A Comparative Analysis of Science and Technology Policies of Three Countries and Its Relevance to Lesotho

by

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DECLARATION

I, the undersigned, hereby declare that the work contained in this assignment is my own original work and that I have not previously, in its entirety or in part, submitted it at any university for a degree.

Signature: ………………………………………. **Date:** …………………………..

ABSTRACT

The purpose of the study is to investigate and provide an overview of the science and technology systems of three countries, namely South Africa, India and Malaysia. The study seeks to describe the process of science and technology policy development; the relationship of science policy with national policies of these countries and the link between the science and technology policies and national goals. It also identifies the differences, strengths and weakness of the three systems and shows their relevance to Lesotho.

The methodology followed in the study was qualitative, conducted through desk research. The source of data was archival, specifically in the case of historical background of the three science systems and documentary, in terms of the current situation of the science systems of each country. The comparative analysis was textual based on the findings of the three case studies of each country.

The comparative analysis depicts the common features, strengths and weaknesses, pertaining to each country. The common features were identified in the areas of; National System of Innovation, Politicisation of Science, Indigenous Knowledge Systems and Pubic Understanding of Science. The differences of the three systems were characterised on trends in investment on science and technology, in terms of inputs in research and development, institutionalisation of science, nature of the policies and their implementation process inclusive of the policy instruments, and provision of conducive environment for the prolific growth of science and technology, as a key to socio-economic development of any nation.

The comparative analysis also provides lessons to be learned for a Least Developing Country (LCD) like Lesotho. This is in view of the current situation where the country is at its infancy stage to establish a stable, well-coordinated science and technology system.

The study recommends pragmatic solutions and strategies that can be copied and be employed, in order to enable science and technology have meaningful contribution towards socio-economic imperatives of Lesotho.

OPSOMMING

Die doel van die studie is om die wetenskaplike -en tegnologiese stelsels van drie lande, Suid-Afrika, Indie en Maleisie te ondersoek. Die studie behels die proses van wetenskaplike - en tegnologiese beleidsontwikkeling, die verwantskap tussen wetenskaplike staatsbeleid in die lande asook die verwantskap tussen die wetenskaplike en tegnologiese beleide en die landsdoelwitte. Die studie identifiseer ook die verskille, sterk-en swakpunte van die stelsels en toepaslikheid op 'n land soos Lesotho.

Die metodiek wat gevolg is tydens die studie was kwalitatief deur bestaande dokumente na te slaan. Die vergelykende analise vir die lande is gebasseer op die bevindinge van die gevalle studies wat vir elke land gedoen is.

Die vergelykende analise beskryf die algemene kenmerke asook die sterk-en swakpunte van elke land. Die gemeenskaplike kenmerke is geidentifiseer in die volgende areas; Nasionale Sisteem van Verandering, Politiseering van die Wetenskap; plaaslike kennis van Stelsels en die Algemene Publiek se kenis van die Wetenskap, Die verskille tussen die drie stelsels word gekenmerk deur die tendens van investering in wetenskap en tegnologie in terme van insette in navorsing en ontwikkeling, institusionalisering van die wetenskap, aard en implementering van beleide en die beleidsinsturmente wat gebruik word asook die skepping van'n omgewing bevorderlik vir die groei van die wetenskap en tegnologie binne 'n land.

Die vergelykende ontleding bevat ook lesse wat geleer kan word deur onder ontwikkelende lande soos Lesotho. Dit verskaf 'n mening van die huidige situasie waar 'n land in die begin stadium is om 'n wel deurgedagte wetenskaplike en tegnologiese stelsel te implementer .

Die studie beveel oplossings en strategie aan wat kan verseker dat 'n land soos Lesotho, deur die aanwending van die wetenskap en tegnologie ook sosiaal-ekonomiese voordele kan behaal.

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CHAPTER 1

1. INTRODUCTION

1.1 Background of the Study

The aim of the study is to provide an overview of the science and technology systems of three countries, namely, South Africa, Malaysia and India, to describe the process of science and technology (S&T) policy development, as well as establishing the relationship of a science policy with the national policies of the three countries; and to identify how the S&T policies link with national goals. The study also seeks to compare the selected countries, depict the common features of their various science systems, and identify the differences, strengths and weaknesses. The result of this comparative analysis will be to find its relevance and value for Lesotho. The study will assist in revealing possible solutions that are recommendable to a less developed country such as Lesotho.

The three countries, South Africa, Malaysia and India, were chosen on the basis of their identification as developing nations from various geographical settings, namely Africa, Asia and East Asia. Their economic levels as developing nations were considered to provide an ideal base for comparison.

Lesotho is a country that is in its infancy in establishing a stable, well-coordinated science and technology system. It is currently striving to come up with an articulate and judicious science and technology policy, which in turn will be coupled with pragmatic strategies that will implement the policy effectively and efficiently.

The need for an S&T policy becomes inevitable as it is seen as a powerful tool for driving the country towards achieving its national goals and objectives, namely, Vision 2020 and the Poverty Reduction Strategy Paper (PRSP). It is on this note that this comparative study will hopefully provide a point of reference from which to learn from the experience of other nations (in this case the selected countries).

The methodology followed in this study was qualitative through desk research. The source of data was archival, particularly in the case of historical background of the three countries' science systems and documentary in terms of the current situation of the science systems of each country. The comparative analysis was textually based on findings and content of the study.

The study is structured as follows:

- Chapter One is an introductory chapter;
- Chapters Two, Three and Four constitute the case studies of the three selected countries. Each case study is characterized by an overview of the S&T system of the country (history of the science system at various levels and timeframes), and a review of the S&T policies and their instruments, such as institutional arrangements, which include the fiscal and legal framework;

- Chapter Five is the Concluding/Analysis chapter. It proceeds in identifying the relevance of the study to Lesotho and providing recommendations.

CHAPTER 2

2. SOUTH AFRICA CASE STUDY

2.1 Introduction

The main aim of this chapter is to give an overview of the South African science and technology system and to describe and review the process of S&T policy development, while also establishing the relationship of the science and technology policy with other national policies and how it links with national goals. In an endeavor to achieve the above objectives and as a point of departure, the case study will outline a brief history of the science system in the pre-apartheid era, during the apartheid era and post-1994. The case study will also review the key issues of the S&T policy.

It is hoped that the case study will reveal the strengths, weaknesses and challenges that face the South African science and technology system. On the basis of the findings, a comparative analysis with other nations will be made; in order to establish existing challenges and come up with possible solutions that are recommendable to less developed nations, such as Lesotho.

2.2 The Overview of the Science and Technology System in South Africa

2.2.1 Science in South Africa: Pre-Apartheid and Apartheid Era (1700's – 1994)

South African science and technology activities date back to the mid-eighteenth century. (Although there were certainly S&T activities in the 18th century, it is probably anachronistic to talk of an S&T "system" then.) The development of S&T becomes evident over approximately three centuries: it originated during the time of the Cape Colony in the works of English traders who, through intellectual curiosity and exploration, ventured into scientific and technical practices and became amateur natural historians. These initiatives eventually paved the way, through a gradual shift from amateur science to more formalized and institutionalized modes of knowledge production[1] in the nineteenth century (Mouton, 2001). In this era, science could be interpreted as *Science for the Sake of Science*, as evidenced by studies and discoveries in the areas of astronomy, ethno botany (in view of the rich and diverse nature of flora in the Cape specifically at that time), anthropology, geomorphology and mineralogy, to mention but a few.

As rightly shown by Boshoff et al. (2000), in the mid-eighteenth century, botany among other disciplines, became a predilection in Europe together with what was called exploration, and was putting taxonomy to the test and enriching the body of knowledge. It is at this point, at which geographical distance and margins had no limit, that the adventure of modern science began, as it

> … was a matter of a science whose hub remained in Europe, its theorists voyaging very little, but delegating to their trusty disciples, the task of making good use of ground already covered by a myriad of local observers and of methodically collecting the field data which was to be the food for their deliberation. (Boshoff, et al., 2000 pp 5-6)

The institutionalization of science is clearly seen from the 1820's to the 1880's through, among others, the establishment of the following institutions: the Royal Observatory, founded by a brilliant astronomer in 1820 (Herschel, Fellow of the

Royal Society of London) and the South African Museum, founded in 1825 by Andrew Smith. Science then, was characterized by its far-reaching impact, that is, the Science for Knowledge effect was indisputably evident. In addition to these two institutions, learned societies were established and, between 1850 and 1870, colleges emerged that subsequently gained the status of universities, forming part of the broad basis of the higher education sector today.

Towards the end of the nineteenth century, that is, from the “Science for Knowledge” stage, the South African science system developed into what Boshoff et al. (2001) refer to as the *Industrialization of Science*, the stage at which science was put to practical use. The science agenda was then dictated by the social needs of the nation, such as, disease outbreaks and other natural disasters. As a result, science played a critical role in solving most societal problems of that time. In other words, the social contract between the nation and scientific enterprise grew.

The industrialization of science can also be clearly linked, firstly, to the discovery of gold and diamonds in 1867-75, when the mining enterprise grew rapidly, and secondly, to the need for qualified personnel (engineers, geologists etc), as well as adequate rail and road infrastructure for transportation/communication of goods and services. The situation, therefore, completely changed science’s grounds of operation (Boshoff et al., 2001). Scientific activity was no longer conducted predominantly for knowledge or for science itself, but to benefit the health and welfare of society and the economy (for both the scientist and the government of the time).

Subsequent to the aforementioned initiatives that promoted the *institutionalization of science*, the following efforts were also undertaken:

(a) The establishment of a scientific and technological committee, The Industry Advisory Board, in 1916;

(b) The appointment of a science advisor to government, the then engineer H.J. van der Bijl, at the end of the First World War;

(c) The establishment of science councils[2] (Council for Scientific and Industrial Research (CSIR) and the Human Sciences Research Council (HSRC) in 1945 and 1946 respectively. The HSRC was however enacted later in 1969;

(d) The introduction of a funding policy for the established institutions and a higher education sector policy relating to science, as well as the adoption of the National Party Policy on Science and Technology, to mention but a few (Boshoff et al., 2001; Marais, 2000).

Though research remained autonomous in various disciplines, the commitment and support of government became pre-eminent for investing in knowledge production through the establishment of laboratories, professional associations and research institutes, like the Onderstepoort Veterinary Research Institute, which was established in 1908. A second research centre was established around 1912, the South African Institute for Medical Research. The role of scientific research and its applications became even more imperative through the discoveries of cures and vaccines for a broad spectrum of diseases (both for human and animal), through inventions and so forth.

This institutionalization phase became more prominent from 1948, when the Nationalist Party came to power with its apartheid policies. This change in government ultimately had major consequences for the way in which post-Second World War science developed in South Africa up to 1994 (Mouton, 2001).

After the Second World War, South Africa became increasingly insular and isolated because of international sanctions and boycotts against apartheid. Faced with the intensified struggle against apartheid, both at home and abroad, the Nationalist Government was compelled (as a defence mechanism) to transform the science and technology base, emphasizing nuclear and energy research, and missile and weapons systems. Hence, science faced a transitional period of construction, consolidation and expansion to reinforce the rules of apartheid (Mouton, 2001).

[2] After the establishment of the CSIR and HSRC, the Medical Research Council and Agricultural Research Councils followed in 1969 and 1990 respectively.

The history of science councils (the CSIR in particular) in South Africa also offers many case studies that clearly demonstrate the interaction of science and technology with politics, that is, different ways in which government took a steering role in the system. In other words, this history clearly depicts the notion of the *politicization of science.* As Marais (2000) shows, since the 1950's and even more so since the early 1980's, the CSIR, like other organizations, was exposed to political and administrative pressures from a government that increasingly tried to steer the S&T system as one of its responses to the increasing political and economic isolation of the country.

The government's motivation and a driving force behind the establishment of research councils were characterized by what Mouton (2001) refers to as "strategic research", which served the national security goals of the government of the day. This eventually led to the development of an indigenous nuclear research industry that was able to build atomic bombs (Mouton, 2001).

Nonetheless, as rightly shown by Marais (2000), the role played by the councils, specifically the CSIR, in the science and technology system of South Africa cannot be overlooked. This organization is seen as the largest, oldest and most successful R&D institution in Africa, in terms of keeping abreast with international trends and developments. Moreover, the CSIR played a leading role in several bodies on the African continent; it took an active part in the world programmes of the ICSU: such as geophysical years, Antarctic research and many others. The councils could also be seen as constituting a good basis for research capability, operating along the lines of the endless frontier vision of science,[3] unlike the HSRC, which clearly followed the *centrist* [4] pattern.

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[3] The general vision of science guided by the CSIR during this phase was in the spirit of **science, the endless frontier**, whereby, inter alia, the council promoted growth and employment of high-caliber scientists, invested in human resource development, and embarked heavily on fundamental research.

[4] The **centralism** characteristic of the HSRC is based on the fact that staffing was strictly composed of the Afrikaans—or at least the pro-government--sector of the population and, in generic terms, the organization was perceived as the social research arm of the Nationalist Party Government, which was cautious and conservative in externalizing its programmmes. Most of the research portfolio consisted of applied research, mostly directed to the benefit of the white population.

However, various studies show that the weaknesses that were prominent in the councils, coupled with the apartheid regime, were as follows:

- The skewed nature of the distribution of research and development capacity to the nation. The focus on building capacity in science and technology was only on the white minority of the population;
- By the end of the 1970's, a series of reports provided an indictment of the councils' failure, the CSIR in particular, to address the R&D needs of the economy and a failure to provide a strategic framework of national priorities;
- The failure to address the long-standing challenges of social and economic inequalities, slow growing economy, significant unemployment and low productivity, vast health care and education needs, as well as the demographic complexity in the country; and
- The lack of coordination within the country's national innovation system (IDRC, 1993).

Owing to the political stress that became more evident towards the end of the apartheid era in the late 1980's at different levels of the system, the councils were compelled to adopt the system of Framework Autonomy[5]. As Marais (2000) indicates, the root cause of the stress and frustration was a political dispensation that was inevitably approaching its end, coupled with uncertainty about the nature of the dispensation that would succeed it.

In generic terms, by most definitions, the apartheid economic policy had relegated the country to the status of a peripheral economy within the global framework. Furthermore, apart from the moral considerations of apartheid, the existing segregation, by which the politically *dispossessed* constituted the large majority of the population, created the negative impact of a chronic incapacity to develop to a significant degree the technological capabilities. Hence, the science and technology

[5] The main features of the framework autonomy of the science councils are:

- introduction of clear delegation of authority and accountability to boards and management of each council;
- introduction of baseline funding principle; and
- setting of goals for funding generated through contract research, from outside councils.

system was deeply affected and deeply fragmented, specifically in the education and research and development sectors.

2.2.2 The Recent History of the S&T System (post-1994)

In view of the prevailing situation, the scene was set for change during the period 1990-1994. This is the period that Marais (2000) considers to represent contours of manifest and latent stress, within the South African science and technology system. To redress the problems alluded to above, the following initiatives were taken:

- Open communication channels between government and the African National Congress (ANC), which resulted in conventions and some structures, for example, the Groote Schuur and Pretoria Minutes (1990), the National Peace Accord (1990), and the Convention for a Democratic South Africa (CODESA) of 1992 (Marais, 2000);
- The commissioning of the IDRC study on the status of the National Innovation System in 1993.
- The strategic review accorded to science and technology and the higher education system at various levels.

The consequences of the above initiatives constituted the interim approach to levelling the playing field for the first 1994 democratic election, as well as the further development of a new policy on science and technology. During this period, the science and technology initiatives (STI's) made available information on the existing S&T system to all relevant stakeholders. The initiatives were effective in promoting transparency and influenced the existing decision–making and advice-formulating processes, as well as existing processes. As a result, the following initiatives were undertaken:

- A future national science and technology management system in South Africa;
- Affirmative action in the science and technology system; and
- Governance structures for components of the science and technology system.

It is out of the results of these initiatives that a massive reconstruction and restructuring of the South African science and technology system was undertaken. It was therefore obligatory for the government of the day to make a paradigm shift in all spheres, in order to transform the historically and politically driven S&T system of South Africa to a more coherent, equitably driven system, geared towards addressing the needs of the public-at-large, while at the same time not underestimating the extrinsic factors emanating from global trends.

2.3 The South African S&T System

As Boshoff et al. (2000) shows, after the IDRC study of 1993, several processes paved the way for restructuring the S&T system from a fragmented to a more coherent system based on a national system of innovation. For example, the status of S&T in South Africa was raised to the level of national governance in the post-1994 period. In the apartheid years, S&T existed within the Department of National Education, which was then advised by the Scientific Advisory Council.

2.3.1 Governance Structures at Macro-level

The reconstruction and restructuring of the system elevated the status of S&T management to national level, as is evident by the formation of the new structures, all aimed at coordinating the then scattered government initiatives to stimulate the National Innovation System at macro-level. Among others, the structures are as follows:

- A National Ministry of Arts, Culture, Science and Technology;
- The Minister's Committee for Science and Technology (MCST); and
- Department of Arts, Culture, Science and Technology.

The Ministry Responsible for Science and Technology

The Ministry for Science and Technology is responsible for policy formulation and decision-making concerning the national government in the field of arts, culture, science and technology. However, it is worth noting that in August 2002, the Department of Arts, Culture, Science and Technology (DACST) was divided into two separate departments, namely, the Department of Arts and Culture, and the Department of Science and Technology. The Minister for both departments is also responsible for several structures at the advisory, funding and research performer level, which will be discussed later. These structures are:

- National Advisory Council of Innovation (NACI);
- National Research Foundation (NRF);
- Innovation Fund; and
- National Facilities for Research (Boshoff et al., 2000).

Ministerial Committee on S&T

The committee is composed of cabinet ministers and senior staff of relevant line ministries or departments, whose functions cut across several sectors of the economy, as is the case with science and technology. The ministers' portfolios obviously have a stake in science and technology related matters across government. As indicated by Marais (2000), the committee was established by the cabinet to facilitate matters requiring co-ordination among ministries.

This committee is an executive body that steers the system and plays a decisive role at the *macro- level* of governance. The committee is also charged with the vital role of adopting policies and by its nature disseminates S&T crosscutting issues in government for implementation. It comprises ministers whose portfolios encompass a significant S&T component, and is the principal policy coordinating and information disseminating body for S&T related matters across government. The secretariat of the Ministerial Committee for Science and Technology is housed in the Department of Science and Technology (DACST, 2001).

Figure 2.1 below represents an overview of the institutional arrangement the South African Science and Technology system.

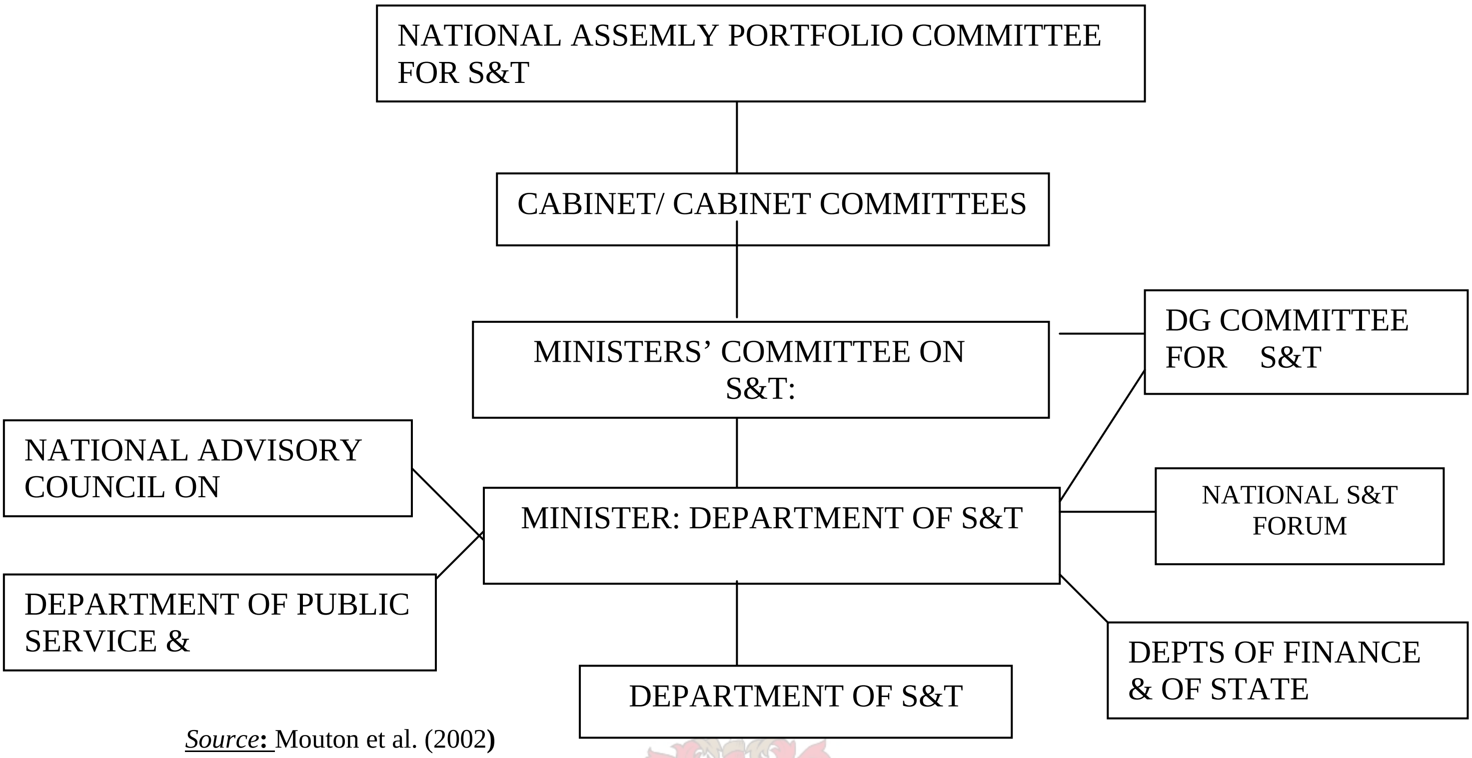
The Department of Science and Technology (DST)

The Department of Science and Technology (DST) is a central S&T policy formulating and coordinating body playing a pivotal role in both developing innovation related SET policy options and in integrating innovation related thinking across other line departments (DACST, 1996:15). It was formed with the aim of supporting the new ministry in its implementation of relevant policy (Boshoff et al., 2000).

The mission of the department is to develop, coordinate and manage a national system of innovation that will bring about maximum human capital, sustainable economic growth and improved quality of life for all citizens, while the vision of the Department of Science and Technology is to create a prosperous society that derives enduring and equitable benefits from science and technology (DST, 2004).

Among other functions, the DST is mandated to design government SETI’s, provide coherence and clarify their role within the national system of innovation and, further, devise a means for evaluating SETI’s performance in regard to their contribution to national development. This mandate includes preparation and allocation of the Science Budget as well as commissioning and/or conducting relevant policy related research (DACST, 2000).

