilitate the achievement of its objectives • Advising **the dti** and NRF on resource requirements, including the THRIP budget • Assisting **the dti** and NRF in fulfilling their respective fiduciary responsibilities in ensuring the effective and efficient use of THRIP funds • Board members are eligible for re-appointment after the conclusion of their first three-year term.	• Business Unity South Africa (BUSA) • Nuclear Energy Corporation of South Africa NECSA • The Innovation Hub • Department of Science and Technology (DST • Engineering Council of South Africa (ECSA) • The Department of Trade and Industry (**the dti**) • National Black Business Caucus (NBBC) • Higher Education South Africa (HESA) • Small Enterprise Development Agency (Seda) • Science Councils Cohort (SCC)
Management Committee (MANCO)	• The joint Management Committee is responsible for overall monitoring and evaluation. It consists of representatives of **the dti** and the NRF. A primary function of the committee is to develop business and strategic plans for THRIP (in consultation with the executive structures of the NRF; **the dti**; and the THRIP Advisory Board), as well as to oversee Programme implementation.	• The Department of Trade and Industry (**the dti**) • National Research Foundation (NRF)

3.1.4 Application and adjudication processes

Since its establishment THRIP has developed a well-defined structure for the processing of collaborative proposals. **Appendix D** outlines the THRIP application processes, the types of grants available and their associated conditions. The appendix shows a process that is aligned to application procedures for most public research funding grants.

It is clear that the NRF has an explicit funding framework and an efficient system of operations for THRIP. Manuals guide applicants, staff and officials to apply, manage and administer the Programme in a consistent and transparent way, while international benchmarking provides a performance base on international best practice. Other agencies can use the THRIP processes and activities as examples of good practice.

It is important in a programme evaluation such as the current one to specify the adjudication process, since THRIP is a relatively complex funding instrument in which academic researchers and industrial stakeholders are involved. The expert evaluation panel uses the Multi-criteria Decision Model (MDM; NRF, 2012a) as evaluation tool. This adjudication model is a research-based project application assessment tool that is based on the principles of value measurement theory.

During the first stage, projects must pass “hurdles” and may be judged as “not fundable” if any hurdle is failed. The second stage is a merit-based assessment that scores projects in terms of the objectives, priorities and focus of the Programme. The decisions to fund or not to fund a proposal and the level of funding are therefore based firstly on the “hurdles” and secondly on the MCDM score. In principle all “fundable” projects are funded, but the perception has been encountered that fundable projects may not be recommended by review panels for funding due to, e.g., a shortage of funds, redress targets, etc. The seven (7) hurdles are summarised below, since they represent – indeed exceed – international best practices:

3.1.4.1 Improved competitiveness of South African industry

The project proposal must be of a high quality science, engineering and/or technology research project, the outputs of which are likely to make a significant contribution towards improving the capacity of the industry partner to improve the competitive edge of the South African industry.

3.1.4.2 Innovation and technology transfer

The project proposal must demonstrate that new knowledge will be created or that existing knowledge will be applied and that the industry partner and/or industry sector is highly likely to implement a new process or produce a new product as a result of the research.

3.1.4.3 Prototype development

The project proposal must demonstrate that a project outcome will be a product, process, procedure, model or technique that will benefit the industry partner.

3.1.4.4 Defined scientific and technological merit and outputs

The project proposal must demonstrate appropriate, high quality science, engineering and/or technology research methods and approaches. These should be provided at a level of detail enabling a specialist to evaluate quality. The project must also indicate the phase of development of the research in terms of funding cycles.

3.1.4.5 Benefits for South Africa (in case of a contributing foreign company)

The project proposal must demonstrate how SA will benefit if the technology is developed for a foreign company.

3.1.4.6 Additionality

In the case of large industry partner, the project proposal must identify those research activities that would not occur without THRIP funding. The benefits to the industry partner must be clearly demonstrated.

3.1.4.7 Causality and implementation

In the case of a large industry partner, the project proposal must clearly show the intention to fulfil some of the following obligations:

i. Project results e.g., technology outputs (product, process, procedure, model or technique) and research outcomes (technical reports, research papers, student graduation, skills development); and

ii. A clear plan for the implementation of research outcomes to the benefit of the industry partner/s and/or the industry sector.

Once the seven hurdles have been successfully crossed, a proposal should meet a number of (MCDM) criteria - 18 in fact.

Table 4 shows these criteria and their maximum weighting.

Table 4: THRIP criteria

Project characteristics	
i.1 Alignment to **the dti** priorities	
i.1.1. **the dti**'s National Industrial Policy Framework alignment	80
i.1.2. Job creation	80
i.1.3. Commercial potential	80
i.1.4. Investment potential	80
i.1.5. Environmental impact	65
i.2. Scientific and technological merit	80
i.3. Additionally	25
i.4. Causality and implementation	25
ii Research collaboration	50
iii Continuation and progress	65
iv Capacity building	
iv.1. General student capacity building	65
iv.2. Capacity building with regard to black researchers	65
iv.3. Student corrective action	65
iv.4. TIPTOP placements	65
v Characteristics related to industry partner(s)	50
v.1. Project management and structure	50
v.2. Number and nature of companies in joint planning	50
v.3. Size of companies	50

Source: NRF, 2013c: 57

The number of evaluation criteria appears to have been increasing over the years. As argued in subsequent sections, this number is considered high and it affects the number of key performance indicators for THRIP.

It is sufficient at this point to quote the chairperson of the THRIP Advisory Board on the subject: "*While we acknowledge the extraordinary achievements of the Programme and*

the new approaches being rolled-out to improve performance of the Programme, we are concerned about the failure of THRIP to achieve more than half of its targets, two years in a row. On deeper assessment of and engagement with this problem, our interpretation was that the Programme is not necessarily applying an appropriate rationale in setting the targets and that it may be setting too many targets in any one year. We are pleased that management has taken cognisance of this and has set more realistic targets for the next cycle and have committed to rationalise on the number of KPIs against which targets are to be set" (THRIP, 2012: 7).

It should also be mentioned here that the large number of criteria makes the assessment process extremely cumbersome if not even ineffective. For example, "scientific and technological merit" (one of the most important criteria internationally) only has a weighting of 7.7%. Obviously, with such a small weighting, projects with minimal merit could find their way into the list of successful projects.

3.2 Government's involvement in innovation

The preceding sections highlighted the nature and unique properties of THRIP as a funding programme aiming to promote research to provide technology solutions, on the one hand, and produce highly skilled researchers and technology managers for the South African industry, on the other. This section offers an overview of the national science, technology and innovation context within which THRIP as a government intervention is situated.

3.2.1 Economics and innovation

The pervasiveness of innovation in economic growth has changed our understanding of economic growth and international trade fundamentally. Based on findings from work in the field, a number of researchers (e.g. Romer, 1990) have rewritten some of the fundamental assumptions of classical and neoclassical economics, which were originally based on trade in simple, technologically unchanged commodities. Currently, innovation is recognised internationally as the fundamental cornerstone of economic growth and employment. The "discovery" of innovation has also inspired a great volume of publications on the relationship between research, development, innovation and economic growth; **Appendix E** offers a selective overview of some of this literature.

3.2.2 The role of government in the economy

As discussed below, traditionally, governments' interference with the market has been justified because of the existence of public goods; externalities; increasing returns to scale; and informational asymmetries. More recently, however, international competitiveness in a globalised economy added an additional dimension to the issue.
Public goods have the property that one person's consumption does not diminish their availability to others. This implies that their price to consumers should be zero, since their consumption by one party is at no cost to others. However, in many cases, the production of public goods is costly, which creates a contradiction.

Private firms are not supposed to charge for public goods, in which case they will not

produce them, or if they are able to charge for them, there will be too few of them consumed. A free market alone will not produce an optimal result, so the state must intervene to do so.

An externality occurs when production or consumption by one firm or individual influences the well-being of another and the effect is not valued on any market. There is a tendency for overproduction of negative externalities, such as pollution, and a likelihood of underproduction of positive externalities (such as knowledge).

Government intervention related to returns to scale refers to the investments that need to be made at the outset for the establishment of a new industry, industrial sector or facility for which the costs may be prohibitive from the perspective of one firm or involve high-risk long-term return potential. Research also falls under this category.

Informational asymmetries may arise in a number of circumstances. Debt and equity finance create informational asymmetries between shareholders and managers, and between lenders and borrowers. For example, because monitoring intangible investments (for example, R&D intensive companies) is so difficult, such investments may not be able to secure debt finance. Government should find a way to accommodate finance if these types of investments are required.

Finally, the advent of competitiveness in a global economy sets the background for a different and additional role for governments. In this context, governments have the responsibility to promote and protect the interests of their industries. Game theory provides a natural way to think about the interactions of nations. As governments from competing countries promote their interests through the introduction of certain policy instruments, other countries have to follow suit in order to maintain their relative competitiveness. Issues of citing R&D facilities by multinationals, of brain drain, promotion of particular cultural values and of adoption of particular methods and techniques can be considered in this context. Israel and Canada have been successful in attracting R&D activities from abroad and currently 30% of their R&D expenditures are from abroad. The relevant figure in South Africa is 10% mainly for clinical trials. The issue of R&D is probably the only one that qualifies for government support across all counts.

In this context, it should be mentioned that South Africa spends a relatively small amount on R&D. The DST's strategic plan for fiscal years 2011–2016 was accompanied by a statement by the Minister of Science and Technology. It was stated that "South Africa will be able to spend R45 billion on R&D by 2014 and reach its target for gross expenditure on research and development of 1.5% of the gross domestic product (GDP)" (DST, 2011b: 4). The DST also indicated that, during 2008/2009 (the most recent year for which figures exist), the country spent R21 billion or 0.92% of the GDP on research and development. This figure is relatively small in comparison to other countries with an interest in a knowledge economy. For example, Israel spends just below 5% of its GDP on R&D. In this context, THRIP is a critical mechanism in the promotion of R&D in general and in the provision of funds from the business/industrial sector for this objective.

Governments all over the world, regardless of their philosophical predisposition, enter the marketplace in order to promote and support R&D activities.

3.2.3 Models of innovation and their effects

The approaches used by governments to support innovation depend on their understanding of the innovation process. Two models have dominated this thinking in the recent past – the linear model and the chain-linked model.

3.2.3.1 Linear model

The ***linear model*** of innovation (referred to as first-generation innovation policy; cf. OECD, 1994) is based on a system in which the development of new technologies follows a clear-cut time sequence that originates in research, involves a phase of product development and leads on to production and commercialisation, as illustrated in **Figure 2**.

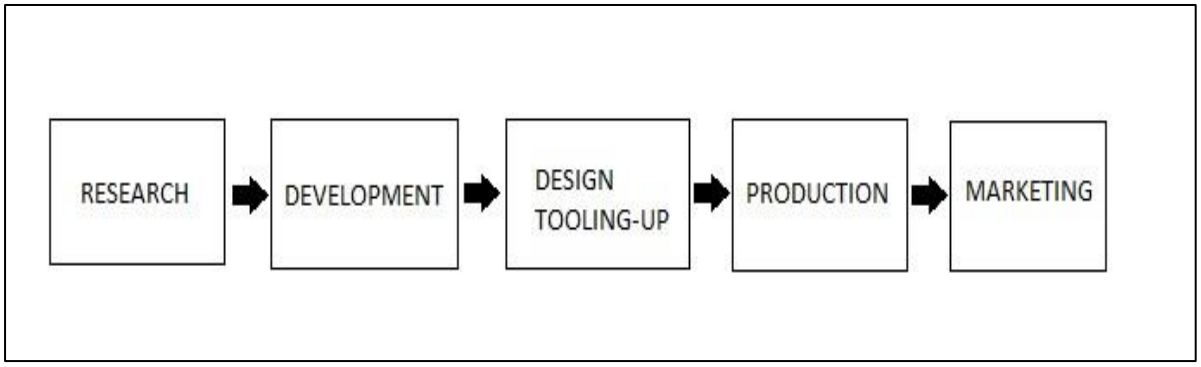

Figure 2: A linear model of the linkages from research to production (OECD, 1994)

3.2.3.2 Chain-linked model

The In the ***chain-linked model*** (second-generation innovation policy)[2], innovation is presented as a process of continuous and repeated interactions and feedbacks. This model emphasises the central role of the feedback effects between the downstream and upstream phases of the earlier linear model and the numerous interactions between science, technology and the innovation process in every phase. **Figure 3** on the next page illustrates innovation as an interactive process (OECD, 1994).

[2] The third-generation innovation policy paradigm makes innovation a government-wide policy and aims to maximise the chances that regulatory reform in other domains (for example, government procurement, competition and taxation) will support innovation objectives, rather than impede or undermine them.

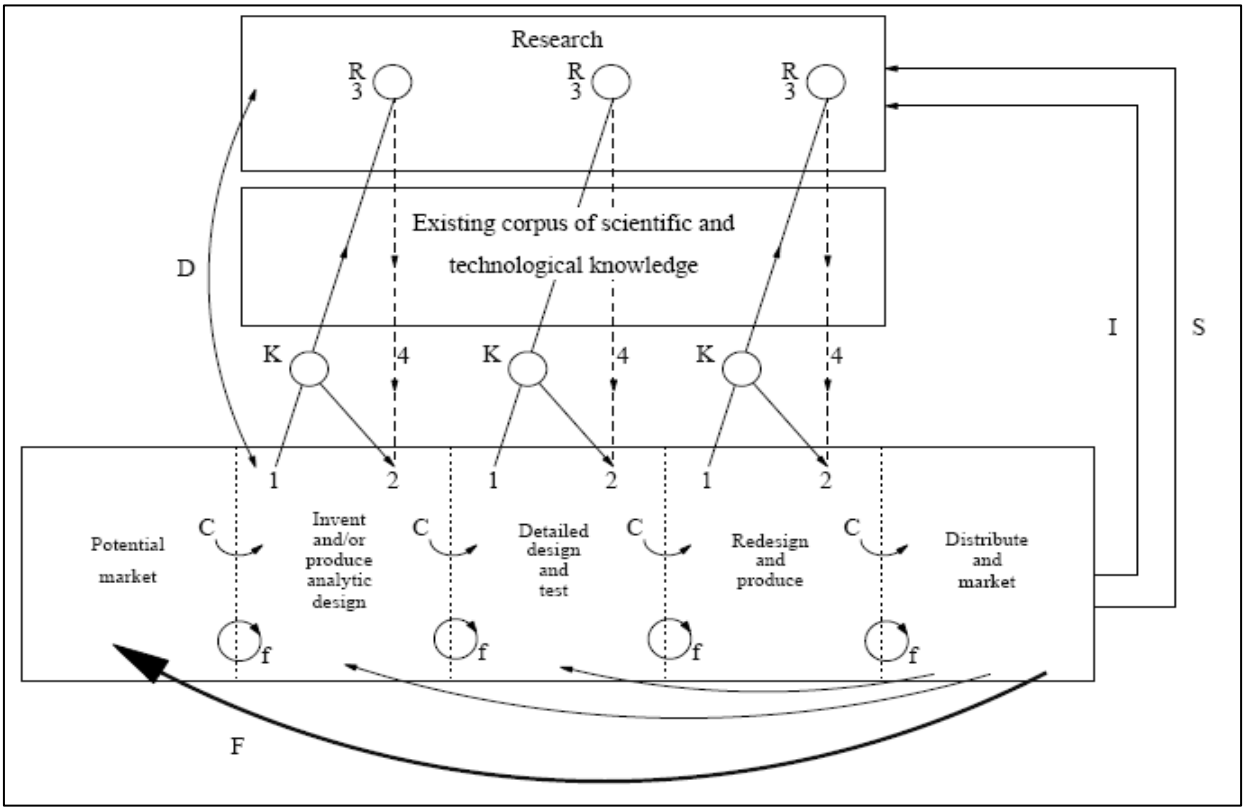

Figure 3: The integration model of the linkages from research to production (OECD, 1994)

3.2.3.3 The effects of the models on public funding of R&D

Applying each of the above-mentioned models has different consequences, as outlined below:

Effects of the linear model

When the linear model prevails, governments support R&D through a number of approaches. The most common are:

- Government-sponsored R&D;
- Government procurement of new technologies;
- Direct subsidies, loans and repayable contributions to businesses, universities and non-profit organisations; and
- Tax incentives.

An important issue in the use of these types of instruments is to develop the policy instrument in such a way that it encourages investment in R&D or increase private rates of return to R&D investments to levels closer to social rates of return, without necessarily conferring monopoly power to R&D performers.

A strict interpretation of neoclassical economics allows financial support for pre-competitive R&D, but warns against "government failure" where policies may distort the market with more damage than the market failure which they seek to rectify e.g., by crowding out competitors' R&D or limiting competition.

A Canadian study is insightful on this matter. McFetridge (1995) reviewed evaluations of government-sponsored R&D, procurement policies, direct subsidies, concessionary financing and tax incentives for R&D in Canada. In the case of government-sponsored R&D, he found that research projects with industry-wide applicability were characterised by high rates of return, while those that conferred proprietary advantages on individual firms were characterised by rent seeking and low rates of return (McFetridge, 1995: 32). This general finding also holds in the case of direct subsidies for R&D and extends to evaluations of R&D subsidies in the USA and the United Kingdom (UK). Cost-effectiveness was highest in situations where such subsidies were aimed at solving industry-wide or multi-industry technological problems (McFetridge, 1995: 77).

Effects of the chain-linked model

When the chain-linked model prevails, emphasis is placed on the development of strategic research partnerships (SRP). These SRPs are defined as cooperative relationships that involve organisations that conduct or sponsor R&D. Examples include research joint ventures; strategic alliances and networks; licensing; sponsored research agreements that involve universities, government laboratories and firms; university-based entrepreneurial start-ups; etc.

Such activities allow partners to share R&D costs, pool risks and enjoy access to firm-specific know-how and commercialisation resources (Hagerdoon et al., 2000). For the past 20 years the EU's research framework programmes have focused on supporting cooperation between universities, research centres and firms, as well as the international mobility of scientists. Similarly, the LINK Programme in the UK and the Advanced Technology Programme (ATP) in USA may be considered leaders in the field.

A particularly interesting subset of strategic research partnerships is the one between public and private partners (PPP). These partnerships account for a growing share of R&D funding in the OECD countries. In France, PPPs accounted for 78% of all competitive research funding in 2002, which is an increase from 37% in 1998, and the Dutch government reserved €805 million for PPPs in strategic areas between 2003 and 2010. Existing PPP programmes in Australia, Austria and Sweden have also been reinforced with additional funding, and new PPPs have been established in the Czech Republic, Ireland, Hungary and Switzerland.

3.3. International programmes and incentives similar to THRIP

In recent years, many industrialised countries have developed strategies to link research institutions to industry, according to the chain-link model, and in this way contribute to the solution of industrial challenges as well as the training of researchers and creative industry staff.

In view of this development, it follows that a very important input to the evaluation of THRIP is the analysis of similar programmes in selected other countries. Since the literature review only represents a subsection of the present evaluation, it follows that only a selection of countries could be reviewed and it was decided, partially on advice of the THRIP evaluation Steering Committee, to select countries that have already recorded

considerable success with their programmes and whose STI systems bear at least some resemblance to the South African one.

Eventually, the following countries/regions were selected for this overview: Canada, China, the European Union, Finland, the UK and the USA. To offer a sense of the detail of the programmes two countries, viz. Canada and China, are presented in Sections 3.3.1 and 3.3.2, followed by a comparative and less-detailed overview, with THRIP as reference of all the selected programmes in the five countries in Section 3.3.3. The international comparisons are concluded with a tabulated summary of the key features of THRIP against those of the selected programmes.

3.3.1 Canada: NSERC

The programme with objectives most similar to THRIP is the set of grants grouped under the theme “Industry-driven collaborative research and development programme”. These grants form part of the Natural Sciences and Engineering Research Council (NSERC) Programme in Canada (see, e.g., web site available at https://www.ic.gc.ca/eic/site/ito-oti.nsf/eng/h_00641.html). Different grants have different specific objectives. For example, the NSERC Engage grants are intended to foster the development of new research partnerships between academic researchers and companies that have never collaborated before, by supporting short-term research and development projects aimed at addressing a company-specific problem. Similarly, the NSERC Interaction grants are intended to financially support researchers from Canadian universities to meet with Canadian-based companies with the objective of identifying a company-specific problem that they could solve by collaborating in a subsequent, newly established research partnership. The Collaborative Research and Training Experience (CREATE) Programme is designed to improve the mentoring and training environment for the Canadian researchers of tomorrow by improving areas such as communication, collaboration and professional skills, as well as providing experience relevant to both academic and non-academic research environments. The training initiative should be focused on providing a value-added experience to the university training environment to better prepare research trainees for their future careers in industry, government or academia.

The Collaborative Research and Development (CRD) grants support well-defined projects undertaken by university researchers and their private-sector partners. CRD awards cover up to half of the total eligible direct project costs, with the industrial partner(s) providing the balance in cash and in kind. Applications are evaluated on the following criteria: scientific merit; research competence; industrial relevance; and contribution to the training of highly qualified personnel.

The CRD Grant is the Canadian equivalent of THRIP. Other CRD grants include the partnership workshops grants, which are designed to seed new collaborations and partnerships between Canadian university researchers and potential new non-academic partners; chairs in design engineering; industrial engineering chairs; and others.

The comprehensive character of support of the “Industry driven collaborative research and development programme” should be contrasted with THRIP. The ultimate objective in Canada is separated into separate grants, while the South African approach is to provide a “one-size fits all” solution.

3.3.2 China: National Key Technologies R&D Programme

In view of China's rapid economic growth in recent years and its membership of the five (5) major emerging national economies: Brazil, Russia, India, China and South Africa (BRICS) it was suggested by the Steering Committee that reference could also be made to that country's strategies that might be similar to THRIP. In China, the Ministry of Science and Technology offers a programme similar to THRIP, which is called the National Key Technologies R&D Programme. The Programme was initiated in 1982 and was implemented through five-year plans. It focuses on promoting the technical upgrading and restructuring of industries, and tackling major technical issues concerning public welfare.

Projects are approved on a rolling basis with their terms generally less than three (3) years. The National Key Technologies R&D Programme introduced intermediary agencies as part of its management mechanism. Priority is given to supporting joint efforts made by universities, research institutes and enterprises to undertake projects. A major pre-condition for project approval is that enterprises take part in technical development and industrialisation.

Areas of emphasis funded through the National Key Technologies R&D Programme include the following:

- Agro-product processing;
- Manufacturing;
- Engineering research in application technologies;
- Technologies and equipment for clean energy;
- Intelligent traffic system;
- Textile post-treatment;
- Urban environmental pollution control;
- Rational utilisation of water resources;
- Technologies for improving the regional ecology and environment;
- Technical research in the exploration and development of oil and gas fields and strategic solid mineral resources;
- Technical supporting systems for the disaster prevention and mitigation; and
- Traditional Chinese medicine.

The Programme pays particular attention to the production of patents. During 2005, there were 2 102 active projects and 3 365 (of which 186 foreign) patent applications and 1 173 (of which 32 foreign) granted patents. In 2009, the total fund of the National Key Technologies R&D Programme was approximately €2.4 billion (MoST, 2012). The supporting period is no more than five years.

The main rules for participations are as follows:

1. The application unit should be a Chinese university, research institute, or a private company legally set up in mainland China for more than one (1) year, with strong R&D capacity. The entity should be well operated, have an asset-liability ratio under 60% and no negative credit history. Individual applications are not accepted.

2. The lead applicant should meet the following requirements: age below 58, with senior professional titles or PhD degree, a good academic performance and no negative credit history in science and technology activities. The lead applicant should work for no less than six months (some projects require nine months) in China each year and devote to the project no less than 60% of his/her working time.

3. The lead applicant can only apply for one (1) programme (863 Programme, 973 Programme, or Key Technologies R&D Programme) in the same application period. Other applicants can only participate in no more than two (2) projects under these programmes.

4. The application unit should have good research basis and preliminary research experience in the corresponding R&D areas; a high-level scientific research team; sound research performance; and strong demonstration and promotion capabilities.

3.3.3 International comparisons

A comparison of THRIP with international programmes similar to THRIP is presented in **Table 5** (on pp. 38 and 39). A few aspects are highlighted below:

3.3.3.1 Mission statements

The "mission" row in **Table 5** shows that comparable programmes do not include the production of relevant human resources. This may be the result of the chronic lack of appropriate human resources in South Africa. It should be mentioned that some international projects include training for specialised skills (for example, the Linkages Projects in Australia), but they are not part of the criteria for the approval of the project (or they have a very small weight factor).

3.3.3.2 Partnerships and facilities

The row "who leads" shows that a number of programmes require the industry to lead the project. Requiring projects to be industry-led is a deliberate approach designed to provide firms the incentive to pursue subsequent commercialisation activities of project results with private sector funds. For example, the reason for **the Advanced Technology Programme (ATP)** of the USA for being industry-led is that economic benefits only result when the new technology is transitioned from the knowledge stage into new and better products, processes, and services for users (for example, a new, improved medical treatment that is actually delivered to patients who then benefit from its use).

It should be emphasised that the ATP criteria[3] do not force collaboration between firms or between firms and universities or non-profit organisations. Although leaving the decision of how best to structure their projects up to applicants (businesses), the ATP criteria have some built-in criteria that encourage partnering. The ATP pledges approximately $1 million /year/project, with the award recipient sharing an equal or greater amount of the cost.

[3]. Available at http://www.atp.nist.gov/atp/kit-04/final-kit.pdf

Some international programmes (such as the ATP) allow industry to decide whether research should be undertaken at their own facilities with or without limited support from the science base. This allows business to undertake R&D closer to the commercialisation side of the innovation chain.

LINK is a programme aimed at enhancing the competitiveness of UK industry and the quality of life by supporting pre-competitive research in areas of strategic importance to the UK economy. LINK does not require firms to take the lead role, but requires project proposals to be a collaborative effort between firms and universities (like THRIP). One reason for this requirement is greater assurance that university ideas are adopted by the UK industry and not by foreign firms. The Programme promotes technology transfer out of the universities.

The EU's Framework Programme for Research and Technological Development provides financial assistance for pre-competitive research to trans-European consortia. Each project must have a minimum of two independent partners based in two different member states. The addition of a geographical element to the eligibility criteria reflects the Programme's political objective of creating a united European research community. The average funding per project is €1.6 million. Different programmes have different averages. The Integrated Projects Programme receives on average a European Community (EC) contribution of €9.5 million for a period of four years.

3.3.3.3 Technologies and themes for funding

The Technology Partnerships Canada (TPC) Programme in Canada provides funding for activities related to

- the development and demonstration of products, processes, and technologies (including research, development and technology commercialisation; sustaining technology; quality management; and technology integration and acquisition);
- pre-production to develop production capabilities; and
- studies on potential projects or the identification and assessment of strategic technology opportunities.

In contrast to the American and Canadian hybrid programmes, the **UK's LINK Scheme and Finland's TEKES** (the Finnish funding agency for technology and innovation) favour pre-selected themes. Programme areas in Finland included

- planning and manufacturing technology for electronics;
- computer-integrated manufacturing technology;
- construction technology;
- mining technology; and
- pulp and paper technology.

In summary it should be noted that programmes that are open to all technologies may be more responsive to where industry wishes to go and more flexible in responding to changes in the marketplace. In the same vein, a programme that limits its funding to pre-selected technologies may be less flexible in responding to changes in the marketplace, but may on the other hand benefit the nation by concentrating a critical mass of funding in

specific technology areas that meet particular national goals. THRIP belongs to the former category of funding programme that allows the possibility of funding for any type of technology.

3.3.3.4 Selection of projects

The literature study shows that all comparable programmes make use of formal assessment and selection approaches.

T**he Advanced Technology Programme (ATP)** has a formalised, peer-review process for selecting projects. Selection criteria and application guidelines are published in a booklet called the Proposal Preparation Kit, which is updated, re-issued periodically and widely disseminated.

A selection board composed of technologists from government laboratories and agencies, business experts, and economists is established for each announced competition. Each project proposal is reviewed in terms of the following broad aspects:

- Strength of its plan to pursue high-risk research;
- Its potential of delivering broad-based economic benefits to the nation and plans for diffusing results and bringing technologies developed during the project to commercial fruition;
- The proposed organisational structure to accomplish project goals;
- Commitment to carry the research through to commercialisation; and
- Experience and qualifications.

The board does not consider geographic balance, political concerns, and company relationships with staff or other factors in its decision-making process. It only considers the “official” selection criteria which are as follows:

- Scientific and technological merit (50%):
  This selection criterion has three critical components: (1) technical innovation, (2) technical risk with evidence of scientific feasibility and (3) technical plan.
- Potential for broad-based economic benefits (50 %:
  This selection criterion has three critical components: (1) national economic benefits, (2) need for ATP funding and (3) pathway to economic benefits

The Board chooses projects that score highest against these published selection criteria to receive financial assistance awards.

The EU’s multi-annual Framework Programme encompasses several thematic programmes. Applicants submit proposals to specific programme announcements. A step-by-step published guide provides applicants with general information on the submission and selection process.

Proposal evaluators are given a set of formal, established criteria against which proposed

projects are reviewed[4].

It should be noted that generally, excellence is the major criterion of evaluation. It is applied to the evaluation of both the Principal Investigator and the research project. Evaluation questions to this effect include:

- To what extent are the achievements and publications of the Principal Investigator ground breaking and demonstrative of independent creative thinking and capacity to go significantly beyond the state of the art?
- To what extent does the proposed research address important challenges at the frontiers of the field(s) addressed?

Although the Framework Programme does not require a plan for future commercialisation as part of the proposal, it still provides funding to projects that are aimed at the following:

- Creation of new technologies;
- Training and mobility of researchers; and
- Establishment of standards and measurements.

Another international example, the **Linkage Projects in Australia** use the following three selection criteria:

- Investigator's track record and capacity (20%);
- Project content (55%); and
- Nature of alliance, commitment and budget (25%) (ARC, 2010).

The maximum funding per project is $500 000 per calendar year. In exceptional circumstances, the Australian Research Council (ARC) is prepared to consider higher funding levels of up to $2 million per year

The literature review indicates that most international programmes have a limited number of selection criteria for the assessment of applications. In contrast, THRIP's MCDM identifies seven hurdles and 18 criteria, which are divided to sub-criteria.

A summary of the comparison of THRIP with some international programmes is presented in **Table 5** (on pp. 38 and 39).

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[4] Available at: http://ec.europa.eu/research/participants/portal/ShowDoc/Extensions+Repository/General+Documentation/Specific+guidelines/ERC+specific+guidelines/erc-guide-for-applicants-stg_en.pdf

Table 5: Comparative features of THRIP and its analogues*

Features	THRIP	Canada Technology Partnerships Canada (TPC)[5]	China Key Technologies R&D	EU Framework Programme[6]	Finland Tekes	UK LINK Scheme	USA Advanced Technology Programme[5]
Programme duration	1992 to present	1996 to present	1982 to present	1984 to present	1983 to present	1988 to present	1988 to 2007
Mission	Technology for competitive industry and highly skilled researchers	Encourage economic growth and create jobs, specifically to help companies develop new products for export	Technical upgrading and restructuring of industries and public welfare	Develop European science and technology capability and to meet other objectives	Stimulate economic growth	Enhance the competitive-ness of the UK industry and the quality of life	Stimulate economic growth and accelerate the commercialisation of technologies
Technical scope (Is the project open to all technologies?) **Is it a pre-selected list or a hybrid?**	Open to all technologies	Hybrid • Pre-selected: aerospace & defence; environmental & enabling technologies • Open to technologies that can create new industries	Pre-selected list	Pre-selected list	Pre-selected list	Pre-selected list	Hybrid • General competitions open to all • Focused competitions fund specific technology areas • All technologies must be high risk and enabling

[5] See Section 3.3 for a discussion of some of the table entries. See also, e.g. http://www.atp.nist.gov/atp/kit-04/final-kit.pdf. A new, successor programme, called the National Institute of Standards and Technology (NIST) Technology Innovation Programme, was enacted. The Technology Innovation Programme (TIP) was established for the purpose of assisting American businesses and HEIs or other organisations, such as national laboratories and non-profit research institutions, to support, promote, and accelerate innovation in the USA through high-risk, high-reward research in areas of critical national need.

[5] See, e.g. at https://www.ic.gc.ca/eic/site/ito-oti.nsf/eng/h_00641.html

[6] see, e.g. *http://ec.europa.eu/research/participants/portal/ShowDoc/Extensions+Repository/General+documentation/Specific+guidelines/ERC+specific+guidelines/erc-guide- for-applicants-stg_en.pdf*

Features	THRIP	Canada Technology Partnerships Canada (TPC)	China Key Technologies R&D	EU Framework Programme	Finland Tekes	UK LINK Scheme	USA Advanced Technology Programme
Who leads?	Either industry or university	Either industry or university	Either industry or university	Industry	Industry	Either industry or university	Industry
Nature of research	All; there is no limitation on the type of research to be supported	Close to product development	All types of R&D	Beyond basic science, prior to product development	Beyond basic science, prior to product development	Mainly prior to product development	Beyond basic science, prior to product development
Formal or informal selection process	Formal	Formal	Formal	Formal	Formal	Formal	Formal
Cost-share requirement	THRIP: large company 1:2 THRIP: SME 1:1 THRIP: SME B-BBEE 2:1	Typically 70% to 75% of total project costs	Comprehensive coverage according to needs	Minimum 50% for industry, 0% for university partners	Minimum 50% of total project costs	Minimum 50% of total project costs	If it is a single proposer, 100% of indirect costs. If it is a large business, minimum 50% of total project costs. If it is a joint venture, greater than 50% of total project costs.

Note: * After Chang (1998)

3.3.4 Summary

In summary, the international overview shows that THRIP follows international best practice. Many countries in the world develop programmes cultivating utilisation of research in the science basis and promoting collaborative efforts.

In contrast to other programmes abroad, THRIP has an exceedingly large number of objectives. International good practice suggests a low number of objectives/criteria.

An additional observation is that a number of international programmes (for example, ATP) provide flexibility and allow business organisations to decide whether the required research could be undertaken in their own facilities with or without limited support from the science base. Such an approach gives the opportunity to the business stakeholders to undertake R&D closer to the commercialisation side of the innovation chain.

3.4 Innovation and technology support in South Africa

South Africa traditionally has a pluralistic system of governance of its national system of innovation (NSI). In a pluralistic system, government departments receive an appropriation and decide how much money to spend on research and on its various elements. No supervision or co-ordination is present and therefore science and innovation policies are the sum total of the activities of the various departments. Under such a system, the onus is on the individual government departments to ensure that their requirements for R&D are met.

Since the 1994 democratic elections, the government began a series of initiatives to transform the NSI and to ensure that it could be benchmarked favourably against its peer countries (for overviews see: OECD, 2007; Marais and Pienaar, 2010; Kraemer-Mbula and Pogue, 2012; and DST, 2012). Some of the highlights of the period after 1994 are the following:

- The creation of a separate line department, namely the DST;
- The publication of the *White Paper on Science and Technology* in 1996;
- The publication of the *National R&D Strategy* in 2002;
- The establishment of organisations supporting technology transfer;
- Commercialisation (GODISA and Tshumisano Trusts) as well direct support for R&D within performing institutions (the Innovation Fund and the Technology and Human Resources for Industry Programme); and
- The introduction of a research and development tax deduction system in 2006.

More recently, the *Ten Year Innovation Plan* was published in 2007 and the Technology Innovation Agency (TIA) and the South African National Space Agency (SANSA) were established during 2008. The Intellectual Property Rights from Publicly Financed Research and Development Act, 2008 (Act No 51 of 2008) was also promulgated in 2008 with the aim to promote patenting in the country.

Similarly, a number of policies have been introduced. Examples include "*The new growth path: the framework*" (2010), the "*Accelerated and Shared Growth Initiative for South Africa*" (AsgiSA, 2006), and "*The National Industrial Policy Framework"* (NIPF, 2007) (**the dti**, 2007).

3.4.1. Manufacturing sector

It is important to describe briefly the state of the country's manufacturing sector. South Africa and sub-Saharan Africa are small contributors in the international manufacturing activities. The United Nations Industrial Development Organization (UNIDO) report (2011) shows that sub-Saharan Africa's major contribution (among the developing regions) is in printing and publishing 1.8% and food and beverages 1.7% of the world value added during 2009. For comparison Latin America was contributing 31.1% in printing and publishing and 27.4% in food and beverages; Asia contributed 74.2% in printing and publishing and 67.5% in food and beverages.

Similarly UNIDO (2011) developed the Competitive Industrial Performance index in order to benchmark national industrial performance. The Index is made out of 6 variables: manufacturing value added (MVA) per capita; manufactured exports per capita; share in world MVA; share in world manufactured exports; share of MVA in GDP and the share of medium- and high-technology activities in MVA; and share of manufactured exports in total exports and the share of medium- and high-technology products in manufactured exports. In both years, the overall leaders were Singapore, the United States, and Germany. South Africa was ranked 45 in 2005 and 49 in 2009.

3.4.2 The Department of Trade and Industry (the dti) policy instruments

The two government departments that are most supportive of research, technology and innovation in the country are those of Trade and Industry; and Science and Technology.

This section offers a brief overview of the major **dti** policy instruments that support technology in the country and that are directly and indirectly relevant to THRIP stakeholders i.e., the research community and industry (**the dti**, 2012).

THRIP, as described in the preceding sections, is a partnership programme that is funded by **the dti** and managed by the NRF.

THRIP promotes partnerships in pre-commercial research between business and the public-funded research base, including universities and research institutions. **The dti** annually contributes approximately R150 million to the Programme.

The **Support Programme for Industrial Innovation** (SPII) is designed to promote and assist technology development in the South African industry. It is an innovation support programme supported by **the dti** and administered by the Industrial Development Corporation (IDC). The Programme consists of three schemes:

- **The Product Process Development Scheme** provides financial assistance of between 50% and 85% (depending on the extent of B-BBEE ownership) of the total qualifying costs incurred in pre-competitive development activity – for small, very small and micro firms during the technical development stage (with a maximum grant of R2 million per project).
- **The Matching Scheme** also targets SMMEs (medium firms are not included in the Product Process Development Scheme). Financial assistance consists of a 50% to 75% grant with no payback, for innovative development of new products and processes (maximum grant of R5 million).
- **The Partnership Scheme** is open to all companies. Funds are provided in the form of a conditionally repayable grant of 50% (minimum grant of R3 million) of the qualifying cost incurred during development activity – repayable on successful commercialisation of the project.

The funds dispersed by SPII during 2010 and 2011 were just short of R50 million.

the dti established the **Strategic Industrial Projects (SIP)** to encourage investments into South African industry from both local and foreign investors. Its primary aim is "to significantly contribute to the growth, development and competitiveness of specific industry sectors by providing industrial investment allowances, in the form of tax relief, to qualifying industrial projects. Emanating from this industrial investment to South Africa is the key objective to create much-needed employment opportunities and involve the full spectrum of the country's economic citizenry in the benefits thereof" (**the dti**, 2012a). As technology can be acquired through equipment acquisition (in contrast to tacit knowledge), the Programme assists in acquiring equipment technology.

The **Manufacturing Investment Programme (MIP)** is a reimbursable cash grant for local and foreign-owned manufacturers who wish to establish a new production facility, expand an existing production facility, or upgrade an existing facility in the clothing and textiles sector. Benefits are investment grants of 15% to 30% of the investment cost of qualifying assets (machinery and equipment, buildings and commercial vehicles) for new establishments or expansions. The Programme assists in acquiring equipment technology.

The **Manufacturing Competitiveness Enhancement Programme (MCEP)** aims to encourage enterprises to upgrade their production facilities, processes, products and up-skill workers. It distinguishes two schemes – the production incentive scheme and loan facilities. Under the Production Incentive (PI) scheme, applicants can use the full benefit as either an upgrade grant facility or an interest subsidy facility, or a combination of both.

A benefit, equal to 10% for the year ending March 2011, of a company's Manufacturing Value Addition (MVA). The Programme assists in acquiring embodied in equipment technology.

The **Seda Technology Programme (STP)** offers up to R600 000 for tools, machinery and equipment on a 35:65 cost-sharing basis (contribution by **the dti** is 35%, contribution by the enterprise is 65%. The Programme assists in acquiring equipment and technology.

The **Automotive Investment Scheme (AIS)** is an incentive designed to grow and develop the automotive sector through investment in new and/or replacement models and components that will increase plant production volumes, sustain employment and/or strengthen the automotive value chain. The AIS provides for a taxable cash grant of 20% of the value of qualifying investment in productive assets, as approved by **the dti**. An additional taxable cash grant of 5% to 10% may be made available for projects that significantly contribute to the development of the automotive sector.

The **Black Business Supplier Development Programme (BBSDP)** provides a grant to a maximum of R1 000 000 (R800 000 maximum for tools, machinery and equipment and R200 000 maximum for eligible enterprises (SMMEs) to improve their corporate governance, management, marketing, productivity and use of modern technology).

Section 12I Tax Allowance Incentive (12I TAI) is designed to support Greenfield investments, being new industrial projects that utilise only new and unused manufacturing assets, as well as Brownfield investments, being expansions or upgrades of existing industrial projects.

The new incentive offers support for both capital investment and training. The incentives are structured as tax allowances.

3.4.3 The Department of Science and Technology (DST) policy instruments

The DST developed the **Advanced Manufacturing Technology Strategy (AMTS)** during 2002 which was adopted in 2003 (DST, 2003). The strategy identified a number of technologies of critical importance. These technologies are advanced materials; product technologies; production technologies; logistics; cleaner production technologies; ICT in manufacturing; SMMEs development; and standards, quality, accreditation and metrology technology issues.

The strategy argued that implementation will be achieved through a combination of centres of innovation, innovation networks and specific initiatives or projects. The report identified existing centres – Automotive Industry Development Centre at the Council for Scientific and Industrial Research (CSIR), the National Product Development Centre at (CSIR) – and suggested the establishment of the Logistics Innovation Centre and the National Textile and Clothing Innovation Centre. Similarly, it identified a number of networks and special projects including projects like aluminium, magnesium and titanium light metals development; coating technology innovation, including paints and thin films with a focus on nanotechnology and others.

During 2007, it was announced that R16 million was allocated to establish 10 fabrication laboratories, also known as "FabLabs", around the country. These labs provide disadvantaged communities with opportunities in the design, testing and fabrication process. FabLabs are a state-of-the-art resource venue aimed at promoting cutting-edge design, product development and process technologies for crafters and designers.

During 2009, Deputy Minister Hanekom reported the following as successes of the AMTS:

- The Smart Factory project is offering small, medium enterprises (SMEs) a low-cost measurement and reporting system that will improve the efficiency of their manufacturing processes and lead to improved quality;
- Good progress has also been made in developing the capability to produce high-quality castings in titanium alloys for aerospace applications;
- Some 25 doctoral degree (PhD) and 60 master's degree (MSc) students registered for degrees. One PhD student and 14 MSc students have already graduated.
- Two (2) external reviews of the projects in the Advanced Production Technologies Programme and in fibre-reinforced composites were conducted. Both these reviews have reported positively on the quality of the work and focus areas of the projects.[6]

The DST Annual Report 2010/11 stated, inter alia, that it had invested over R300 million in the Advanced Manufacturing Technology Strategy in the previous seven years, primarily in the form of research grants for flagship programmes and human capital development (DST 2011).

Discussions with officials of the DST and the Technology Innovation Agency (TIA) identified that most existing AMTS Programmes were phased out during 2012 and that during 2013 the available budget was only R35 million. This amount is expected to be invested on unmanned aerial vehicles and materials for agro-processing.

Another DST initiative is the **Centres of Excellence (CoE)**. These centres have been created in South Africa, to stimulate the sustained distinction in research, while generating highly qualified human resource capacity in order to impact national and global knowledge and innovation generation. The following seven centres have been established in South Africa:

- The Centre of Excellence in Biomedical Tuberculosis (TB) Research
- The Centre of Excellence in Invasion Biology
- The Centre of Excellence in Strong Materials
- The Centre of Excellence in Birds as Keys to Biodiversity Conservation at the Percy Fitzpatrick Institute
- The Centre of Excellence in Catalysis
- The Centre of Excellence in Tree Health Biotechnology at the Forestry and Agricultural Biotechnology Institute (FABI) at the University of Pretoria
- The Centre of Excellence in Epidemiological Modelling and Analysis

The **South African Research Chairs Initiative**, developed by DST and NRF, aims to attract and retain the best and the brightest to South African higher education institutions.

[6] Address by Deputy Minister of Science and Technology Derek Hanekom, at the 2009 Advanced Manufacturing Technology Strategy (AMTS) Annual Symposium". Available at http://www.info.gov.za/speech/ DynamicAction?pageid=461&sid=3947&tid=4092.

Currently, 192 research chairs have been established in research and knowledge areas that are important for South African needs and priorities covering science, engineering, social sciences and humanities.

During the mid-2000s, the DST allocated resources for the **South African Nanotechnology Strategy.** The DST established two national nanotechnology innovation centres (NIC) in 2007, which are housed at the CSIR and Mintek. The National Centre for Nano-Structured Materials at the CSIR focuses on research into energy and materials. The centre at Mintek is concerned with health, mining and minerals, and water.

The **NRF Nanotechnology Flagship Programmes** aim to support platform projects in the field of nanoscience and nanotechnology over a three-year period. The *NRF (2007/08) Nanotechnology Flagship Manual* states that: "Its purpose is to demonstrate the benefits of nanotechnology and nanoscience and its impact on some of the key challenges facing South Africa". The Programme invested just over R60 million in nanotechnology (excluding R30 million in relevant research chairs) during 2010. The Programme aims to develop expertise and capacity in the field of nanotechnology.

The **Technology Innovation Agency (TIA**) is a new public entity that aims to address the lack of home-grown technology and commercialisation available to South African firms. It was created by the TIA Act (No 26 of 2008) and falls under the management of the DST. Existing entities that have been incorporated into the TIA are the Biotechnology Regional Innovation Centres (BRICs), the Innovation Fund, AMTS and the Tshumisano Trust. These entities ceased to exist. TIA has just activated certain programmes and it is not clear on their impact and direction. It should be emphasised that BRICs were the only vertical Programme in the country, supporting biotechnology across the whole of the innovation chain.

The **Industry Innovation Partnerships – Sector Specific Innovation Funds** (SIF) is also a new DST initiative aiming to support research and development in the private sector on a co-funding mode (government-industry). A characteristic of the initiative is that the benefits from the research outcomes will accrue to the whole sector as opposed to a single entity or company.

3.4.3 Summary and comparative assessment

The majority of the list of incentives reflected in **Table 6** (p. 46) do not promote technology directly, but indirectly as an embodiment to new equipment and facilities. Some incentives are aimed rather at the promotion of basic research than technology development. It should be noted that there are no incentives to specifically facilitate indigenous technology development.

Most of the incentives are in the form of grants, as opposed to tax incentives.
Collaboration incentives are in the minority and in most technology development programmes universities are not involved directly.

Table 6: South African incentives and their characteristics

Programme	Collaboration	Funding mode	Sectors	Industry involvement	Technological support	University involvement
THRIP	Yes	Grant	All	Yes	Direct	Yes
SPII	No	Grant	All	Yes	Direct	No
SIP	No	Tax	All	Yes	Embodied	No
12I TAI	No	Tax	All	Yes	Embodied	No
MIP	No	Grant	All	Yes	Embodied	No
MCEP	No	Grant	Specific	Yes	Embodied	No
SEDA STP	No	Grant	All	Yes	Embodied	No
BBSDP	No	Grant	All	Yes	Embodied	No
AIS	No	Grant	Specific	Yes	Embodied	No
AMTS	No**	Grant	All*	Yes	Direct	Yes
Nanotech	No	Grant	All*	No	Direct	Yes
CoE	Yes**	Grant	Specific	No	Basic Research.	Yes
Research chairs	No	Grant	Specific	No	Basic Research.	Yes

* Specific generic technologies
** No co-funding is required

Most of the incentives are horizontal and therefore apply to all sectors. Horizontal policies (i.e., support for all disciplines, sectors and products) are a general characteristic of incentives in the country's national innovation system.