Figure 2.1 Government Organizational Structure of Science System



Source: Mouton et al. (2002)

According to its 2000/2001 report, the Directorate had undertaken activities centered on the aforementioned goals of the National System of Innovation. The activities included the following:

- Management of the science vote process, that is, distribution of parliamentary grants, funding across the S&T base of the country;
- Promoting of public awareness, appreciation, critical evaluation and understanding of science, engineering and technology through systemic, coherent and coordinated programmes (www.dst.gov.za);
- Management of the Innovation Fund.
- Introduction of an equipment placement programme for science councils. The programme is designed to address the deficit in the state-of-the-art equipment;
- Stimulation of debate about statistical measurements of science, engineering and technology performance, particularly in the context of developing nations; and
- Serving as a link between government and the National Advisory Council of Innovation (NACI) (Marais, 2000).

The Department of Science and Technology strives towards introducing measures that put science and technology to work and make an impact on growth and development in a sustainable manner, in areas that matter to all the people of South Africa. This initiative includes focused interventions, networking and acting as a catalyst for change, in terms of both productive components of the economy, making it competitive in a globally competitive liberalized environment, and also in respect of the huge development backlog existing among the poorest components of the South African society.

The goal of realizing this vision is underpinned by development and sourcing strategies for the formation of human capital in science, engineering and technology, democratization of state and society, promotion of an information society and ensuring environmental sustainability in development programmes (www.dst.gov.za) .

Among other structures at governance level, the following institutions are key in partnership, as part of the system, with the aforementioned bodies:
South African Agency for Science and Technology Advancement (it is now known as SAASTA – check the NRF website) www.saasta.ac.za/aboutus/background.shtml

- Department of Education
- The Parliamentary Committees and Portfolio Sub-committees on Science and Technology

2.3.2 The Meso-level of the South African Science and Technology System (Advisory Bodies and Funding Framework).

The meso-level of governance of the system can be considered as an “aggregate” or a “buffer” between government and the S&T performance level/executing bodies of the national S&T system. This level includes both advisory bodies and the funding framework of the S&T system. The role of the intermediary bodies in any system cannot be overemphasized. The analysis of these bodies can be viewed thus: firstly, they are bodies that translate values between financiers and the recipients. Secondly, they form a basis on which representatives from relevant sectors meet, for example, government, research organizations, and other interest groups in society. Thirdly, the bodies are charged with advising and funding the national science and technology system, to foster its effective functioning.

Similarly, South Africa has set intermediary structures in place, primarily between government, at policy-making level, and various interest groups including other bodies at the performance level of R&D. The structures are: National Research Foundation (NRF), National Science and Technology Forum (NSTF), National Advisory Council on Innovation (NACI) and Council for Higher Education (CHE)

Funding Agencies

The S&T system has been operating on the basis of a *System Framework Autonomy*, adopted in 1987 as a process of allocating state funding to SETI's, in the form of a "Science Vote". This science vote allocates 20% to the Innovation Fund to the SETI's budget (through line ministerial budgets). Subsequent to that and since 1994, the government has been proactive in setting in place a new funding "regime" that supports its commitments to national priorities (Mouton, 2000). This regime includes the following funding "strategies":

- The establishment of the National Innovation Fund to support strategic, collaborative research;
- The consolidation of the existing funding agencies into one national funding agency (the National Research Foundation) and a new policy for the theme-oriented funding;
- Significant increases in funding via two strategic funds: THRIPS[6] and SPII[7], both of which encourage closer links between academia and industry; and
- The Partners in Industrial Innovation (PII) is spearheaded by the Department of Trade and Industry.

As Mouton and Boshoff (2001) show, there is no single integrated framework that summarizes the various modes and mechanisms of funding that are operative in the public sphere in South Africa. However, the White Paper on Science and Technology (DACST, 1996) sets as an ideal an integrated and comprehensive science budget that

[6] The Technology and Human Resources for Industry Programme (THRIPS). Its mission is to improve the competitiveness of South African industry by supporting research and technology development activities and enhancing the quality and quantity of properly skilled people.
[7] SPII

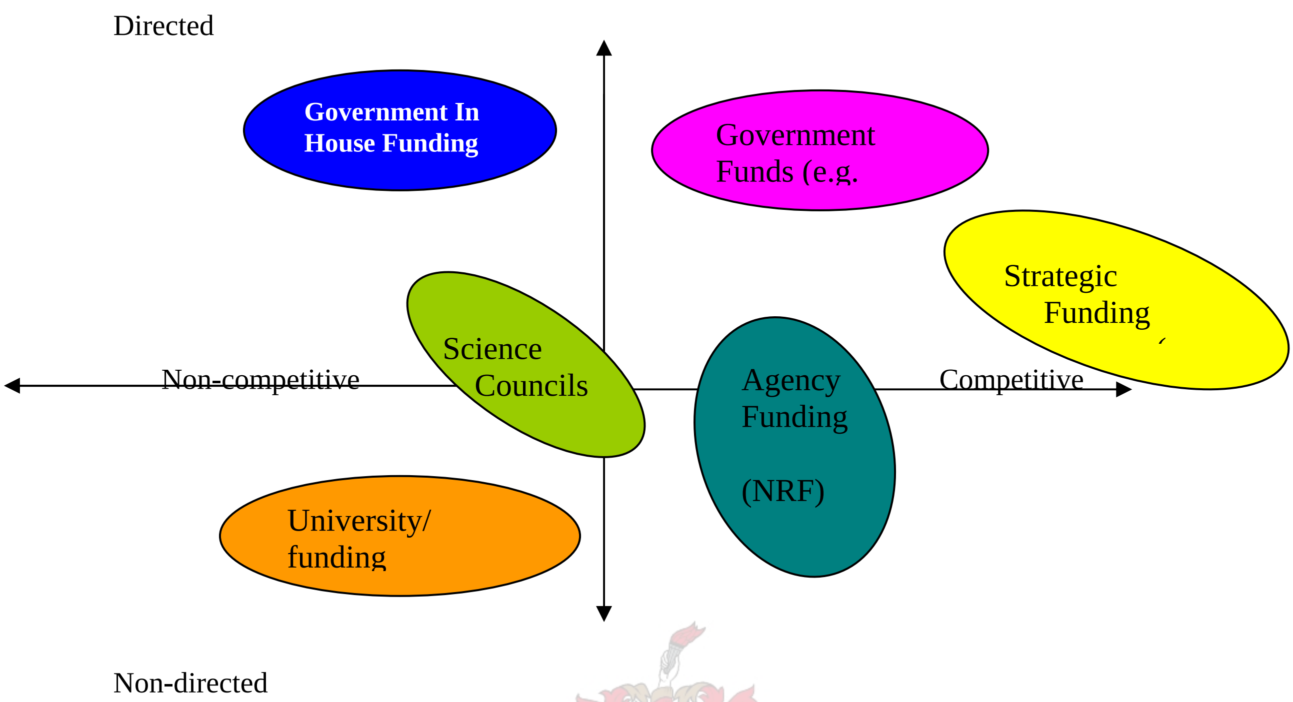
will be put in place in the foreseeable future. Currently there are at least five *modes* or *mechanisms of funding* that are utilized in order to support public research and development. These are:

- Core funding of science councils and national facilities;
- Agency Funding (NRF, MRC, ARC, and WRC);
- Competitive funding (National Innovation Fund);
- Formula-based funding of universities and technikons; and
- Contract funding

Figure 2.2 schematically represents a wide range of mechanisms used for funding in the South African S&T system. As Mouton and Boshoff (2001) rightly show, this pattern developed for historical reasons (the long tradition of a relatively autonomous higher education sector) and more recent policy decisions to create a more coordinated and integrated national system of innovation (the establishment of the National Innovation Fund). In addition to all the factors shown above, the model depicts the impact of international trends on South African science and technology, which leans towards more "strategic" research, as well as trends related to increase shaping and steering of the national science system. This impact is reflected in the fact that, with the exception of the higher education R&D, the four remaining modes of funding are closer to the DIRECTED pole of the vertical axis. On the other hand, there is a shift or an intention, on the part of government, to also move their funding more towards the COMPETITIVE pole of the horizontal axis (fig 2.2).

National funding agencies have been part of the South African S&T landscape since 1918. What is noticeable from this history, however, is the fact that these agencies have been separated along disciplinary lines, both in the past and recently. It is precisely this kind of fragmentation that the IDRIC report addressed in its assessment of the national system of innovation in 1993. Hence the White Paper identified the need to establish a new, coordinated, national funding agency as part of the new S&T system, the National Research Foundation (Mouton & Boshoff, 2001). The mandate of this agency will be fully discussed later.

Figure 2.2: Modes of government funding



Source: Mouton and Boshoff (2001)

The National Research Foundation (NRF)

The key to achieving national and continental prosperity rests with South Africa's ability to conquer the following three primary challenges:

- A robust knowledge culture underpinned by quality education accessible to all;
- The eradication of poverty and widespread diseases; and
- Wealth creation that is not limited to a privileged minority.

The National Research Foundation Act, Act 23 of 1998, provides a mandate that positions the NRF as a key agency in confronting these major challenges, as the government's national agency responsible for promoting and supporting research. The Foundation's task is to advance research in all fields of the humanities, social and natural sciences, engineering, and technology. By forging strategic partnerships locally and abroad, the Foundation extends the resources that researchers need to foster and expand South Africa's research capabilities to ultimately improve the quality of life for all (www.dst.gov.za).

The NRF carries the dual function of a *funding* agency and of an *administrative address* for six National Research Facilities. The specific functions of the NRF are:

- To set priorities, evaluate needs and allocate funds;
- To emphasize the development of human resources and capacity in all fields;
- To facilitate national and international collaboration and multidisciplinary and cross-disciplinary project funding, while at the same time allowing for integration of work in different fields;
- To maintain an information infrastructure, such as, the national registry of research; and
- To administer the national research facilities.

The National Research Foundation can be regarded as a moderator or facilitator of research. It is seen as a body that supports large multidisciplinary programmes with the emphasis on relevance to social needs linked to industrial value (Lickendorf, 1999:6). The NRF is structured through representation and the merger of the former Foundation for Research and Development (FRD) and the Centre for Science Development (CSD). It is also a mother body for all the national facilities, which are discussed under the performance of the system.

Currently, the NRF undertakes the following activities**:**

- **Research and Innovation Support**
  - parliamentary core grant funding
  - the Technology and Human Resources for Industry Programme
  - the Innovation Fund
- **Astro/Space/Geo Sciences**
  - the South African Astronomical Observatory
  - the SALT Foundation (Pty) Ltd
  - the Hartebeesthoek Radio Astronomy Observatory
  - the Hermanus Magnetic Observatory
- **The National Zoological Gardens**

- **Biodiversity/Conservation**
  - the South African Institute for Aquatic Biodiversity
  - the South African Environmental Observatory Network
- Nuclear sciences
  - iThemba Laboratory for Accelerator Based Sciences

Innovation fund

The new policy for S&T clearly provides a special fund that promotes or enables long-term, extensive innovation projects in all sectors that have a stake in science and technology (the SETI's, higher education sector, industry, civil society, private sector and so forth) to shift from the historical paradigm of an unbalanced allocation of resources, which led to regional inequalities, towards more of a performance and production oriented approach (Marais, 2000).

As Marais (2000) indicates, the special features in the new funding policy are that, with time, the private sector, which is taken to be the nucleus of innovation and development, will become more entitled to a larger share of the science vote. This element has been ignored in the past.

The R&D strategy (2002) also views the Innovation Fund as the key instrument in the implementation of the strategy, perceiving its role as being closer to the marketplace in the specific development of new products, processes and services. To this end the Innovation Fund has set itself a mission to promote the economic competitiveness of South Africa through investments in technological innovation that leads to the establishment of new enterprises, and the expansion of existing industrial sectors, to the benefit of all South Africans.

In an attempt to promote R&D in South Africa, the S&T White Paper makes explicit reference to the existence of tax incentives for R&D. The White Paper takes cognisance of the legislation covering the treatment of R&D expenses for tax purposes, which is covered in Section 11 of the Income Tax Act of 1962. The law outlines ways in which expenditure can be exempted from taxable income.

Nevertheless, South Africa operates a simple tax deduction for R&D purposes and there are no tax credit schemes provided for in the law (Mani, 2002).

From Kaplan's (2000) empirical exercise and conclusion, which measured the attractiveness of the South African tax regime using the B-index[8], it becomes evident that South Africa's tax regime is not very favourable to R&D. Given the existence of some proof concerning the efficacy of tax incentives in promoting R&D in developing countries in particular, Kaplan makes a strong case for extending and strengthening tax incentives for R&D in South Africa.

Advisory Bodies

Prior to 1994, the Scientific Advisory Council (SAC), in its advisory role, was the single most important source of independent advice on science policy and programmes to the South African government. But, according to the findings of the IDRC Mission (1988), the SAC had the following deficiencies:

- Lack of transparency. No independent assessment could be made concerning the extent, quality, relevance or impact of its advice;
- Lack of an independent secretariat, as the Department of National Education was found to be inappropriate since its major focus was on educational matters and the management of the science vote rather than on full secretariat assistance; and
- Vagueness of the SAC's responsibility for advising on matters related to technology policy. Instead, the SAC's membership was heavily weighted in favour of pure science interests and appears to have believed that technology policy should not have been within the SAC's mandate.

To address these shortcomings, the new post-1994 government established the following advisory bodies charged with certain specific roles (the functions of which will be discussed later):

- The National Advisory Council on Innovation, NACI;

[8] B-index represents the ratio of after-tax cost (ATC) of expenditure on R&D divided by 1less the rate of tax on corporate income (t) The generic formula for the B-index : B = ATC(1-t).

- Council on Higher Education; and
- Other sectoral stakeholder advisory bodies.

The advisory bodies are generally mandated to *advise* the Government on:

a) technical aspects and policy matters relating to S&T;
b) research priorities;
c) commercialisation of research results;
d) human resource development in S&T fields;
e) infrastructure support;
f) financing S&T activities.

To bridge the gap that previously existed, each of the bodies mentioned above was charged with a specific function, which is described thus:

The National Advisory Council on Innovation (NACI*)*

The National Advisory Council on Innovation (NACI) is a statutory body enacted in 1997 with the mandate of advising the Minister, the Ministers' Council for S&T, as well as Cabinet, on the ways in which science, mathematics, innovation and technology (including indigenous technologies) may contribute towards achieving the national objectives (NACI, 1997)[9].

Coupled with the advisory role, NACI is also responsible for the identification of mechanisms for targeting S&T research and information relevant to socio-economic development. Hence NACI advises the Minister's Committee and the Minister on the division and usage of the *science vote*[10] to science councils. Among other functions, NACI identifies R&D priorities and links them to funding. The Department of Science and Technology also provides the secretariat to NACI.

[9] The National Objectives are: - improve and sustain the quality of life of all South Africans
- develop human resources for science and technology
- build the economy
- strengthen the country's competitiveness in the international sphere

[10] The science vote is fully described under the system funding framework.

NACI is broadly representative of all sectors and is constituted in a manner that ensures a spread of expertise and experience regarding national and provincial interests: scientific and technological disciplines, areas of innovation, needs and opportunities in various socio-economic fields, and research and development in all sectors (NACI, 2001).

The functions of NACI are as follows:

- Coordination and stimulation of the National System of Innovation (NSI);
- The promotion of cooperation within the National System of Innovation; the development and maintenance of human resources for innovation through selective support for education, training and research and development in the higher education sector and at science councils, other science and technology institutions in public and private institutions; and
- Provision of funding for the science and technology system regarding its contribution to innovation.

The Council on Higher Education

In view of the history of discriminatory exclusion regarding the community-at-large in South Africa, the government found it necessary to ensure the existence of a quality assurance system that would enhance access not simply to higher education, but to high standards of provision and their concomitant intellectual and economic benefits (CHE, 2001) As a result, the South African Council on Higher Education (CHE) was established as an independent statutory body in May 1998, in terms of the Higher Education Act, Act no 101 of 1997. The Higher Education Act and the Education White Paper 3 of 1997, A Programme for the Transformation of Higher Education, establish the responsibilities of the CHE as advising the Minister of Education on all matters related to higher education policy issues and assuming executive responsibility for quality assurance within higher education and training. The Council on Higher Education (CHE) is also an independent statutory body whose mandate and functions are:

- To advise the Minister of Education on any aspect of higher education at the Minister's request;

- To arrange and co-ordinate conferences and publish an annual report on the state of higher education; and
- To promote and assure quality in higher education through its permanent committee, the Higher Education Quality Committee.

Other Advisory Bodies

These are sectoral stakeholder advisory bodies operating at different levels in the South African S&T and education system. They are:

- Committee of Heads of Science Councils (CHSC);
- South African University Vice-Chancellor's Association (SAUVA); and
- Committee of Technikon Principals (CTP).

The Committee of Heads of Science Councils (CHSC) represents the collective interest of the science councils at a national level and plays a central role in the leadership of the National Science and Technology Forum (NSTF), while SAUVA and CTP assume an advisory role in the interests of higher education sectors at national level as well (Boshoff et al., 2000).

2.3.3 The Performance Level of the System

The performance level of the national science and technology system comprises public research and development executive bodies and institutions, as well as those activities undertaken to promote the technological capability of the country.

Mouton and Boshoff (2001) clearly distinguish major public R&D performers within the South African S&T system according to the following five categories (i.e. excluding the business or private sector):

- The Higher Education Institutions (Universities and Technikons);
- The Science Councils;
- State corporations;
- In-house government research departments; and
- National research facilities.

It is necessary at this juncture to highlight the vital role played by the "science councils", particularly at this level of the system. These councils are the key implementers of the S&T oriented policies and programmes. There are eight national science councils (statutory R&D bodies) and one science commission, which are charged with development and promotion of all spheres of science and technology in South Africa. Six of these bodies are involved in significant R&D performance. The only exceptions are the South African Bureau of Standards, which is predominantly a standards controlling body, and the National Research Foundation, which is now the largest state funding agency in the country (Mouton & Boshoff, 2001).

Science Councils

Eight science councils were established to cater for specific disciplines of S&T. "One enduring strength of the South African S&T system is the fact that it has a rich tradition of different R&D performers" (Mouton & Boshoff, 2001: 7).
The councils are:

I. The Medical Research Council (MRC)
II. National Research Foundation (NRF)
III. Council for Scientific and Industrial Research (CSIR)
IV. Council for Geo-science (CGS)
V. Human Sciences Research Council (HSRC)
VI. Agricultural Research Council (ARC)
VII. South African Bureau of Standards (SABS)
VIII. Minerals Research Organization (MINTEK)

Higher Education Sector

Prior to the year 2000, there were currently 21 universities and 15 technikons in South Africa. The oldest universities (University of Cape Town and Stellenbosch University) were established in the 1860's. The sector has presently undergone restructuring process, which includes the merger of certain universities with technikons as part of capacity building (specifically relating to historically disadvantaged institutions of the sector). The new system comprises of 21 higher education institutions, consisting of 11 universities, 6 technikons and 4 comprehensive institutions. According to the 2004 data, the estimated R&D expenditure by the sector will be approximately R1,896,156 million. The expenditure on higher education sector constitutes 25.3% of the total Gross Expenditure on Research and Development (GERD)

National Research Facilities

The National Research Foundation is the mother body of these laboratories/national facilities, for administration purposes, while their funding mechanism remains similar to that of institutions outlined for grand funding.
In general, the White Paper for S&T has placed emphasis on and broadened the scope of the NRF's in terms of their responsibilities to be centred on national priority needs and to have the broad support of the SET community.

These are six research institutes that fall under the auspices of NRF:

(a) The Hartebeesthoek Radio Astronomy Observatory (HartRAO) is devoted to research into radio wavelengths. Objects that emit radio waves in the earth's Milky Way Galaxy and other galaxies are studied. The radio emissions at 13cm wavelength from the whole southern sky have been mapped with the HartRAO telescope by a team from Rhodes University in Grahamstown, in order to study the faint outer reaches of the earth's own galaxy. Arrayed with telescopes on other continents, HartRAO forms part of a set of "super" telescopes that are able to discern details hundreds of times more finely than the best optical telescopes. The technique used, called Very Long Baseline Interferometry (VLBI), enables the masers of the earth's galaxy to be pinpointed and the fine details in jets from distant quasars (black holes in the hearts of distant galaxies) to be observed. The HartRAO is located west of Johannesburg, South Africa (www.nrf.ac.za/hartrao/).

(b) The South African Astronomical Observatory (SAAO) is the national observatory of South Africa and is one of the national facilities that are administered by the NRF. The SAAO headquarters are located in Observatory, Cape Town, but the major observing facilities, consisting of modern instrumentation and large telescopes, are situated near Sutherland in the Karoo. The SAAO was founded as the Royal Observatory, Cape of Good Hope in 1820 and the main building, used now for offices for the staff, was completed in 1828. There are various telescopes of historical importance on the grounds.

(c) The South African Institute for Aquatic Biodiversity (SAIAB) serves as an interactive hub focused on serving the nation through generating, disseminating and applying knowledge to understanding and solving problems on the conservation and wise use of African fishes and aquatic biodiversity. The South African Institute for Aquatic Biodiversity, formerly the JLB Smith Institute of Ichthyology, is an internationally recognized centre for the study of fishes. Prof JLB Smith, famous for naming and describing the living *Latimeria chalumnae* or coelacanth, established the Ichthyology Department at Rhodes University. On his death in 1968, his wife, Margaret Smith, established the institute that grew rapidly to become, in 1980, an independent, declared cultural institution.

(d) iThemba LABS (iThemba Laboratory for Accelerator Based Sciences) at Faure in the Cape, is a multi-disciplinary research centre, established in 1977 under the control of the CSIR (Council for Scientific and Industrial Research). Since 1988, it has been one of the national research facilities now administered by the NRF. iThemba LABS provides facilities for basic and applied research using particle beams, particle radiotherapy for the treatment of cancer, and the supply of accelerator-produced radioactive isotopes for nuclear medicine and research.

(e) The Hermanus Magnetic Observatory (HMO)
The expertise vested in the HMO is of great strategic importance, and its aim is to become a significant player in the space and earth sciences, as well as in geospatial information.

The HMO was transferred to the NRF from the CSIR in August 2001, following a study on the future of the observatory undertaken by Professor Friedel Sellschop of the University of the Witwatersrand. The study emphasized the importance of the HMO as a national asset and suggested that it be made a national facility. High-level human resource training and research capacity building are top priorities in the transformation of the observatory into a national facility. The HMO is expanding its scientific research capacity by:

- Redeveloping and expanding past research collaborations;
- Re-establishing participation in the South African National Antarctic Research Programme;
- Expanding contacts with higher education, particularly with historically black universities;
- Participating in South Africa's satellite programme by developing contacts with Stellenbosch University and the Institute for Satellite and Software Applications at Houwteq;
- Establishing collaborations with research organizations and universities abroad; and
- Encouraging visiting scientists to work at the HMO.