However, horizontal policies may not have a direct impact on the effectiveness of the production system and, of course, they do not have the capability to create priorities and new industries.

Although Finland, for instance, was traditionally relying more on horizontal policy to build up the knowledge base, the country has concentrated its resources for basic research in bio-centres since the mid-1990s. During the 2000s Finland also introduced a growing number of biotechnology specific programmes (European Commission, 2003).

In the research system, the use of horizontal instruments affects all scientific disciplines by definition. Therefore, strong/overemphasised disciplines have the opportunity to improve their dominance in the research system. For example, overemphasis may be the result of the availability of more researchers in a discipline. As the policy instrument distributes incentives equally to all researchers, the research activity of the overemphasised discipline has the potential to strengthen even further. The large number of researchers in the particular discipline has the potential to attract more postgraduate students and the marketing is easier for larger disciplines. Strength brings further strength.

The incentives have relatively limited budgets. For example, the South African government spends less than one fifth on nanotechnology compared to the governments of India, Italy, South Korea and others. After TIA took over the biotechnology regional innovation centres, there is currently no programme that supports biotechnology in the country. Similarly, the AMTS has a limited budget while in the USA, the relevant Programme aims to provide more than $1 billion.

It should be noted that the South African list of incentives (policy instruments) is relatively short compared to those in other countries. For example, the main innovation related programmes of **the dti** are THRIP and SPII. In the European Union (Europe Innova, 2008), each country has, on average, more than 50 programmes/incentives that support technology development.

The above are confirmed in the recently published National Advisory Council on Innovation report, *South African Science and Technology Indicators 2013* (NACI, 2014), which shows that the country should double or triple the size of its incentives to business in order to be comparable with the rest of the world.

From the above, it is concluded that THRIP is unique in the South African context. Some of its unique characteristics are as follows:

- It provides incentives for local technology development;
- It promotes collaboration among the various stakeholders of the innovation system;
- It provides a prioritisation mechanism for the higher education sector based on industrial needs;
- It is versatile that can support different size challenges (small or big grants);
- Its priorities are industry-based; and
- It is open to all qualifying organisations (a number of incentives are structured to benefit particular institutions and technologies, for example, the Nanotechnology Programme).

A possible weakness is that as THRIP supports only technologies and challenges from the existing industrial sector because it is demand based. The Programme is not designed to develop technologies for new industries. This and related implications are developed further as recommendation in the final chapter.

4. Theory of Change for THRIP

4.1 Introduction

A theory of change can be described as a theory of how and why an initiative, such as a policy intervention, programme, or strategic development should be expected to work (cf. e.g., the useful overview by Stein and Valters, 2012). In the present case, the theory of change is represented in the form of a critical and dynamic map of constituent components and processes (at macro, meso and micro-levels of the Programme), required to attain a long-term goal of, e.g., in the case of THRIP, producing a flow of highly skilled researchers and managers in technology. The map shows the types of programme interventions required to bring about the intended change and outcomes.

The stream of work leading to the use of theories of change in evaluation can be traced to the Kirkpatrick's "Four Levels of Learning Evaluation Model" (Kirkpatrick, 1959). Further progress in the development of thinking on theory of change included Stufflebeam's CIPP (context, input, processes and products) (Stufflebeam, 2003) and the widely used logical frameworks (log-frames), which set out causal chains usually consisting of inputs, activities, outputs and outcomes coupled to long-term goals. Stakeholders value theories of change as part of programme planning and evaluation, such as the present one, because they create a commonly understood vision of the long-term goals; how they will be reached; and what will be used to measure progress along the way. In an evaluation such as this one, a theory of change further forms the basis for the operationalisation of implementation and impact measures as well recommendations on the further development of a programme.

4.2 Development of the THRIP theory of change

There was no theory of change posited at the launch of the THRIP, one of the main reasons being that putting a theory of change at the centre of a support – and evaluation – programme was a relatively new development in evaluation theory and methodology at the time. Against this background, the analysis of the mission, objectives and processes of THRIP presented in Chapter 3 were utilised to develop a theory of change for THRIP as it was functioning at the time of the evaluation. **Figure 5** (p. 53) shows the process from the THRIP inputs to the final objective of competitiveness, economic growth and employment.

The THRIP incentives promote the creation of partnerships among the various stakeholders (such as firms, universities, and SMMEs). THRIP personnel take care of marketing, receiving proposals, assessing them; informing stakeholders about results and monitoring results. Funds are transferred to universities to support collaborative research and development and to support postgraduates.

The partnerships in turn accelerate R&D through a number of mechanisms. For example, partnerships may expand the R&D scope of projects, make technical risk more acceptable, and increase interest in long-term research. These may be considered underlying assumptions.

These mechanisms lead to technology development, which can be manifested in research publications, patents, models, algorithms and prototypes.

The next step includes outcomes such as organisation credibility, availability of additional resources and increased collaborative propensities in the short term. In the intermediate future, commercial benefits such as new products, new processes, productivity gains and relevant licensing appear. The commercial benefits lead to competitive participants and firm growth and then to competitive industry and economic growth.

It is indicated that the "initial collaboration" may lead into increasing collaborative propensities in general. For example, the participants may collaborate on different projects that are not supported or are not in the THRIP domain.

The existing theory of change underlying THRIP as summarised in **Figure 4** (p. 50), indicates that the direct financial support of THRIP is not extended beyond the outputs column (for example, funded projects and postgraduates). This means that THRIP does not control the absorption and transformation of outputs into outcomes. If industry does not see the benefits of transforming the outputs into outcomes, the process may stop at this stage. In a number of countries, governments offer incentives to facilitate this transformation (outputs to outcomes).

A critical issue that has to be clarified how competitive participants lead to competitive industry. Private firms' R&D activities generate widespread benefits, not only for the particular firm, but also for other firms, consumers and society at large. For example, other firms can benefit by activities such as the "reverse engineering" of products or by monitoring a particular firm's abandonment of a research line and its acceptance of the signal that the line is unproductive. This monitoring saves firms the expense of discovering this themselves.

As a result, the overall economic value to society often exceeds the economic benefits innovative firms enjoy because of their research efforts. Economists describe a positive externality or spill-over as the excess of the social rate of return over the private rate of return that innovating firms enjoy. These spill-overs imply that private firms will invest less in research than is socially desirable, with the result that some desirable research projects will not be undertaken and others will be undertaken more slowly, later, or on a smaller scale than would be socially desirable.

These spill-overs flow through a number of distinct channels. First, spill-overs occur because the workings of the market or markets for an innovative product or process create benefits for consumers and non-innovating firms ("market spill-overs"). Second, spill-overs occur because *knowledge* created by one firm is typically not contained within that firm, and thereby creates value for other firms and other firms'' customers ("knowledge spill-overs"). Finally, because the profitability of a set of interrelated and interdependent technologies may depend on achieving a critical mass of success, each firm pursuing one or more of these related technologies creates critical economic benefits for other firms and their customers (network spill-overs) [7]

[7] Jaffe BA (1996) Economic Analysis of Research Spill overs : Implications for the Advanced Technology

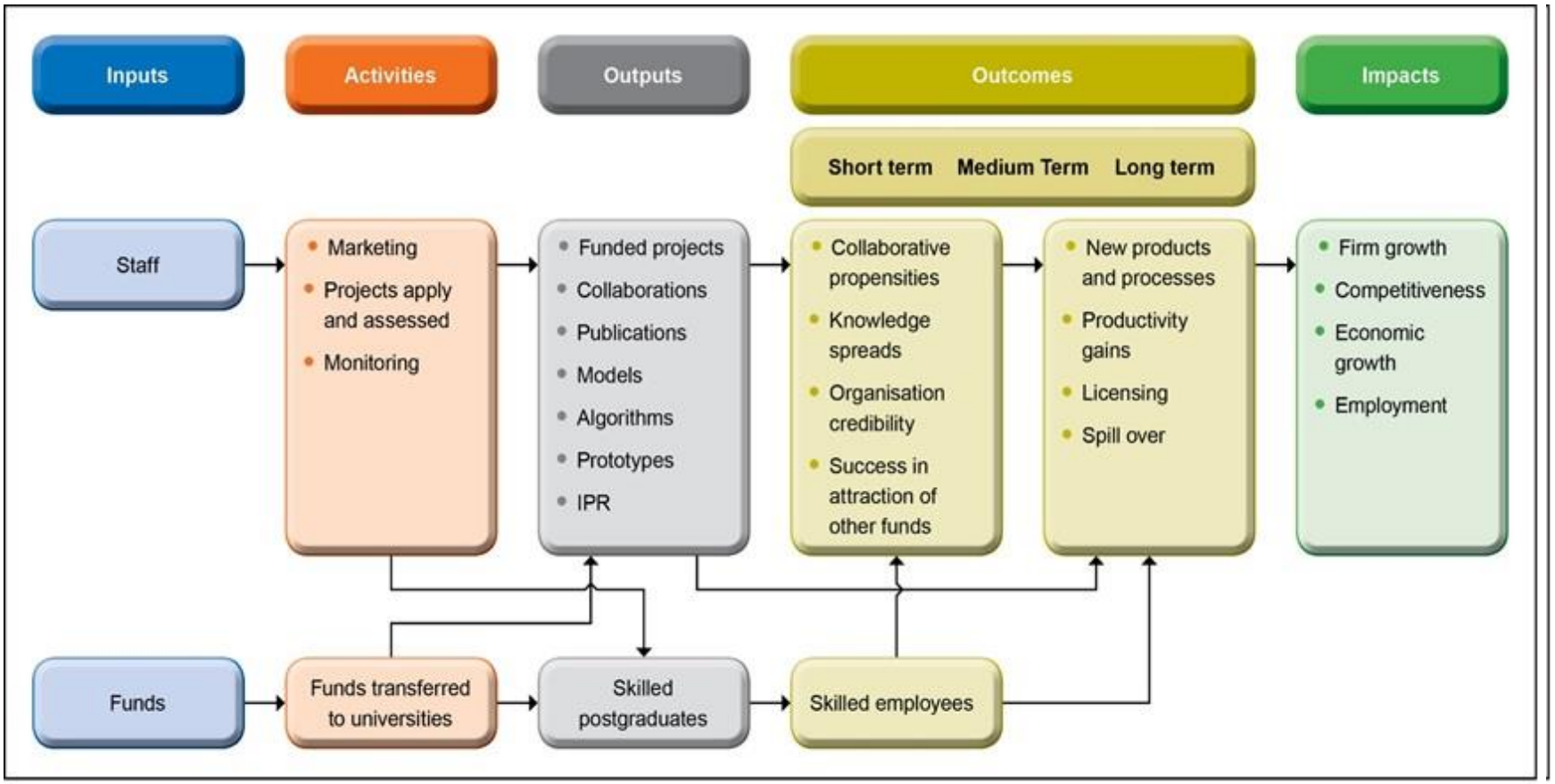

Figure 4: Existing theory of change - Pathway of change

THRIP's structure brings together more than one firm and scientific entity, which propagates those spill-overs.

The literature review showed that the ATP in the USA allows industrial partners to be supported to continue with the commercialisation of research without participation of universities or research institutes. Hence, the Programme includes, as part of its operational mechanism, the requirement that all projects have well defined goals and identified pathways to technical and economic impacts.

The amended or proposed theory of change, reflected in **Figure 5** (p. 53) shows how THRIP can be modified to support the commercialisation of the developed knowledge. THRIP will provide financial support for pilot scale activities, pre-production facilities, technology integration and similar projects, which will create direct long-term outcomes. International practice shows that governments support between 25% and 40% of such activities with the ratio increasing when more than one industrial firm participate in the effort.

4.3 Log-frame for THRIP

There is general agreement in the literature that a log-frame is normally more specific than the broader theory of change that often reflects multiple pathways to change (e.g. Funnell and Rogers, 2011).

In the present case, the THRIP theory of change (see Section 4.2) was converted to a log-frame for THRIP, as it stood at the time of the present evaluation, by explicating the intervention logic; the indicators of the key variables (inputs, activities, outputs, outcomes and impact); the verification sources for each; and the assumptions underpinning each variable.

As such the log-frame can be looked upon as a useful operationalisation for the monitoring and evaluation of a programme.

The design of the log-frame closely followed the model developed for Business Process Services recommended by DPME and is represented in **Table 7** (p. 54).

It should be emphasised that THRIP does not provide incentives for commercialisation and does not support the full innovation chain. Hence, according to log-frames principles, the Programme cannot be held accountable for that part of the innovation chain.

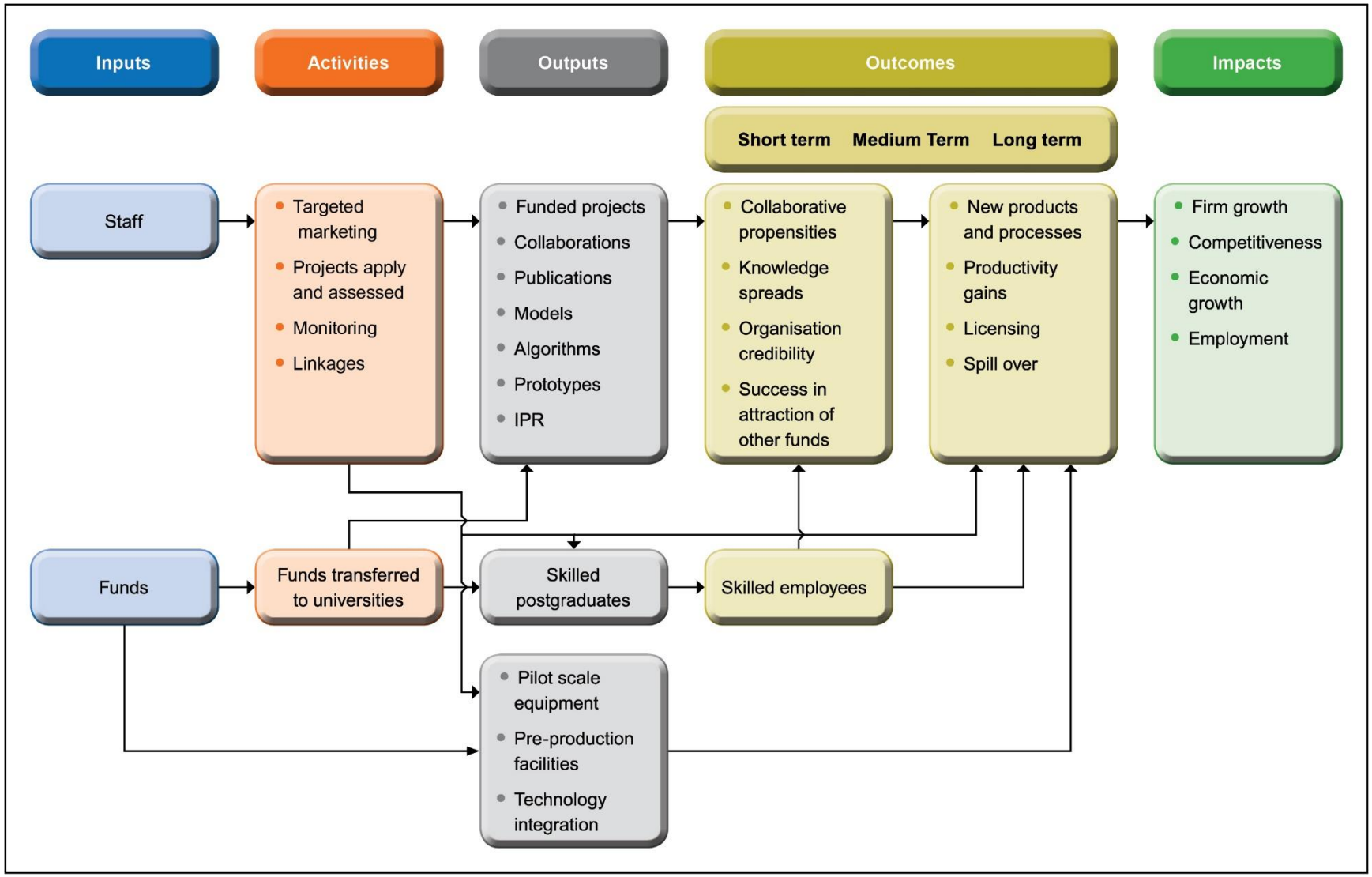

Figure 5: Proposed theory of change including support for activities closer to commercialisation

Table 7: Proposed THRIP Log Frame

Programme description		Indicators	Verification sources	Assumptions
Overall objective	Competitive industry	Competitive Industrial Performance Index	UNIDO	
Programme purposes	Creation of R&D partnerships through co-funding	Number of partnerships/projects	Programme statistics[1]	• Partnerships are funded appropriately/fully • Research efforts are successful
	Development of skilled human resources	Number of postgraduates participating	Programme statistics	• Availability of appropriate graduates
Outputs 1	Funded projects Collaborations Publications Patents Algorithms Prototypes	Number of artefacts produced	Programme statistics	• Participation of good researchers
Outputs 2	Skilled postgraduates with industrial exposure	Number of postgraduates participated	Programme statistics	• Postgraduates are able to complete relevant studies on industrial topics
Outputs 3	Pilot scale equipment Pre-production facilities Technology integration	Numbers of pilots; pre-production facilities and integrated technologies	Programme statistics	• Research leads to the need for pre-production facilities
Outcomes	New products/processes/ services Productivity gains Firm growth Knowledge spread Spill-over effects Long term collaborations Availability of skilled human resources in industry	Outcomes in participating firms and in firms benefiting from spill-overs Availability of skilled human resources in industry	Monitoring statistics and evaluation exercises[2] Survey statistics	• Outputs are diffused in industry. • Availability of support in the next level of development (absorption) • Skilled human resources find employment in local industry
Impacts	Increased GDP Employment gains International competitiveness Improved quality of life	National and international statistics	National and international statistical offices	
Activities	Targeted marketing Application processing Monitoring Funding Linkage with other instruments	Projects supported Funding satisfaction Joint funding Partnership projects	Programme statistics Evaluation exercises	• Sound relationships and communication between THRIP staff, stakeholders and other instruments

Notes:

[1] Statistics supplied by the THRIP office and culled from official documents, such as the guide and other reports.

[2] Higher education and industrial partners' surveys

4.4 Conclusions

The first outcome of this review in general and this chapter in particular has been the development of a first theory of change that offers a rationale underlying THRIP's mission and attaining its goals as they existed at the time of this review. Inputs to this first theory of change consisted of an analysis of THRIP's mission, objectives and processes as well as the overview of international programmes similar to THRIP described in Chapter 3. The second outcome of this chapter is amendments to the THRIP theory of change that should reflect amendments recommended in the final chapter of the review. A third outcome of this chapter is the development of a log-frame that can be used for future evaluations of THRIP. It served in the design of the present evaluation and review.

The measurement instruments and indicators reported on in the next chapter can be looked upon as operationalisation of the THRIP theory of change and log-frame.

In general, THRIP's following of international good practice in the design and implementation of the Programme led to a sound theory of change approach. This approach was validated by means of a focus group of government officials (see section 5.5) who were first required to generate elements of a theory of change and were subsequently invited to comment on **Figure 5** (p. 53).

5. Evaluation of THRIP

The THRIP theory of change presented in the previous chapter (**Figure 5**, p. 53) offers a mapping of the factors, relationships and processes involved in THRIP and that had to be covered in this evaluation of the Programme. The THRIP log-frame presented in that same chapter (**Table 7**, p. 54) provides an overview of the type and format of information that was required to evaluate the implementation and impact of the Programme. Against this background, this chapter first provides a number of quantitative characteristics of the Programme, followed in Sections 5.2 and 5.3 by the empirical findings on stakeholder perceptions from two surveys that contained quantitative and qualitative items; as well as from a summary of the outcomes of a focus group conducted with representatives of **the dti**, DPME and the NRF.

5.1 Presentation of THRIP aggregate data

This section offers an overview of the structure of THRIP applications; funding and contributors to THRIP funding; cost effectiveness of the Programme; and outputs generated by the Programme. The information offered in this section was provided by NRF/THRIP officials intimately involved in the management and administration of the Programme; culled from official publications such as funding guides, annual and other reports; and obtained through interviews and enquires addressed to officials.

5.1.1 Structure of applications

Table 8 provides an overview of the applications THRIP received during the period 2001/02 to 2012/13. The number of funded applications peaked at 338 during 2006/07. Furthermore, the gap between received applications and funded applications appears to be increasing during recent years.

Table 8: THRIP: structure of applications

Financial year	Applications received	Funded applications	Large enterprises	SMMEs
2001/02	N/A	289	167	201
2002/03	N/A	251	156	197
2003/04	N/A	253	184	224
2004/05	N/A	268	154	198
2005/06	N/A	300	176	195
2006/07	N/A	338	161	210
2007/08	322	270	131	264
2008/09	260	240	106	207
2009/10	233	214	103	185
2010/11	286	235	104	178
2011/12	319	246	139	191
2012/13	347	276	102	198

Figure 6 shows that the number of participating large enterprises (e.g., EXXARO, SASOL, ESKOM, etc.) declined from 184 during 2003/04 to just above 100 during the most recent years. The number of SMMEs (e.g., GTron, Solar23, Sunshine Seedling Services, etc.) remained constant during the period.

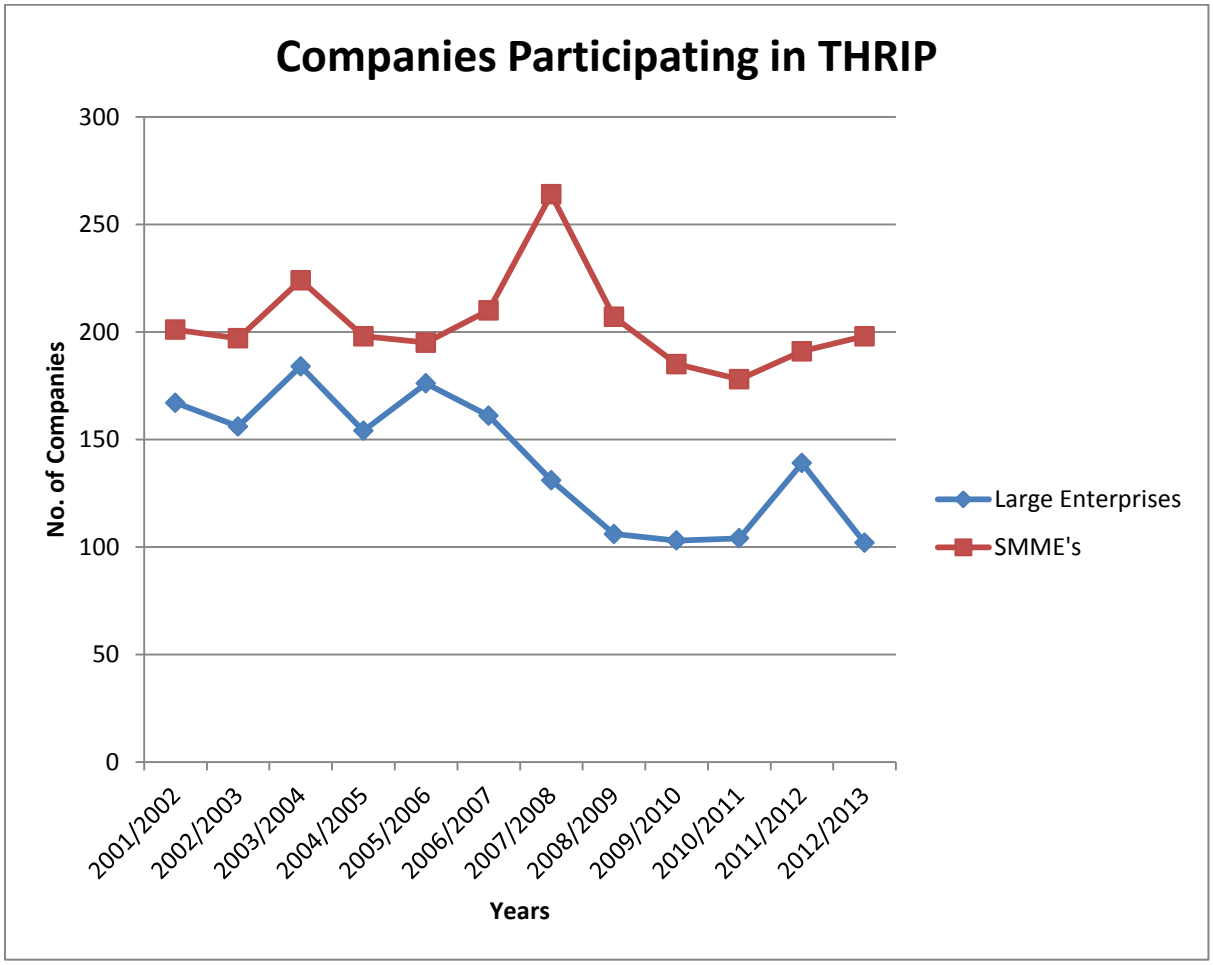

Figure 6: Companies participating in THRIP

5.1.2 Funding and contributors

Table 9 and **Figure 7** (both on p. 58) show the funding contributions of the various stakeholders. The THRIP contributions remained constant over the period at a level of below R150 million. The industry contributions show an increasing trend as does the contribution of the SMMEs. Participation of B-BBEE enterprises increased from 17 (2006/07) to 149 during 2012/13. It should be emphasised that the THRIP budget has remained at around R150 million for the last ten years. This means that, in real terms, the government contribution is almost half of the original value of ten years ago.