The HMO consists of four functional groups:

- The Space Physics group conducts fundamental and applied research of the Earth's magnetic field and space environment.
- The Geomagnetism group is responsible for the continuous monitoring of geomagnetic field variations, modelling of the geomagnetic field, and providing data, models, and information to users.
- The Technology group provides quality controlled magnetic field and sensor-related services to clients and carries out contract based research and development work on a commercial basis.
- The Education and Science Awareness group is responsible for the development and implementation of science awareness programmes, particularly for school children.

(f) The Pretoria National Zoological Gardens

The Pretoria National Zoological Gardens have been declared a national research facility, subject to the provisions of the National Research Foundation (NRF) Act. All the assets and liabilities of the Pretoria National Zoological Gardens are to be transferred to the NRF from 1 April 2004 as stated in the Government Gazette of 27

February 2004.The declaration of the Pretoria National Zoological Gardens as a national research facility presents a remarkable opportunity for the zoo to redefine and reposition itself as one of the leaders in breeding and research of endangered species.

The Pretoria Zoo, as it is popularly known, was established in 1899 and is the only zoo in South Africa with national status. It is rated as one of the top zoos in the world, attracting scores of local and international visitors annually. The facility extends over an area of about 80 ha. It has breeding centres in Mokopane in Limpopo and Lichtenburg in the North West, where especially endangered animal species are bred.

(www.nrf.ac.za/news/zoo.stm**).**

State Corporations

There are a number of public corporations (more service oriented state enterprises) that have sizeable R&D functions, for example: Telkom, Eskom and the National Energy Corporation of South Africa (NECSA) (formerly known as the Atomic Energy Corporation).

In-house government departments

These incorporate a number of government department housed research institutes and centres that perform public R&D at significant levels, for example: the National Institute of Virology (Department of Health), the Weather Bureau, Institute for Marine and Coastal Management (IMCM), the Botanical Institute, the Department of Environmental Affairs and Tourism, the National Centre for Curriculum Research and Development (Department of Education) and so forth.

It is worth noting that, apart from above-mentioned public R&D performing institutions, there is the private sector or industry based SETI's.

2.3.3.1 Research and Development in South Africa

The Frascati Manual (1992) further describes research and experimental development (R&D) as creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications.

The world Competitive report (1995) maintains that the principles most useful for analyzing S&T data to gauge competitiveness are;

- Efficient and innovative application of existing technologies, which builds competitive advantage;
- Investment in basic research and innovative activity, which creates new knowledge, is crucial for a country in a relatively mature stage of economic development;
- Long-term investment in R&D, which is likely to increase the competitiveness of a firm; and
- Non-defence private business investment in R&D, which is likely to increase the competitiveness of a country more that public investment in defence R&D.

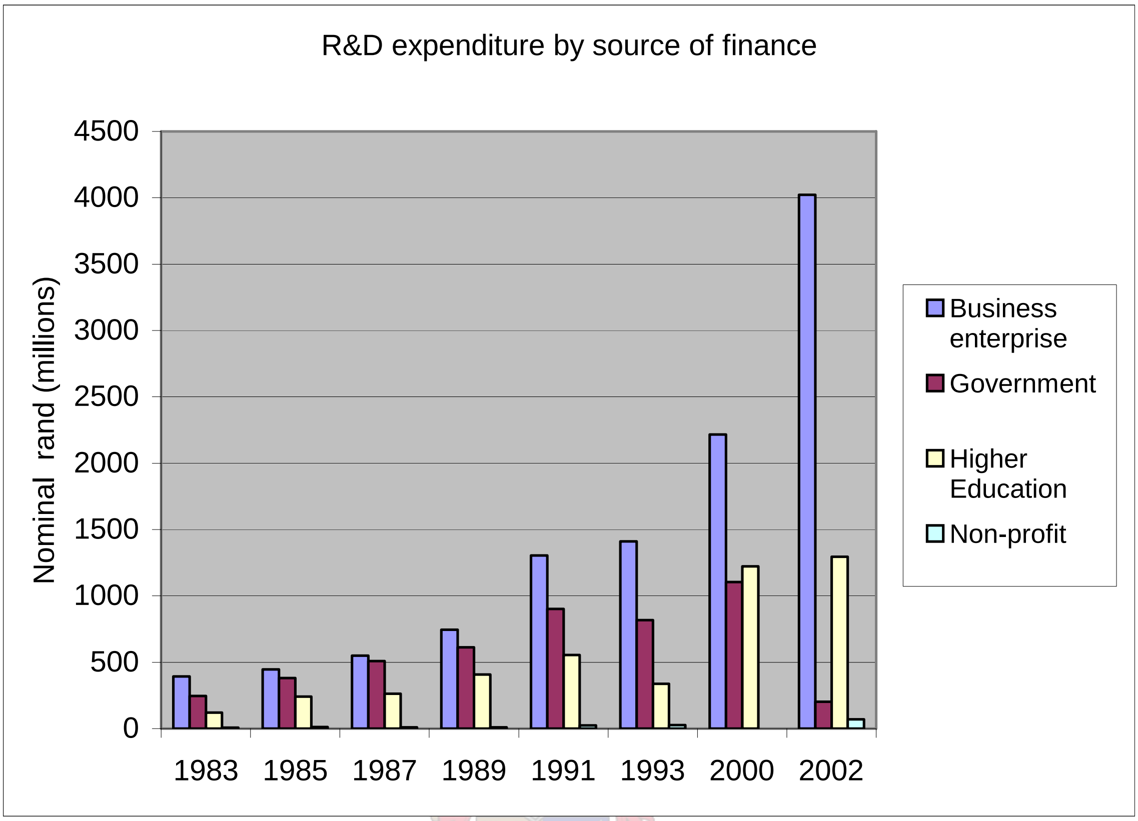
As a point of departure, it would be ideal to attempt to establish a link between *research and development* and its significance to science and technology, particularly in the South African context. Mouton (1996) describes *science* as a body of knowledge and as a product or outcome of scientific research. *Scientific research*, in turn, is a process of inquiry or search for truth based on four perspectives, namely, the epistemic, sociological, economic, and management of scientific research. The epistemic model is seen as a search for “truth”, the sociological model as problem solving of social activity, the economic model resembles research as production of knowledge, and the management model portrays research as a project management process.

On the basis of the above, the role of research and development as instruments or engines of scientific and technological development becomes more evident. Even in the absence of clearly stated national policies or priorities for R&D, the allocation of R&D spending by performers provides a useful indication of national priorities. Most countries that have active R&D programmes undertake some national survey of R&D on an annual basis. South Africa is no exception and has been assessed (biennially) on its R&D expenditure as one of the inputs towards scientific and technological investment (FRD, 1996) It is, however, worth noting that a direct correlation between inputs to R&D and its outputs or products, specifically linked to innovation, has not yet been established (FRD, 1997).

According to the latest National Survey of 2002, the gross expenditure on research and development (GERD) for 2001/02 totalled R7,488 billion. Business expenditure on research and development (BERD), at 53.7% of the spend, is the largest performer; higher education expenditure on research and development (HERD) comes next at 25.3%, while government expenditure on research and development (GOVERD)--that is, government combined with science councils--accounts for 20.0%. Regarding human resources, the survey counted a grand total of 32,501 R&D personnel. This figure includes 19,406 researchers. The total full-time equivalent for researchers is 8707.6 (excluding masters and doctoral students).

These figures compare unfavourably with the levels of expenditure in other countries (especially developed ones), such as 3% in Japan, 4% in Germany and 6% in the US (FRD, 1996). See Figure 2.3

Figure 2.3



Source: FRD, 1996; SA Science and Technology Indicators: DST, 2004; National Research and Development Survey of 2001/02

From the international perspective, South Africa was apparently a relatively minor player in international R&D activity with R&D expenditure in 1991/92 equivalent to 0.22% of the world total and with approximately 0.28% of the world's R&D scientists and engineers. The overall ranking, as indicated by the World Competitive Report of 1995, places South Africa 28th out of 48 countries on the factor of science and technology (including R&D), but 42nd on its overall ranking on the world competitiveness scoreboard (FRD, 1996).

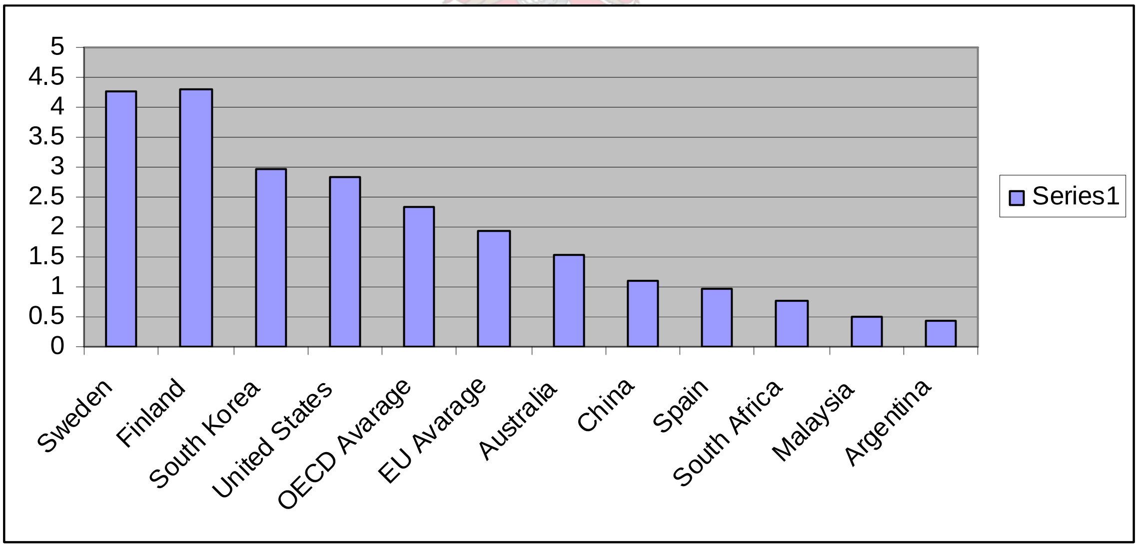
On the African continent, South Africa is a major player in S&T and R&D and accounted for about 60% of all R&D expenditure and about 28% of R&D scientists and engineers in Africa in 1990 (FRD, 1996).Table 2 below shows that the overall government support for R&D in Africa is the lowest in the world (0.2 per cent of

GNP). Only South Africa and Seychelles spent 1 per cent or more of GNP on R&D in 1993 (FRD, 1996).

In nominal terms, funding of R&D by government decreased by 9.4%, from R903 million in 1991/92 to R818 million in 1993/94, while the business enterprise and non-profit sector showed a nominal increase of 8.2% and 8.0% respectively (Fig.2.3). On the whole, all sectors showed a sharp decrease in providing funds for R&D between 1991 and 1993, ranging from a drop of 13% for the non-profit sector to a drop of 51.2% for the higher education sector (FRD, 1996; DST, 2004).

However, in 2001/02, the total R&D expenditure in South Africa reached R7.5 billion, representing an average annual real growth of 2.5% since 1991. Nevertheless, it should be noted that previous surveys followed variant methodologies and fieldwork plans and therefore the changes should be seen in this context (DST, 2004).

Figure 2.4: Gross expenditure on R&D as percentage of GDP 2001



Source: International Comparison-OECD Main Science and Technology Indicators (2003) and Individual Country Reports

As the 2001/02 R&D international survey shows, an important indicator for economic competitiveness of countries is the intensity of R&D. Figure 2.4 shows that Sweden is the OECD leader in R&D intensity, with R&D expenditure equivalent to 4.27% of the GDP. South Africa has a higher R&D intensity than many developing countries but needs to keep pace with competitor countries where R&D is increasing rapidly (DST, 2004).

Trends in R&D Outputs

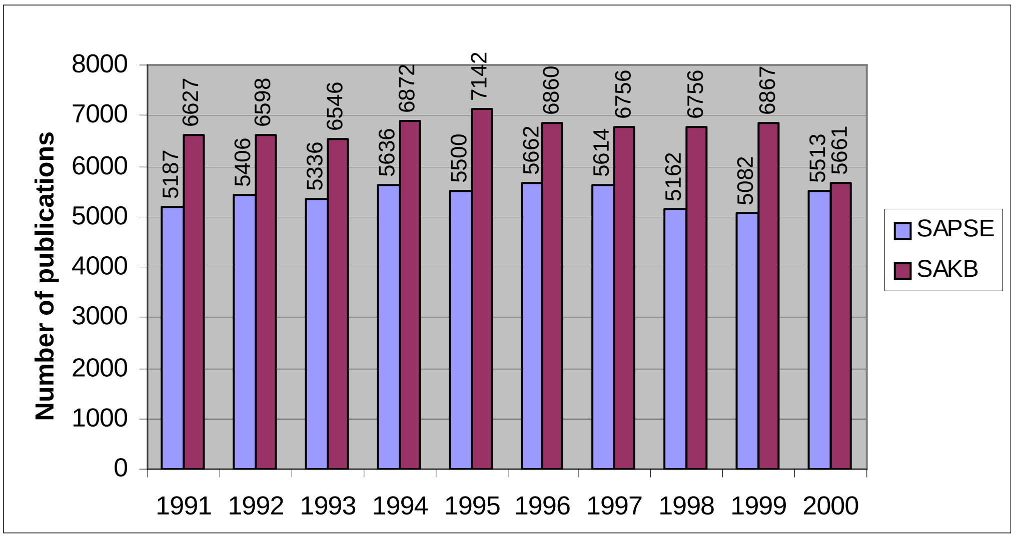
In terms of R&D outputs, South Africa has not performed well and its world share of publications as indexed by the Institute for Scientific Information (ISI) has dropped by 20% from the peak of 0.60% of world articles in 1988 to 0.48% in1994. There has also been a decline in numbers of South African patents registered at the South African Patents Office, as well as an increased deficit in national balance of payments for high technology goods (FRD, 1996).

As Mouton and Boshoff (2003) highlight, any bibliometric analysis of South African scientific output is confronted with the fact that a large proportion of South African journals are not indexed in ISI citation indices. This fact on its own contributes to the skewed nature of the reflection or indication of the overall R&D outputs in South Africa.

However, efforts are been made through various institutions to overcome these impediments by developing databases such the SA Knowledgebase under the auspices of the Centre for Research on Science and Technology, and the South African Post-Secondary Education (SAPSE) database led by Education Departments, *inter alia.*. Figure7 summarizes the main trend in the output of scientific articles, as represented in the SAPSE database and SA Knowledgebase (SAKB).

As Boshoff and Mouton (2003) point out, Figure 2.5 clearly indicates that South Africa's scientific output remained fairly stable during the first part of the 1990's. From 1995 onwards, however, there was a small decline in scientific output. Whether the trend points to real decline or whether it suggests that the shift is in the form of scientific publication is a matter for debate. For example, authors may be doing more contract research, which results in technical and contract reports that would generally not be published.

Figure 2.5:Total Scientific Output, 1991-2000



Sources: CREST SA Knowledgebase, Stellenbosch University (n.d.); SAPSE, Department of Education (n.d.)

Notes: 1.SAKB used fractional counts to account for multiple authorship (e.g. if an article has two authors, each author published 0.5 of an article).

2.SAKB data for 2000 still contain critical gaps.

Human Resource Base of the South African S&T System

Science and technology are linked to human resource development in one of three ways. Firstly, new and adopted product technologies directly enhance human development (for example, a new vaccine improves quality of life). Secondly, technology contributes to economic growth through the productivity gains it generates. These gains, in turn, create employment opportunities, thereby indirectly building human resource capabilities. Lastly, human resources constitute direct input to technological innovation because science and technology activities require a skilled workforce (UNDP, 2001:28)

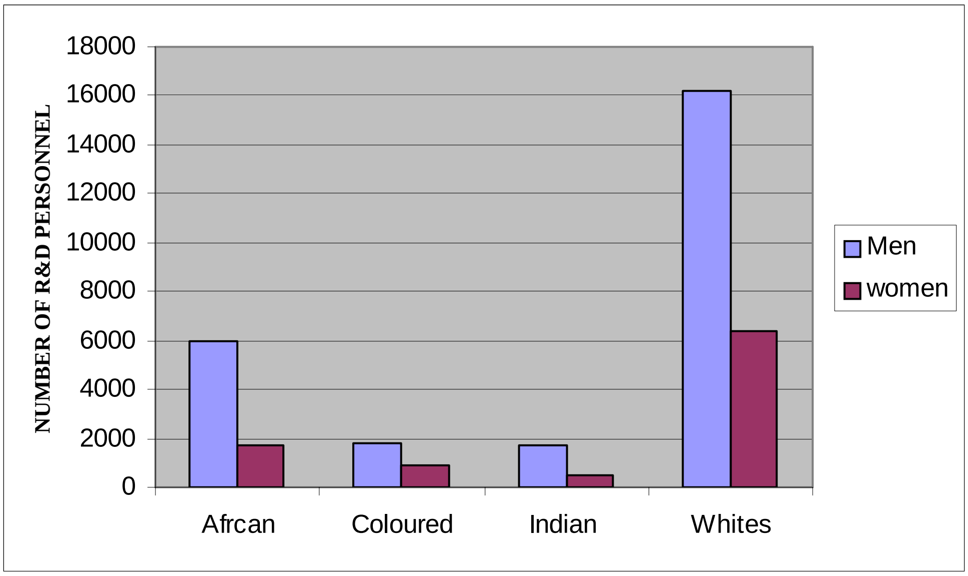
The human resource and population distribution in the South African science and engineering workforce are also crucial factors that contribute to a conducive environment for a fully functional science and technology system (specifically at performance level). Hence there is a need for a brief overview of the status of human resource development with regard to science, engineering and technology.

Due to the historical fragmentation of society caused by the apartheid regime, there has been a low percentage of “African” science and engineering students and graduates, which has inevitably affected competition among science and engineering students as the Africans constitute a larger population nation-wide (FRD, 1996).

The demographics of the R&D workforce, based on the latest 2001/02 R&D survey, are also not impressive with only 36.5% of the ranks drawn from previously disadvantaged groups (Africans, Indian and Coloured). However, these demographic changes have progressed from a very low base since 1994 (see Fig.2.6). In the 2001/02 R&D survey of the science councils, R&D staff from disadvantaged groups have increased to represent 45.9% of the total (DST, 2004). It becomes apparent that South Africa has made sound progress towards the goal of achieving greater equity in the R&D workforce, though the challenge of imbalance within the demographics of R&D still remains.

Another factor that needs serious attention is the development of mechanisms for retaining the skilled workforce in the country. As Tracy Bailey (2003) illustrates, South African has been experiencing a brain drain since before 1994, and this trend looks set to continue. The contributing factors to this problem appear to be, among others: concerns about crime and violence, poor economic growth rates, the decline in public service of the country, and lucrative job opportunities overseas. Bailey (2003) also considers the globalizing labour market for highly skilled professionals to be another factor that impacts on skills migration trends in South Africa. The latter factor on its own poses a challenge for scientific community as well as policymakers, since it negatively affects the country’s potential for sustainable economic development.

Figure 2.6: R&D Workforce By Race and Gender (headcount)



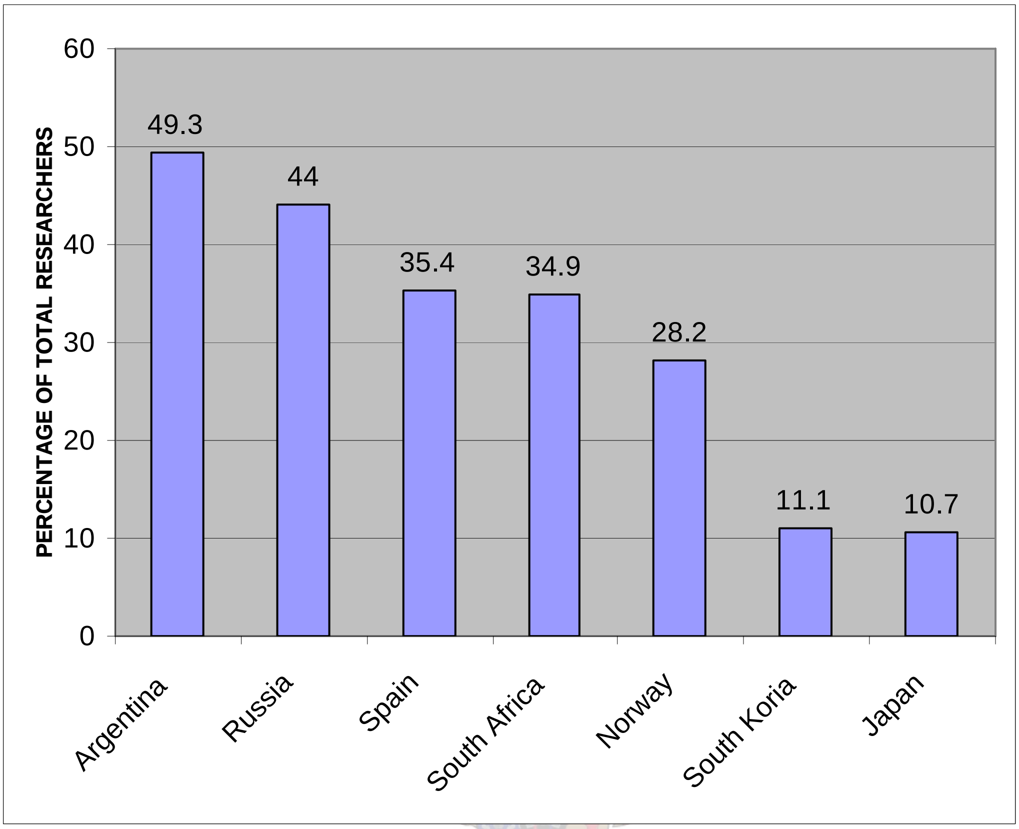
***Source*,** DST (2004), National Survey on Research and Experimental Development of 2001/02

The disproportionate representation of women in the science and engineering workforce becomes apparent. While South Africa's figure of 34.9% women researchers leaves much room for improvement, the country appears to be performing better than several other countries. Figure 2.6 and 2.7 reflects the distribution of the national workforce and clarifies the disparity highlighted earlier on, specifically in the scientific and technological fields. In many African countries (South Africa included), women thus constitute a largely untapped human resource in terms of broadening the science and technology base as it is reflected in Figure 2.7.

Based on the above highlighted facts, South Africa is faced with the challenge of mobilizing and strengthening the *science, engineering* and *technology* sectors in a holistic fashion with full participation of all relevant stakeholders, in order to promote economic growth and social development of the nation. This approach may enhance the present transition process and ensure a more stable and dramatic social, political and economic change.

<u>Figure 2.7: Women Researchers as a percentage of Total Researchers (headcount)</u>

<u>2001</u>



<u>Source</u>**:** DST (2004): National Survey of Research and Experimental Development of 2001/02

The above description is an overview of the institutional arrangement of the South African S&T system. It is, however, worth noting that the system is evolving all the time and, as Boshoff et al. (2000) put it, no steady state has yet been reached and will not be for some time to come.