Table 9: Funding contributions

Financial year	THRIP contribution	Industry contribution	SMME contribution	
2001/02	R134 060 783	R165 339 929		
2002/03	R123 332 152	R173 689 753	R51 600 000	
2003/04	R148 016 684	R208 937 399		
2004/05	R121 720 288	R183 384 859		
2005/06	R117 151 533	R218 117 272		
2006/07	R135 176 363	R170 047 608	R21 320 749	
2007/08	R130 544 827	R163 015 526	R75 767 041	
2008/09	R138 930 275	R227 485 394	R58 821 448	
2009/10	R152 474 976	R233 278 370	R84 400 000	
2010/11	R139 972 000	R241 931 000	R83 300 000	
2011/12	R141 079 420	R208 216 823	R93 000 000	
2012/13	R148 900 000	R227 000 000		

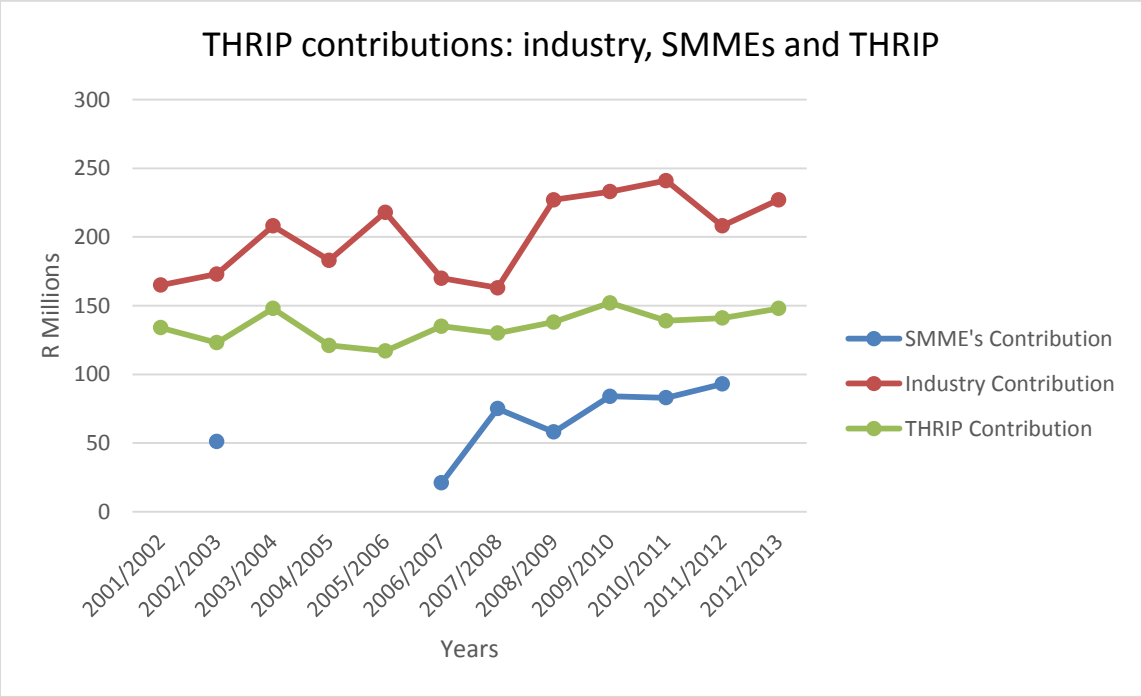

Figure 7: THRIP Contributions: Industry, SMMEs and THRIP

The NRF THRIP team identified the THRIP budget's decline in real terms as the most important constraint for the Programme. On the question "What could be done by **the dti** (or other agents such as the NRF, IDC, and TIA) to improve the performance of your Programme?" the NRF responded: "Availability of grant funding is required for THRIP as the projects' budgets are reduced due to limitations of funds. Continuation of this reduction or the decision not to fund some projects could de-motivate researchers from participating in THRIP". The NRF officials

mentioned that THRIP could easily absorb twice to three times its current budget. This issue is confirmed by the fact that THRIP is currently funding the successful projects only partially and a number of qualifying projects are not funded at all. A doubling of the Programme's funding will bring it in its initial levels in terms of purchasing power parity (value of money over time).

NRF provided lists of applications that involved at least two or more industrial partners. The list contained more than 230 applications. This indicates the character of research and the extent of dissemination of the THRIP results to industry. Knowledge and findings generated by THRIP projects appear to be distributed between the partnering firms and among others.

Table 10 shows the funding distribution to industrial clusters during 2011/12. Manufacturing is the largest sector absorbing just below 30% of the resources. Agriculture, Information and Communications Technology (ICT) and mining are following with smaller shares.

The distribution of funds can be attributed to the fact that THRIP is supported by **the dti** and the Programme in turn supports the priorities of **the dti**. As mining and agriculture take place in rural areas, these figures may be considered as the lowest boundaries of the benefits accruing to rural areas.

Table 10: THRIP funding (including industrial contribution): Distribution to industrial clusters

THRIP distribution to standard industrial clusters (2011/12)		
	Rand	**%**
Agriculture	49 960 594	14.3
Animals	16 291 337	4.7
Bioprocess	26 513 867	7.6
Business	6 891 198	2.0
Food	2 069 684	0.6
Forestry	19 572 091	5.6
Health	4 868 022	1.4
ICT	42 765 060	12.2
Manufacturing	104 417 511	29.9
Materials	9 280 581	2.7
Mining	42 627 975	12.2
Power	24 038 270	6.9
Total	**349 296 190**	**100**

Source: THRIP Annual Report 2011/12

5.1.3 Cost-effectiveness

The cost-effectiveness of THRIP can be gauged through determining the estimated overheads of the Programme.

Table 11 (p. 60) shows the share of operational funding on the disbursed funds for THRIP. As the disbursed funds remained constant over the period, and the operational funds increased (because of inflation, for example), the share of operational funds increased from 0.027 during 2003 to 0.077 during 2012.

Table 11: Operational funding as share of disbursed funds

Year	THRIP disbursed funds (R million)	Operational funding (R million)	Share of operational funds
2012	149	11.527	0.077
2011	141	9.856	0.070
2010	140	8.492	0.061
2009	139	7.984	0.057
2008	131	8.507	0.065
2007	131	6.186	0.047
2006	135	5.222	0.039
2005	117	4.754	0.041
2004	122	4.568	0.037
2003	148	3.971	0.027

For 2008/09, THRIP overheads were R8.5 million in a government budget of R131 million which means overheads of 6.5% (2008/09) per year. Discussions with NRF identified that THRIP operations, which make the Programme efficient, are embedded in the NRF infrastructure. It should be mentioned that there are economies of scale in programmatic activities and there is a need of a minimum number of staff. This minimum does not change proportionally to the invested resources.

> To the question "What are the advantages and shortcomings of the current modus operandi in terms of cost-effectiveness?" the NRF's officials responded: "THRIP shares its cost with other funding instruments at the NRF to reduce costs of administering research projects at funded institutions. These include sharing of administration staff, infrastructure and expertise required to administer THRIP projects. The challenge with THRIP is that it is more complicated than most funding instruments due to the involvement of companies. One of the shortcomings of THRIP is the fact that, due to the expensive nature of running a THRIP project, smaller projects are difficult to implement due to small budgets. Most are very short term and these end up having little contribution to THRIP objectives."

The estimated overheads of THRIP can be compared with those of SPII and AMTS. SPII overheads were R10 million for a budget of R68.4 million for 2008/09. Hence, the estimated overheads were 14.6%. Similarly, the AMTS overheads were 12.3% during 2008/09. It should also be noted that funding transfers to CSIR (for AMTS) also attracted Value-added Tax (VAT), which further increased the overheads. In summary, it appears that the THRIP overheads are approximately half of those of the other two programmes.

The THRIP overheads were also compared with those of the CRD in Canada (Science-Metrix, 2010). The THRIP overheads are of the same magnitude as its Canadian counterpart, even though the Canadian Programme has a bigger budget.

5.1.4 Outputs

Table 12 below shows the THRIP outputs. During the most recent years, the Programme produced approximately 30 patents per year and 1 000 research articles per year. Approximately 300 honours degree, 750 master's degree and 400 doctoral degree graduates are participating in the projects and gaining industrial relevant experience.

These outputs should be considered as satisfactory in comparison with other instruments. For example, the Department of Higher Education and Training funds universities, among others, according to the number of articles they produce. The current subsidy is R120 000 per article. Hence, the THRIP production of 1 000 articles can be valued at R120 million, and compares very favourably to the approximately R150 million of total annual government support to THRIP.

Table 12: THRIP outputs

Financial year	Patents (local and international)	Research articles	Honours degree graduates	Master's degree graduates	Doctoral degree students
2001/02	103	3 774	248	445	138
2002/03	128	3 916	193	427	158
2003/04	39	1 740	463	1 171	585
2004/05	39	1 151	169	1 126	564
2005/06	117	3 052	199	951	528
2006/07	30	1 780	487	1 427	665
2007/08	30	1 151	373	928	534
2008/09	19	993	303	888	548
2009/10	19	987	311	790	487
2010/11	22	1 081	268	774	381
2011/12	26	965	336	760	379
2012/13	32	1 282	218	695	368

The number of post-graduate students directly associated with THRIP over the past 12 years is worth highlighting.

Figure 8 (p. 62) shows that more than half of the graduates were involved in master's programmes (normally an average period of 2 years) and more than a quarter of the students were enrolled for their doctor's degrees (normally an average of 3 years).

The fact that the minority of the students were at the honour's level – the gateway to advanced studies - may be a reason for concern.

The number of students and the level of study is summarised in **Figure 8.**

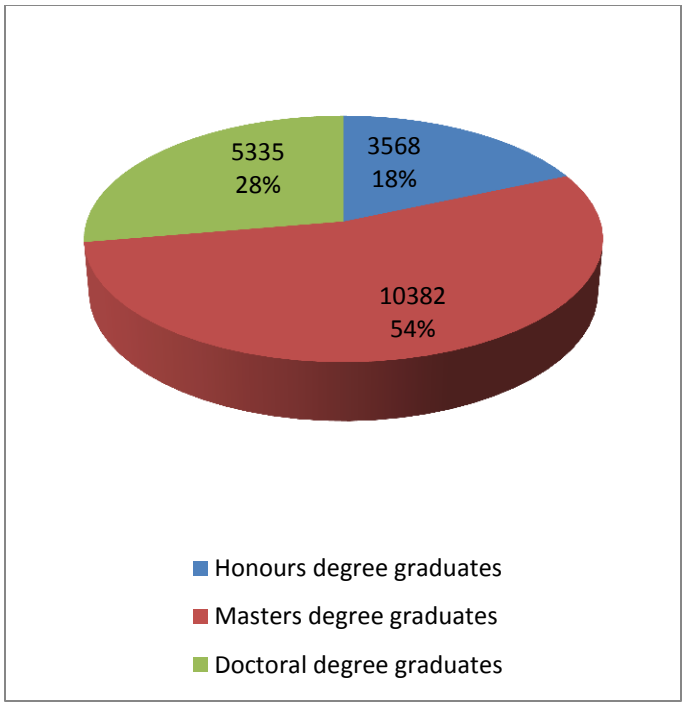

Figure 8: Profile of students involved in THRIP (2001/02-2012/13)

5.1.5 Conclusions

The Programme archives were used to present an overview of the main performance inputs and outputs of THRIP and from an assessment perspective a picture emerges that seems to be positive. The overview shows, first, that the Programme appears to be receiving an increasing number of applications even though the funded applications appear to have peaked during 2006/7. During the period examined (2001/2-2012/13) SMME participants were larger in number than large enterprises, for instance, during 2012/13 there were twice as many SMMEs as large organisations participating in the Programme. Manufacturing is the sector with the highest participation rate followed by agriculture, ICT and mining.

Secondly, and on the negative side, in real terms government funding (support) was on the decline.

Thirdly, a notably positive finding reported in this section is the Programme's outputs that show that during the most recent years, it produced approximately 30 patents and 1 000 research articles per year. Approximately 300 honours degree, 750 master's degree and 400 doctoral degree graduates were participating in the projects and gaining industrially relevant experience.

Finally, another positive finding concerns the estimate of the THRIP overheads (operating budget as percent of the government funding) that shows that these costs range between 6 and 7 percent during the most recent years. These percentages are competitive in comparison to

those of other local and international programmes. These conclusions are reflected in the recommendations offered in Chapter 6.

5.2 THRIP and the higher education sector

5.2.1 Introduction

This section of the chapter presents THRIP as it is perceived by the higher education stakeholders and provides an estimate of the Programme's impact through the higher education sector.

Box 1 presents an analysis of THRIP's impact on the economy through the higher education and economic interface. It is estimated that the total GDP generated from THRIP (the above-mentioned interface) is R508 million. This figure is very significant given that government only contributes approximately R150 million per year to the Programme. Furthermore, it is estimated that the Programme, in terms of employment, supported 2 290 jobs in the economy.

Box 1: Contribution of higher education institutions and THRIP to the economy

A recent research article in *the South African Journal of Science* (Pouris and Inglesi-Lotz., 2014) estimates the contribution of the country's higher education institutions in the country's economic growth and employment by considering the sector's economic outputs and employment creation. The article further considers additional output and employment created by the higher education institutions in other economic sectors through *secondary* or "knock-on" multiplier effects. Benefits from knowledge creation, maintenance and dissemination, and skilled graduates were not accounted for.

The article estimates that the higher education sector is producing value addition in the economy similar to those of the gold industry and hospitality sector. Furthermore, it is estimated that the total employment impact of the sector (direct and indirect) is 228 978 employees during 2009.

THRIP makes a direct contribution of approximately R400 million to universities per year (government and industry contributions).This is just above 1% of the universities income. Using the above figures, it can be estimated that the total GDP generated from THRIP is R508 million. The importance of the figure becomes profound when we take into account that the government during 2009/10 contributed R150 million to the Programme.

Similarly, taking into account that THRIP contributes 1% to the education sector's activities we can estimate that the Programme generates 2 290 jobs (according to 2009 data).

5.2.2 The survey: Higher Education

Surveys were undertaken among university stakeholders and industrial stakeholders. The emphasis was on universities as they have direct knowledge of the implementation of the Programme. The university questionnaire (see **Appendix A**) consisted of three sets of Likert-type scales (summated ratings) and nine open questions to which respondents could motivate and or elaborate on the structured items (the responses to the open questions were content-analysed by two analysts with extensive knowledge of THRIP and an engineering master's student; the results of the content analyses are selectively reported below). A sample of 110 principal investigators was randomly drawn from a list who has participated in THRIP and questionnaires were sent to them; five questionnaires failed to be delivered. Of the 105 valid questionnaires, 61 responses were received – a return rate of 58% (twelve respondents mentioned that they did not have corporate memory as their participation was many years earlier, leaving 49 questionnaires for further analysis). The institutional representation of the respondents was as follows: Universities: 38; Comprehensive Universities: 3; Universities of Technology: 4; and Science councils: 4.

The institutional profile of dispatched and returned questionnaires overlapped to a reasonable extent suggesting the external validity of the exercise. A number of respondents provided responses that, according to them, were based on a number of THRIP projects in which they had participated. The internal validity checks on the university questionnaire indicated a satisfactory degree of validity, e.g., a positive overlap between responses among selected Likert items and comments on relevant open items.

5.2.3 Results of the Higher Education survey

Table 13 summarises the responses of the universities related to the effects of THRIP on a number of variables. The table shows the average rating and the median. The median shows the rating of at least 50% of the responses.

Table 13: THRIP effects

How do you rate THRIP's effect on the following (high – 5, average – 3, low – 1)?			
	Mean	**St Dev**	**Median**
Technology transfer from university to industry	4.02	0.83	4
Supporting students to complete their studies	4.32	1.06	5
Linking industry and academia/councils	4.37	0.88	5
Support students from previously disadvantaged back grounds to complete their studies	4.05	1.09	4
Making the university responsive to industry's priorities	4.19	1.08	4
Making the university responsive to government's priorities	3.80	1.14	4
Produce graduates with skills demanded by industry	4.47	0.62	5

Linking industry and academia; supporting students; and producing graduates skilled for industry received the highest ratings. The relatively low standard deviations produced by these items also showed that the perceptions were quite focused.

The comments to the open questions were also complementary, e.g., a Fort Hare respondent remarked, "The Programme is able to breach the gap between laboratory research and technology transfer to industry because it links industry with research institutions, thereby enabling technology transfer…" providing students with the much-needed financial resources and "enabling them to be much competitive in the job market. (and) …also makes our institution responsive to industry needs…".

Table 14 summarises the responses related to THRIP's administration performance. The table shows the mean and the median ratings. All median values are at 4 with a maximum 5. The lowest mean value of 3.28 relates to the appropriateness of the available resources.

Table 14: Performance rating by universities/science councils

How do you rate THRIP's administration (high – 5, average – 3, low – 1)?			
	Mean	**Std Dev**	**Median**
Effectiveness of application process	3.73	0.97	4
Effectiveness of application requirements	3.58	1.19	4
Appropriateness of evaluation criteria	3.74	1.09	4
Effectiveness of monitoring procedures	3.71	0.99	4
Effectiveness of marketing of Programme	3.50	1.23	4
Appropriateness of resources available	3.28	1.21	3
Accessibility of management team	3.81	1.16	4
Effectiveness of disbursing funds	3.41	1.24	4
Efficiency of funds auditing system	3.94	0.97	4
Cost-effectiveness of Programme	3.87	1.10	4

Note: Std Dev: standard deviation

5.2.3.1 Selected comparisons

Initial inspection of the information in **Tables 13** and **14** (pp. 64 and 65 respectively) seems to suggest that perceptions of the effects of THRIP were more favourable than perceptions of its administration. Further statistical analyses were consequently done to explore the reliability of such differences. First, the significance or otherwise of the difference in perception between effects and administration of THRIP was determined. For this purpose, the scores of the items reflected in **Table 13** (effects) and **Table 14** (administration) respectively were summed and the significance of the difference, if any, were computed by means of the non-parametric Wilcoxon Signed Ranks test and the parametric *t* test . The difference proved to be significant (Z=-3.624; p=. 000; t=4.128; p=.000) indicating that the more positive perception of the effects of THRIP as opposed to the perception of its administration was not a mere coincidence.

Secondly, the Kruskal-Wallis test was used to ascertain whether subgroups differed with regard to their perceptions of effect and administration separately. Subgroups were formed on the basis of nature of the research institute/university and the rank of the respondent. Only one

significant difference was found (*chi-square*=9.927, *p*=.007) and that was between the perceptions of respondents at the management level scoring the highest (e.g. DVCs and research directors), senior researchers, scoring the lowest (professors-senior lecturers) and middle researcher levels scoring relatively low (lecturers and entry-level researchers). The findings suggest that the role of THRIP is very favourably perceived, but that its administration is somewhat less favourably rated, although still towards the favourable end of the scale. In addition, management of institutions seem to rate the administration of THRIP more favourable than senior staff. Implications of these findings are accounted for in the recommendations.

With regards to administration, the majority of the comments to the open questions were related to the limitations of funding. A participant states: "The current funding model where allocations are cut by very large amounts each year (understandably due to lack of sufficient funds) is very disruptive to effective planning and research management. Not knowing what funding one will have in advance makes it difficult to accept and support deserving students. Given the high impact of the Programme – a return to the 1:1 support model would clearly result in greater impact". Delays or a long wait to receive payments was also mentioned by a number of participants. The following comment provided a synoptic picture over time: "Having been in this Programme for over a decade, I have witnessed great improvements in the application process and the evaluation process. All in all, it is up to the Principal Investigators to knock at the right doors to seek assistance in any matter related to the Programme."

Table 15 summarises the factors facilitating and/or inhibiting the beneficial effects of THRIP. The most important factors facilitating THRIP are a pre-established relationship with industrial partners (rating 4.76) and relevance of research to industry (rating 4.41). The most important inhibitor factors are the requirement to find an industrial partner willing to make a cash contribution (rating 2.93) and IP agreement/management issues (rating 3.33).

Table 15: Factors facilitating and inhibiting THRIP

What factors facilitate or inhibit the beneficial effects of THRIP? (strongly facilitate – 5, average – 3, strongly inhibit – 1)		
	Mean	**Median**
Assistance/advice from NRF	3.76	4
Assistance/advice from your institution	4.04	4
Your geographical location	3.44	3
Pre-established relationship with industrial partners	4.76	5
Ability to find new industrial partners	3.64	4
Requirement to find industrial partners willing to make cash contribution	2.93	3
Availability of postgraduate students	3.60	4
Relevance of your research to industry	4.41	5
Intellectual property agreement/management issues	3.33	3

In response to the invitation (last open question) to specify additional inhibiting factors, 19 respondents (41%) identified 23 factors that they perceived as inhibiting the beneficial effects of THRIP.

Figure 9 shows a summary of the results of an analysis of the perceived inhibiting factors.

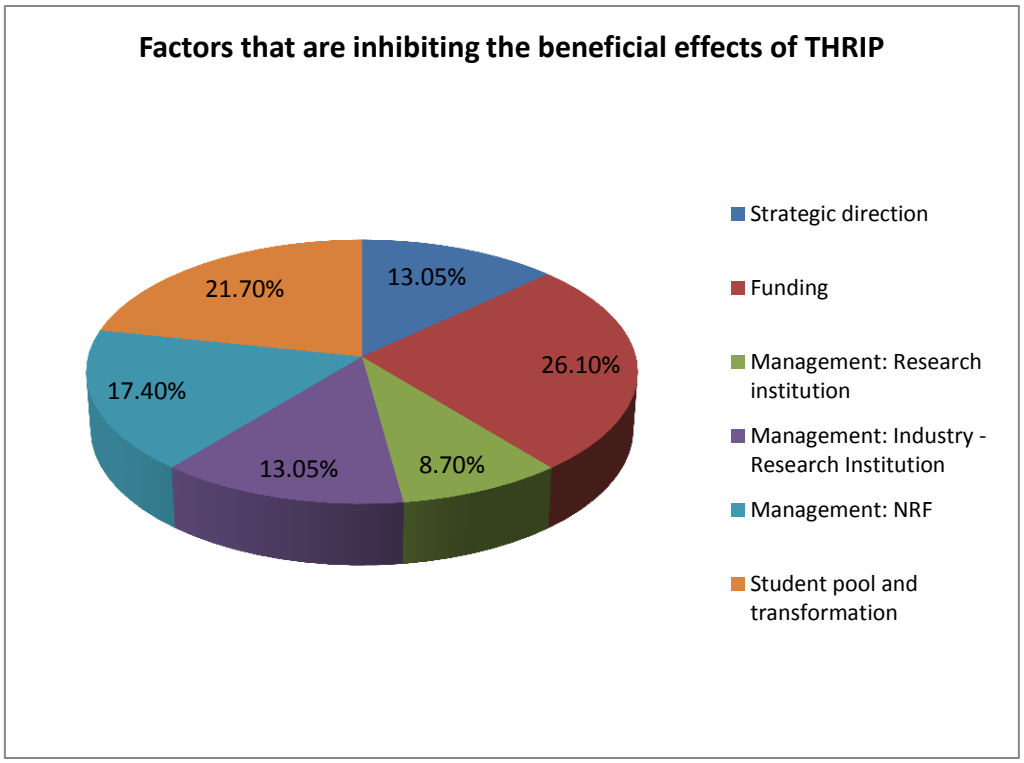

Figure 9: Spontaneously identified inhibiting factors

Respondents were allowed to choose more than one factor. A number of participants mentioned as a constraint the requirement of using only local postgraduates on the Programme. Participants also referred to examples of other countries that aim to attract international postgraduates. It is emphasised that even though this is a political issue the technological system will benefit from attracting international postgraduates.

With regard to the statement: “Please provide an indication of the number of postgraduate students that participated in THRIP and were subsequently employed by the industrial partner or your institution”, the participants declared that, on average, the industrial partner employed 7.36 postgraduates and the university/science council appointed 2.6 postgraduates. It is apparent that the postgraduate students who participate in the Programme find jobs.

The issue of intellectual property also attracted the attention of the stakeholders. They argued that IP issues keep industrialists away from the Programme as they often prefer to fund research abroad in more favourable regimes. The concern is valid and we developed a relevant recommendation. In relation to the question: “Are you aware of any new fields of research that emerged in your institution because of THRIP?” seven participants mentioned that they were aware of relevant fields. The included fields are big data and predictive analytics; breast imaging

system development; metal matrix composite; grid/cloud-based mobile computing; Tsunami seismic hazard and risk analysis; and others. Some of the topics mentioned are in the forefront of technology internationally. One participant mentioned that "it is due to the THRIP and industry partnership that we have now ventured into a research programme in the Internet of Things for Smart Cities."

Similarly, to the question: "Has THRIP created long-term collaborative activities of your university with industry?" participants responded positively. Examples of responses include: "Much of the advanced genetics and genomics work at the ARC (and at UWC previously) has been funded by THRIP as industries have not been willing to fund these areas directly. The impact is therefore on allowing the implementation of cutting-edge technology for industry without their initial commitment to the direct investment. As it becomes an effective tool, then the direct funding becomes attractive" and "Through the combined effort of our main industry partners (Anglo American Operations, Anglo American Kumba Iron Ore and Glencore), supported by THRIP, we could establish a Centre for Pyrometallurgy in 2009, followed by the establishment of a new field of research within our centre, that of pyrometallurgical modelling, in 2013". To the question: "Please indicate how many FTE new jobs THRIP creates in your institution annually", the average response was 9.6. Six institutions mentioned figures above 15. The maximum number of people employed in one institution is 35. It is apparent that universities/science councils with active THRIP projects need more relevant employees than dormant institutions.

The stakeholders' concerns were related mainly to the financing of the Programme. They identified that, apart from the government contribution which has diminished in real terms over the years, the rules of the Programme provide limitations to funding from industry. Examples provided included the funding ratios; the inability of university spin-offs to participate in the Programme; and the reduction in the number of large corporations participating in the Programme. The issues identified are real and cumulative. **Figure 10** summarises the suggested changes to the implementation of THRIP.

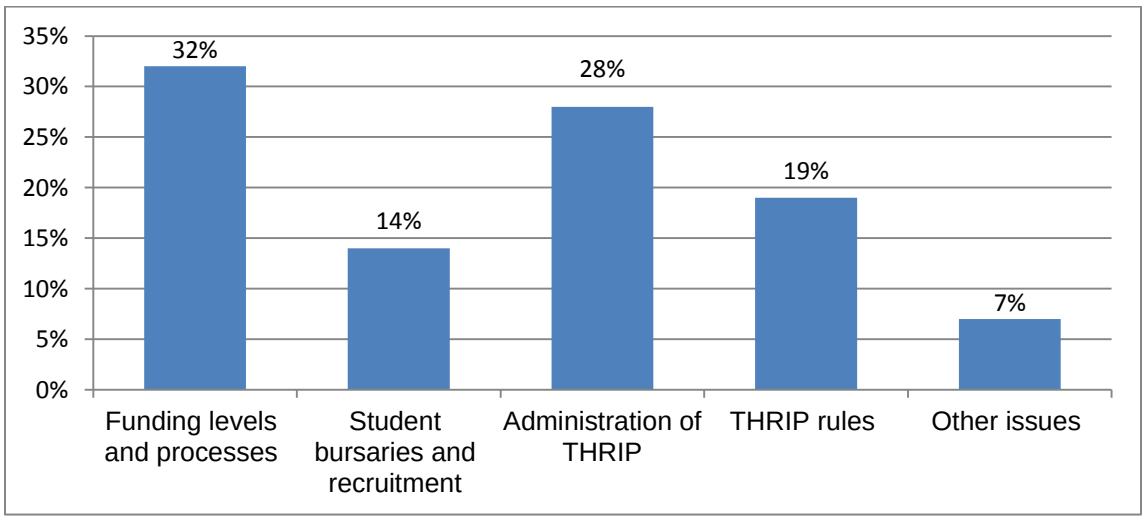

Figure 10: Spontaneously suggested improvements to the implementation of THRIP

Although the majority of recommendations were related to funding, discussions with relevant stakeholders confirmed that administratively THRIP has a strict schedule in the provision of funding, which creates a bureaucratic burden to the participants. Participants suggested that the NRF should delegate certain responsibilities to universities in order to accelerate its processes and reduce documentation load.

5.2.4 Conclusions

This section offers an overview of the main findings of a survey, containing quantitative and qualitative items, of the research community's (universities and science councils) perceptions of key aspects of THRIP. With caution the following conclusions can be generalised to the South African research community.

- First, the research community seems to be quite favourably orientated towards the objectives and performance of THRIP, but less so, although still positive, with regard to the administration of the Programme.
- Secondly, a history of collaboration with industry promotes the effects of THRIP, while issues such IPR and the relatively limited funding inhibit the potential benefits of the Programme.
- Thirdly, the survey registered a number of positive outcomes of the Programme, such as the number of advanced students finding employment in industry; job creation; the emergence of new fields of research in the own institution; and the establishment of long term collaboration with industry.

These conclusions are developed further as higher-order recommendations in Chapter 6.

5.3 THRIP and industry

5.3.1 The survey

Two hundred questionnaires, the names of respondents randomly drawn from NRF/THRIP lists of industrial participants in the Programme, were emailed to the major collaborators/partners (see **Appendix B** for the questionnaire.

Apart from biographical information, the questionnaire consisted of 12 structured items measuring perceptions and quantitative experiences and five open/qualitative items. Of the 187 valid addresses, 45 completed questionnaires were returned – a response rate of 24.6% (three respondents did not have corporate memory of the Programme).

This response rate is common in web based surveys. Nineteen of the respondents (42%) declared that they were SMMEs.

There are strong indications of internal validity (e.g., convergent and discriminant validity) that offer reason to accept the results as valid at least for the industrial partners that did respond to

the questionnaire, but caution is required when generalising to the population. This cautionary note applies especially for the open questions to which not all respondents replied.

5.3.2 Results of the industrial partner questionnaire

The following tables and figures present the results from the responses of the industrial partners. The results are arranged under the following headings: reasons for participating in THRIP; nature of the partnership project; outputs outcomes and impact; contributions to policy; perceptions of administrative support; and conclusions.

5.3.2.1 Why participate in THRIP?

An obvious and initial question was why respondents participated in THRIP. The four main classes of reasons for the participation of respondents are reflected in **Figure 11.** The figure shows that more than 55 percent of the responses could very broadly be classified as commitment or company image (viz. contribution to national objectives and improved reputation); while immediate financial considerations (only source of funding and risk reduction) represented 43 percent of the motivations. Respondents could further add to the list ("other reasons") and those included "improve quality of industry-directed research"; "improve competitiveness"; and "cooperation vehicle between small R&D institution pools in South Africa".

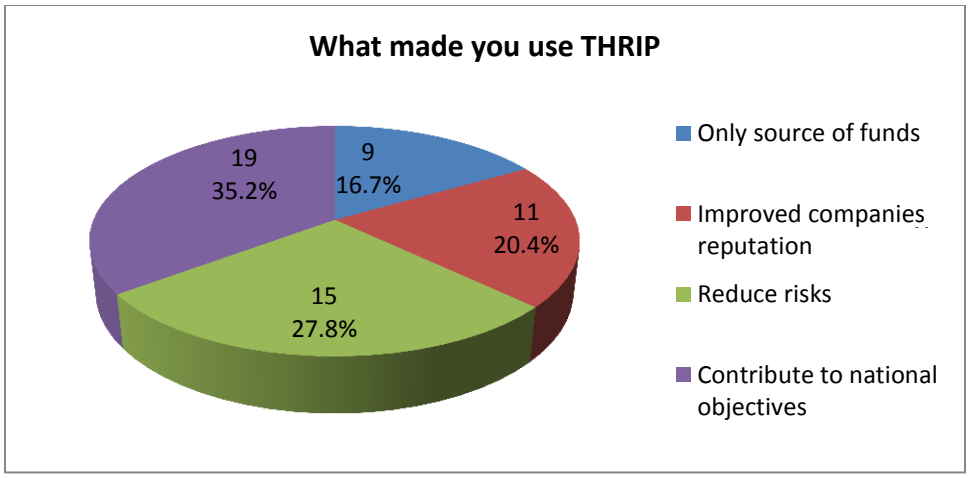

Figure 11: Main reasons for using THRIP

5.3.2.2 Nature of the partnership projects

Table 16 and **Table 17** (p. 71) show the importance of the project (as perceived by all the industrial partners and SMME subgroup, constituting just above 42% of the sample) and the commercial returns (current and future).

The results of the SMME subsample are also included in the tables. More than 50% of the industrial stakeholders declared that the project was of major importance (mean rating 4.44) and that the expected commercial returns would be bigger in the future.

It is also relevant to note that the SMME industrial partners were more positive than the total sample and thus than the partners from big companies. **Table 16** focusses on the SMME view of the strategic importance of THRIP and Table 17 on the commercial returns of THRIP for SMMEs.

Table 16: Nature of project: Sample vs SMMEs subsample

Nature of project			
Strategic Importance of project (1: minor to 5: major)			
Mean: All	**Mean: SMMEs**	**Median: All**	**Median: SMMEs**
4.44	4.75	5	5

Table 17: Commercial returns

The project has led to significant commercial returns for your organisation and whether any are expected in future			
Negligible commercial returns to date(1) to significant commercial returns to date (5)			
Mean: All	**Mean: SMMEs**	**Median: All**	**Median: SMMEs**
2.84	3.13	3	3
Negligible commercial returns expected in future (1) to significant commercial returns expected in future (5)			
Mean: All	**Mean: SMMEs**	**Median: All**	**Median: SMMEs**
4.11	4.75	5	5

Table 18 shows the responses of the industry partners to the question: "What would have happened if the project as a whole had not received THRIP funding?" (Participants had the opportunity to tick more than one box). Approximately 50% of the participants declared that, in the absence of THRIP support, the project would still have been undertaken, but with longer time scales and reduced funding. To the question on money spent on R&D since the end of THRIP project funding, the mean was R3.84 million. The median was R1 million.

Table 18: Probability of the project in absence of THRIP?

What would have happened if the project as a whole had not received THRIP funding?	
Project would not have been undertaken by any of the partners	10*
Project would have continued without THRIP funding, but your organisation would not have participated in them	1
Your organisation would have participated but:	
With no partners	3
With fewer local partners	5
With same partners	8
With reduced funds	20
Review objectives	7
With longer time scale	13

* The numbers refer to amount of responses (counts) from the 45 industry partners.

Against the background of the mission and objectives of the THRIP (see Chapter 3) the questionnaire further explored what functions the THRIP project served to the organisation's capabilities, performance and behaviour (item 2 of the questionnaire). The findings are shown in **Figure 12**.

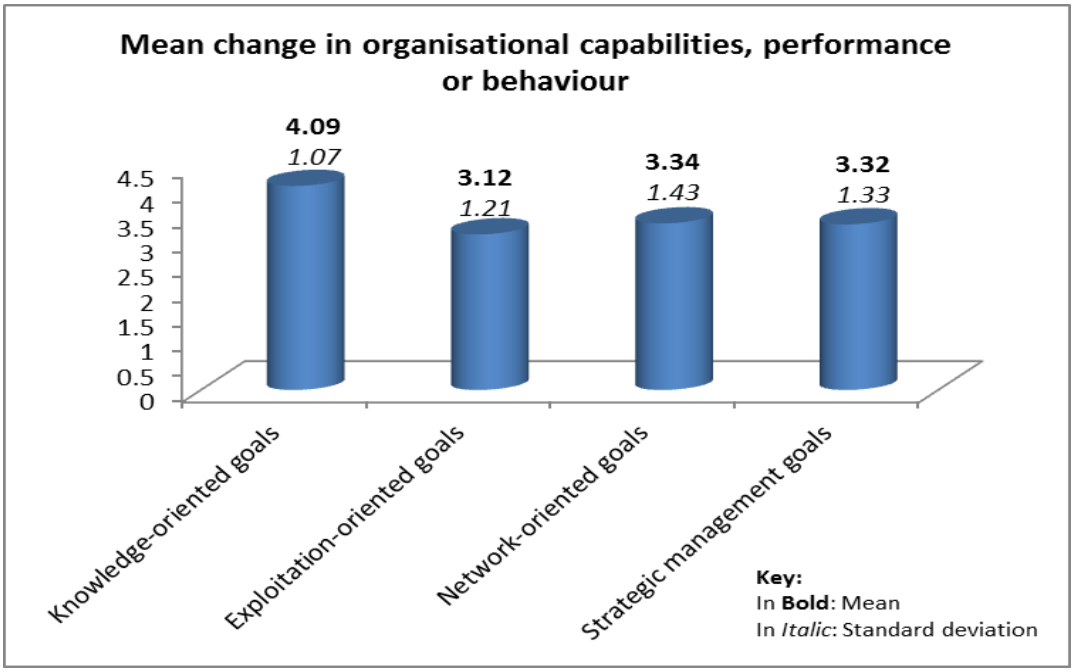

Figure 12: Goal-orientation of the project

The highest mean and smallest standard deviation shown in **Figure 12** clearly confirm that participation in the THRIP project contributed mostly to the expansion and consolidation of the know-how and knowledge bases – outcomes that include the development of new tools and techniques as defined in the questionnaire question. Interestingly enough goals concerned with commercial matters, such as patents and the improvement of competitiveness, were rated lowest, although the differences were relatively small.

5.3.2.3 Outputs, outcomes and impact

Table 19 (p. 73) shows the average number of the various types of outputs during the period of the THRIP project and those that are expected up to three years after the completion of the project.

Qualifications earned by personnel as results of the THRIP project and new tools or techniques are the most prolific outputs.

Stakeholders expect the number of all outputs to increase after some time after the completion of the project.

Table 19: Outputs of THRIP: During project and expected after the end of the project

Type of output	Average number of outputs during project	Average number of outputs expected 0–3 years after project end
New tools or techniques	5.04	8.69
Demonstrators, prototypes, pilots, etc.	3.45	7.52
Patent applications	1.57	4.82
Patents granted	1.25	3.50
Copyrights, trademarks, designs, etc.	1.75	3.20
Licences issued	1.67	3.13
Qualifications earned by personnel	7.70	10.00

Question 4 went a step further and probed the actual and overall expected economic impacts of the THRIP projects (**Table 20**). The table also offers the mean scores on each of the options for SMMEs separately, since one might expect THRIP to play a bigger role in an SMME than in a big company.

Inspection of the information in **Table 20** shows, first, that the score for actual impacts stay close to the middle position between 'minor' and 'major'; secondly that future returns were expected to be slightly higher; and thirdly that the SMME respondents scored higher on all the options. Finally, "Improved financial viability" and "increased competitiveness" received the highest ratings on both actual impacts and expected returns – also in the case of the SMME subsample.

Table 20: Actual and expected economic impacts (all companies and SMMEs separate)

Economic impacts (minor – 1 to major – 5)						
	Actual impacts			Expected returns		
	Mean		Median	Mean	Median	
	All	SMME	All	All	SMME	All
Increased turnover	2.56	3.25	2	3.04	4.11	3
Increased profits	2.63	3.43	2	3.10	3.80	3
Greater savings	2.84	3.13	3	3.31	3.67	4
Improved financial viability	3.36	4.00	4	3.72	4.50	4
Expanded share of existing markets	2.64	3.67	2	2.85	4.00	3
Creation of entirely new markets	2.44	3.63	2	2.38	3.89	2
Entry: new markets for your organisation	2.79	3.25	3	2.93	3.60	3
Entry: new geographical markets for organisation	2.68	3.38	3	3.64	3.78	4
Increased productivity	3.23	3.89	3	3.69	4.36	4
Increased competitiveness	3.48	4.38	3	3.85	4.45	4

As mentioned above, an important issue to probe in an evaluation of THRIP concerns the overall expected commercial returns as a result of the Programme. (item 4). Increased competitiveness was found to be one of the two main actual and expected economic impacts

The economic outcome/impact of THRIP partnerships for respondents from industries was explored in two questions. On the question 5.2(a): "How much revenue does your company expect to earn from selling goods or services incorporating THRIP technology?" the median respondent (50%) answered that after five years after the completion of the project, the expected revenue amounts to R5 million and the mean is R24 million. Ten years after completion, the median revenue increases to R40 million and the mean to R224 million.

The expected tax rate at the above revenues was estimated by the stakeholders at 30%. This means that, on average, from the 5th to the 10th year, each project is expected to generate R7.2 million in taxes, and after 10 years, the tax revenue will be R67 million. These tax revenues are substantial given that each project receives on average below R1 million per year. These revenue expectations justify the conclusion that the Government receives a considerable return on its investment for THRIP.

Question 5.2(b) focused on the issue of spill-overs. The respondents estimated that the horizontal spill-overs are higher than the vertical ones. Furthermore, the median respondent estimates that the spill-over will be above 75% of THRIP-created knowledge.

Table 21 (p.74) shows the ways that THRIP enhances competitiveness in industry. The indicators of or routes to industrial competitiveness that were rated highest included higher quality goods and services; expanded reputation for THRIP and leading edge technology; and improved innovation performance.

Table 21: Routes to enhanced competitiveness

Routes to enhanced competitiveness (minor 1 – major 5)				
	Actual impact		**Expected impact**	
	Mean	**Median**	**Mean**	**Median**
Reduced labour costs	2.70	3	3.23	3
Reduced capital costs	2.48	2	2.87	3
Reduced material input costs	2.67	3	3.14	3
Lower energy calls	2.27	2	2.71	3
Reduced overheads	2.70	3	3.18	4
Higher quality goods, services, etc.	3.59	4	3.81	4
Lower prices	2.50	3	2.92	3
Expanded product/service range	3.00	3	3.18	3
Expanded reputation and leading-edge technology	3.83	4	3.93	4
Improved innovation performance	3.71	4	3.86	4
Reduced throughput time	2.77	3	3.22	3
Faster time to market	2.86	3	3.10	3
Greater production flexibility	3.09	3	3.48	4
Establishment of *de facto* standards	2.82	3	3.27	4

As in the case of other questions, the respondents expected the contribution of the different routes to increase in future.

5.3.2.4 Contribution to policy

Table 22 below shows the perception of industry respondents regarding whether THRIP makes a contribution to its various policy objectives. Contributing to policy objectives is an important issue which denotes a significant outcome and even an impact of research (cf. Marais, 2013).

The highest ratings (means and medians on a 10-point scale) were received by the following policy objectives of the Programme:

- improved preservation of the environment;
- improved economic development and growth;
- improved competitiveness;
- improved standards of living in rural and semi-rural communities; and
- the establishment of critical mass in R&D.

It is worth noting, though, that all the listed policy objectives received ratings above the theoretically expected mean and median of 5.

The lowest rating was that of employment – incidentally one of the main objectives of THRIP.

Table 22: Contribution to policy objectives

Policy goals 0–10		
	Mean	**Median**
Improved employment situation	5.80	6
Improved quality of life	6.53	7
Improved preservation of the environment	7.14	8
Improved economic development and growth	7.11	8
Improved competitiveness	7.97	8
Improved standards of living in rural and semi-rural communities	7.11	8
Contributed to poverty alleviation	6.17	7
Improved S&T capability	6.63	7
Establishment of critical R&D masses	7.62	8
Increased levels of investment in R&D	5.93	7
Development of standards	6.86	7
Improved inputs to policy formulation	6.38	7
Improved inputs to regulation and legislation	7.32	7
Implementation of South African government goals	6.84	7
Other (please specify)	6.87	7

The open question 5.1 enquired about the extent to which THRIP contributed towards achieving economic growth and employment, *namely Outcome 4* of the *President's delivery agreement*. The content analysis of the 26 comments elicited by this question produced the four overarching themes shown in **Figure 13**). Inspection of that figure shows that the most prominent contributions focussed on industry competitiveness and student development with direct and indirect job creation in the third position.

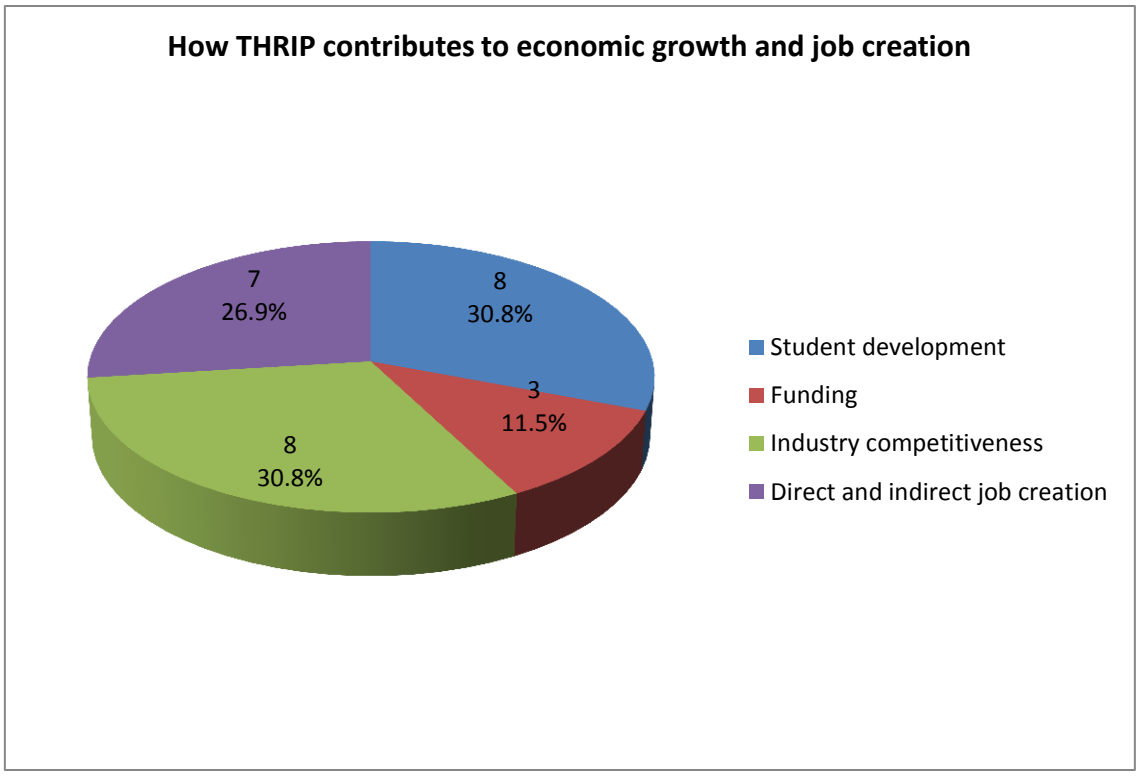

Figure 13: THRIP's contribution to the President's Delivery Agreement

5.3.2.5 Perceptions of administrative support

An important aspect of the partnership between the THRIP (NRF), universities and industry is the administration of the Programme. The experiences of industry respondents were probed in question 6 by means of 11 five-point Likert scales.