2.4 South African Science and Technology Policy

2.4.1 The History of the South African S&T Policy

The first S&T policy documents in SA go back to the 1960's and 1970's, however, as Scerri (1998) reiterates, the aim of the S&T White Paper of 1996, was to redefine national S&T policy in line with the requirements of the political and economic system that emerged from the changes in the country's history, particularly after the 1994 elections.

As shown earlier, following the 1993 IDRC study, several processes have paved the way for a restructuring of the S&T system to a more coherent system, based on a national system of innovation. After 1994, two policy documents clearly focused on the central role of science and technology in economic and social reconstruction, by meeting basic social needs such as eradication of poverty, provision of employment, infrastructure, housing, electricity and other human basic needs. The two policies are further complemented by other initiatives to articulate, facilitate and evaluate the implementation of these policies as well as to set priorities and determine the future trends of the system. Examples of such initiatives are the NRTA, system-wide reviews, and Research Foresight exercise (Mouton & Boshoff, 2001).

In summary, Mouton and Boshoff indicate that the South African Government has produced, in recent years since 1994, a number of policy documents[11] on research, science and technology. The central theme in these documents is a call to the scientific community to mobilize its resources in the service of the new national social and economic goals. Scientists are called to contribute to the reconstruction and development of the new society through "strategic science", collaborative and trans-disciplinary "new modes" of knowledge production.

[11] The three policy documents are: a) The IDRC report on the state of science and technology in South Africa, which appeared in 1993 (Towards a science and technology policy for a democratic South Africa).
b) The final report on the National Commission on Higher Education which appeared in 1996 and
c) The White Paper on Science and Technology produced in 1996 by the Department of Arts, Culture, Science and Technology.

The new science and technology policy of South Africa was developed in two stages. The first stage was represented by the Green Paper, which is a synthesis of interactive discussion among all citizens on how science and technology could best be applied to national interests. The paper provides an overview of the potential role science and technology could play in post-isolation society by reviewing key issues relevant to South Africa and delineating alternatives (Boschoff et al., 2000). The second stage involved the White Paper on Science and Technology, which articulates the vision, and gives direction to that vision, together with supportive instruments.

The new vision for the S&T system, as described by the White Paper, is two-dimensional. On the one hand, South Africa should use science and technology to become *economically competitive* on a global scale and therefore to attain excellence. On the other hand, S&T should *provide essential services, infrastructure, and effective health care for a better quality of lif*e for all South Africans (DACST, 1996).

The science policy for South Africa is a more or less "mission-oriented" type of policy whereby government is steering the process. A mission-oriented type of policy, according to Mintzberg's (1979) description, is the emergence of a policy that is associated with shared common values. The key factor to the policy's success is a high level of commitment by the role players, while the major weakness that needs to be avoided would ensue from a lack of control and formal sanction. This implies that, for technological innovation to take place in South Africa and innovation that is driven by a mission-oriented type of policy, it will be imperative to have a vibrant, self-committed nation with a clearly articulated sense of direction based on common goals and objectives.

From the case study there are a lot of lessons to be learned but it becomes apparent that, in the process of development, South Africa has a strong base system of science and technology nurtured over two centuries and through three major phases. Firstly, science was pursued for *learning* and was based more on a "curiosity-driven" push. Later, science was turned into *practice*, shifting to a fulfilment of the "social contract" to meet national needs, although this was not attained fully due to the segregation and fragmentation brought about by apartheid regime. The strong base was more skewed thus skewed towards the white minority group of the overall population.

In the third phase, the strength of the South African S&T system further becomes obvious through the *institutionalisation* of science, which created powerful tools for running the system over time: the establishment of councils, universities, laboratories and, above all, investment in a core of skilled and knowledgeable people. This institutionalisation provides clear examples of technology achievements in both mission-oriented research and development as well as achievements in the industrial processes.

As a way of conclusion, it becomes apparent through this study that the long history of South African science system, depicts strengths, opportunities and challenges that face the country. The strengths of the system should become a basis for achieving the objectives of national science and technology policy, on the other hand, there is a need to utilize the opportunities like; the well established institutional set-up and other infrastructural facilities, in order to attain and maximize the vibrant national system of innovation, in an attempt to face the national challenges that currently are facing South Africa.

CHAPTER 3

3. THE INDIAN CASE STUDY

3.1 Introduction

Similar to the other two case studies, namely South Africa and Malaysia, the main aim here is to provide an overview of the Indian science and technology system. The case study describes and reviews the process of science and technology policy development, as well as its relationship with the national and regional policies of other countries in the East Asian region. This overview includes the national goals, objectives, plans and strategies of India. To achieve the above, the study gives a brief history of the science system in India during the period of pre-colonialism, during colonialism and post-independence. Furthermore, it reviews the science and technology policy and its key elements.

It is expected that the case study will depict the strengths, weaknesses and challenges that face the Indian science and technology system. As a result, the study will form a base for comparison with other selected nations and possibly come up with possible solutions that can be recommended to less developed nations, such as Lesotho.

3.2 The Overview of the Science and Technology System in India

3.2.1 Pre-colonialism

The development of science in India has a long history that dates back to the Gupta Age or what is referred to as the Classical Age (ca. AD 320-550). The most significant achievements of this period were, among others, the **institutionalisation of science** through the establishment of the world's first university in Takshila in 700 BC, at which more than 10,500 students from all over the world studied more than 60 subjects. The University of Nalanda, which was built in the 4th century, was one of the greatest achievements of ancient India in the field of education (www.indianchild.com/ ; Valluri in Lavakare & Waardenburg,1989).

Furthermore, India has obvious achievements in the education sector, particularly in metaphysics, mathematics (algebra, trigonometry and calculus), medicine and astrology. These subjects became highly specialized and reached an advanced level. They are exemplified by the Indian inventions of that period, namely, the numerical system -- sometimes erroneously attributed to the Arabs (who transferred it from India to the Roman system) -- including the decimal system. The Aryabhatta's expositions on astronomy in the year AD 499 also gave remarkably accurate calculations of the solar year, along with the shape and movement of astral bodies.

In the field of medicine, Charaka and Sushruta wrote about a fully evolved system, resembling the writings of Hippocrates and Galen in Greece. Although progress in philosophy and biology was hindered by the religious injunctions against contact with dead bodies, which prevented dissection and discouraged the study of anatomy, Indian physicians excelled in pharmacopoeia, caesarean section, bone setting and skin grafting (www.indianchild.com/gupta_empire.htm).

This period can be seen as the time of scientific evolution through discoveries and practical applications. It can be referred to as the era of "**science for the sake of science",** coupled to some extent with the beginning of the **" industrialisation of science"**.

The industrialization of science in India became more pronounced during the coming of Islam in the thirteenth century, the time when both the Quran and sharia (Islamic law) provided the basis for enforcing Islamic administration on independent Hindu rulers The advent of Islam is evidenced by growth in the agricultural sector in the north of India, which resulted in the construction of new canals and the introduction of new irrigation methods, including what came to be known as the Persian wheel, prolonged political instability and new taxation methods. Trade and a market economy, then encouraged by the aristocracy, acquired new impetus both inland and overseas. Experts in metalwork, stonework and textile manufacture responded to the new patronage with enthusiasm (www.indianchild.com/coming_of_islam.htm). During that time (around 600 BC), settlement and emergent states were identified with growth in agriculture while, through collected revenues, armies were maintained and new cities and highways were built.

3.2.2 Colonial Rule - British Empire

The quest for wealth and power brought Europeans to Indian shores. Vasco da Gama, the Portuguese voyager, arrived in Calicut (modern Kozhikode, Kelara) on the west coast. Among other invasions, in 1510, the Portuguese took over the enclave of Goa, which became the centre of commercial and political power in India and which they controlled for nearly four and a half centuries.

As a strategy against Portuguese supremacy, the then Indian rulers enthusiastically accommodated other newcomers - the British in particular - as their envisaged protectors against the Portuguese. Hence in 1619, Jahangir granted the British permission to trade in his territories on the west coast and the east. These and other locations on the peninsula became centres of international trade in spice, cotton, sugar, raw silk, saltpetre, calico and indigo (www.indianchild.com/british_invasion_in_india.htm).

The British Empire (1757-1857) in India originated from a multipurpose perspective: among others, it was motivated by commerce, security and a purported moral uplift of the people. These motives gave birth to private and company trade which eventually led to the conquest or annexation of Indian territories in which spices, cotton, and opium were produced. Their sense of superiority allowed the British intellectuals to spearhead a movement that sought to introduce Western intellectual and technological innovations to Indians.

The institutionalisation of science during the British rule was also aided by the Christian missionaries who with aggressive moves, made an indelible impact through publishing, building schools, orphanages, vocational institutions, dispensaries and hospitals.

Notwithstanding British education policies in the 1830's, which influenced the socio-economic division that existed at that time within Indian society, the 1850's witnessed the introduction of what is seen as three "engines of social improvement", namely, the railroads, the telegraph, and the uniform postal service. The result was that communication between the rural and the metropolitan areas became easier and faster. The increased ease of communication and the opening of highways and waterways accelerated the movement of troops, and the transportation of raw materials and goods to and from the interior, including the exchange of commercial information. (www.indianchild.com/amazing_facts_of_india.htm). According to the Gemological Institute of America, until 1896, India was the only source of diamonds to the world, within the mining sector. These accomplishments could be seen as a major stride in the industrialization process.

In the late 1850's, the civil war became a turning point in the history of modern India. This war led to downfall of the British East India Company and it was replaced with direct rule under the British crown. This brought about a gradual socio-political transformation that resulted in a political impasse on the side of colonial rule. Through the emergence of movements and congresses, Indian independence was eventually attained in 1947 (www.indianchild.com/india_independence_movement.htm).

3.2.3 Indian Post-Colonial Era

As Sikka (1997) shows, science in India after the Second World War shifted from an era of personal pursuit to the era of a governmental regime of science or Institutionalisation of science in a more proper and systematic manner. According to Sikka (1997), this shift was evidenced in most countries around that time by the devotion of more financial resources to the creation of S&T infrastructure, and R&D laboratories and by the provision of promotional measures and incentives for generating science-based economies.

Economic backwardness was one of the serious challenges that India faced at independence. Science and technology were therefore incorporated as a special component of the national five-year economic plans (CSD/HSRC, 1993; Sikka, 1997). And indeed, under three successive five-year plans, instated between 1951 and 1964, India showed an increase in food production. The production still did not allow self-sufficiency until 1984, when India emerged as a nation with the seventh largest gross national product (GDP) in the world (Centre for Science Development -CSD/ Human Sciences Research Council-HSRC, 1993).

Nevertheless, India is beset by the same problems that face various developing countries, such as, poverty, urbanization, population growth, heterogeneity, illiteracy, and low economic growth. The majority of its population lives below the poverty line and its complex nature is depicted by a large variety of classes, social groups, languages, religions and tribes (CSD/ HSRC, 1993.) Only after independence did science and technology became purposeful national pursuits (Shravastava and Swaminathan in Lavakare & Waardenburg, 1989).

Despite the lack of food, potable water and shelter for the growing population, there is a strong belief among Indians that improved standards of living can be obtained by massive industrialization, backed by the development of science and science-based technologies (CSD/HSRC, 1993).

After independence, Jawaharlal Nehru, India’s first Prime Minister, expressed faith in the use of science to increase the material well being of the Indian people. Nehru called the infrastructure of science such as universities and laboratories, *the temples of modern India.* The belief in science became a guideline with the first five-year plan of the government of India in 1951 and was reaffirmed by the passing of the *Science Policy Resolution* in 1958.

The government of India put the focus of the Resolution on national prosperity in the effective combination of three factors, namely; technology, raw material and capital, among which technology takes precedence as a national priority. The Resolution further indicates that the government of India had decided that the aims of its scientific policy would be to foster, promote and sustain the cultivation of science and scientific research in all its aspects in order to ensure an adequate supply of research scientists of the highest quality and to recognize their work as an important component of the strength of the nation and, in general, to secure for its citizens all the benefits that can accrue from the acquisition and application of scientific knowledge (Government of India Scientific Policy Resolution in UNESCO,1972)

The 1958 Science Policy Resolution additionally reiterates the importance of scientific and technological self-reliance. However, Mrinalini and Sandhya (Science Public Policy, 1996) consider the resolution to have failed to institute the link between research activity and the production system. The authors identify this as one of the common problems affecting developing countries, namely, the inability to link the knowledge-generating activity to the productive activity (Sagasti F.R, 1979).

3.2.4 The Recent History of the Post-Independence S&T System

The period from the 1980's onwards was marked by what the CSD/HSRC (1993) report refers to as the phase of accountability and performance, with more emphasis on acquisition of technological capability or technology transfer, including the identification of returns that accrue from S&T investment. Short-term strategies were launched to redress the immediate national needs, namely; access to water, literacy, food security, health services and rural communication.

The CSD/HSCRC report (1993) also describes the period between 1970 and 1980 as an Assessment and Re-orientation Phase in the history of S&T development in India. According to the report, this period was characterized by the expectation that research institutions would contribute to economic development and that the links between the research infrastructure and socio-economic system would be strengthened. Consequent to the development of a plan on science and technology by the National Committee on S&T, a restructuring process was earmarked with, *inter alia*, the following milestones;

- Creation of the Department of Science and Technology;
- Setting up of a Science and Engineering Research Council in emerging and interdisciplinary areas;
- Increased selective funding to universities;
- Regulatory measures undertaken in order to promote an ‘import substitution’ policy in R&D activities; and
- Industrial in-house R&D promoted by introduction of tax incentives. Write-offs of 100% on capital investments for R&D, and 133% for expenditure on sponsored research was made available to industry
  (CSD/HSRC, 1993).

The success of government initiatives, including the policy orientation towards self-reliance and self-sufficiency, can be seen in the success of the industrial pesticide sector of which India not only developed production capabilities but also technological capabilities (Mrinalini & Sandhya, 1996).

Though the institutionalisation of science was implemented to a greater degree after independence in 1947, it was meaningfully established with the creation of a Ministry of Education and Scientific and Natural Resources in 1951, which led to the creation of the Ministry of Science and Technology (1970), and Departments of Space (1972), Atomic Energy (1954), Electronics (1970), Environment (1980), Ocean Development (1981), Biotechnology (1986) and many others. In addition, there was the emergence of R&D laboratories (about 3000) and scientific and technical institutions, technical/engineering and medical institutions all over India (Sikka, 1997).

3.3 The Science and Technology System of India

3.3.1 Governance Structure at Macro-level

At macro-level, the Prime Minister is the minister responsible for S&T. The Scientific Advisor's *advisory* role to the Prime Minister's Office extends to technology missions and to the independent Science Advisory Council (Fig 3.1). The Science Advisory Council consists of eleven scientists and is supported by the Department of Science and Technology. *Inter alia*, the Council also advises the Prime Minister on:

- National issues pertaining to science and technology;
- Status of science and technology, and;
- Direction in which science and technology should move, including facilitation of decision-making.

(CSD/HSRC, 1993).

The Department of Science & Technology (DST

The Department of Science & Technology (DST), was established in May 1971 with the objective of promoting new areas of Science & Technology and of playing the role of a nodal department for organizing, coordinating and promoting S&T activities in the country. The DST holds the major responsibilities for specific projects and programmes as listed below:

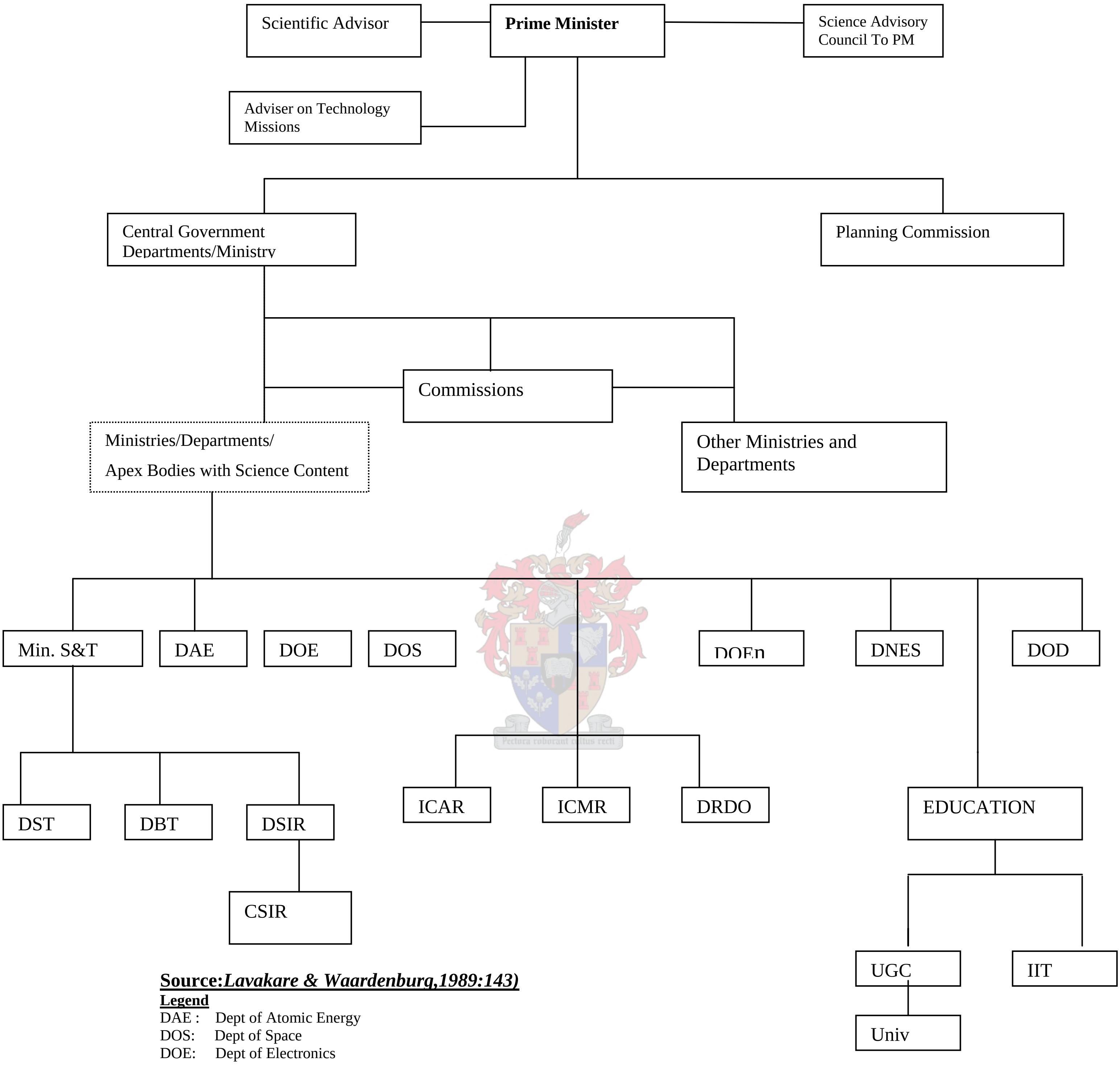
- Formulate policy and guidelines on science and technology, including coordination of areas of science and technology in which a number of institutions and departments have interests and capabilities;
- Support basic and applied research in national institutions throughout the country, and provision of mini-infrastructure facilities for testing and instrumentation;
- Support socially oriented S&T interventions for rural areas and weaker sections of economy;
- Support entrepreneurship development to create self-employment opportunities, especially for those which are science and technology oriented;
- Popularise science and technology;

- Provide scientific services in terms of surveys and mapping for Defence, External Affairs, State Government and several other development agencies through the Survey of India (SOI), and National Atlas and Thematic Mapping Organization (NATMO);
- Foster international cooperation and establishment of special joint centres/projects such as, International Advanced Research Centre for Powder Metallurgy and New Materials, Indo-French Centre, NAM S&T Centre, and Indo-Uzbek Centre; and
- Management of Information Systems for Science and Technology Coordination.

Source; www.dst.gov.in .

Figure 3.2 illustrates the organizational structure of the Department of Science and Technology in India.

Fig. 3.1The Organizational Structure of Indian S&T System

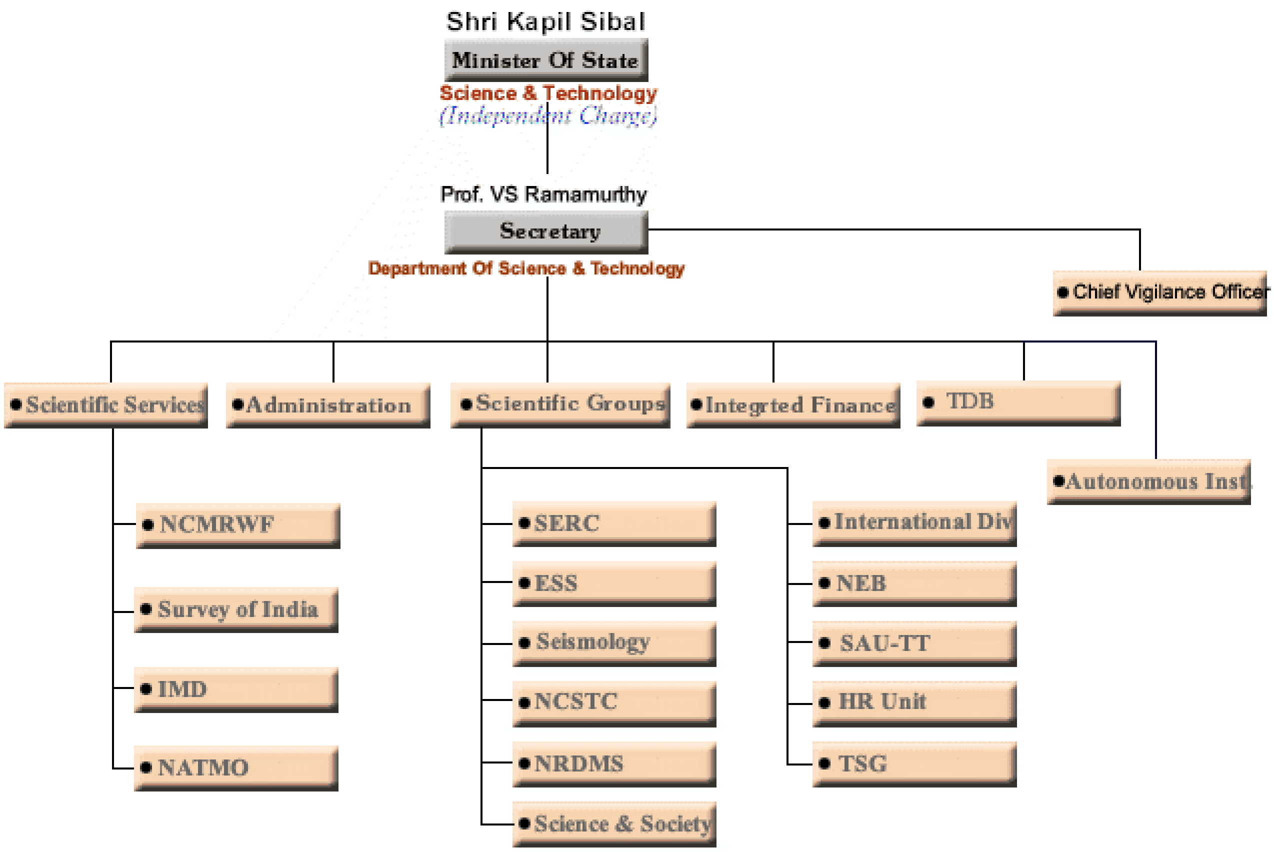


Source:*Lavakare & Waardenburg,1989:143)*

Legend

DAE : Dept of Atomic Energy
DOS: Dept of Space
DOE: Dept of Electronics
DNES: Dept of Non-Conventional Energy Sources
DOD : Dept of Ocean Development
DBT: Dept of Biotechnology
DST: Dept of Science and Technology
DSIR: Dept of Scientific and Industrial Research
ICMR: Indian Council of Medical Research
ICAR: Indian Council of Agriculture
DRDO: Defence Research and Development Organization
CSIR: Council of Scientific and Industrial Research
UGC University Grants Commission
IIT: Indian Institute of Technology
Univ: University

Fig. 3.2 Department of Science and Technology Organizational Structure



Source: http://dst.gov.in/org_structure.htm

Abbreviations Stands for :

TDB	Technology Development Board
NCMRWF	National Center for Medium Range Weather Forecasting
IMD	Indian Meteorological Department
NATMO	National Atlas and Thematic Mapping Organization
SERC	Science and Engineering Research
ESS	Earth System Sciences
NCSTC	National Council for Science and Technology Communication
NRDMS	National Resource Data Management System
NEB	National Entrepreneurial Board
SAU-TT	Special Assignment Unit on Technology Transfer
TSG	Technology Systems Group

3.3.2 The Meso-level of the Indian Science and Technology System (Advisory Bodies and Funding Framework)

In order to understand the institutional arrangement of the Indian science system, with particular reference to the key performers of R&D, first and foremost, one has take note of the following three categories of R&D institutions as classified by Joshi (1992), based on the source of finance or the ownership. They are:

a) Central/State Government

- National Agencies (CSIR, ICAR, DRDO)
- Departmental Institutions (RDSO etc.)

b) In-house R&D Units of Industrial Firms

- Public Sector
- Private Sector

c) Non-governmental, publicly-funded Institutions (Research Foundations)

-Central Government structures

In order to build a strong scientific human resource base in a more systematic manner, the government of India has put in place two agencies of the central government whose role is to provide financial assistance to the universities. These agencies are the University Grants Commission (UGC), which is a unit within the Ministry of Education, and the Department of Science and Technology. The main function of the UGC is to monitor and maintain the standards of Indian universities, colleges and institutions and award grants for their development (CSD/HSRC, 1993).