Figure 14 offers an overview of the mean evaluations and standard deviations.

The information in **Figure 14** below shows that the industrial partners rated the THRIP administration above average. The highest mean of 4.12 (with a relatively low standard deviation) was for "efficiency in administration". The lowest means were received for "speed of application process" (3.54) and "marketing of the Programme" (3.58), but it should be noted that

five-point scales were used which means that these relatively low evaluations were still above average.

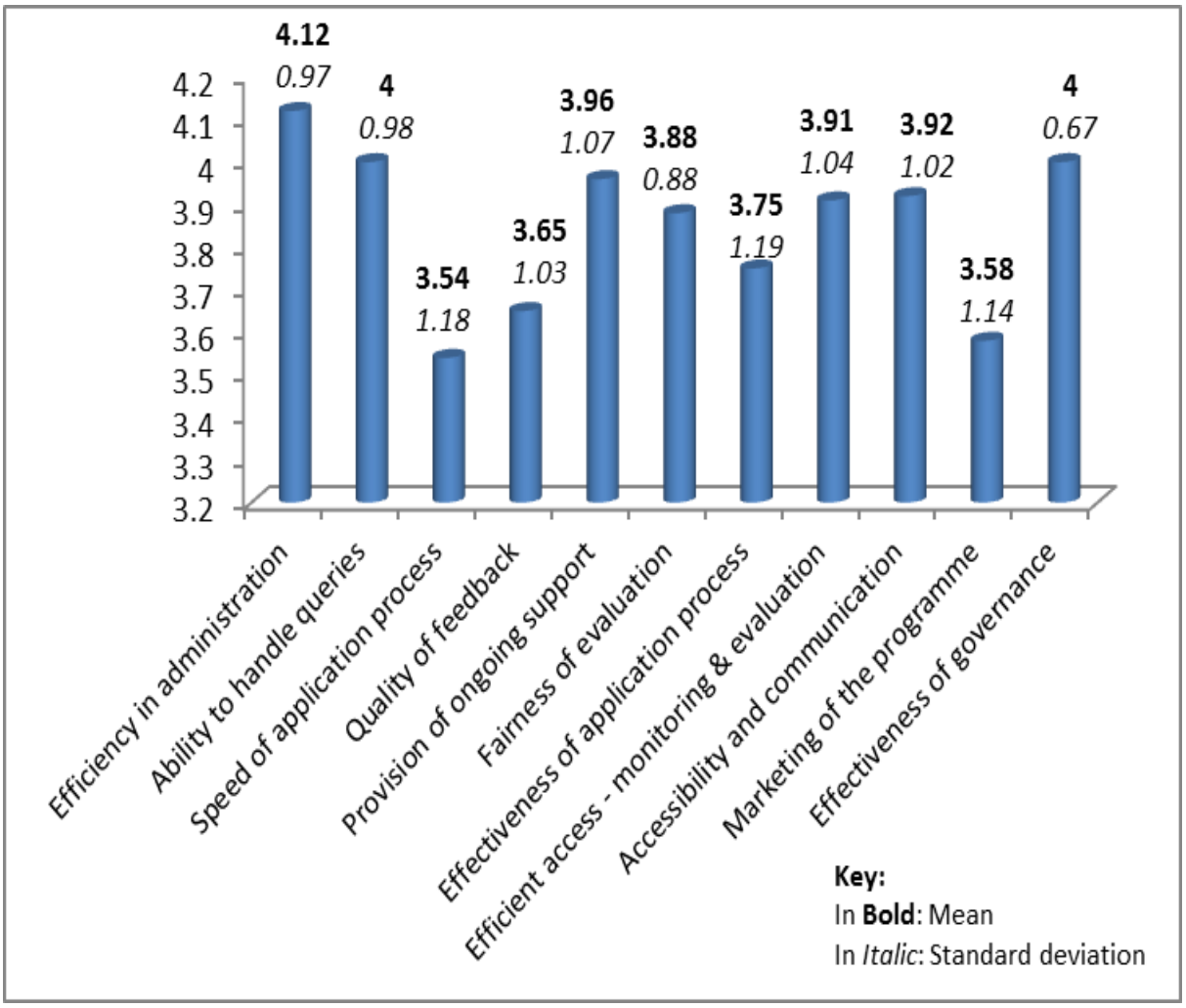

Figure 14: Evaluation of various administrative support functions

Respondents were also offered the opportunity to define in their own words what they saw as strengths and weaknesses of THRIP (see **Figure 15**, p. 78). It is interesting to note that the strengths were more of a symbolic/orientation nature, e.g., encouragement and reputation, while the weaknesses were operational matters, such as funding and administration.

The industrial respondents listed as strengths the collaboration between universities and industry and the production of relevant skills for industry human resources. One stakeholder stated: “THRIP is one of the best initiatives of government.

The Programme provides the necessary infrastructure and know-how to enable job creation in a scarce skills environment and to improve the quality of industry-directed research through enabling fundamental directed research. No weaknesses are present.”

Figure 15 summarises the industry perceptions of the strengths and weaknesses of THRIP

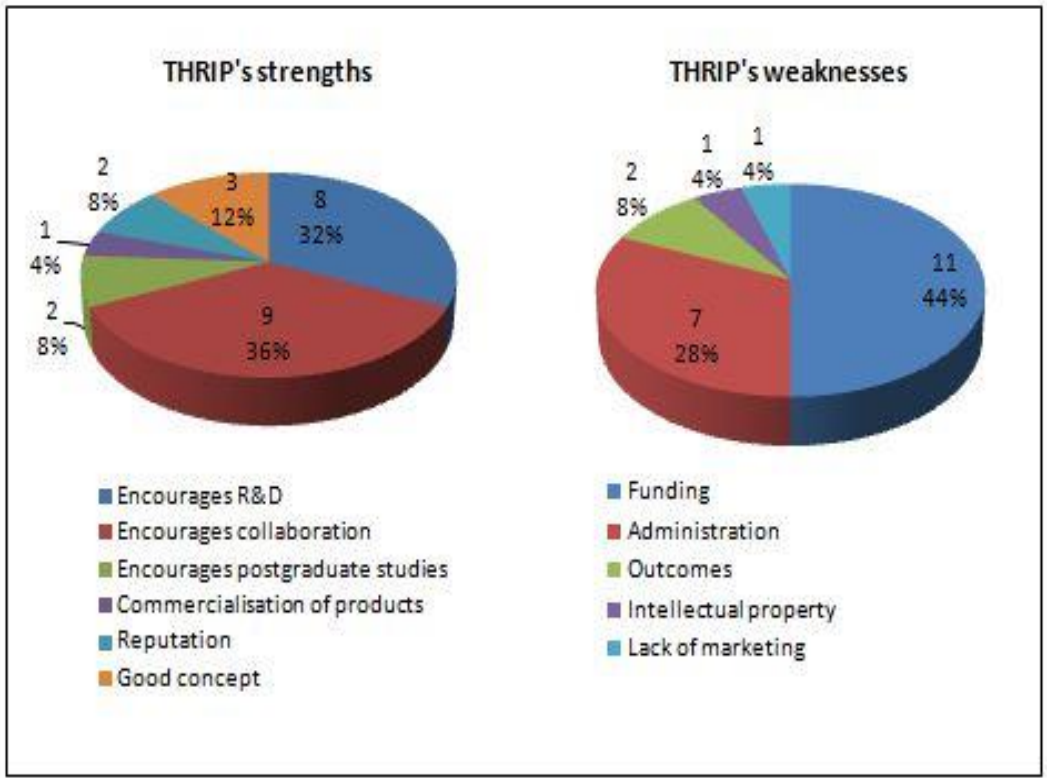

Figure 15: Opinions on strengths and weaknesses of THRIP

Identified weaknesses include: “the progress reports should be evaluated faster and the outcome communicated earlier”; “weakness would be the timeframe of getting projects approved”; “a major weakness that has developed over the past 10 years is the reduced effective matching rate, which has limited the scope and scale of projects that could otherwise have been undertaken”; and “red tape, not enough and flexible support to small companies willing to participate, long time to release the funding after approval, changing the financial support after the approval, which, in turn, is leading to either abandoning of the approved project or scaling it down, which minimises the planned impacts” .

The results of the content analysis of the responses to the open question regarding how THRIP-based projects could improve their chances to be commercialised, are presented on p. 79 as **Figure 16.**

The small number of responses on suggestions for improvement included policy on the placement of equipment; reliable funding; funding of pilots giving industry access to THRIP support from the NRF directly and not via research institutions; visionary project leadership; and a closer work relationship with TIA. The final item of the questionnaire, that did not elicit many responses, probed the need for changes to the implementation of THRIP. A number of stakeholders responded that one should not try to fix a working system and “continue as is”, but

there were also opinions on increasing the funding; alleviating funding constraints; and simplifying application processes.

Figure 16 summarises opinions on how commercialisation of THRIP projects can be improved.

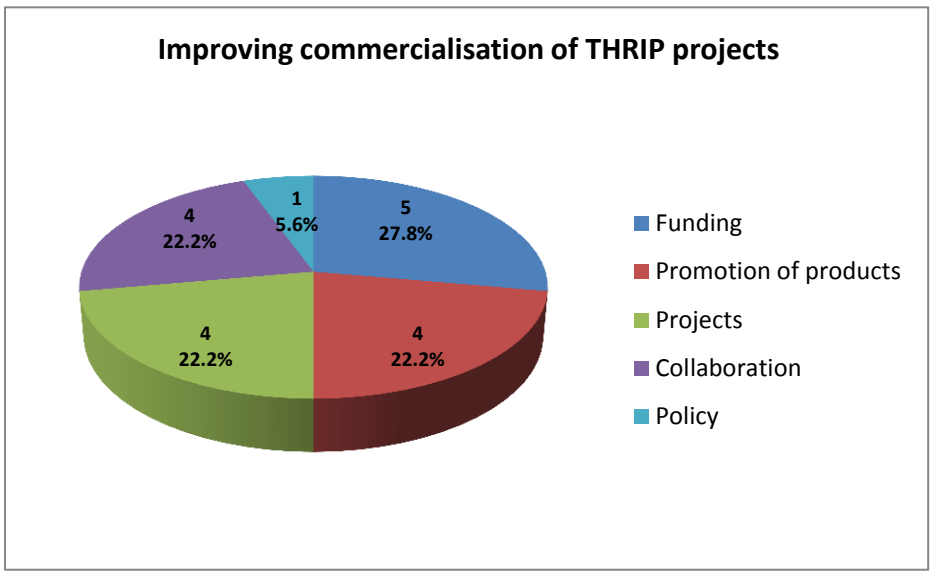

Figure 16: Options for improving commercialisation of THRIP projects

5.3.3 Conclusions

The industrial questionnaire covered the following relevant range of themes by means of quantifiable and qualitative questions on the perceptions of industrial partners: nature of the project; motivation for participation; outputs, outcomes as well as impact; and the specific position and performance of SMMEs. The following overarching conclusions seem justified on the basis of the information offered in this section.

First, the industrial partners showed a positive orientation towards participating in THRIP the main reasons being for the strategic value, its contribution to national objectives and reduction of risk. Participation also yielded substantial commercial returns (participation in the THRIP seemed to be relatively more positively rated by SMME partners than by others). Some of the projects would have been challenged in terms of time scales and availability of resources had it not been for THRIP funding, while others would probably not have been undertaken.

A second conclusion pertains to the major types of outputs created by the projects which are qualifications earned by personnel and new tools and techniques. Thirdly, and in general, outputs and income are expected to be higher a few years after conclusion of the project than during the duration of the THRIP project. Fourthly, participation in THRIP is expected to yield favourable commercial returns. Nearly a quarter of the respondents indicated that the expected return was between R100 million and R1 billion while almost 25% declared commercial returns above R1 billion. Estimates of the tax revenues generated by THRIP show that on average,

from the 5th to the 10th year, each project is expected to generate R7.2 million in taxes and after 10 years, the tax revenue is to amount to R67 million.

Finally, industrial respondents rated the THRIP administration above average on most dimensions but the speed of processing applications; the quality of feedback; and marketing of the Programme require attention. The major weakness of THRIP is its funding limitations.

In interpreting the findings it is important to keep in mind that the response rate was relatively low, not allowing unconditional generalisation to the population of industrial partners of THRIP.

5.4 Evaluation of aspects of THRIP by dti

Officials of the Department of Trade and Industry (**the dti**), being the sponsor of the THRIP, were also invited to give their views on key aspects of the Programme, namely "the effectiveness and efficiency of the current model of implementation" of the THRIP (Appendix C). Although only one official responded others gave similar answers in personal interviews conducted by the reviewer responsible for the first phase of this evaluation. In view of the importance of the role of **the dti** as programme principal of THRIP, a summary of the main conclusions are briefly offered below.

- Most of THRIP's objectives are met, but equity objectives are not always met due to the mandate of the implementing agency (NRF).
- **the dti** is considering clustering technology programmes under one roof.
- **the dti** accepts inputs from THRIP's Advisory Committee, if they are not misaligned with departmental objectives.
- THRIP is appropriately situated in the current implementing agency, but the integration of technology programmes as a cost cutting measure is aligned with government policy and those implications should be considered.

5.5 Theory of change workshop

A workshop on the THRIP theory of change (ToC), and by implication its logical framework, was organised. The rationale for this workshop was:

- first, the ToC had been used as framework of this evaluation;
- secondly, it would serve as point of departure in the immediate future for possible amendments to THRIP; and
- thirdly it would serve as an opportunity for selected members of the management and governance structures of THRIP to reflect on this important component of the Programme.

The workshop consisted of two parts, viz. a focus group (cf. Gibbs, 1997; Morgan, 1997) on necessary elements to be accounted for in the ToC, and a critical discussion of the draft ToC. The workshop was attended by well-informed officials of **the dti** (5), the Presidency (1) and the NRF (1). Apart from the facilitator two (2) officials of the BE at UP were also in attendance.

In summary, the workshop produced the following outputs (see **Appendix F** for a summary):

- Focus group on potential elements of a ToC:
    - Government support for R&D takes place in an ecosystem of policies and strategies that requires alignment between all departments, agencies and, in this case, the private sector.
    - There is a need for regular and structured communication between all stakeholders.
    - The management and administration of the Programme need to consider the nature of the THRIP context, e.g., optimal coordination within the funding agency (NRF), short response and quick turn-around times, and provision of data for monitoring and evaluation.
- The workshop on the draft ToC (see Chapter 4):
    - Outputs, outcomes and impact – as far as THRIP is concerned – are located on a continuum and should not be seen as necessarily absolute or impenetrable demarcation lines. It would, in some cases be useful, though, to differentiate between macro-level and firm level impacts.
    - Funding: THRIP's funding of equipment may have to consider pre-production initiatives and spin-offs that could be shared by a number of institutions - even by scaling down on research equipment for universities.
    - Coordination between funding instruments needs to be optimally calibrated and any future changes to THRIP's current mandate and objectives should not to lead to a duplication with other programmes of **the dti**, such as ISP and TIA's Technology Stations.

5.6 Summary

The information offered in this chapter should be understood within the context of the THRIP theory of change that maps the mission, intentions and processes of the Programme. The information should further be assessed against the THRIP log-frame that lists the kinds of indicators, verification sources and underlying assumptions that should be used in an evaluation of the Programme. The evaluation design presented in this chapter largely complies with the requirements of these two evaluation dimensions, viz. theory of change and log-frame.

The aggregate data on THRIP (Section 5.1) show a relatively positive picture of growth in terms of participation rates and outputs on the one hand and overheads that favourably compare to other similar national and international programmes, on the other. A negative finding was the fact that financial support from the public coffers was declining in real terms.

Sections 5.2 and 5.3 reported on two surveys, namely of principal investigators at universities and SETIs as well as major industry collaborators/partners. Both focussed on perceptions of

outputs, outcomes, impacts, and activities of THRIP (cf. log-frame in **Table 6**, p. 47), but from the perspectives of the different partners. Notwithstanding differences on emphasis, an overlap in perceptions emerged from the analyses of the two surveys. First, both groups were positively orientated towards THRIP and the required collaboration involved. Secondly, outputs, outcomes and impact of the Programme were highly valued with the expectation that these would grow in future after the conclusion of the projects concerned. Thirdly, the administration of THRIP was rated above average, although certain administrative functions elicited qualified responses. Finally, both groups perceived funding of THRIP an inhibiting factor.

Section 5.4 reported on the views of a **dti** official that is involved in the technology programmes of **the dti.** The open-item questionnaire covered a range of issues on THRIP's mission, performance and location in the NRF and the responses can be summarised at a high level as follows:

First, THRIP's mission and objectives are important to **the dti**, but must in all respects be aligned to government and **the dti** policy. Secondly, new funding processes plus an increase in the THRIP budget is expected to improve the funding challenge. Thirdly, the integration of technology programmes in **the dti**, including THRIP, was being considered.

Section 5.5 summarised the findings of a productive workshop on the necessary requirements of a THRIP theory of change (ToC), on the one hand, and an evaluation of the ToC proposed in a previous daft of this report, on the other. An overarching summary of this workshop showed that the governance, design and management of THRIP should account for:

- the relevant policy environment of funding instruments;
- the business environment within which THRIP operates;
- the optimisation of all its administrative practices; and
- avoidance to duplicate the missions and practices.

This chapter serves as a source for a number of recommendations that are presented in the next and final chapter.

6. Conclusions and recommendations

This document reports the results of a project aimed at assessing the implementation and - to a lesser extent - the impact of THRIP.

The present review has used a relatively wide spectrum of tools, including existing data bases; stakeholder interviews; two stakeholder surveys; and a workshop, to review the performance of THRIP. The triangulated findings support strongly the conclusion that for more than 20 years the programme has successfully been fulfilling its objectives to address the challenges of skills development in science, engineering and technology and to promote competitiveness in the South African industry. Following international best practice the Programme attracts substantial resources from industry and create linkages between industry; academia and government. During the most recent period the Programme has so far had a substantial impact on SMMEs as well. THRIP can indeed serve as an example of the positive effects on the NSI by a collaborative funding programme.

The chapter "Theory of change and THRIP", and Sections 3.4 and 3.2 ("Innovation and technology support in South Africa" and "Government's involvement in innovation") show that the design basis of THRIP is that of the second-generation innovation policy (chain-linked model of innovation); that the Programme follows international best practice; and it constitutes a unique instrument in this country's domain.

Below, the findings are discussed and recommendations are developed. It should be emphasised that, since its inception, THRIP has seen many changes, but it has also maintained a level of continuity that is an important factor for both sponsors and participants. The changes suggested below aim to maintain the Programme's flexibility and, at the same time, keep in sight some core (best practice) principles ensuring that THRIP is "fit for purpose".

6.1 Findings

6.1.1 Implementation related questions

The findings below address the questions posed in the original Terms of Reference (Section 1.1).

6.1.1.1 Relevance

> *Is THRIP still relevant when considering other instruments in the innovation landscape? What factors in the South African context enable or constrain THRIP's positive impact, including the long term sustainability of those impacts?*

The positioning of THRIP within the NSI identified it to be a unique instrument in the NSI. The unique characteristics of the Programme are that it:

- Provides incentives for technology development locally;
- Promotes collaboration among government, academia, science councils and industry;
- Is versatile and can support different size challenges (small or big grants);
- Focusses on industry-based priorities;
- Is open to all qualifying organisations (a number of incentives are structured to benefit particular institutions and technologies); and it
- Addresses the government priority of increasing the country's R&D expenditure.

It should be noted that, while **the dti** has a number of instruments promoting the acquisition of technology embodied in equipment and facilities technology, (e.g., MCEP, MIP and others), THRIP is unique in promoting technology development locally.

Similarly, through the international benchmarking analyses and by applying the theory of change it was found that the Programme complies with international best practice and follows a sound approach. Almost all countries in the world develop programmes that promote the utilisation of scientific research through collaborative efforts.

The stakeholders identified that the "pre-established relationship of the universities with the industrial partners" and "relevance of university research to industry" strongly facilitate the beneficial effects of THRIP. "Geographic location", "requirement to find industrial partners willing to make a cash contribution" and "IP agreement/management issues" are relative inhibiting factors. Similarly, the stakeholders (both from the science base and the industrial sector) declared that the Intellectual Property Rights from Publicly Financed Research and Development Act, Act No. 51 of 2008, is an inhibiting factor.

The theory of change analysis identified that the Programme is not designed to promote commercialisation of the knowledge produced beyond the applied stages of research. Further incentives across the innovation chain can enhance THRIP's long-term impact and sustainability.

6.1.1.2 Process of THRIP

> *What effect do institutional mechanisms (structure, management, administration, and processes) have on the efficiency and effectiveness of delivering the Programme outcomes?*

It was concluded that THRIP has a commendable structure (including an Advisory Board) and it follows good practices in managing, processing and monitoring the projects. The selection criteria applied by the Programme enable it to meet broad national needs and help ensure that the benefits of successful awards extend across firms and industries.

The Programme produces guides/manuals for its processes, has effective digital archives and receives unqualified reports by the Auditor-General, including PFMA compliance. Universities

and science councils provided above-average ratings for THRIP's administration across ten issues (effectiveness of application process, effectiveness of disbursing funds, etc.*)*. The lowest score was on "appropriateness of resources available".
The THRIP approach also contributes to the development of scientific and technological infrastructure. On the question: "Has THRIP created long-term collaborative activities of your university with industry?" participants were positive. Examples of responses include: "Much of the advanced genetics and genomics work at the ARC (and at UWC previously) has been funded by THRIP as industries have not been willing to fund these areas directly. The impact is therefore on allowing the implementation of cutting-edge technology for industry without their initial commitment to the direct investment. As it becomes an effective tool, then the direct funding becomes attractive". Another response stated: "Through the combined effort of our main industry partners (Anglo American Operations, Anglo American Kumba Iron Ore and Glencore), supported by THRIP, we could establish a Centre for Pyrometallurgy in 2009, followed by the establishment of a new field of research within our centre, that of pyrometallurgical modelling in 2013."

The stakeholders identified weaknesses in the Programme's funding ratios (industry to government) and on the partial funding of projects. The partial funding of projects forces the universities to renegotiate with the industrial stakeholders and revisit the research project's scope and objectives. This creates additional costs to both universities, science councils and industrial partners.

The international benchmarking analyses concluded that THRIP has a large number of criteria or objectives in comparison with other internationally relevant programmes. In South Africa the monitoring of project impacts is discontinued when the project is no longer funded. Abroad the tracking of project impacts continues for a number of years after project completion.

Finally, in the process of the current evaluation, the 10-year horizon does not seem feasible. One institution that was asked to mobilise its researchers to participate in the THRIP evaluation identified "about 44% of the 2002 project leaders have left the University (mostly retired, left for Australia, one person died)". Similarly, the international efforts show that programmes similar to THRIP are assessed every five years.

6.1.1.3 Cost-effectiveness

> *Is the current model of delivering THRIP cost-effective in comparison to alternative models?*

THRIP operations are embedded in the NRF infrastructure, which makes the Programme efficient. The estimated operating expenses, i.e. overheads, as a percentage of the Programme's contributions to the projects have been between 6% and 7% during the recent years. As the Programme leverages resources from the industrial partners as well, the operating expenses, as a percentage of the total funds mobilised, is approximately 3%. In comparison to other programmes, THRIP has substantially smaller overheads. This overhead is comparable

with international programmes (such as the Canadian programmes), even though the programmes abroad handle substantially more resources.

6.1.1.4 Benchmarking

How does THRIP's performance compare to similar programmes nationally and internationally?

THRIP is unique in the country in its effort to support locally developed technologies through collaboration with the industry and scientific institutions such as universities and science councils. This collaboration facilitates increasing the number of people with appropriate industry-related skills and stimulates industry and government to increase their investment in R&D, innovation and technology diffusion. Internationally, most countries in the world provide incentives to their industries that are similar to THRIP's incentives. Examples include the industry-driven CRD Programme in Canada, the ATP in the USA and the Framework Programmes in the European Union.

An important difference identified in the course of the evaluation is that abroad, different programmes/approaches are followed for different objectives, while THRIP attempts to accommodate a broad spectrum of objectives. For example, in Canada, the NSERC Engage grants are intended to foster the development of new research partnerships between academic researchers and companies that have never collaborated before, by supporting short-term research and development projects aimed at addressing a company-specific problem. The Interaction grants are intended to financially support researchers from Canadian universities to meet with Canadian-based companies with the objective of identifying a company-specific problem that they could solve by collaborating in a subsequent, newly established research partnership. The Collaborative Research and Training Experience (CREATE) Programme is designed to improve the mentoring and training environment for the Canadian researchers of tomorrow by improving areas such as communication, collaboration and professional skills, as well as providing experience relevant to both academic and non-academic research environments.

It is noted that the ultimate objectives of Canada's programmes are separated into discrete grants, while the approach in South Africa appears to be "one size fits all".

THRIP is following international best practice by benchmarking its activities with those abroad, using review committees for the assessment of the projects and producing guides/manuals to guide its officials in their tasks.

Differences include the low budget of THRIP in general and the small contribution of government in comparison to the contribution of the industrial partners in particular. These findings are particularly important to the competitiveness of the country's industry (both big and small enterprises). It was found that the THRIP budget has remained at around R150 million over the past ten years. This means that, in real terms, government's contribution is almost half of what it was ten years ago. During interviews some NRF officials mentioned that THRIP could

easily absorb twice to three times its current budget. This issue is confirmed by the fact that THRIP is currently funding successful projects only partially and a number of qualifying projects are not funded at all. A doubling of the Programme's funding would bring it to its initial levels in terms of purchasing power parity (value of money over time).

6.1.2 Perceived impact of THRIP

The following findings relate to the impact-related questions described in the ToR.

6.1.2.1 Technology development

What impact does THRIP have on technology development?

The industrial stakeholders declared that the THRIP projects are strategically important to their organisations. They mentioned that the Programme's cost-sharing, industry-driven approach has shown considerable success in advancing technologies that can contribute to important societal goals, such as improved health (for example, controlling air pollution from domestic fires with the *Basa Magogo* project); developing tools to add value in the country's mining resources (for example, gold-based catalysts); and improving the efficiency and competitiveness of the South African manufacturing industry. Furthermore, they emphasised that technology fields like big data and predictive analytics; breast imaging system development; metal matrix composites; grid/cloud-based mobile computing; and Internet of Things for smart cities would not have been available in South Africa without THRIP.

THRIP facilitates additionality. More than a quarter of the business stakeholders declared that their projects would not have been undertaken in South Africa without THRIP support and the rest declared that the project would have suffered from reduced objectives, longer time scales and a lack of partners.

6.1.2.2 Return on Investment (RoI)

Do industry partners realise a significant return on investment?

The industrial stakeholders declared that they expect substantial revenues from selling goods or services that incorporate THRIP technology. The expected average revenue is R 24 million after five years from the completion of the project and R224 million 10 years after the completion of the project.

6.1.2.3 Small, medium and micro enterprises (SMMEs)

What impact does THRIP have on SMMEs?

THRIP pays particular attention to SMMEs and, during the recent years, there were twice as many participating SMMEs than large corporations. There are not only twice as many SMMEs as large organisations in THRIP, but they also declare that high benefits arise from their

participation. Comparisons of the SMME responses with those across all industries show that SMMEs receive commercial returns and economic impacts well above those in the average participating industry. SMMEs gave full marks on the statements that their participation in THRIP: "increased competitiveness", "improved turnover", "improved financial viability" and "increased productivity". Furthermore, the SMMEs declared that the projects are strategically important to their organisations.

Public/private partnership arrangements targeting SMEs are an international phenomenon. There are two reasons for this. The first is that successful innovation in firms will increase the number of competitors, leading to improved performance in product markets and consequently facilitating job creation. The second is that there is a general perception that SMEs face higher risk and uncertainty in technological innovation because of their limited R&D portfolios and lack of resources, such as information, and human and financial capital. Market failures may also arise in product markets when the dominant position of large firms or the oligopolistic structure of a given market impedes innovations by SMEs.

However, the above does not mean that large corporations do not need innovation support. Asia's emergence was based to a large extent on the ability of large corporations to enter international export markets. For example, the government of General Park Chung Hee (1962–1979) came to the conclusion quite early on that Korea needed big companies if it were to compete in the international markets. To achieve that goal, they promoted a series of national champions called *chaebols*. (Yergin & Stanislaw, 1998). These firms were nurtured with low-interest government loans, tax advantages and other incentives to enable them to become large and strong industrial groups. Thus were born companies of which the names are now globally known, such as Hyundai, Samsung and Daewoo.

Similarly, the OECD suggests that "blindly promoting partnerships between SMEs and universities could divert resources away from projects with larger firms that may have potentially higher social and private returns" (OECD, 1998).

6.1.2.4 Skills development

What is the impact of THRIP on skills development?

THRIP's mission states that the Programme aims to "produce a flow of highly skilled researchers and technology managers for industry". The investigation found that the Programme engages just under 300 honours graduates, more than 750 master's students and over 400 PhD candidates per financial year. Apart from the number of graduates participating in the Programme, what is of critical importance, is the fact that those postgraduates are involved in research topics chosen and relevant to industrial partners. In addition, the industrial partners declared that part of the benefits of the THRIP project in their organisation were "qualifications earned by their staff". The average organisation declared that, during the period of the THRIP project, eight (8) members of staff earned additional qualifications, and during the three (3) years following the end of the project, ten (10) members of staff earned additional qualifications. Taking into account that approximately 300 projects are initiated annually, the

number of staff members earning qualifications after the end of the project becomes substantial. THRIP makes a substantial contribution to the development of human resources for industry.

6.1.2.5 National return on investment

Does South Africa as country realise a significant return on investment?

THRIP supports economic growth through a variety of channels. The HEIs in the country produce, except for knowledge and skilled graduates, their own economic output. They also employ numerous employees of different professions and at various qualification and skills levels. In addition to their own output and employment, universities generate additional output and employment in other economic sectors through secondary or "knock-on" multiplier effects. It is estimated that the total GDP generated from THRIP (through the interface with the education sector) is R508 million. The importance of the figure becomes profound when one takes into account that government contributes approximately only R150 million to the Programme. Furthermore, it is estimated that the Programme supports 2 290 jobs in the economy (through direct and indirect effects). It should be emphasised that the above figures do not take into account economic growth and employment effects due to e.g., new knowledge, skills development, industrial competitiveness, etc.

The industrial stakeholders were asked to rate from 1 to 10 the contributions that THRIP makes in a number of its policy objectives. In the rating, the objectives "improved economic development and growth"; "improved employment situation"; "improved preservation of the environment"; "improved standards of living in rural and semi-rural communities"; and "improved competitiveness" had a median of 8. This means that more than 50% of the respondents rated the objective at 8 or higher.

The industrial stakeholders were further asked to provide estimates of the expected revenue from their THRIP projects and from the relevant tax rates. Estimates of the expected taxable revenue created by each THRIP project show that from the 5th to the 10th year after completion, each project is expected to generate R7.2 million, and after the 10th year, the tax revenues increase substantially. These amounts are considerable, taking into account that THRIP contributes less than R1 million to the average project. THRIP not only provides a substantive return to the industrial participants, but it also provides a return on investment to the country.

Industrial stakeholders ranked THRIP's impact on competitiveness highly. They were asked to rank the indicators for and routes by which THRIP enhances competitiveness in industry. The highest-rated routes are "higher quality goods, services, etc."; "expanded reputation for THRIP and leading-edge technology"; and "improved innovation performance". The long-term expected impacts are more important than the impacts during the undertaking of the project.

THRIP-supported research is producing, on average, 30 patents per year, as well as copyrights, trademarks and designs. The stakeholders mentioned that a number of technologies are commercialised, even though the Programme does not provide incentives after the prototype stage. In the question: "Since the end of THRIP project funding, how much has your company

spent on continued R&D and commercialisation of your THRIP project?" the average respondent mentioned that they had collectively spent R3.84 million. It is apparent that THRIP projects are supported by the industrial partners well after the THRIP funding of the relevant project ceased.

6.1.2.6 Intellectual property and commercialisation

What happens to the IP and is it commercialised?

The stakeholders (both from the science base and the industrial sector) declared that the Intellectual Property Rights from Publicly Financed Research and Development Act, Act No. 51 of 2008, is a challenge. It is emphasised that this is not an implementation challenge, but an inhibiting environmental factor.

The issue of IP is an interesting one in the THRIP context. Patents are a performance indicator reported by NACI to the DST. However, the country's innovation system produces a limited number of international patents. It can be argued that this is the result of the structure of the economy (lack of high-technology industries and large multinationals) and probably a lack of appropriate government support.

THRIP statistics show that the Programme produces just over 26 patents per year (locally and abroad). As there are no detailed statistics, it is difficult to judge the quality of these patents. For example, local patents are not examined for novelty, usefulness, etc. (Pouris, 2011). On the other hand, South Africa produces less than 120 patents in the United States Trademark and Patent Office (USPTO) per annum. Hence, if THRIP patents are granted by the USPTO, the Programme makes a substantial contribution in the field.

It should be emphasised that THRIP does not support near-market development. Hence, from an incentive structure perspective, the Programme cannot influence the progress of IP to commercialisation. However, the industrial partners declared "licenses issued" among the outputs produced (1.6 licences issued during the period that the Programme was running and just over three (3) during the three (3) years after completion of the project).

On the question: "What changes in the IP regulations can improve chances of commercialisation of the THRIP projects?" the majority of respondents mentioned the adverse effects of the Publicly Financed Research Act on THRIP.

6.1.2.7 Benefits for South Africa

To what extent are benefits of THRIP realised in South Africa?

THRIP prevents foreign companies to benefit from the Programme. It is also important to quote **the dti** (2008) report, which states: "*In-depth analysis, however, indicates that if there are technologies that have been "lost" abroad during the period under examination – in the sense that they have been successfully commercialised and provide an income to their current owners (without benefit to original inventors) – they are not profound. The case studies that we*

investigated did not identify any technologies that have been transferred abroad (to the detriment of the inventors); are successfully commercialised; or provide an income to their current owners."

THRIP creates benefits for the South African national system of innovation and its benefits are not lost abroad.

6.2 Recommendations

A review of a research support Programme with a relative broad scope of objectives and initiated 12 years ago should generate a broad spectrum of recommendations. However, it was decided to reduce the recommendations to the minimum number of high level advices, namely six. The findings and evidence reported here justify the following six recommendations; each recommendation is accompanied by cross-references to the relevant findings discussed in Section 6.1:

6.2.1 Recommendation 1: **the dti** should retain THRIP and enhance the government's financial support. A doubling of the Programme's funding should be the first objective over the intermediate term.

From the evidence presented, (relevance, benchmarking and impacts) it becomes apparent that THRIP is a valid and important element of the South African government's portfolio of innovation support measures. Following international best practice, it offers considerable value for money and has not yet reached the stage where it is running into diminishing returns. It is recommended that THRIP should be retained and its available funding should be increased according to industrial absorptive capacity and needs.

6.2.2 Recommendation 2: **the dti** and NRF should protect and enforce the core principles contributing to THRIP's successes**.**

The success of THRIP in contributing to national objectives, according to evidence from benchmarking and relevant stakeholders' opinions, depends on its ability to retain a number of core principles. Failure to do so will result in a dilution of the Programme and diminishing its contribution to technology transfer and innovation in the country. The recommended principles that should constitute the Programme's "hurdles" (minimum entry requirements) are as follows:

- Collaborative research involving at least two partners – one business and one from the research base;
- Scientific quality of research;
- Pre-commercial character of research, which can be safeguarded through the participation of more than one firm; and
- The maximum funding available from government of 1:2 for most research and 1:1 for projects with particular requirements should be reconsidered by **the dti** with the objective

of bringing the Programme on a par with international standards and supporting the local industry appropriately

6.2.3 ***Recommendation 3:*** **the dti** and NRF should act to improve the operational challenges of the Programme, namely the number of Programme objectives; partial funding; participation of companies partially owned by HEI/SETIs; participation of unsuccessful universities; and Programme evaluation

Evidence from the process question and benchmarking reveals that there is a need to continuously review the processes that underpin and support THRIP in order to ensure that users are provided with the most efficient and effective service possible. Areas where refinements are required as a matter of priority are the following:

- THRIP should reduce the number of Programme objectives following international good practice;
- The issue of partial funding of projects should be applied only when the committee has reasons to believe that the relevant costs are inflated;
- The monitoring of the projects should be expanded so that their impacts could be tracked after their completion;
- THRIP should consider accepting contributions from companies owned wholly or partly by HEIs/SETIs up to a limit of 25% ownership;
- THRIP should consider developing separate approaches linking unsuccessful universities with relevant industrial establishments and successful THRIP institutions; and
- Programme evaluations (like this one) should be undertaken every five years. The ten-year horizon is too long for evaluation as the majority of the early participants are not available to contribute to the evaluation.

6.2.4 ***Recommendation 4:*** The THRIP management and executive should create links with similar international programmes and learn from their experiences.

There are a number of programmes similar to THRIP internationally. In the review, the following were ones identified, the Canadian CRD grants and the ATP in the USA. THRIP could benefit by establishing linkages with such programmes and learn from their experiences and approaches.

6.2.5 ***Recommendation 5:*** **the dti** should consider the expansion and supplementation of THRIP in support of industry for the uptake and commercialisation of the knowledge generated, including the monitoring and evaluation of THRIP project outcomes beyond project conclusion.

THRIP plays a unique role in the country's system of innovation. However, its domain covers all research necessary to resolve industrial challenges. Following international good practise and

according to evidence from the theory of change it is important for **the dti** and the country to develop additional programmes and streamline the existing ones that support industry to take the projects further and commercialise THRIP-produced know-how. Such an approach would have the additional advantage that existing programmes will not have to operate on the basis of the "one-fits-all" approach.

6.2.6 Recommendation 6: **the dti** should engage with the DST in order to resolve the challenge of intellectual property ownership.

THRIP participants identify the IP regime within which the Programme operates as an obstacle to commercialisation. THRIP and **the dti** should engage with the DST to identify ways of simplifying the IP regime for THRIP projects. The *IP Draft Policy* that is being developed by **the dti** could also provide relevant recommendations.

6.3 Concluding summary

This chapter provides evidence-based responses to the implementation and impact questions contained in the original Terms of Reference and offers a small set of recommendations based on the findings. The evidence was produced by a mixed methods evaluation design that offered the opportunity of triangulation of the findings.

In summary, it can be concluded that:

- THRIP is a valid and important element of the South African government's portfolio of innovation support measures. It is efficient and offers considerable value for money both in terms of technology development and in terms of developing human resources with industry related skills. Its core principles of collaboration and quality of research and development are in accordance with international best practise. It is recommended that THRIP should be retained and its total funding available should be increased according to industrial absorptive capacity and needs.
- While the Programme is efficient and achieve its main objectives (new technologies and knowledge and human resources for industry) it can benefit by reducing the number of its objectives; streamlining its funding to meet stakeholders requirements; introducing post-project monitoring and assisting non-participating universities to participate in the Programme.
- THRIP plays a unique role in the country's system of innovation, but its domain is primarily designed to support applied research. Following international best practise it is important to develop additional programmatic activities supporting industry to take further and commercialise the THRIP produced know-how, including the monitoring and evaluation of THRIP project outcomes beyond project conclusion.
- Two major challenges confronting THRIP are addressing the intellectual property regime surrounding THRIP and increasing the public financial support.

The various sources of information utilised in this evaluation, viz. official statistics and analyses of the NSI strategic ecology, stakeholder interviews, comparative international analysis of similar programmes, two stakeholder surveys and a theory of change workshop, converge to support the overriding conclusion that THRIP has up to the time of the evaluation been a highly successful programme. Furthermore, there seems no reason why its success should diminish in future, especially if it would respond positively to the recommendations in this evaluation report.

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Absa¸ member of Barclays
AEL Mining Services
Aerosud
Agricultural Research Council
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Amathole Forestry
Anglo American Thermal Coal
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Durban University of Technology
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Exxaro Resources
Gaborone Engineering Consulting
GEA Aircooled Systems
Genio Roasters
GEW Technologies
GMSA National Research Foundation
GMSA University of Pretoria
Horse Racing South Africa (Pty) Ltd
Hortgro Science
Howden Africa Holdings Limited
Jeenel Technology Services Pty Ltd
Key Structure Holdings
Komatiland Forests (Pty)Ltd
Lumegen Laboratories
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Mondi
NCT Forestry Co-Operative
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National Research Foundation (NRF)
Paper Manufacturers Association of South Africa
Post-Harvest Innovation Programme
Rhodes University
Richards Bay Minerals
SA Chamber of Commerce and Industry
Sasol Technologies

Simmentaler/Simbra Cattle Breeders Society of South Africa
South African Ostrich Business Chamber
South African Sugarcane Research Institute
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Telsaf Data (Pty) Ltd
the dti
Tshwane University of Technology
University of Cape Town
University of Fort Hare
University of Johannesburg
University of KwaZulu-Natal
University of Pretoria
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University of the Witwatersrand
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Appendix A: Implementation and impact evaluation of THRIP: Survey questionnaire for universities/research organisations

This survey is part of the DPME/dti's effort to review THRIP (see attached letter).

It will be important to complete the short questionnaire and also disseminate it to your relevant researchers.

Please complete the questionnaire and email it to Prof A Pouris at apouris@icon.co.za or anastassios.pouris@up.ac.za by……. For any further information please do not hesitate to contact Prof Pouris at 083-630 5996.

Name and position	
Email	
Institution	

A. How do you rate THRIP's effect on the following? Please tick one in each row.

The Programme's effect on:

	High		Avg		Low
1. Technology transfer from university to industry					
2. Supporting students to complete their studies					
3. Linking industry and academia/councils					
4. Support students from previously disadvantaged back grounds to complete their studies					
5. Making the university responsive to industry's priorities					
6. Making the university responsive to government's priorities					
7. Produce graduates with skills demanded by industry					

Please elaborate on your impressions of THRIP's effects.

B. How do you rate THRIP project's administration?

		High		Avg		Low
1.	Effectiveness of application process					
2.	Effectiveness of application requirements					
3.	Appropriateness of evaluation criteria					
4.	Effectiveness of monitoring procedures					
5.	Effectiveness of marketing of Programme					
6.	Appropriateness of resources available					
7.	Accessibility of management team					
8.	Effectiveness of disbursing funds					
9.	Efficiency of funds auditing system					
10.	Cost-effectiveness of Programme					

11. How would you like to see the structure and administration of the Programme change for the better?

C. What factors facilitate or inhibit the beneficial effects of THRIP?

		Strongly facilitate		Avg.		Strongly inhibit
1.	Assistance/advice from NRF					
2.	Assistance/advice from your institution					
3.	Your geographical location					
4.	Pre-established relationship with industrial partners					

5.	Ability to find new industrial partners					
6.	Requirement to find industrial partners willing to make cash contribution					
7.	Availability of postgraduate students					
8.	Relevance of your research to industry					
9.	Intellectual property agreement/management issues					

10. Others, please specify

D. Please provide an indication of the number of postgraduate students that participated in THRIP and were subsequently employed by the industrial partner or your institution (your best estimate will do).

Industrial partner	Your own institution

E. Outcome 4 of the *President's Delivery Agreement* emphasises economic growth and job creation. To what extent does THRIP contribute towards achieving this outcome?

F. What changes in the intellectual property regulations can improve chances of commercialisation of the THRIP projects?

G. Are you aware of any new fields of research that emerged in your institution because of THRIP? Please elaborate.

H. Please indicate how many full-time equivalent (FTE) new jobs THRIP creates in your institution annually (your best estimate will do).

I. Should THRIP be implemented differently? If so, what changes could be made?

Thank you for your participation.

Appendix B: Implementation and impact evaluation of THRIP: Survey questionnaire for industrial partners

To be completed by the project coordinators of organisations most likely to benefit directly from the conduct of the project. Please complete those questions that are relevant to your participation to THRIP. Please return the questionnaire to Prof A Pouris at anastassios.pouris@up.ac.za. For any information please contact him at 083 630 5996.

Please return by 10 March 2014

Respondent details:

Name of person completing the form					
Position within the organisation		Tel:		Email:	
Name of your organisation					

Project details:

Recent project title:	
Amount invested in THRIP projects	

Name of project leader:	
Name of research institution:	

1. Nature of your project

In hindsight, please indicate the strategic importance of this project to your organisation

Minor importance							Major importance

Please indicate whether or not the project has led to significant commercial returns for your organisation and whether any are expected in future. Leave blank if there are none realised or anticipated.

Negligible commercial returns to date						Significant commercial returns to date
Negligible commercial returns expected in future						Significant commercial returns expected in future

In hindsight, what would have happened if the project as a whole had not received THRIP funding?

Project would not have been undertaken by any of the partners	
Project would have continued without THRIP funding, but your organisation would have not participated in the project	
Project would have been undertaken only abroad	
Your organisation would have participated but:	

With no partners		With reduced funds	
With no international partner		Reviews objectives	
With fewer local partners		With longer time scale	
With other partners		Other (please specify)	
With same partners			

What is the expected rate of return on investment that your company typically applies to research and development investment decisions.

a) 5 years after project completion ____ b) 10 years after project completion ____

Since the end of the THRIP project funding, how much has your company spent on continued R&D and commercialisation of your THRIP project?

(Your best estimate will do) R million ____

2. Outcomes for your organisation

The goals normally associated with R&D programmes can be classified as follows:

- **Knowledge-oriented goals.** These are goals of a technical nature concerned with the expansion and consolidation of know-how and knowledge bases. Examples include “deepen understanding”, “upgrade skills”, and “develop new tools and techniques”.

- **Exploitation-oriented goals.** Some goals have a strategic or commercial orientation and are more concerned than others with the eventual exploitation of knowledge and skill bases. Examples include: “develop new products”, “production of patents and licences” and “improve competitiveness”
- **Network-oriented goals.** These relate to network formation and the establishment of new links and partnerships. They have a structural or systemic nature in that they invariably refer to the relationship between an organisation and its environment. Examples include: “access academic know-how” and “establish new academic-industry links”.
- **Strategic management-oriented goals.** Goals such as “access additional funds”, “reduce costs” and “spread risks” reflect a combination of opportunistic, economical and parsimonious practices characteristic of sound R&D management and stewardship.

Participation in R&D programmes provides organisations with an opportunity to attain goals such as these. Please estimate the scale of actual changes in organisational capabilities, performance or behaviour in the following areas as a consequence of your organisation’s participation in this project.

Goals	**Actual change in organisational capabilities, performance or behaviour** Minor 1 2 3 4 5 Major
Knowledge-oriented goals	
Exploitation-oriented goals	
Network-oriented goals	
Strategic management goals	

3. Project outputs. Please provide actual data and/or estimates for the following outputs from your organisation related to THRIP.

Output	**Number of outputs during project**	**Number expected 0-3 years after project end**
New tools or techniques		
Demonstrators, prototypes, pilots, etc.		
Patent applications		
Patents granted		

Output	Number of outputs during project	Number expected 0-3 years after project end
Copyrights, trademarks, registered designs, know-how agreements, etc.		
Licences issued		
Qualifications gained by personnel as a result of the project (PhDs, etc.)		

4. Economic impacts on your organisation

Please indicate the relative scale of the following downstream impacts to date as a result of your participation in this project. Also indicate the likelihood of future impacts and their expected scale, with a quantitative estimate of percentage change where applicable. Leave blank if not relevant, or when no further impacts are expected.