The government of India is the chief patron of promoting and funding science in the country with overall support of about 80% of the total S&T expenditure, while the industrial/private sector contribution is of the order of 20%. As far as R&D expenditure is concerned, the central government contributed 75.0% in 1995, the state governments 8.6% and the private sector 16.4%. The public and private sectors' respective shares of the total remained relatively stable over the fourteen (14) years to 1995 (DST, 1996a)

At meso-level, the government of India administers science and technology through Central Government and Commissions. The Central Government consists of departments and ministries, along with Science and Technology Advisory Committees (STACs) that are placed in various ministries. These inter-sectoral advisory committees, among others, are charged with the following:

- Identify and address the needs for S&T inputs and investment in their specific sector;
- Examine application potential of S&T development; and
- Establish strategies for accelerating the process of technological change

(DST, 2000).

According to the DST 1999/2000 annual report, the STACs are set up in 24 socio-economic ministries with the aim of providing S&T inputs to the concerned sectors. Furthermore, the Central Government is responsible for support and planning, in addition to integrating R&D with production.

An Inter-sectoral Science and Technology Advisory Committee (IS-STAC) also exists within the Department of Science and Technology and plays a coordinating role by working closely with the STACs in order to enable multi-partnership efforts (DST, 1999/2000).

Furthermore, the government of India supports S&T policy related issues in various ways, including funds for promoting scientific research. Scientific departments to the universities and research laboratories/institutes make use of these funds. Special funds for technology development and Venture Capital/Risk Capital have been created for the development of indigenous technologies in India (Sikka, 1997).

The other agency that assists universities and colleges is the Department of Science and Technology (DST) of the central government. Among other responsibilities, the department is charged with the development of policies and guidelines for S&T, and promotes new areas of effort for S&T such as the provision of financial support to several S&T research institutes and for many special programmes.

On the same note, in the 1999/2000 fiscal years, thirteen autonomous research institutions, which had been supported by the DST, continued to achieve excellence in their areas of specialization. The outputs of these institutions can be reflected in an

increasingly high number of publications, and they have transferred a number of technologies to industries and user agencies. Furthermore, stronger links between research and development and economic activities were established by the institutionalisation of risk investment mechanisms through the creation of a Technology Development Fund within the financial institutions and Science and Technology Advisory Committees of the different socio-economic sectors.
(DST, 1999/2000).

At project level, there are two modes of funding R&D related project in India. They are:

- The *intramural mode*, which is also referred to as *In-house R&D*, in which national laboratories, universities/colleges, public and private sector industries and other research organizations carry out projects using their annual grants.
- The *extramural projects* are designed to build general research capability and encourage scientists to pursue a research career. Extramural funding has increased from Rs 186.48 crores for R&D activities during 1996/97 to Rs 349.84 crores during 1998/99. The Ministry of Information Technology (MIT) and the Department of Science and Technology were the two agencies that played a major role in Extramural R&D funding (DST, 2001).

3.3.3 Performance Level

Apart from the institutions that are established in the central government, there are state government institutions whose role is primarily to meet the R&D needs of the traditional sectors, such as, agriculture, public health and forestry. These institutions also engage in survey and extension activities. In addition to the aforementioned institutions, there are non-governmental, publicly funded institutions (research foundations and others) that are involved in R&D activities, such as associations of industries, research foundations set up by industrial houses or philanthropic organizations, voluntary groups and professional societies. These institutions may receive funds from government or other sources (CSD/HSRC, 1993).

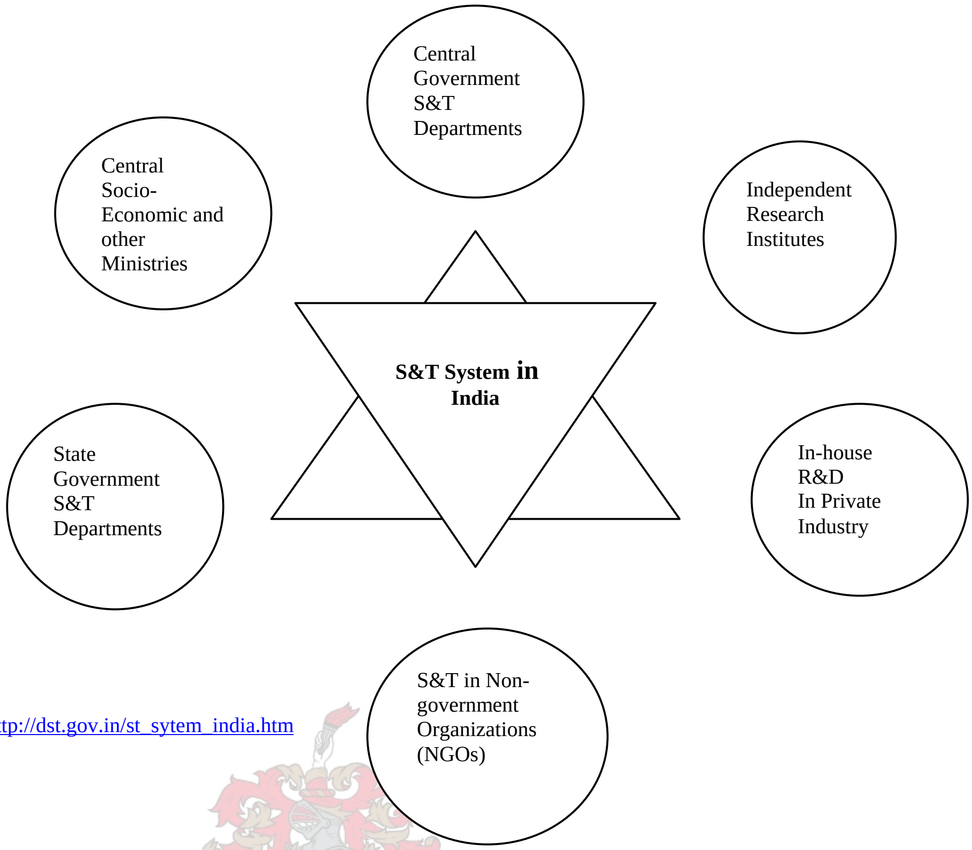
There are five umbrella organizations for R&D at the national level. As the CSD/HSRC (1993) shows, since 1988 there have been research institutions, controlled by a department, under the auspices of the central government. These institutions are usually grouped under councils or commissions to provide flexibility and autonomy. They are:

- The Council of Scientific and Industrial Research (CSIR) – the premier organization for industrial research. The metamorphosis of the CSIR, which ranked first among the top patentees in the country, illustrates well the new face of publicly funded R&D (CSIR, 1994; 1996).
- Indian Council of Agricultural Research (ICAR) – the principal body of agricultural research, which comprises forty-six research institutes, four of which are regarded as universities, and four are national bureaus for plant genetics, animal genetics, fish, soil conservation and land use.
- The Indian Council of Medical Research (ICMR) -- the principal body of biomedical and health research, constituted by twenty permanent research institutes and six regional and medical centres.
- The Indian Council of Social Science Research (ICSSR) -- the institution responsible for the promotion of research in the social sciences, which includes: six regional centres to decentralize administration and to broaden the base of social science research, and a national social science documentation centre.
- Defence Research and Development Organization -- the institution consists of forty-seven research institutions/laboratories.

The combination of state support at the highest level and the active involvement of the scientific elite have, over time, spawned a broad S&T infrastructure in India, consisting of S&T institutions in the public sector, R&D units within the private sector, and some voluntary organizations with overriding involvement in S&T. Over and above these was the existence in 1998-99 of a total of 220 universities, including 11 Indian Institutes of Technology and 11397 colleges, forming part of the higher education sector of the country (Jain, 1998; DST, 2001).

In summary, the overall science and technology system of India can be reflected thus (see Figure 3.3);

Figure 3.3: S&T System in India



Source DST,2002 : http://dst.gov.in/st_sytem_india.htm

3.3.3.1 Research and Development in India

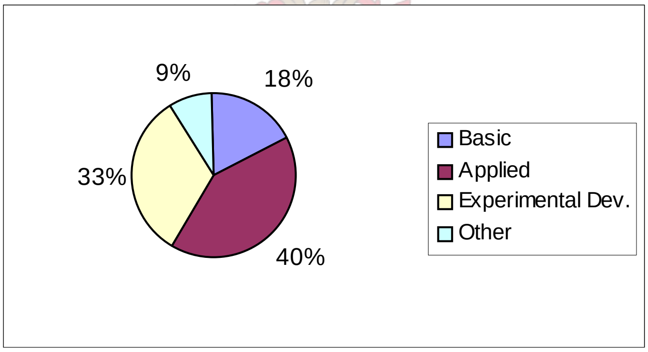
Recognizing the fact that, by devoting a higher percentage of GNP to R&D related programmes, the developed countries have achieved higher industrial productivity, India has now set targets for devoting 1.5 to 2% of its GNP to R&D activities by the year 2020 (Sikka, 1997).

There has been observed R&D growth over time attributed to: the introduction of incentive schemes, liberalization of the economy, widening of avenues for upgrading technology, and the move to raise international industrial competitiveness as a result of increased expertise, particularly among private sector units. Notwithstanding the steering role played by the public sector, there is a vigorous private sector, which plays a major role in industrial development. The annual growth in industrial production is 7.7% (Jain, 1998).

Since one of the most commonly used indicators for international comparison of S&T efforts is the proportion of Gross National Product (GNP) devoted to R&D activities, the latest biennial statistical report of 2001 highlights the following regarding R&D expenditure:

- The national investment in R&D, which can be considered as Gross Expenditure in Research and Development, totalled Rs 17660.21 crores[12] in 1988/99, which constitutes about 0.81% of the GNP.
- India's per capita R&D expenditure was Rs 103.26 (US$3.1). Sector wise, the percentage share of this national expenditure during 1998/99 was thus: Central Government 62.5%, State Governments 8.0%, Higher Education 2.9%, Public Sector Industries 5.0% and Private Industries 21.6%.
- In terms of *the type of research,* about 18% of the total expenditure was spent on basic research, 40% on applied research, 33% on experimental development, and the remaining 9% on what is referred to as appropriate activities, as indicated in fig3.4 (DST, 2001).

Figure 3.4: National R&D Expenditure by Type of Research



Source: DST, 2001:National Research and Development Survey 1998/99

Table3.1 demonstrates that, engineering and technology were more proactive in R&D, particularly in the industrial/private sector, which implies that the sector is committed to an increase in productivity and innovation. On the other hand, the Table depicts that agricultural science was more engaged as a government priority. The Table also shows that Central and State governments take a leading role.

[12] 1 crore = 10 million

Table 3.1 Expenditure on Research and Development by Field of Science 1998-99

(Rs Lakhs)

Field of Science	Central Government	State Government	Public Sector	Private Sector	Total
Natural Sciences	20,8890,77	3,530.34	11,480	32,988.14	256,889.90
Engineering and Technology	47,4225.85	4,725.51	52,541,39	72,378.95	603,871.70
Medical Sciences	29,694.10	2,874.15	1,079.44	63,512.86	97,160.55
Agricultural Sciences	92,689.82	91,523.55	0.00	56,468.07	240,681.44
Total	805,500.54	102,653.66	65,101.37	225,348.02	1,198,603.59

Source DST, 2001: National Research and Development Survey 1998/99

Notes: Data do not include Small Scale Industries
Data for private sector refer to 1144 in-house R&D units including 176 Industrial Research Organizations (SIRO)
1 Lakh = 0.1 Million

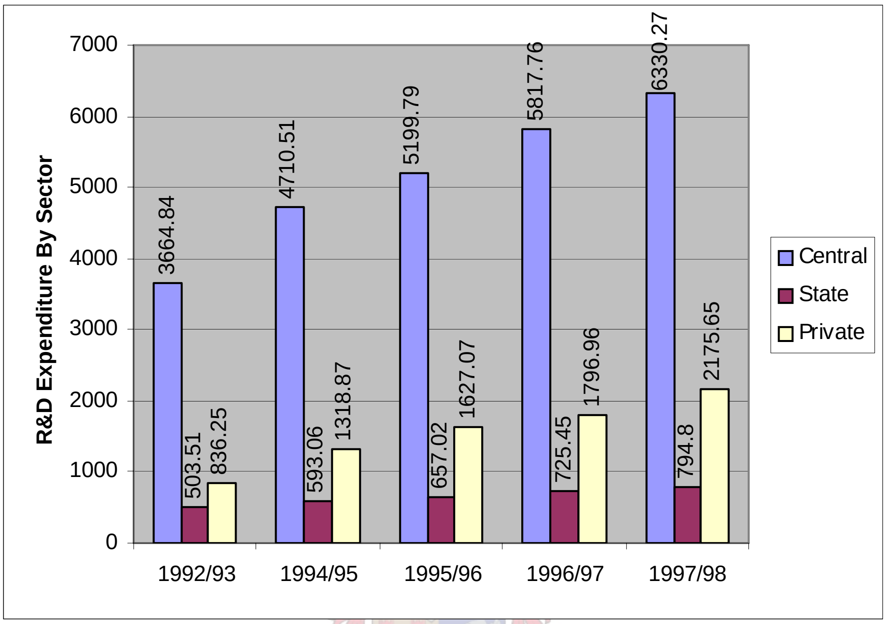
The Indian *public sector* has been assigned a predominant role in transforming the industrial sector, with the aim of enhancing industrialization as a means of economic development. On the other hand, about 88% of investment in R&D activities by the State sector was devoted to the development of agriculture and allied areas in institutions located in the States of Gujarat, Maharashtra and Uttar Pradesh, which incurred more than the overall total state sector on R&D expenditure (DST, 2001).

The public/joint sector has made large investments for the development of major industries. There are 160 manufacturing enterprises in the public sector. The major industrial sector includes: mining, metallurgical, mechanical and electrical engineering, chemicals and allied industries, drugs and pharmaceuticals, textiles, and food (British Council, 1996; DST, 2001). The in-house units of industrial firms constitute more than 1,031 private industrial in-house R&D units in India (DST, 2001).

Sector-wise, the percentage share of national expenditure during 1998-99 was: Central Government 62.5%, State Governments 8%, Higher Education 2.9%, Public Sector Industries 5% and Private Industries 21.6% (DST, 2001). Figure 3.5 shows the trend in R&D expenditure by sector over five fiscal years (from 1992/98 to 1997/98). It is, however, worth noting that the data for 1997/98 have been estimated by applying the rate of growth from the period 1992/93 to 1996/97. Furthermore, data for the year 1993/94 were not available in this survey (DST, 2001).

Fig 3.5 National Expenditure on Research and Development by Sector/Source of Finance

(Rs Crores)[13]



Source: DST,2001

As B. Bowonder (2001) indicated, the economic liberalization[14], along with an intellectual property regime, has facilitated the creation of new knowledge, inclusive of entrepreneurial firms in India. He also reiterated that the growth of these firms can be attributed to economic liberalization in India. Previously, protection from competition had limited innovation and entrepreneurship. Furthermore, government funded R&D was mostly directed towards supplying technology such as atomic energy, space technology and defence technology. On the other hand, since liberalization, there has been an increase in R&D spending by major private corporations. The liberalization has also facilitated entrepreneurial orientation, leading to demand for technology and its commercial exploitation.

[13] Rs. 1 Crore = 10million

[14] Since 1991, India's manufacturing sector has been undergoing a wave of liberalization, the main objective of which is to reduce both external and internal barriers to entry.

On the same note, Mani (2002) also agreed with the sentiment that the Indian manufacturing sector has continued to be protected from external and internal competition, though in some cases, certain sections of it have definitely been subjected to a modicum of competitive pressure. However, the demand for innovation for the average enterprise in the manufacturing sector continued to be very low.

Table: 3.2

Country	R&D EXPENDITURE PER CAPITA AND PERCENTAGE OF GNP FOR TEN SELECTED COUNTRIES (1997-1998)		
	Per capita R&D Expenditure (in U.S $)	Per Capita GNP (1999)	R&D Expenditure as % of GNP
Austria	-	25970	1.53
Canada	317.90	19320	1.66
China	-	780	0.66
Czech Republic.	-	5060	1.20
Denmark	-	32030	1.95
Germany	598.40	25350	2.41
France	527.12	23480	2.25
India	**3.10 (1998)**	**480**	**0.81**
Israel	-	-	2.35
Italy	202.44	19710	2.21
Spain	-	14000	0.90

Source: UNESCO Statistical Year Book of 1999; World Development Report of 2001

Notes: 1. (-) Data not available

2. Figure in parenthesis represents the year for which the data were available.

From the international perspective, it becomes evident (Table3,2) that India did not show favourably in terms of R&D expenditure per capita and of percentage of GNP in the years 1997-98, when compared to most countries, particularly the developed nations. The situation calls for a more serious commitment by all partners in R&D, particularly the private sector and academia. Government, the private sector and academia need to form a stronger and more systematic partnership in order to address pragmatically the priorities and needs that face the nation, through the use of research and development. In other words, there is a need to decrease much of the steering done by the public sector in the overall management and implementation of the national policy, specifically the science and technology policy.

Trends in R&D Output in India

As Ashok Jain (1998) indicated, by taking the number of papers published as a measure of scientific output, it becomes evident that agriculture dominates the research agenda of the countries in the region. In all but India and Pakistan, papers on agricultural related topics far outnumber those published in other scientific fields, which points to a pattern of research in India, and to a lesser extent in Pakistan, that is closer to the industrialized model than in other South Asian countries.

It has become inevitable that in India, S&T is regarded as an integral solution for the socio-economic problems facing the nation. Although considerable progress has been made in S&T, advances are still dwarfed by the continuing problems of poverty, illiteracy and poor health affecting at large majority of the people living in rural areas (CSD/HSRC, 1993).

Notwithstanding the challenges facing the Indian nation, the following outputs should be taken into consideration:

- In terms of published papers, India makes its greatest contribution to world science in agriculture (as shown earlier, on Indian status at regional level). Globally, India contributes 7.1% in agriculture, 2.2% in chemical sciences, 2.1% in physical and earth sciences, 2.0% in engineering, 1.7% in mathematics and 1.4% in biology. (Jain, 1998).

According to the DST National R&D survey of 2001, 1800 patents were sealed in the year 1998-99. Of the 645 Indian patents that were sealed, the maximum number of patents filed by Indians was from the state of Marashtra, with a percentage of 30.9%. The United States of America topped the list of applications filed by countries with a share of 41.8% (DST, 2001).

Human Resource Management of the Indian S&T System

From the regional perspective, a very low density of R&D personnel characterizes South Asia. In most countries, the number of scientists and engineers engaged in R&D per million population falls well below the average for the developing countries. Science in the formal universal sense is yet to diffuse into the economies of the region in any significant manner (Jain, 1998).

One of the crucial requirements for a functional S&T system is an adequate human resource base. India is one of the leading countries in the world when it comes to availability of S&T human resources. The country, however, suffers from an "external brain drain" to Western countries and an " internal brain drain" in that highly qualified scientists have to settle for non-science careers because of the inability of the economy to absorb them in appropriate jobs (Joshi, 1992).

India's investment in building its human resource capacity can be traced back to 1956 with the establishment of the University Grants Commission Act, which regulates the standard of the higher education sector throughout the country. The act also monitors the founding of new tertiary establishments in order to ensure that higher education grows in response to the needs of society, with appropriate levels of professional training (British Council, 1996).

The commitment of the Indian government to education and training is well articulated in the National Policy on Education (1986), translated into action by a request for investment in education exceeding 6% of the GNP from the Eighth Five-Year Plan onwards (British Council, 1996). As shown earlier in the text, in 1995, there were 204 universities, 36 of which were deemed universities.[15] There were also 8 613 colleges across the country (DST, 1996*b*).

Higher education in India is a large enterprise; this fact is alluded to by the R&D National survey of 2001. There were 220 universities/deemed universities, 11

[15] A deemed university is recognized by central government as being capable of awarding its own degrees. Institutions without this status must affiliate themselves to a university in order to award degrees.

institutions of national importance and 11,397 colleges in 1998-99 (DST, 2001). Mani (2002) also states that India has as extensive university system, in which enrolments have increased by a factor of 20 since 1947. Almost all the universities are owned and governed by the state.

Traditionally speaking, science and engineering have been given much importance and are essentially supported by massive governmental subsidies. This has ensured a steady supply if scientists and engineers. Mani (2002) also shows that, according to estimates, the country has a total stock of about 4.3 million S&T personnel. Despite this, the number of researchers, scientists and engineers engaged in R&D is the lowest compared even to other Asian countries; it has shown a little increase since 1992 (Table3.3 .) and barely any increase over the last two decades.