Economic impacts	Scale of actual impacts by project end Minor Major 1 2 3 4 5	Overall expected returns Minor Major 1 2 3 4 5
Increased turnover		
Increased profits		
Greater savings		
Improved financial viability		
Expanded share of existing markets		
Creation of entirely new markets		
Entry into new markets for your organisation		
Entry into new geographical markets for your organisation		
Increased productivity		
Increased competitiveness		

Please indicate the relative scale of actual impacts to date. Also indicate the likelihood of future impacts and their expected scale, with a quantitative estimate of percentage change where applicable. Please leave blank if not relevant, or when no further impacts are expected.

Routes to enhanced competitiveness	Scale of actual impacts by project end Minor Major 1 2 3 4 5	Overall expected returns Minor Major 1 2 3 4 5
Reduced labour costs		
Reduced capital costs		
Reduced material input costs		
Lower energy calls		
Reduced overheads		
Higher quality goods, services, etc.		
Lower prices		
Expanded product/service range		
Expanded reputation for THRIP and leading-edge technology		
Improved innovation performance		
Reduced throughput time		
Faster time to market		
Greater production flexibility		
Establishment of *de facto* standards		

Overall expected commercial returns R Million	
	5 >10,000
	4 1 000–10 000
	3 100–1 000
	2 10–100
	1 0–10

5. National policy goals

THRIP is intended to achieve a range of high-level policy goals. Please indicate the probability of your project contributing to each of the following policy goals using a scale of 0 (no probability) to 10 (absolute certainty). Leave blank if no impacts are expected, and indicate negative impacts with a minus (-) sign.

Policy goals	Probability of contributing to policy goal 0-10

Policy goals	**Probability of contributing to policy goal** **0-10**		
Improved employment situation			
Improved quality of life			
Improved preservation of the environment			
Improved economic development and growth			
Improved competitiveness			
Improved standards of living in rural and semi-rural communities			
Contributed to poverty alleviation			
Improved science and technology capability			
Establishment of critical R&D masses			
Increased levels of investment in R&D			
Development of standards			
Improved inputs to policy formulation			
Improved inputs to regulation & legislation			
Implementation of SA government goals			
Other (please specify)			

5.1 Outcome 4 of the *President's Delivery Agreement* emphasises economic growth and job creation. To what extent does THRIP contribute towards achieving these outcomes?

5.2 In your opinion, how do you think THRIP has contributed, if at all, to SA's growth, skills development and job creation, in comparison to other programmes? Please indicate if we can quote you.

Please indicate the relative scale and timing of expected impacts in the following areas, together with a quantitative estimate of overall expected impact. Leave blank if no impacts are expected, and indicate negative impacts with a minus (-) sign. Your best estimates will do.

Employment	**Scale of impacts**					
	0-3 years after project end			**3-10 years after project end**		
	Minor		**Major**	**Minor**		**Major**
	1	**2 3 4**	**5**	**1**	**2 3 4**	**5**
Net employment growth in own R&D workforce						
Net employment growth in own organisation						
Net employment growth in project consortium						
Net employment growth in customer and supply chains						
Net employment growth in economy at large						
Net employment growth in rural & semi-urban areas						

How much revenue is your company expected to earn from selling goods or services incorporating THRIP technology?

a) 5 years after completion (R million) ☐ b) 10 years after completion (R million) ☐

What is the expected tax rate on the above revenue? ☐

Spill-over effects	Scale of expected impacts						Overall expected level of vertical/horizontal spill over effect (100% spill-over = all THRIP knowledge)		
	0-3 years after project end			3-10 years after project end					
	Minor		Major	Minor		Major			
	1	2 3 4	5	1	2 3 4	5	% spill-over		
It created positive vertical spill-over effect up and down the value chain									
It created positive horizontal spill-over effects in industry and/or region									

What made you use THRIP

Only source of funds	
Improve company's reputation	
Reduce risks	
Contribute to national objectives	
Other (please specify)	

6. Administrative services

Please assess the quality of services provided by THRIP offices in the administration of services

	Low				High	Comments/Recommendations
Efficiency in administration						
Ability to handle queries						
Speed of application process						
Quality of feedback						
Provision of ongoing support						
Fairness of evaluation						
Effectiveness of application process						
Efficient access of monitoring and evaluation						

Accessibility and communication						
Marketing of the Programme						
Effectiveness of governance						

7. What are the THRIP's strengths and weaknesses? How can obstacles be overcome?

8. How can THRIP-based projects improve their chances to be commercialised?

9. Should THRIP be implemented differently? If so, what changes could be made?

Thank you for your participation!

Appendix C: Information for the implementation evaluation of THRIP: Questionnaire for dti

Our organisation has been commissioned by the Department of Performance Monitoring and Evaluation (DPME) and **the dti** to conduct an implementation/impact evaluation on THRIP. The purpose of this evaluation is to provide insight into the effectiveness and efficiency of the current model of implementation.

Please complete the questionnaire and email it to Prof A Pouris at apouris@icon.co.za or anastassios.pouris@up.ac.za by……. For any further information please do not hesitate to contact Prof Pouris at 083 630 5996.

Given your knowledge and experience with the Programme, you are requested to respond to a few questions.

1) THRIP has a long history in **the dti's** efforts to enhance business competitiveness. Are there particular issues of interest from the department's perspective?

2) To what extent are THRIP's objectives being achieved?

3) How does THRIP set targets according to its objectives?

4) Outcome Four of the *Presidency's Delivery Agreement* emphasises economic growth and job creation. To what extent would you say THRIP contributes towards achieving this outcome?

5) Are there other alternative models that **the dti** considers for improving cost-effectiveness of THRIP?

6) The THRIP Board is concerned about the Programme's large number of performance indicators. What is **the dti's** position on the matter?

7) The THRIP budget has been static for a number of years. What could be the reasons for this?

8) Do you think that THRIP is appropriately situated in the National Research Foundation (NRF)? If yes, why do you think so? If no, what other agency might be appropriate?

9) Are there other issues that **the dti** would like to discuss on the implementation of THRIP?

Thank you!

Appendix D: Background on THRIP application processes and grant types

1. Process for application for THRIP funding

THRIP, as a funding instrument, is managed and administered through NRF processes. The NRF has a well-developed process that takes care of each stage of the process from preparation of relevant documentation for the call for proposals to receipt of monitoring reports (NRF, 2013a). The NRF produces manuals that dictate processes that are endorsed by the Board (NRF, 2013c). The manuals are used as guidelines by the auditors for monitoring compliance. Officials of the NRF Grants Management and Systems Administration (GMSA) emphasised that all their processes are guided by international best practice. Each stage is linked to control and quality mechanisms, as well as PFMA requirements. Specialised directorates take care of the IT and evaluation needs of the Programme.

The GMSA research administrator accountable to the NRF for a specific HEI or Science, Engineering and Technology Institution (SETI) is responsible for:

- Validating all online applications before submission to THRIP; and
- Ensuring that the industry partner has informed the NRF of support or rejection and that the project leader is informed.

The assessment of applications for grants forms the cornerstone of a funding programme and the basis for determining whether it follows best practices. The THRIP assessment procedures are therefore reported in some detail in this section. The assessment takes place as follows (NRF, 2012b: 7):

- NRF involves external experts, in various technical fields, to assess the applications. Panel members declare any interests and recuse themselves where appropriate;
- MANCO makes the final decision on support;
- The first communication of outcomes is sent from the NRF to the research administrator at the HEI by email; and
- Letters of regret for unsuccessful applications are prepared and mailed to the HEI research administrator, individual project leaders and their industrial partners (NRF, 2012b: 7).

In the case of successful applications, the project leader is responsible for:

- Signing the latest set of conditions of grant;
- Submitting proof of payments to the research administrator within three (3) weeks of industry receiving payment;
- Nominating students on the NRF online system (funds will not be released before students are nominated); and
- Submitting copies of the signed Memorandum of Agreement between the industry partner and the project leader (NRF, 2012b: 7).

The research administrator and financial officer at the HEIs and SETIs are responsible for:

- Collating and sending the validated (stamped/signed) conditions to THRIP before grant funds can be disbursed;
- Validating proof of payment and that expenditure will be project related; and
- Collating and sending validated payments to THRIP on a monthly basis (NRF, 2012b: 7).

THRIP requires the following types of reporting from grant-holders:

- An annual progress report;
- A financial report; and
- A final report at the conclusion of a project.

Furthermore, once a year THRIP engages in a technical audit of randomly selected THRIP projects. The purpose of these audits is to:

- Witness some of the outcomes (technology, human resources, publications, etc.) as was expected through the project proposal and/or reported in the Progress Report;
- Witness the facilities and equipment supported through THRIP; and
- Interact with project leaders, team members, students and industrial partners involved in THRIP projects (NRF, 2014: 25).

A relevant manual (NRF, 2013b) guides the process related to technical audits.

2. Types of grants and conditions

THRIP funds projects according to the type of industrial partner. The funding ratios for respective partners have evolved over time (Botha, 2010). Initially, the ratios of the Programme were 1 to 1. Stakeholders still recommend such a ratio. The recent (2014) funding ratios are as follows:

Large organisation:	THRIP 1: Organisation 2
SMMEs:	THRIP 1: Organisation 1
Black female grant-holder:	THRIP 1: Organisation 1
SMMEs and B-BBEE entities:	THRIP 2: Organisation 1

Furthermore, the THRIP contribution awarded to a project is calculated based on the number of students involved, as well as the industry partner's financial contribution.

The following funding limits currently (2014) apply:

- For every R200 000 or part thereof of the THRIP-awarded amount, at least one South African student must be involved in the project. The student must be at fourth-year level of

study or higher, and spend at least 20% of their time on the project. In the case of students from African countries, the equivalent amount is R85 000.

- A THRIP contribution to the Technology Innovation Promotion through the Transfer of People (TIPTOP), according to the approved project support ratio, to a maximum annual package of R300 000.

- A once-off contribution to a SMME or to a project leader based at an HEI of maximum R10 000 towards the cost for legal advice on the development of an agreement on the treatment of intellectual property rights (IPR). This amount needs not be matched by an industrial partner contribution. The IPR budget items must form part of a THRIP application.

- The maximum level of THRIP funding per grant-holder is set at R8 million across any number of projects per annum.

TIPTOP, which is an incentive to encourage industry employees to further their studies while continuing their employment, is part of THRIP. It also encourages academia to obtain industry experience while being involved in their research activities. The transfer of knowledge is possible through the physical relocation of participants between the organisations involved in the projects (from the HEI or SETI to the industrial laboratories, or from the industrial laboratories to the HEI or SETI). The salary cost of the TIPTOP candidates is shared between THRIP and the particular industry partner.

Appendix E: Economic gains from R&D

The importance of R&D and of the associated innovations, for growth and employment, is well established in the economic literature. Estimates from both the firm and industry levels indicate that the social rate of return to R&D ranges from 20% to 100%, depending on the sector and the average is approximately 50%. By comparison, the net private rate of return on R&D varies from 20% to 30%. This difference justifies government involvement in order to improve social benefits.

The following studies are some of the most-cited studies in the field:

Solow[1] identified the factors that underlie the doubling in gross output per hour of work that the USA enjoyed between 1909 and 1949. He estimated that of all factors (capital, labour, savings, etc.) technical change had contributed seven eighths of the improvement in economic growth. Solow won the Nobel Prize for his studies in economics in 1987.

ZVI Griliches,[2] in a study of 883 companies representing more than 80% of the entire industrial R&D conducted in the USA, found a 17% rate of return to total R&D, private plus government funded, for the period 1957 to 1965. There was a wide range in the rate of return by industry, with the chemical industry at the top at 93%, electric equipment, and aircraft and missiles at the bottom at 3% to 5%, and metals, machinery, and motor vehicles in the middle at 23% to 25%. For privately financed R&D alone, Griliches found a substantially higher average return of 32% to 40%.

Terleckyj[3] found Griliches' rate of return to be quite comparable to his own value for the manufacturing industries of 37% return on private R&D when only direct R&D inputs were considered.

Chand[4] examined the performance of 19 Canadian industries according to the amount they invested in R&D. He estimated that research-intensive industries over a period of 13 years had a 50% higher growth in output, 29% higher growth in productivity and 56% lower growth in prices than other industries. In comparison with industries that did not undertake research, employment in the research-intensive industries grew by 231%, output expanded by 66%, there was a 43% higher growth in productivity and 57% lower growth in prices.

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[1] Solow, R. (1957). Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics,* 39: 312-320.

[2] Griliches, Z. (1985). Productivity, R&D and Basic Research at the Firm level in the 1970s. *National Bureau of Economic Affairs*, working paper (1547). Cambridge, MA.

[3] Terleckyj, N.E. (ed). (1977). *The state of science and research: Some new indicators*. Boulder, CO: Westview Press

[4] Chand, U.K.R. (1978). Does R&D boost industrial growth? *Canadian Business Review*, 5(3**)**: 27-31.

Edwin Mansfield[5] refined Terleckyj's work on the 20 manufacturing industries by dividing R&D into its basic and applied components. He found a "strong relationship between the amount of basic research carried out by an industry and the industry's rate of productivity increase during 1948 to 1966". In a further study of 37 innovations, Mansfield[6] compared the return on R&D for those innovations to the firm, making the investment (the "private return") with the return to society as a whole (the "social return"). He found a median private rate of return of about 25%, but a median social return of close to 70%.

The Office of Technology Assessment[7] in reviewing the productivity return to agricultural research concluded that "all but one of the studies has shown a very high internal rate of return on public sector agricultural research… The rate of return varies from a low of 21% to a high of 110%, with the vast majority of the 33% to 66% range".

Coe et al.[8] of the Centre for Economic Policy Research examined the links between R&D and productivity gains in OECD countries from 1970 to 1990. They concluded that an increase in business R&D increases total factor productivity (TFP - the output for a given input of labour and capital) with a response which was related to the total "stock" of R&D from domestic and foreign sources. The rate of return on industrial R&D was over 100% at the national level.

Bernstein[9] estimated the rates of return to R&D in the Canadian communications equipment industry and the Canadian manufacturing sector. The estimated social rates of return were found to be 22.5% and 24% greater than the private rates of return respectively.

The OECD[10] found that R&D is beneficial to the creation of employment. A country that lags behind in innovation tends to lose jobs to those countries that lead in the introduction of new technology.

Finally, in their latest report, the National Association of Manufacturers (NAM)[11] identify that tax incentives offered by governments to industrial establishments have a substantial positive effect on the economy.

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[5] Mansfield, E. (1980). Basic research and productivity increase in manufacturing. *American Economic Review,* 70(5**)**: 863.

[6] Mansfield, E. (1982). How economists see R&D. *Research Management,* 25(4): 23-29.

[7] Office of Technology Assessment. (1986). *Research funding as an investment: Can we measure the returns?* Congress of the USA, Office of Technology Assessment.

[8] Coe, D.T., Helpman, E., and Hoffmaister, A.W. (1995). *North-South R&D spill-overspill-overs*. UK: Centre for Economic Policy Research.

[9] Bernstein, J.I. (1996). *R&D and productivity growth in Canada: Communication, equipment and manufacturing.* Working Paper No. 10, Industry Canada. Ottawa.

[10] Organisation for Economic Cooperation and Development. (1986). Technology and jobs. *STI Review*, 1: 9-46. Paris.

[11] National Association of Manufacturers. (1998). *The R&D tax credit: Lasting gains in research and GDP.* Washington: National Association of Manufacturers

Econometric simulations run by NAM to assess the benefits of a 20% tax credit show that the economy will be 203% or $28 billion higher after 20 years than it would be in the absence of the tax credit. Further, NAM examines the impact of a full 10% credit allowed on annual R&D investments made by companies instead of the incremental credit. The result is that GDP increases by $174 billion over 20 years. The study, which was submitted to the Congress, concludes that increasing the credit will lower the cost of R&D even more, leading to more investment in research, faster gains in productivity and significantly larger gains in GDP.

More recent research (Kafouros, 2007) [12] concluded that R&D also drives significant organisational adaptations that favour business performance.

[12] Kafouros, M.I. (2007). *Industrial innovation and firm performance: The impact of scientific knowledge on multinational corporations.* Northampton, Massachusetts: Edward Elgar.

Appendix F: Summary of THRIP evaluation: Theory of change focus group

29 August 2014, 09h00 – 11h15 at BE at UP (Pty) Ltd, Hatfield

Attendance

Mr Ephraim Baloyi (**the dti**), Mr Mlungisi Mtimunye (**the dti**), Mrs Varsha Harinath (**the dti**), Mr Tim Dladla (**the dti**), Ms Shareen Osman (**the dti**), Mr Nsovo Mathebula (NRF), Mr Jabu Mathe (DPME), Dr HC (Bok) Marais (facilitator; BE), Mr Jaco Snyman (host; BE) and Mr Ruan van Buuren (scribe; BE).

Purpose of the meeting

1. To create a common understanding of the nature of a theory of change (ToC) and its functions in the evaluation of a Programme. For the purpose of the meeting a ToC was described as a mapping of the necessary constituent components and sub-processes required for an effective programme.

2. To give representatives of stakeholder organisations opportunity to identify what should be necessary dimensions and processes in a THRIP theory of change and to evaluate the ToC included in the current version of the draft report.

Focus group

The purpose of the focus group process was to generate ideas as to what should be included and accounted for in a THRIP ToC; it was not aimed at seeking consensus among the participants.

Main topics listed

- Government funding programmes operate in a policy ecosystem and it follows that THRIP should be aligned with policy, also changes in policy, and other government programmes.
- Provision should be made for the alignment between policy and resources.
- Consistency and co-ordination between government/industry on technology and innovation focus areas are preconditions for a Programme such as THRIP.
- There is a need for productive liaison between stakeholders involved in THRIP and that would imply the establishment of a kind of forum.
- Coordination between NRF sections involved in administering THRIP should be promoted.
- An annual call for applications is not necessarily practical given the dynamic nature of industry, e.g., in the form of intense competitiveness; responsiveness to industry needs would suggest rather an open or multiple calls per annum system.
- The sourcing of data for monitoring and evaluation of a programme represents a challenge. Furthermore, there should be agreement at the application stage on indicators for tracking of a project (and programme). There is a need for quick responsiveness to industry needs and to this end **the dti** is busy integrating all innovation and technology support programmes.
- Commercialisation of the outputs and outcomes of THRIP should be supported.

Feedback on the proposed ToC

The next session centred around two slides depicting the THRIP Theory of Change as it has been developed in the draft report and a proposed Amended THRIP Theory of Change (to support the commercialisation of outputs and outcomes) that was also included in the draft report (both figures are attached to this summary). The consolidated feedback is summarised below.

- There is an imaginary boundary between output and outcomes since THRIP does not support the conversion of outputs to outcomes. This contributes to the situation that different role players operate in/as silos; THRIP needs to link with other programmes to break silos – one solution is that **the dti**, DST, HEIs and industry participate in a 'forum' so that THRIP may cross the imaginary boundary between outputs on the one hand and outcomes and impacts, on the other. There is also a need for better co-ordination between programmes and actors to avoid 'double dipping' by researchers (Fig. 1).
- The distinction in the ToC between short and long term outcomes seems artificial since outcomes/impacts occur along a time continuum. Furthermore, provision should be made for medium term outcomes. In this regard it should also be remembered that there is often a dynamic movement of developments between outputs, outcomes and impact (Fig. 1).
- From monitoring, evaluation and general analysis perspectives, it would be useful to differentiate between 'macro' and 'firm level' impacts (Fig. 1).
- The suggestion was made to add 'knowledge generation' and IP under outputs, but it was also noted that in the research environment 'publications' is seen as representing knowledge generation (Fig. 1).
- Reciprocal linkages between 'Staff' and 'Funds', as well as insertion of 'R&D' somehow into the already busy Figures 1 and 2 are required.
- The question was raised as to whether the Intent/objective of THRIP was still appropriate for both 'technology' and 'human resources'? Related to this point was the issue of whether Figure 2 should not emphasise 'developing industrialists or entrepreneurs' more than 'employable skills '.
- The possibility was raised that THRIP should consider funding infrastructure in spin-off companies. Further, THRIP could perhaps scale down on the funding of research equipment for universities and instead invest in pre-production facilities in industry in such a way that more than one institution could benefit from it (Fig. 2).
- Any future changes to THRIP's current mandate and objectives should be careful not to lead to a duplication with other programmes, such as **the dti**'s ISP and TIA's Technology Stations (Figs. 1 & 2).

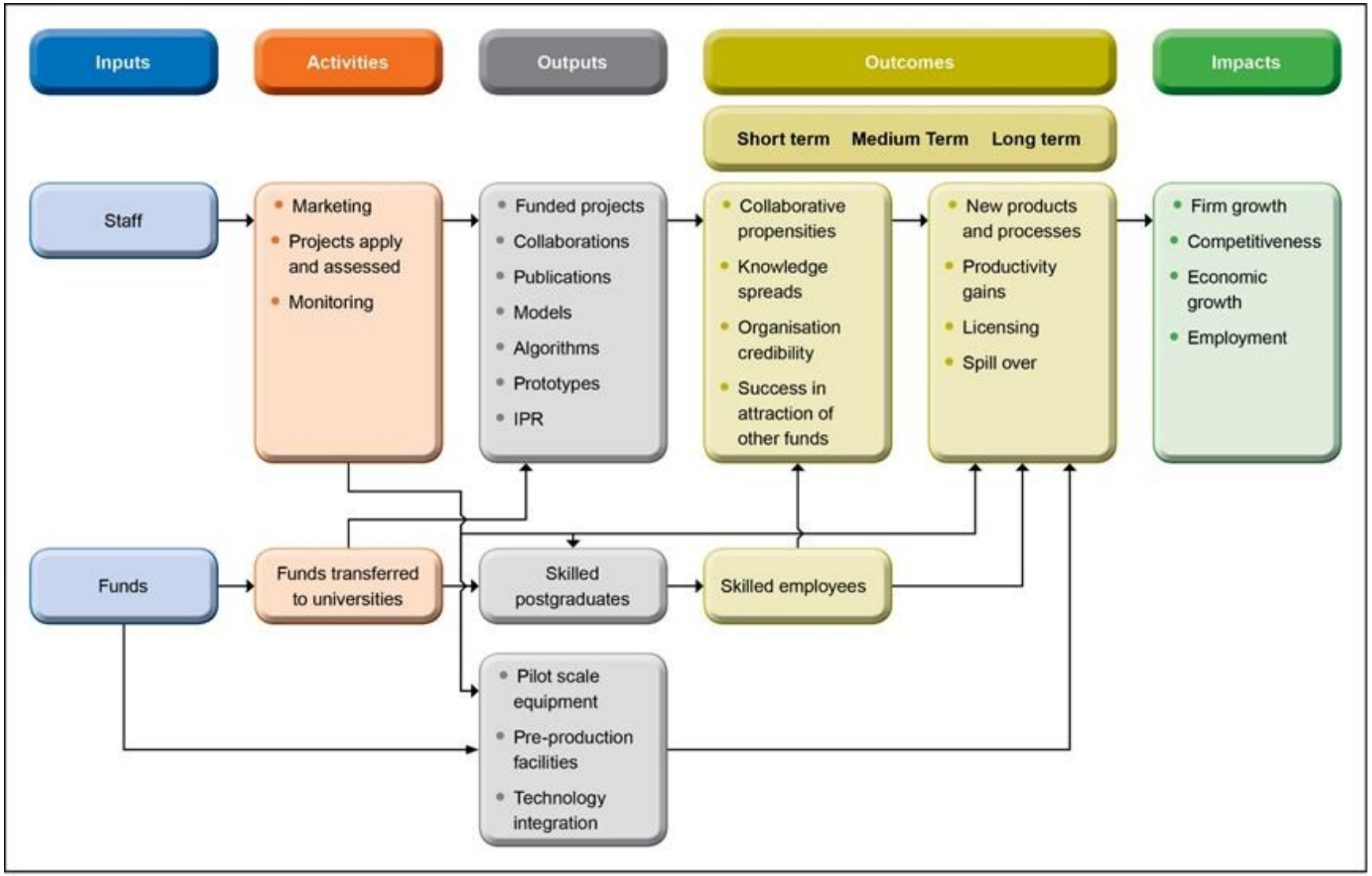

Figure 1: Theory of Change for THRIP