Table 3.3 Density of scientists and engineers in R&D in India, 1992-1998

(per 10,000 labour force)

Year	India	Singapore	Malaysia	South Africa
1992	7.74	39.8	2.1	na
1994	na	41.9	5.8	na
1996	8.23	56.3	5.1	na
1998	na	66.5	7.0	16.3

Source: DST (Various Issues) Chapters 3, 5 and 6

Note; na denotes data not available

Another important dimension is that India has more science graduates than engineers. Over time, the ratio of engineers to people with qualifications in the pure sciences has worsened from 0.63 in 1985 to 0.49 in 1996. This emphasis on natural sciences has resulted in the country's scientific personnel being in high-energy physics, plant biology, solid state and inorganic chemistry, polymers and ceramics (Mani, 2002).

Table 3.4

R&D PERSONNEL IN SOUTH ASIA

Selected Countries

	R&D Personnel	*Total*	*Women*
India 1994	Scientists and engineers*	136 503**	10 505
	Technicians	98 769	9 333
	Auxiliary Personnel	101 317	17 411
Iran 1994	Scientists and engineers*	34 256	-
	Technicians	10 104	-
	Auxiliary personnel	5 966	-
Mongolia 1995	Scientists and engineers*	2 289	939
	Technicians	431	237
	Auxiliary personnel	940	554
Pakistan** * 1990	Scientists and engineers*	6 626	464
	Technicians	9 314	-
	Auxiliary personnel	13 100	-
Sri Lanka 1997	Scientists and engineers*	3 448	1 103
	Technicians	-	-
	Auxiliary personnel	-	-

* Full-time equivalent.

** Conservative estimate, the figure given in the Source for the higher education sector (22 100) dating from 1982.

*** Not including military and defence R&D

Source: UNESCO (1997) *Statistical Year book 1997*; for Sri Lanka: NARESA.

Nevertheless, there has been a sustained growth in female enrolment at tertiary level in recent years. Women represented an estimated 33.8% of students in 1995, compared to 31.7% in 1989. Their representation in S&T fields still remains very low, with women being most present in the natural sciences. This low visibility is reproduced in the S&T workforce, where women represent only 7.7% of scientists and engineers. Table 3.4 reflects women's representation and further compares Indian R&D personnel to those in South Asia.
(Jain, 1998).

3.4 Indian Science &Technology Policy

3.4.1 The History of the Indian S&T Policy

Subsequent to the passing of the 1958 Scientific Policy Resolution, and following the establishment of scientific institutions, the government of India declared a Technology Policy Statement in 1983, which focused on the following:

- Indian S&T must unlock the creative potential of the people. Human resources are highly regarded and conditions must be created for the fullest expression and utilization of scientific talent. Hence the need for massive investment in S&T education or training.
- The base of science consists of trained and skilled manpower in all disciplines, and an appropriate institutional, legal and fiscal infrastructure.
- Consolidation of the existing base and strengthening of thrust areas are essential.
- Special attention must be given to promotion of the technology base in frontier areas, such as information and materials science, electronics and biotechnology.
- Basic research and building of centres of excellence will be encouraged.

(Lavakare & Waardenburg, 1989:45).

As has been indicated in the early parts of the case study, the S&T policy is strongly influenced historically by the colonial period; by the need to expand the country's S&T capabilities and by the drag of illiteracy and poverty (CSD/HSRC, 1993).

The CSD/HSRC study (1993) further argued that the challenge for the S&T system, including the S&T policy, is to strike a balance between different interests within the country. There are those who expect that science will ultimately lead to socio-economic growth and those who want to have more money available immediately for the upliftment of the poor and the alleviation of socio-economic needs. Also, a balance has to be found between the high levels of illiteracy and the need for S&T specialization. The problem of having both developed and developing sectors in one country is very real.

As Mrinalini and Sandhya (1996) explain, in the post-independence era, the policy orientation of self-reliance and self-sufficiency did attain the goal of establishing production capacities over a wide range of industrial sectors, although indigenous production was, in most cases, based on imported technology.

Ashok Jain (1998) also describes the history of Indian science since Independence by dividing it into three phases: the *first* phase served to establish a scientific infrastructure; the *second*, beginning in the 1960's, concentrated on capacity building and on the establishment of a firm basis of political support for science. The *third* phase begins from the mid-1980's and beyond, when the formal adoption of a liberalized economy was effected. Since 1991, science has been striving to make production and manufacturing more demand responsive and internationally competitive.

The dichotomy in the national policy has been expressed in channelling public expenditure to programmes of rural development and in satisfying basic needs. With regard to direct S&T input into poverty eradication[16] and the satisfaction of basic needs, special programmes known as *Technology Development Missions* are being pursued. Launched in the late 1980's, these programmes focus on achieving targeted results, i.e. R&D, and follow through to the application and diffusion of results (Jain, 1998).

[16] According to a 1996 economic survey, 21.7% of the rural population and 11% of the urban population live beneath the poverty line in India

According to the United Nations Economic and Social Commission for Western Asia-ESCWA (1999), India has clearly stipulated S&T policy priorities that reflect a preoccupation with competitiveness, the need for foreign technologies and promotion of domestic innovation.

To implement this policy, the government has instituted a number of programmes aimed at providing incentives for innovation, accelerating the commercialisation of research and technology transfer. The programmes include:

- Tax benefits for private enterprises that perform R&D;
- Funds for upgrading obsolescent technologies;
- Funding research that embodies high risks for individual enterprises, with an accent on micro-electronics, pharmaceuticals, and biotechnology;
- Funding those programmes that target domestic sources of innovation, through strengthening the existing Technology Development Fund; and
- Encouraging the creation and growth of software parks[17].

Developments in biotechnology are, however, being made at a slower pace. This is thought to be at least partly owing to the level of Government support (ESCWA, 1999).

The newly reviewed 2003 Science Policy complements the old one. The new policy takes cognisance of the dramatic changes that take place, and continue to do so, in the practice of science and technology development, and their relationships with and impact on society. Similar to that of South Africa, the Indian S&T policy also is focused on commitment to participating as an equal, vigorous and competitive player in generating and harnessing advances in science and technology for the benefit of all her citizens and humankind (DST, 2003).

[17] The software parks are supported by the Indian government for obvious commercial reasons, for the role they play in developing the country's innate technology capabilities and for their contribution to the annual industrial growth rate, which has been exceeding 50% for the past five years. This includes growth in Foreign Direct Investment.

3.4.2 Integration of the S&T Policy with other National Policies

The need for a linkage of the Science and Technology Policy of India with other national policies becomes inevitable as stipulated in the Ninth Five-Year Plan of 1997-2002. With regard to education and building the human resource base, these policies stated that the Indian government strives to create an environment in educational institutions that is conducive to developing creative skills and innovative capabilities, with greater emphasis on modern management techniques, technology marketing and intellectual property rights (Planning Commission, 1997).

- The academic community should gradually motivate the faculties to do research by giving them a sense of empowerment and autonomy of functioning within the university system.
- The inter-university centres, which are providing very valuable services to the university research community, should be encouraged by means of earmarked support through the University Grants Commission (UGC).
- Efforts should also be made to provide financial support to the universities and related institutions for improving S&T infrastructure.

From the global and regional perspective, India, like many developing countries, has adopted a structural adjustment programme that liberalizes its economy. This initiative has meant greater emphasis is being placed on economic accountability and market-oriented scientific research. South Asian countries, India included, are still at the stage of restructuring and reorienting their decision-making processes. The effect of these changes on the status of science will only become apparent in the years to come (Jain, 1998).

The combination of state support at the highest level with the proactive role played by the state since India's independence, depicts a high level of commitment and at the same time integrates science and technology into the political and national agenda. As Jain (1998) also shows, the Six Technology Missions that were undertaken during the Seventh Five-Year Plan have already yielded significant results in areas that are considered to be of social importance: drinking water, immunization, literacy, oilseeds, telecommunications and dairy development.

From the industrial point of view, in the post-independence era, instruments that favoured India's ability to achieve technological self-reliance were put into place. These include the government's policy of restricting the import of manufactured goods, and banning the import of technology wherever an indigenous method is available. Along with these, the Indian Patent Act of 1970 favoured the indigenous production of all those products whose patents were still effective in the world market. To a large extent, this step assisted in catching up with the international trends in production capabilities. The Indian Patent Act also had a positive impact on the Indian pharmaceutical industry by developing its process capability for the production of a large number of drugs based on indigenous technology (Mrinalini,N.; Sandhya, G.,D., 1996; Sandhya G. D & Visalakshi S., 2000).

On the other hand, it is worth noting that liberalization of trade is one other critical factor that facilitates the orientation leading to demand for technology and its commercial exploitation. Consequently, policies geared towards education, training, acquisition of managerial skills and the encouragement of technological change have been crucial instruments in allowing national communities to face the processes of globalisation (Achibugi; Howells & Michie, 1999). It is on this basis that the growth of firms has increased since economic liberalization in India. Previously, protection from competition had limited innovation and entrepreneurship: prior to liberalization, government funded R&D was mostly directed towards supplying technology such as atomic energy, space technology and defence technology (Bowonder, 2001).

Aradhna Aggarwal (2001) states that the Indian government, in revising its policies on foreign technology acquisition, applied several strategies in order to generate demand for domestic technologies. The government separated areas of technology into three lists:

(a) Where no foreign collaboration was considered necessary;
(b) Where only foreign technical collaboration was permissible; and
(c) Where both financial and technical collaboration could be considered.

Foreign Direct Investment (FDI) was allowed only in core industries; as a result, India achieved near self-reliance in standard techniques and began exporting technology. Furthermore, the Indian government introduced a scheme to recognize in-house R&D units. This scheme included various incentive policies like tax exemptions, relaxation in import licenses to R&D units, and relaxation in R&D related industrial licensing. Consequently, India has built a relatively substantial research base compared to other developing countries such as Korea (Aggarwal, 2001)

In summery, as Mani (2002) illustrates, India has a very systematic approach to its S&T development. Planning for S&T forms part of the national planning effort. However, the S&T plan that is integrated with the national plan is subservient to its objectives. For example, the main thrust of the Ninth Five-Year Plan of 1997/2002 was alleviation of poverty and attainment of self-reliance.

CHAPTER 4

4. MALAYSIAN CASE STUDY ON S&T SYSTEM

4.1 Introduction

Similar to the other two case studies, namely South Africa and India, the main aim here is to provide an overview of Malaysian science and technology system. The case study describes and reviews the process of science and technology policy development, as well as its relationship with the national and regional policies of other countries ("Asian Tigers) in the region. This overview includes the national goals, objectives, plans and strategies of Malaysia. To achieve the above, the study gives a brief history of the science system in Malaysia during the period of pre-colonialism, during colonialism and post-independence. Furthermore, it reviews the science and technology policy and its key elements.

It is expected that the case study will depict the strengths, weaknesses and challenges that face the Malaysian science and technology system. As a result, the study will form a base for comparison with other selected nations and possibly come up with possible solutions that can be recommended to less developed nations, such as Lesotho.

4.2. An Overview of the Science and Technology System in Malaysia

4.2.1 Science System in Malaysia- Pre-Colonialism and during Colonialism

The modern state of Malaysia finds its origins in the colonial period. In traditional times (pre-colonialism), the present Malaysia was part of the wider Indonesian-Malay world. The areas now occupied by Malaysia formed a region of shifting power and alliances. The process led to a stage at which the British colony drew new geographical boundaries that were to become the basis of a new state. Malaysia is characterized by of a lack of ethnic homogeneity, the population being constituted by a majority of Chinese origin and the rest from Indian, Pakistani, and Indonesian origin, as well as the indigenous people of Borneo (that is Non- Malayans).

The nineteenth century was the age of Europe's industrialization. That technological revolution played a major part in accelerating the search for colonial possessions overseas. Colonies were seen as essential elements in the economic pattern that required the supply of raw materials to the industrial countries of Europe. As a result, Southeast Asia (Malaysia included) met the demand for the export of commodities such as rubber, tin and agricultural products (Osborne, 1979). In other words, as indicated by Purcell (1965), British imperialism was in essence the expression of a technological superiority increasingly possessed by the West.

The history of science in Malaysia dates back to the First World War, when the British Empire exerted a greater influence on the Malaysian Federation of Malaya and Brunei. At this time, the two countries experienced major economic advancement with a shift from the curiosity and trade driven discoveries of their predecessors, Chinese and Indian colonies, to the industrialization of science through the mining of tin, and massive plantations of rubber by the a scientist, Henry Ridley. Later, there was exploitation of oil reserves, production of rice, and fishery development. As a result, communications were improved during the same period and, between 1885 and 1918, railway lines and road systems were laid for international linkages as well as with the neighbouring countries: Thai, and Jahore Bahru, Singapore and the entire peninsula. These initiatives were meant to connect the tin and mining industries to ports in other parts of the peninsula.

Historically, rubber has provided for industrial as well as agricultural production. The processing of rubber played an important role - though to a lesser extent than tin mining - in the growth of the Malaysian economy, through the development of Small Scale Enterprises (SME's) for the manufacture of rubber goods (Bastin &Winks, 1966).

With the revenue obtained from these primary products, namely, tin and rubber, the administration had to establish not only roads and railways but also hospitals and schools.

The establishment of an Institute of Medical Research as early as 1901 was evidence of the nurturing of health services. These services included the development of medical and health departments in the Peninsula, with greater focus on the control and eradication of malaria. As a result, the Malay Peninsula was probably one of the first regions in the world in which the scientific research of people like Sir Ronald Ross and the Italian, Giovanni Grassi, revealed that malaria was spread by the anopheles mosquito. Subsequent to that, Dr Malcolm Watson, the district surgeon of Klang, put into practice new methods of controlling this mosquito (through destruction of breeding in swampy areas). Consequently, many malarial towns were declared free of the disease between 1921 and 1930 (Ryan, 1969).

While other sectors of the economy were improved, in the sphere of education, government activities were rather limited until after the First World War, at which time the education policy was put into place. This policy was unbalanced, in terms of gender and ethnic group, as well as selective in subject matter and medium of instruction. The higher education sector was put into place first by the establishment in 1904 of the King Edward VII College of Medicine in Singapore (as part of the then Federation). In 1928, arts and other science courses were provided at Raffles College in Singapore. After the Second World War, the two colleges were merged to form the University of Malaya. This institution later established a separate section in Kuala Lumpur, which took the name of University of Malaya while the original foundation became the University of Singapore (Ryan, 1969).

Since the Second World War, the Asian region has shown remarkable growth in its industrial capacity. Many countries, including Malaysia, have become key industrial players in the world economic arena. This can be attributed to the significant role played by technology (even to date) in the development of Asian countries, which depends on many factors such as local history, social structures, traditions of technology and local perception of the growth of industry in the West and the reaction that this has engendered (Chairatena, 1999).

4.2.2 The Recent History of the S&T System post-Independence

The ***institutionalisation of science*** in Malaysia became more evident in the 1970's when several universities were set up with the aim of providing research capacity for the nation. A few research institutions were also established by the private sector viz. by the plantation houses for agricultural R&D activities (MOSTE, 1986).

Since achieving independence in 1957, Malaysia has undergone economic and social transformation to the pattern of successful five-year development plans. The country has entered an era of rapid *industrialization of science* that will undoubtedly place new demands on high-level technical, managerial and entrepreneurial skills as industrialization stimulates technological development and better utilization of capital. The core technologies for government support in the seventh Malaysian plan (1999 – 2000) are information technology and communication, and advanced manufacturing technology related to energy and the environment (British Council, 1997).

What remains as a challenge in these countries is to strike the right balance in order to maintain sustainable development, to build on the endogenous technological base, and to attract and absorb new technologies without becoming over-dependent on foreign supply (UNESCO, 1998). Another regional feature regarding Malaysia in particular, is the ascendancy of small and medium-sized enterprises (SME's) within the national science and technology system.

As indicated by Pun-arj Chairatana (1999), in terms of welfare improvements, the East Asian "miracle" was judged on the basis of mobilization of resources, prior to the increase in quantity of economic targets, rather than on the basis of achieving sustainable quality. As a result, East Asia (Malaysia included) impressively achieved its goal. Poverty declined, life expectancy and the literacy rate increased and the overall quality of life improved. As implied by the World Bank (1999), this was indeed a real miracle.

Historically, in terms of development, Malaysia has shown a paradigm shift from an agriculture based economy in the 1960's to a production based economy in the 1970's and 1980's, with the current embracing of the *knowledge* based economy or *K-economy* (MASTC, 2001). The trend of all these phases, however, includes science and technology as an engine for socio-economic development.

From a regional perspective, the effect of science and technology in economic development is clearly evident in this region of the ***"tigers"***, that is, South-East Asia and the Pacific Rim, from 1990 to 1995, particularly in specific sectors. Among others, Malaysia, Indonesia and Thailand have shifted from an agriculturally driven economy, towards manufacturing. This shift has put emphasis on science and technology related human resource development policies. The Malaysian economy therefore directs its science policy towards upgrading technology in capital goods.

Early scientific research activities and formal ***institutionalisation of science*** in the Malaysian system can be traced back to the 1900's. At this time there were only a few established research and development (R&D) institutions: The Institute for Medical Research (IMR), Rubber Research Institute (RRI), and the Forestry Research Institute (FRI). Over the years since independence, the government of Malaysia has established more R&D institutions, such as: the Standards and Industrial Research Institute of Malaysia (SIRI), Tun Ismail Atomic Research Centre (PUSTAT), the Malaysian Agricultural Research and Development Institute (MARDI), the Palm Oil Research Institute of Malaysia (PORIM) and other R&D laboratories in the universities. In 1973, the Ministry of Technology, Research and Local Government was established and subsequently, in 1976, was renamed the Ministry of Science, Technology and

Environment (MOSTE), in view of the more targeted role it plays in developing and promoting S&T in Malaysia.

As Mani (2002) indicates, within a short period of ten years, Malaysia has shifted from being an exporter of primary products to a leading exporter of high technology: in fact the country is the third largest exporter of electronic components to one of the most sophisticated markets in the world, namely the United States. So like Singapore, Foreign Direct Investment (FDI) dominates the Malaysian enterprise sector, though the country had a much earlier policy of promoting local capital through the policy on affirmative action *(Bumiputera).*

Currently, Malaysia is paying particular attention to strengthening its institutional capacity and to establishing linkages between industry and the public sector by making research and development institutions and the public sector more responsive to the demands of industry. The aim is to radically increase the proportion of GDP devoted to R&D from 0.4% in 1995 to 2.0% by end of the seventh Malaysian plan, by which time it is hoped that at least 60% of funding will come from the private sector (UNESCO, 1998).

Furthermore, the government of Malaysia intends to give the principal public sector research institutions financial autonomy and encourage them to seek greater private funding. This intention is in keeping with a long-term strategy of using R&D to nurture the nation's "2020 Vision" of itself as a manufacturing economy, as well as accounting for about 80% of the GDP by the year 2020 through the industrial sector.

4.3. The Malaysian Science and Technology System

4.3.1 Governance Structure at Macro-level

Science and technology in Malaysia cut across all levels of governance, including other supportive agencies in the private sector and international linkages. At macro-level, the government, in response to the recommendations of the Chief Secretary, appointed a ***Science Advisor*** in the office of the Prime Minister in 1982. The position of a Science Advisor was driven by the growing awareness of the importance of science and technology in the economic and social development of Malaysia. As a result, there was a need for a coherent and well-coordinated system controlled and monitored at national level.

In essence, the Science Advisor provides insights and advice, and addresses issues on the development of S&T in Malaysia. Among others, the Science Advisor is responsible to the Prime Minister through the following functions:

- Advise the Prime Minister on matters relating to development of S&T in the country;
- Provide comments on Cabinet papers relating to scientific and technological issues;
- Provide comments and a second opinion on technical and scientific proposals received directly from the Prime Minister’s and Minister’s Offices, as well as from organizations and committees;
- Serve as the *ex-officio* member to the National Council for Scientific Research and Development (NCSRD);
- Represent the Prime Minister’s Department in forums that are related to science and technology; and
- Be a prime mover in development activities and initiatives involving S&T.

In general, the Advisor assumes both an advisory role to facilitate decision-making by Government and also serves as a buffer between a policy executing ministry and the Prime Minister.

Ministry of Science, Technology and Environment (MOSTE)

The Ministry of Science, Technology and Environment (MOSTE) in Malaysia assumes the role of promoting and developing science and technology in the country with the aim of:

- Promoting understanding, awareness and appreciation of S&T;
- Implementing S&T research development;
- Conserving and monitoring the environment; and
- Providing technical and management support services on S&T related matters.

MOSTE is an executive arm of government in policy formulation and implementation (at macro-level). In other words, MOSTE can be seen as a link between implementers of policy (performance level) and decision makers (macro-level).
Among others, the functions of MOSTE are:

- S&T policy formulation, implementation and analysis;
- Implementation and monitoring of S&T strategies;
- Management of R&D;
- S&T budgeting;
- Conducting regular technology audits;
- Technology planning, forecasting and intelligence gathering;
- Managing the S&T information system;
- Promoting the commercialisation of technology initiatives;
- Serving as Secretariat to the Cabinet Committee on S&T; and
- Serving as Secretariat to the Advisory Council on S&T

(MOSTE, 1990).

Two main Departments characterize MOSTE, namely the technical and administrative departments. The department are both under the auspices of two Deputy Secretary Generals, which in turn are directly responsible to the Secretary General. The Secretary General reports directly to the Minister (*see the organizational chart)*.

Science and Technology Division

Under the technical department, there are various divisions, among which is the Science and Technology Division. The mandate of this division is to plan, develop and implement the national S&T policy. The division also serves as a secretariat to the National Council for Scientific Research and Development (NCSRD), which will be discussed later.

The ***mission*** of the Division of Science and Technology is to assist in strengthening the nation's technological base through enhancement of Research and Development (R&D) activities, science promotion and the formulation of a comprehensive action plan for technological development.

The ***objectives*** of the division are as follows;

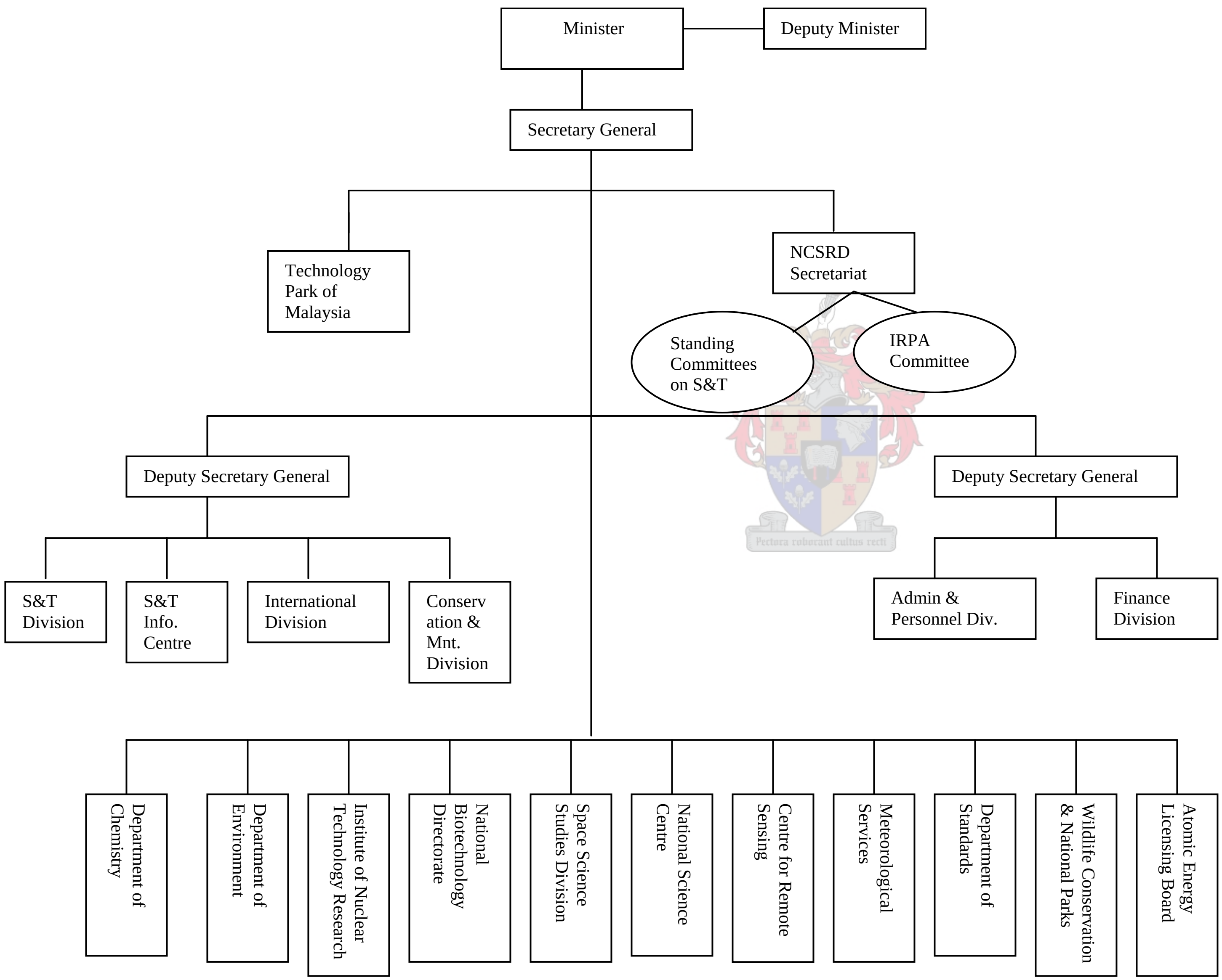
- To encourage R&D activities in areas that have the potential for enhancing the national socio-economic position;
- To strengthen the institutional and support infrastructure for industrial technology development;
- To promote awareness by providing a conducive climate for invention, innovation and technological advancement;
- To enhance market-driven R&D in order to adopt and improve technologies; and
- To develop and increase a pool of skilled manpower in S&T.

To develop the above-mentioned objectives, the S&T Division is undertaking the following major *strategies:*

- Funding R&D projects in critical technological areas of industrial relevance;
- Developing and increasing a pool of skilled manpower in S&T to meet the national needs by 2020; and
- Encouraging more private sector and NGO participation in S&T promotion.

Figure 4.1 below outlines the institutional arrangement of the Malaysian science system.

Figure 4.1 **The Organizational Structure of Malaysian S&T System**



4.3.2 The Meso-Level of the Malaysian Science and Technology System (Advisory Bodies and Funding Framework)

To enable a functional national science and technology system, Malaysia, like other nations, has intermediary bodies whose main function is to play a catalytic role by linking government at policy-making level (the macro-level) with other interest groups, such as those bodies at the performance level of R&D. These intermediary bodies of the S&T system are comprised of a funding framework and advisory bodies, as well as strategies involved in meeting the set national goals and objectives.

The Funding Framework of the Malaysian S&T System

To foster the promotion and development of high technological capability, the Malaysian government has undertaken various initiatives and mechanisms to develop a profound knowledge base coupled with value-added and capital-intensive industries. Such initiatives should lead to a stronger S&T alignment with the national development needs and goals, aimed at attaining a fully developed country status by the year 2020. The following mechanisms, which come under the purview of the National Council for Scientific Research and Development (NPKSN), have been introduced:

i. Intensification of Research in Priority Areas (IRPA) Fund;
ii. Industry, Research and Development Grant Scheme;
iii. Multimedia Super-corridor (MSC) Research Scheme;
iv. Demonstrator Applications Grant Scheme;
v. Malaysia Technology Park;
vi. Malaysia Technology Development Corporation;
vii. Human Resource Development Scheme; and
viii. Other mechanisms, such as: Industrial Technical Assistance Fund, and Malaysian Industry Government Group for High Technology (MIGHT).

The government of Malaysia has additionally put various fiscal incentive packages in place in order to promote high technology and R&D. The incentives are as follows:

- Incentives for high-technology industries: provision of full income tax exemption for a period of five years or an Investment Tax Allowance of 60% on qualifying capital expenditure;
- Incentives for non-high-technology industries: granting of partial exemption from payment of income tax or certain percentage of Investment Tax Allowance;.
- Contract research and development: full income tax exemption or Investment Tax Allowance of 100% on qualifying capital expenditure incurred within a ten year period is granted to contract companies;
- Research and development for associate companies: incentives include the granting of 100% Investment Tax Allowance for ten years to those R&D companies that provide R&D services;
- In-House R&D: 50% Investment Tax Allowance for ten years for companies carrying out in-house research; and
- Other incentives such as: double deductions of expenditure incurred on research projects or services provided, exemptions of import duty and so forth.

(MASTIC, 1999)

The Advisory Bodies

The National Council for Scientific Research and Development

The Malaysian Government set up the National Council for Scientific Research and Development (MPKSN) in 1995 as an advisory council, specifically to oversee public sector research so that the research inputs are directed at enhancing the national development objectives.

The MPKSN's mandate is to advice government and, in particular, the Minister of Science, Technology and Environment on the following:

- Formulation of science and technology policies;
- Identification of S&T priorities;
- Coordination, implementation and evaluation of S&T programmes;
- Utilization of S&T by the public and private sector for national development;
- Enhancement of S&T awareness and appreciation; and
- Monitoring the implementation of the recommendations of the National Action Plan for Industrial Technology Development (NAPITD).

For its effective functioning, the Council is assisted by two committees, namely, the Standing Committee on Science and Technology Development and Management, and the Coordinating Committee on Intensification of Research Priority Areas (IRPA). These committees are further assisted by eight working groups and eleven IRPA panels (*refer to the organizational chart p. 79*) (NCSRD, 1999).

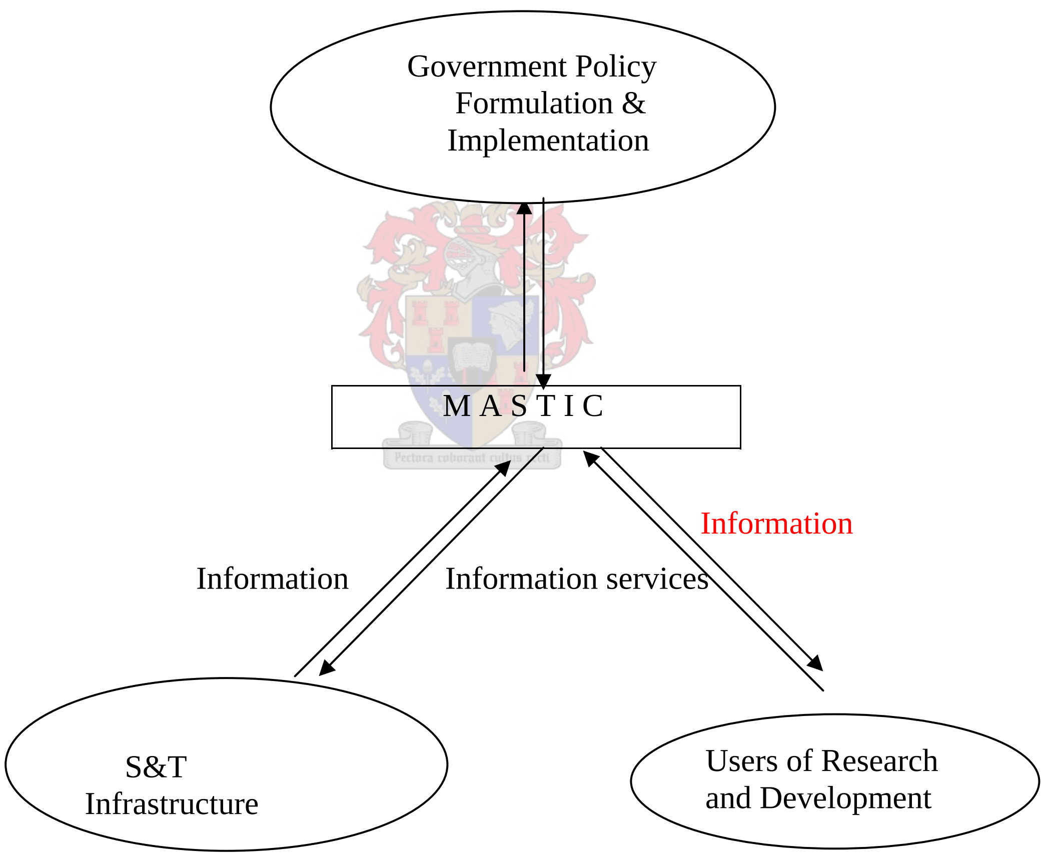
Malaysian Science and Technology Information Centre

The twenty-first century is marked as an information era. The Malaysian nation as an information society regards S&T information as a major component of the infrastructure for promoting R&D and technology development. The ability to create, distribute and exploit knowledge and information is rapidly becoming a major source of competitive advantage and wealth creation A systematic information base will thus enhance prospects of effective decision-making and provide the means of communication for policy-makers, researchers and users (MOSTE, 1999).

In view of the facts mentioned above, the Malaysian government, in 1992, established a division within the Ministry of Science Technology and Environment, The Malaysian Science and Technology Information Centre (MASTIC). The division is entrusted with the responsibility of acting as the ***source*** and ***repository*** of information relevant to the making of policies and decisions on S&T related matters. The beneficiaries of the services provided by MASTIC are the S&T policy makers, the S&T community and the public-at-large.

MASTIC also acts as a conduit between the three major groups of players in the Malaysian S&T system, namely, the policy making and research funding organizations, researchers who make up the S&T infrastructure, and users and developers of research results. Figure 4.2 shows the linkages between MASTIC and the other bodies of the S&T system.

Figure 4.2: Linkages of MASTIC with the Other Bodies of the Malaysian S&T System



Source: MOSTE (1999)

Currently, the scientific and technological services distributed by MASTIC are in the following area:

- On-line S&T database;

- National S&T Indicators Development and forecasting (status, trends and future directions);
- National Research and Development survey;
- Malaysian Public Awareness in S&T survey; and
- Performance indicators (in public, private, and international sectors) (MOSTE, 1999).

Technology Park of Malaysia

The Technology Park of Malaysia (TPM) was established in 1988. The park is situated in close proximity to five universities and nine research institutes. The TPM showcases a symbiosis between nature and human structure. It is developed along the lines of three technology-related cities, namely, an engineering city, a biotechnology city, and an information and communication technology city. Each city combines work, leisure and healthy lifestyle choices in a prestigious park setting.
The objectives of the park are to:

- Promote and improve the technology content of the local industries in order to enhance their competitiveness in the international market by providing linkages to sources of technology;
- Encourage innovation, research and development for industry and fill part of the existing gap in the commercialisation process for start-up companies;
- Provide linkages between researchers and industries; and
- Facilitate government and private sector smart partnerships in technology development.

To meet these objectives, the Technology Park of Malaysia serves, *inter alia,* towards:

- Facilitating technology transfer;
- Providing sites for the growth of small high-technology industries;
- Commercialisation of research results;
- Enhancing research, inventions and innovations by both the private and public sectors;
- Creating job opportunities;

- Serving as an information centre for high-tech industries;
- Acting as an exhibition centre for high- technology products; and
- Providing support through funding services and venture capital.

(MOSTE, 1999; www.tpm.com.my)

4.3.3 The Performance Level of the Malaysian Science and Technology System

4.3.3.1 Research and Development

Building a sustainable, appropriate national research system has therefore been a top priority for many economies that are dependent on high technology, such as those of Hong Kong, Republic of Korea, Singapore, Chinese Taipei and Malaysia. These countries have therefore recorded a rise in gross domestic expenditure on research and development (GERD) in the1990's, which has resulted in a rapid rise in business sector funding. Consequently, some countries have recorded economic rates well above those in Europe or the USA (UNESCO, 1998).

The Research and Development (R&D) system is an integral part of science and technology management in Malaysia. This system is a major determinant of innovation; it generates knowledge and improves total production of knowledge, which is a key to economic growth and wealth creation, as well as a basis for competitive advantage in light of globalisation and trade liberalization. Moreover, R&D can increase the quality of products and services, improve product processes, as well as enhance the image of the nation's technological levels (MASTIC, 1999).

On the basis of the information given above, and in order to fulfil the aspirations of the people of Malaysia through the S&T policy, the 1990 Industrial Technology Development National Plan of Action of Malaysia emphasizes an increase of private and public sector investment in research and development for applications-oriented, market-driven research, The Plan of Action is aiming at Gross National R&D levels of at least

1.5 % of the Gross Domestic Product (GDP) by 1995 and 2% of the GDP by 2000, with at least 60% from the private sector.

Among others, the government's allocation for research and development through Intensification of Research Priorities (IRPA) for the fifth Malaysia Plan funding period has been a timely boost to the research community and has served to emphasize the government's commitment to R&D. Nonetheless, Malaysia's Gross R&D Expenditure(GERD) is only 1.67% of GDP, a figure that compares unfavourably with other competitors. Malaysia's performance in terms of Gross expenditure on R&D (GRED)/GDP ratio was 0.50% for 2000 compared to US 2.65% (1999), Japan 2.8% (1999) and Germany 2.38% (1999)

The S&T policy of Malaysia clearly indicates its full support of Research and Development in the utilization of agricultural and other resources in order to increase productivity. To achieve this goal, priority was given to the establishment of an efficient research management system and the development of research infrastructures such as science information centres, technology parks, patents offices and other institutions involved in research design, creativity and information. This strengthening of the facilities will lead to the smooth transfer of technology and development for new products.

The policy further advocated government’s commitment to strengthen links between the public sector, private sector (industry) and academic institutions such as universities, with a view to scientific activities enhancing economic development through R&D playing a pivotal role in enabling innovation and technological development. This will, on its own, facilitate coordination and the systematic management of research in the country. In the area of scientific research, emphasis will be placed on the need to conduct applied and adaptive (experimental development) research. Basic research will be undertaken to develop specific areas of high priority to the country. The private sector will be encouraged to steadily increase annual expenditure on R&D to a level that will positively support economic growth of the nation.

According to the (2001) National Survey of R&D undertaken by the Ministry of Science, Technology and Environment (MOSTE), Malaysia's overall Gross Expenditure on R&D (GERD) as a proportion of Gross Domestic Product (GDP) has been increased from 0.39% in 1998 to 0.5% in 2001. The trend is very encouraging, though the increase is considerably low, since at least 1% of GDP is usually the accepted level at which R&D can effectively begin to support socio-economic development in a country

Despite the regional economic downturn, the 2000 National Survey of R&D showed that R&D expenditure reached RM 1671.5m, an increase of 48% over that of 1998, and the highest to date in Malaysia.

On the other hand, Mani (2002) observes a sharp fluctuation of gross investment in R&D during the five-year period of 1992-1998 (Table 4.1). He also indicates that R&D intensity has shown sharp fluctuations. (Table 4.2).

Table 4.1 Distribution of R&D Investments in Malaysia by Sector 1992-98 (value in RMm)

Year	Private Industrial	Higher Education	GRI’s	Total
1992	246.3 (45)	50.7 (9)	253.7 (46)	550.7
1994	292.6 (48)	150.9(25)	164.9 (27)	611.2
1996	400.1 (73)	40.4 (7)	108.7 (20)	549.1
1998	746.1(66)	133.6 (12)	247.3 (22)	1,127.0
2000	967.9	286.1	417.5	1671.4

Source: Malaysian Science and Technology Information (Various Issues).

Note: Figures in parentheses indicate percentage share of the total.

: GRI denotes Government Research Institutions

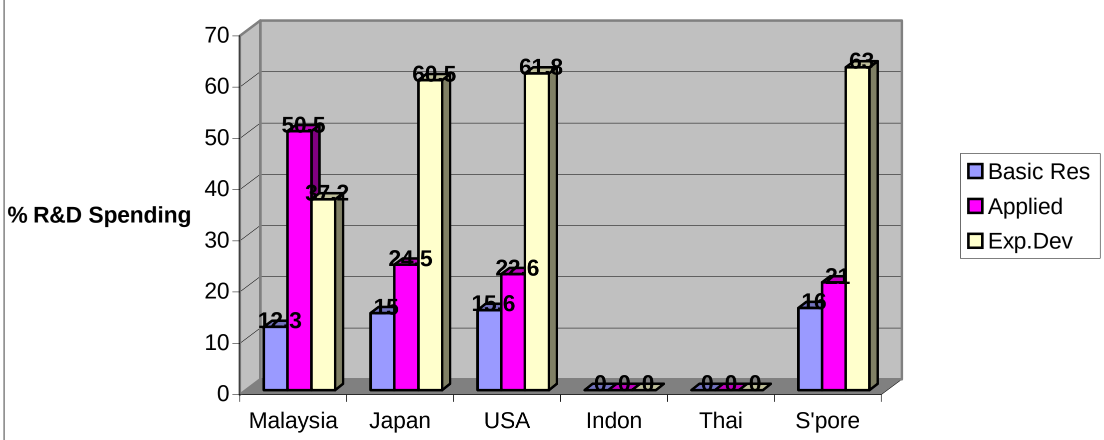
Table 4.2 Financing of Private Industrial R&D in Malaysia, 1994 and 1998 (percentage share)

Year	Own Funds	Government	Other External Funds	Total
1994	92	0	81	100
1998	83	3	14	100

Source: Malaysian Science and Technology Information Centre (various Issues).

At regional level, Malaysia is slightly ahead of some of its ASIAN neighbours, such as Thailand and Indonesia (Singapore excluded) in R&D expenditure. However, in comparison to other global players, Malaysia has been lagging behind, that is, in terms of the overall Gross Expenditure on R&D to Gross Domestic Product (GERD/GDP) ratio, manpower for R&D, as well as expenditure by type of research.

Fig 4.3: International Comparison for Selected Countries -Type of Research



Source; Malaysian Science and Technology Information Center (2001) *National Survey of Research and Development*, Kuala Lumpur: Malaysian Science and Technology Center (MASTIC).

It is interesting to note that in Malaysia, the R&D commitment by private sector constitutes 57.9% of the total R&D spending and compares favourably globally. The example is the United States whose private sector accounts for 65% of the total GERD. The high level of commitment by the private sector in Malaysia clearly indicates the generation of sales revenue for companies (estimated at $ 15 billion) and the creation of new jobs for both the scientific community and civil society (Fig 4.3).

Other than the private sector's contribution of 57.9%, the Government Research Institutions (GRI) account for 25% spent on R&D while the Institutions for Higher Learning (IHL) account for an 17.1 % share of the total R&D spending (mode of sharing for both categories is not yet clear, unlike South Africa where it is through competitive bidding). This also compares positively to the USA where GRI and IHL contribute only 30.2% and 4.7% respectively (Table 4.3).

Table 4.3 International Comparison of the National R&D Profile

	COUNTRY					
	Malaysia	**Japan**	**USA**	**Indonesia**	**Thailand**	**Singapore**
GERD/GDP Ratio (%)	0.62(1998) 0.50 (1999	3.0(1996) 2.8(1999)	2.52(1996) 2.6 (1999)	0.16(1994) -	0.20(1991) -	1.76(1998) -
No. of researchers per 10,000 labour force	7 (1998) 15.6(1999)	82(1995) 136(1999)	76 (1996) 74(1999)	2.6 (1993) -	3 (1994) -	65.5(1998) 83.5(1999)
% **GERD by Sector**						
Private GRI IHL	57.9 25.0 17.1	65.2 9.6 20.7	65.1 30.2 4.7	- - -	- - -	60 34 6
Total	***100***	***95.5***	***100***	**-**	**-**	***100***
% **GERD by Type of Research**						
Basic Research Applied Research Experimental Development	12.3 50.5 37.2	15 24.5 60.5	15.6 22.6 61.8	- - -	- - -	16 21 63
Total	***100***	***100***	***100***	**-**	**-**	***100***

<u>Sources</u>**:** Main Science and Technology Indicators, OECD Countries, 1997 and National Survey of R&D in Singapore, 1998. MASTIC (2000): National Survey of Research and Development

In terms of R&D expenditure *by type* of research, Malaysia spends more on applied research, followed by experimental development and basic research as demonstrated in Fig 4.4 .

The R&D allocation according to type of research was as follows:

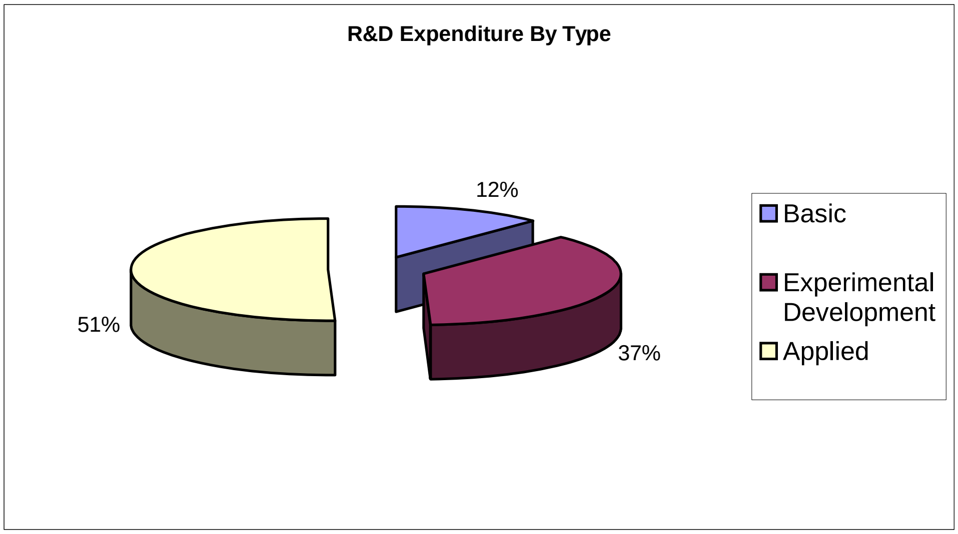


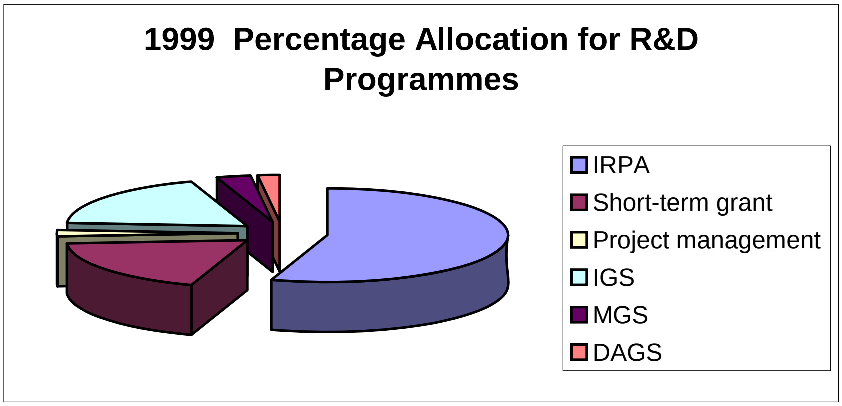
Fig 4.4

Sources: Main Science and Technology Indicators (2001)

In this case, Malaysia shows a different pattern to most countries that allocate more of the total R&D expenditure to experimental development than to applied and basic research. Malaysian Research and Development spending on Information and Communication Technology (ICT) increased from RM4 Million in 1996 to RM 92 Million in 1998, which was consistent with the national aspiration to emphasize ICT development in the country.

For the year 1999, the annual report of the National Council for Scientific R&D further indicates that a total of 849 IRPA projects were approved at a cost of RM150.37 million. The Science and Engineering Panel received the highest allocation of RM26.87 million with 233 projects approved, surpassing the Agro-industry, and Manufacturing Panel with RM21.94 Million and R21.69 million respectively.

Fig 4.5



Source : MOSTE, 1999

In generic terms, as Mani (2002) observes, the following are the emerging points with respect to R&D investments in Malaysia:

- Investment in R&D shows year-to-year fluctuations;
- The R&D intensity of the country is very low and it has shown hardly any increase;
- Much of the investment in R&D is concentrated in the private industrial sector;
- The private industrial sector finances much of its R&D through its own funds, however, the share of government in financing has shown some increases;
- The linkage of the private industrial R&D with local universities and GRI's is poor or virtually non-existent; and
- Much of the private industrial R&D is actually carried out by locally owned and controlled companies. In the foreign companies the share of private sector R&D has actually declined.

Human Resource Management of the Malaysian S&T System

According to the forecast of Malaysia's Science and Technology Human Resources and R&D Needs leading to the year 2020, conducted by SRI International (1996), it is estimated that the maximum manpower requirement for 2020 in research and development will be 493,830 scientists and engineers.

In an attempt to address the situation and to meet the set target by the year 2020, there has been an evident increase of expenditure on R&D as shown by the 2000 national survey of research and development undertaken by MOSTE (Table 4.4). In other words, from 1998 to 2000, research personnel increased from a total of 12,127 to 23,262. Consequently, the ratio of researchers per 10,000 of the workforce increased from 5.1 to 15.6 during the same period. However, the increase is minimal when compared to other leading nations such as Singapore 83 (2000), USA 74 (1999), and Japan 136 (1999). (see table 4.5)

In order to speed up the process, the government of Malaysia has intensified its Human Resource Development Programme activities, targeting them at:

- Increasing the skilled manpower in various R&D priority areas; and
- Developing the critical mass in emerging technologies in line with the nation's technology development policy. The policy states that it will provide training, a conducive environment for R&D, and incentives and awards to attract and retain trained personnel in the appropriate field of public services.

To achieve all these objectives, the following structures and strategies have been put in place:

a) HRD Science and Technology Fund;
b) National Science Fellowship;
c) Science Awareness Programme for Teachers; and
d) Short- and long-term training Programmes.

It is also government policy to increase female representation in science, technology and engineering courses and professions and to ensure their full participation in the workforce.
The annual allocation through the government budget to support this policy has been an integral part of the Seventh Malaysian Development Plan. Other sources of funding to support the Human

Resource Development Programme (HRDP) have been coordinated efforts from the Asian Development Bank (ADB) under ADB-Mal 1086. This programme consists of three components:

- Industrial Technology Development;
- Human Resource Development spearheaded by the Department of Public Service; and
- Enhancement of S&T information system where MASTIC leads the process.

Table 4.4 R&D Personnel by Institution and Qualification, 1998 (%)

	PhD	Masters	Bachelor	Non-degree
Government Research Institute	37.2	54.4	23.1	21.0
Institutions of Higher Learning	54.8	29.0	18.7	33.6
Private Sector	8.0	16.6	58.2	45.4
Total	100	100	100	100

Source: Third Malaysian Development Plan

Table 4.4 above shows there is a higher level of R&D personnel with PhDs in the higher education sector than in other sectors of the economy, by 54.8%. Holders of masters degrees are more pronounced in the government sector, by 54.4%; holders of bachelor degrees and people with no degrees are more engaged in the private sector, by 58.2% and 45.4% respectively.

Over the period 1991-1995, the education and training system was unable to respond adequately to the demands for skilled personnel: a high turnover of skilled and professional workers and skill shortages resulted, especially in new technology areas. Severe shortages were recorded in the supply of engineers and engineering assistants as well as a significant shortage in school teachers (in secondary schools). This situation included a paucity of medical and health professionals (Mani, 2000).

Table 4.5 International Comparison of Number of Researchers per 10,00 Workforce (Headcount)

	Country	Year	Number
1	Indonesia	1991	3.0
2	Philippines	1991	3.0
3	Thailand	1991	5.0
4	**Malaysia**	**2000**	**15.6**
5	Canada	1998	54.0
6	New Zealand	1997	69.0
7	US	1999	74.0
8	Singapore	2000	83.5
9	UK	1995	95.0
10	Australia	1998	99.0
11	Norway	1999	111.0
12	Germany	1998	116.0
13	France	1998	119.0
14	Denmark	1998	120.0
15	Japan	1999	136.0

Source:1. Thurow Lester, 1999; S&T Analysis Section; ISR; derived from ABS, OECD & National Data &Purchasing Power Parties
2. MASTIC (2000) National Survey of Research and Development

As Mani (2002) shows, the root cause of the above problem can be traced to the higher education sector in the country, which consists of 12 universities. The output of degree courses from these universities shows a continued preference for the arts and humanities and with a decline in science graduates over time (15-year period).

4.4 Malaysian Science and Technology Policy

4.4.1 The History of Malaysian S&T Policy

As mentioned earlier, the post Second World War period saw the restructuring and industrialization of the region. As colonialism declined in the 1940's and 1950's, trade patterns changed. Most of the East Asian countries adopted the idea of trade-oriented economies based on private ownership as the means of production.

The mission of the Malaysian S&T policy is to promote competence in science and technology to achieve international competitiveness while ensuring environmental conservation and sustainable development.

The policy can be described as an instrument to promote human physical and spiritual well being and to protect national sovereignty (MOSTE, 1986).

The government of Malaysia is also fully aware of the rapid pace of technology developments and breakthroughs. Hence there is a need for the ability to utilize quickly new technological advancements by either improving the existing industries or by developing new ones. These measures will enable the country to be *economically aggressive* in the process of development. "Leap-frogging" in this case may be considered a pragmatic approach in order to achieve short cuts on the path of development (MOSTE, 1986, MOSTE, 1990).

To ensure effective socio-economic results, technology must be made to permeate all industrial activities, guided by government, with vision, but driven by the market, with realism. A comprehensive, committed and creative national response is also a prerequisite, hence the need for a technological plan (MOSTE, 1990).

The vision of the policy is two faceted. On the one hand, it uses science and technology as a tool for economic competitiveness on a global scale while, on the other hand, it depicts the role of science and technology as improving the social well-being of the nation both physically and spiritually for a better quality of life.

In order to achieve the above goals, the Government of Malaysia needs to have an adequate knowledge content in the areas of R&D, product design, and distribution and marketing. The challenges brought about by globalisation cannot be disregarded; these include economic and environmental factors. Hence there is a need for a strong S&T system that would:

- Overcome the technology dependency trap, which limits future economic growth potential;
- Exploit the opportunities generated by the engine through the emerging knowledge-driven economy to accelerate economic growth; and
- Fulfil the demands of "Vision 2020", which *projects Malaysia as a developed country by 2020* (MASTIC, 2001).

While the S&T policy of Malaysia is characterized by an industrialized nature (more or less diffusion oriented), it is the government's role to pursue the aspirations of the nation and also spearhead their implementation. Consequently, the model of the policy can be considered to be both *diffusion and mission-oriented*.

As rightly indicated by Mani (2002), Malaysia's attempt to formulate a systematic technology policy is very new. It is generally held that the Fifth Malaysia Plan (1986-90) was the first to include a separate budget allocation of RM414 million for S&T development and this has been progressively increased over the sixth and seventh five-year plans.

4.4.2 Integration of S&T Policy with other national Policies

In the Industrial Technology Development-National Plan of Action, together with the Eighth Development Plan, the government of Malaysia clearly indicates the rationale or need for a rapid industrialization process the key to which is technology: "Technology is a crucial factor for production without which the industrial effort will falter."
(MOSTE, 1990 p.15)

Malaysian S&T policy further emphasizes the need to embark on research and development programmes as tools to support industrial development. This emphasis is in view of the fact that the evident indicators of S&T investment and development comprise the national expenditure on R&D.

Another policy implementation strategy is full integration of S&T policy with the national development plans. This integration is being pursued in consonance with other national policies such as the Economic Policy, the National Agricultural Policy, and the Education Policy. Implementation of the policy with a view to solving problems in the eradication of poverty is given urgent attention. The synergy of the policies is expressed in the Seventh Malaysian Plan of 1996-2000.

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The objectives of the five strategic thrusts of the Malaysian Technology Development plan indicate clearly that science and technology are seen as keys to rapid and realistic industrial development in Malaysia. The objectives of the industrial technology plan are as follows:

- To demonstrate clearly the commitment of Science and Technology as one of the national priorities as enshrined in ***Rukunegara***, supported by an organizational structure that actively encourages the building of consensus and the implementation of cooperative endeavours;

- To create awareness of R&D as the key to technological success, to encourage the private sector to adopt a positive attitude to R&D, and to set in place a sound technology infrastructure to facilitate the diffusion and application of technology;
- To build up a body of competence in the new emerging technologies which, with careful guidance and appropriate selectivity, will point to niche areas and provide opportunities in an increasingly competitive global trading environment;
- To nurture the technological manpower base, which forms the most valuable resource in developing industrial capabilities, not only for production, but even more importantly, for design, creativity, and innovation; and
- To heighten the awareness of society regarding science and technology, for an aware and supportive society, as a basic prerequisite for progress in a technology-intensive environment.

These objectives are implemented through clearly defined roles and joint efforts from various institutions: public and private sectors, institutions of higher learning and civil society through guidelines offered by the Seventh Malaysia Plan (1996-2000).

As Mani (2002) shows, the Malaysian government has made considerable improvements in strengthening the technology infrastructure since the 1990's. He divides these improvements into three broad categories:

a. *Revamping the management structure with respect to S&T.* This consisted of the reconstitution of the National Council for Scientific Research and Development (MPKSN). The role of this council has been discussed above (section 3.2.2).
b. *Creation of new institutions.* As discussed above.
c. *Corporatisation of existing research institutes* namely, the Standards and Industrial Research Institute of Malaysia (SIRIM), the Malaysian Institute of Microelectronic Systems (MIMOS), and the Technology Park of Malaysia (TPM).

Malaysia takes cognisance of the need to industrialize if it is to become an advanced and affluent nation. The key to that is *technology*, which is seen as a crucial factor for production and without which, the industrial effort will falter.

In conclusion, Malaysia is performing well in R&D expenditure and in investment in science and technology when compared to some its neighbours and other developing nations, while the "Asian Tigers" like Singapore, Taiwan and South Korea, appear to be investing more than any of the case study countries. Furthermore, Malaysia does not compare favourably with developed countries or with the other two developing nations selected for this study, namely, India and South Africa, in terms of its level of commitment and leadership/steering of government in building the technological capability of the nation.

CHAPTER 5

5. CONCLUSIONS AND RECOMMENDATIONS

The case studies of the three countries, namely, South Africa, India and Malaysia, provide valuable lessons, for example, how science and technology as an enterprise can play an integral part in the socio-political and economic goals of any nation. The studies also outline the direct link of the national goals and objectives with *strategic* science, in which the coordination and management of science for socio-economic development become inevitable.

5.1 The common features of the science systems

The case studies also depict common features, as well as strengths and weaknesses, pertaining to each country. The following analysis relates to the common features:

5.1.1 The National System of Innovation (NSI)

It has come evident that science and technology policies cannot bring about much needed development and transformation without effective and efficient implementation of the action plans envisioned by various stakeholders in the context of a national system of innovation (Teng-zeng, 2003). South Africa, for example, has used the NSI as a driving force behind its S&T system. The national system of innovation in South Africa can also be seen as an enabling framework for S&T, intended mainly (among others) to enhance transfer of technology and to support the six pillars of the Growth and Development Strategy[18]. The White Paper on S&T (1996) is committed among others to:

- the creation of a new policy framework for public science;
- conducting a system wide review of the national system of innovation in order to establish its strengths and weaknesses and future priorities; and

[18] The six pillars of the Growth and Development Strategy are: a) Investing in people; b) Creating employment; c) Investing in household and economic infrastructure; d) Crime prevention e) Government efficiency and f) Safety netting.

- the creation of new structures to develop, implement and monitor the new policy framework.

As Mouton (2003) showed, the science funding regime and the strategies employed enable the NSI to serve the national, strategic goals of the new society: “Science has no alternative but serve the newly formulated and legitimised national goals and interest”.

The Indian case shows that the Indian system of innovation is striving to merge the two domains of knowledge, that is, ‘Western science’ with the indigenous knowledge system, in an attempt to promote community innovation or grass roots innovation. This will generate employment on one hand while, on the other hand, it will enable the use of natural resources sustainably, through the linking of innovation, enterprise and investment. Hence there is the need for new innovation models of development, employment and conservation of natural resources (Mashelkar, 2004). The Indian government has also shown its full commitment, since the post-independence era, through its steering role in massive support of research and development in an attempt to promote innovation and the technological capability of the nation.

In the context of Malaysia, the National System of Innovation is viewed as a web of all the parts and levels of institutions inside the economy, whose activities and interactions learn, acquire, modify, diffuse and create novelty. The Malaysian Science and Technology policy, being more diffusion oriented than mission oriented (Indian and South African), has positioned the NSI as a instrument towards attaining industrial innovations through the integration of the policy with the national development plans. However, there is lack of clear government commitment towards concrete strategies for enabling an efficient and effective national system of innovation, when compared to both South Africa and India.

5.1.2 Politicisation of Science:

In the three case studies, one of the common features that is evident is the way science played a pivotal role in the political trends and history of the three countries.

The history of science development in the three countries is also clearly portrayed as being intertwined with the socio-economic changes of each nation. The history of the science systems of the three countries is commonly structured thus: pre-colonial era (except for South Africa), colonial era, and post-colonial era. In an attempt to follow a similar trend, South Africa's structure is based on "apartheid" periods (though it experienced a shorter colonial period compared to the other two countries), that is, pre-apartheid, apartheid era, and post-apartheid era. The examples of science systems and their relation to various political regimes are as follows:

South African science with its long tradition, as shown in the preceding chapter, had its origins in the curiosity and works of amateur natural historians and astronomers during the period of the Cape Colony in the mid-eighteenth century. In time, this curiosity-oriented science shifted and was driven by industrial, political and social demands (such as mining/geology, veterinary and military science through which the demands were fully exploited). Subsequently, this led to the institutionalisation of science through the establishment of scientific institutions (research centres and eventually universities). The trend took a different face after 1994 when the first democratic election was held. The new S&T policy framework was developed, new governance structures were put in place and various initiatives were launched. The country was becoming more inclined to what Mouton (2003) referred to as "strategic science".

Indian and Malaysian science portray a similar pattern, in the sense that though the countries have different timeframes in terms of historical development, they share a common trend in their science systems, which originated from trade related colonial activities in which science developed also on the basis of "science for the sake of science". In other words, science was driven by curiosity and discoveries. This subsequently led to the industrialization of science during the colonial eras of both countries and, similar to South Africa, institutionalisation of science took its course.

This became more evident in the Indian case in which a broad human resource base was soundly established and still continues to date. Research and development institutions and institutions of higher learning were set up. The Indian government showed its strong commitment in spearheading and investing in research and development by providing financial support for the functioning of the institutions, and applying strategies like fiscal incentives, policies and legal frameworks that support research and development. These initiatives are all geared towards building the indigenous scientific and technological capability of the Indian nation. These initiatives are not clearly evidenced in the Malaysian case.

5.1.3 Indigenous Knowledge Systems

Nowadays, globally, scientists are becoming convinced that Indigenous Knowledge Systems (IKS) constitute another form of knowledge that is in fact embodied in any nation and that, so far, this vital form of knowledge has not been fully utilized. The IKS encompasses technology, social, economic, philosophical learning/education, legal and governance systems. The three nations have common features in this regard and have developed mechanisms to promote and protect this national heritage and intellectual resource that can be also used to address socio-economic goals of the society. Examples of initiatives undertaken are as follows:

South Africa has, under the umbrella of the S&T White Paper of 1996, gone on board to promote IKS through various programmes, such as, establishing databases and taking stock of the status of IKS in the country, developing IKS policy and building the institutional capacity of the systems.

Malaysia, as a way of the government's policy to promote the indigenous knowledge system, has established a Resource Centre in Sarawak (RCB) for biodiversity inventory, monitoring, research, education, utilization, management and conservation. Among other things, SBC assists the state in identifying priorities for research on biodiversity for traditional use among local communities. In Sarawak, there are over 36 ethnic communities, each of which has inherited traditional knowledge from its ancestors. Each group knows its land and is familiar with its environment; the survival of this traditional knowledge needs protection (www.comminit.co.experience).

India

Indian history and its rich cultural diversity provide a profound experience and base of indigenous knowledge systems. As Mashelkar (2004) showed, many societies in India have nurtured and refined their systems of knowledge, relating to such diverse domains as geology, ecology, botany, agriculture, physiology and health. The Department of Science and Technology of South Africa, in its visit to India, reported the following support programmes and key systems in which the Indian government is engaged:

- A dedicated IKS National Programme within the Council for Scientific Research (CSIR);
- "Validated" complementary/alternative medicinal and health care system;
- Database of IK and bio-diverse heritage;
- Memorandum of Agreement with the World Trade Organization (WTO) on "patents searches" to cover IK databases of India;
- Accredited learning/training systems (at college level);
- Technology-enhanced production outlets; and
- Institutional platforms like the National Botanical Research Institute, Notational Institute of Immunology, and the Central Medical and Aromatic Plants Toxicology Research Institute.

It becomes evident that there are profound initiatives being undertaken by the government of India in the promotion of IKS. What remains as a challenge is to continue research on identifying links between the indigenous knowledge holders and scientists and to further explore the relationship between two knowledge systems, namely, "Western science" and IKS and how best they can complement each other to meet the challenges of the twenty-first century.

5.1.4 Public Understanding of Science

In generic terms, the three case studies have revealed one area that is common to all, namely, lack of public understanding of science and its role in socio-economic development. This fact is exemplified by a limited S&T human resource base for all three nations (though at different levels) as shown by the indicators from the respective countries. Nevertheless, the three nations are making every effort to promote and come up with pragmatic approaches, such as the establishment of institutions, and the development of programmes to popularise and demystify science. It is on this note that, hopefully, the trend will shift with time to the point at which science will be easily communicated and be appreciated for its returns to society.

5.2 Differences

The three case studies can be characterized by the following differences:

5.2.1 The timeframe of the history of the science systems varies with each country. As a result, their levels of development in science and technology also vary. What becomes inevitable are features of sound technological infrastructure and high investment in the institutionalisation of science, particularly in India and followed by South Africa as the statistics in the case studies reflect. Malaysia presents a different picture in which little effort is undertaken to broaden the institutional capacity of the country, particularly in research and development. Such capacity is important because institutional capability provides the country with an environment conducive to research activities. Other than that, investing in R&D also nurtures the indigenous competence, in addition to promoting innovation without too much dependence on foreign intervention (like Foreign Direct Investment (FDI), which is the case with Malaysia but not so in India).

5.2.2 There is a high level of government leadership and commitment in S&T investment/R&D expenditure in India, where the private sector is not a major player. This scenario is similar to that of South Africa but to a lesser extent, while in Malaysia the private sector takes a leading role. In other words, the science and technology policies of India and South Africa are “mission-oriented” while that of Malaysia can be considered as a mix of both mission-oriented and “diffusion-oriented”.

5.2.3 Malaysian S&T policy[19] is well interrelated with other national policies as it is clearly turned into action through national development plans with clearly articulated strategies to meet the national goal, Vision 2020. This is not so well articulated in South African or India though various coherent programmes and strategies with clearly defined goals have been put in place to implement their policies.

5.3 Recommendations

5.3.1 IKS can be harmonized with NIS as a strategy towards creating niche areas that may result in developing the competitive advantage of nations. For Least Developing Nations, particularly Lesotho, this is an area in its policy that can be strengthened in view of the fact that it is one nation that is not richly endowed with natural resources. Hence, other than building on the African Renaissance through IKS, Lesotho can pragmatically utilize/commercialise the existing endogenous knowledge in order to nurture and empower the technological capabilities of the grassroots and rural communities. This approach will therefore improve the quality of life of the Basotho (the people of Lesotho).

5.3.2 There is a need for a vigorous outreach programme that will attempt to popularise science in Lesotho in view of the lack of and minimal public understanding of science in the country. Lessons can be learned from the three case studies regarding programmes and strategies that can be taken to address national needs and priorities.

5.3.3 The histories of the science systems of the three countries indicate a high level of commitment to investing in science and technology. The economic returns however, are of a long-term nature; hence the need for sound policies and instruments that will implement those policies in a sustainable manner.

5.3.4 Learning from the weakness of a system will help Lesotho to avoid the mistakes made by the other three countries. Perhaps this can assist Lesotho to "leap-frog"

[19] The updated version of the latest Malaysian Policy on S&T was not available.

certain stages of development and graduate more rapidly from a Least developing nation to a developing one.

5.3.5 Lesotho can learn from the three countries, specifically Malaysia, the use of skilled S&T human resources and *strategic* science as crucial factors, as well as other approaches, without depending too much on natural resources, as it the case with Malaysia.

In conclusion, the comparative study highlighted the key features of various science systems, based on the three countries (Malaysia, South Africa and India). The study also provided insights into existing strengths and weaknesses, including opportunities, of the three nations in relation to the overall management of science and technology for these to have an impact on daily life. Consequently, least developing nations like Lesotho can learn from the experiences offered by this study.

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