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Industrial Capability and National Technological Competitiveness: The Case of South Africa's Civil Aircraft Industry

Daphney Hellen Mayindi

A thesis submitted in partial fulfilment of the requirements for the degree

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DECLARATION

I, Daphney Hellen Mayindi, declare that the thesis *Industrial Capability and National Technological Competitiveness: The Case of South Africa's Civil Aircraft Industry* is my own work and that the views and opinions expressed in this work are those of the author and relevant literature references as shown in the reference list.

I further declare that the content of this thesis will not be handed in for any other qualification at any other tertiary institution.

Daphney Hellen Mayindi

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THESIS SUMMARY

INDUSTRIAL CAPABILITY AND NATIONAL TECHNOLOGICAL COMPETITIVENESS: THE CASE OF SOUTH AFRICA'S CIVIL AIRCRAFT INDUSTRY

by

DAPHNEY HELLEN MAYINDI

Supervisor: Professor MO Kachienga

Department: Graduate School of Technology Management
University of Pretoria

Degree: PhD (Technology Management)

The thesis is about analysing the capability of the civil aircraft industry in contributing towards improved national technological competitiveness. The South African government recognises the potential for the country's aircraft industry to contribute to the growth of the national economy. However, it is not known if the current support mechanisms are adequate for developing the appropriate technological base and for promoting the innovative capabilities of the industry.

Countries with successful aircraft industries were studied: South Korea and Brazil were used to represent emerging economies and France was used to represent developed economies. This was done to analyse existing models or frameworks and/or commonalities that led to the successful development of technologically competitive civil aircraft industries internationally. The South African civil aircraft industry was also studied, and its technology development competence was compared to that of successful countries. How the local technology development framework could be structured or improved, using lessons from successful countries, was considered. Participants were representatives of the South African government departments or ministries (Department of Trade and Industry; and the Department of Science and Technology), academia (The University of the

Witwatersrand – Wits; and the University of Cape Town – UCT), research institutions (CSIR and NRF), and firms (Aerosud, Denel, and Aerospace Monitoring and Systems – AMS).

Based on the analysis of the findings, frameworks aimed at improving the technological base of the South African civil aircraft industry were proposed as follows:

- The development of technology capability building through government interventions. This emphasises aggressive government interventions that encourage collaboration between firms in the industry, and with research and higher education institutions, followed by major investment in research and development.
- An institutional structure for the development of national aircraft technology. This is aimed at strengthening the technology development arena of the South African aircraft industry, through acquired projects, but with less emphasis on business acquisition.
- The establishment of the South African Aircraft Industry Corporation (SAAIC), a technology development and skills-transfer programme.

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LIST OF ABBREVIATIONS

AAD:	Agency for Aircraft Development
ACARE:	Advisory Council for Aeronautical Research in Europe
ACSA:	Airports Company South Africa
ADD:	Advanced Agency for Defence Development
AeIGT:	Aerospace Innovation and Growth Team
AIDC:	Aero Industry Development Centre
AISI:	Aerospace Industry Support Initiative
AITRAM:	Advanced Integrated Training in Aeronautics Maintenance Program
AMD:	Aerospace, Maritime and Defence Association
AMS:	Aerospace Monitoring and Systems
AMTS:	Advanced Manufacturing Technology Strategy
ASSEGAI:	A Strategy for a Sustainable, Economical and Growing Aerospace Industry
ATAG:	Air Transport Action Group
ATE:	Advanced Technologies and Engineering Company
ATR:	Avionics de Transport Regional
BAE:	British Aerospace company
CASA:	Construcciones Aeronáuticas SA (Spanish aircraft manufacturer and a branch of EADS)
CAST:	Center for Aviation and Space Technology
CoPS:	Complex product system
CSIR:	Council for Scientific and Industrial Research
DMA:	Defence Manufacturers Association
DOD:	Department of Defence
DOT:	Department of Transport
DPE:	Department of Public Enterprise
DST:	Department of Science and Technology
DTI:	Department of Trade and Industry
EADS:	European Aeronautic Defence and Space Company
EU:	European Union
FAA:	Federal Aviation Administration
FAC:	Farnborough Aerospace Consortium
FDI:	Foreign direct investment
GA:	General Aviation
GDP:	Gross domestic product
GE:	General Electric
Govt:	Government
GRI:	Government Research Institutes
HFC:	Hankook Fibre Company
HEIs:	Higher education institutions
HRD:	Human resource development
IADF:	International Aircraft Development Fund
IAI:	Israel Aircraft Industries
IAS:	International Aviation Support
ICAO:	International Civil Aviation Organization
ICT:	Information and communication technology
IF:	Innovation Fund
IPP:	Industrial Participation Programme

IPR: Intellectual Property Rights
IPTN: Industri Pesawat Terbang Nusantara
JAA: Joint Aviation Authorities
JADC: Japan Aircraft Development Corporation
KARI: Korea Aerospace Research Institute
KAI: Korean Aerospace Industries Company Ltd
KIAT: Korea Institute of Aerospace Technology
KIAFAR: Korean Industrial Association for Aerospace Research
KIMM: Korea Research Institute of Machinery and Metals
MOCT: Ministry of Construction and Transport
MOD: Ministry of Defence
MOST: Ministry of Science and Technology
MOTIE: Ministry of Trade, Industry and Energy
MOCIE: Ministry of Commerce, Industry and Energy
MRO: Maintenance, repair and overhaul
NASA: National Aeronautics and Space Administration
NIC: Newly industrialised country
NIE: Newly industrialising economy
NRF: National Research Foundation
NSI: National system of innovation
OEM: Original equipment manufacturer
R&D: Research and development
SA: South Africa/n
SAA: South African Airways
SAAIC: South African Aircraft Industry Corporation
SARS: Severe acute respiratory syndrome
SBAC: Society of British Aerospace Companies
SETAs: Skills and education training authorities
SETIs: Science, engineering and technology institutions
SIC: Samsung Industry Company
SIH: Systems integration hierarchy
SMEs: Small and medium enterprises
SMMEs: Small, medium and micro enterprises
SPII: Support Programme for Industrial Innovation
TCs-proxies: Technological capabilities proxies
THRIP: Technology and Human Resources for Industry Programme
TISA: Trade and Investment South Africa
UAVs: Unmanned aerial vehicles
UCT: University of Cape Town
UKAI: The United Kingdom Aerospace Industry
UK: United Kingdom
US: United States
USA: United States of America
Wits: University of the Witwatersrand

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CHAPTER I: BACKGROUND AND RESEARCH QUESTIONS

1.1 Introduction and background

Air travel with its reliability, affordability and reduced time spent compared to land travel, is becoming more convenient for business demands that are associated with globalisation and competitiveness.

The aircraft industry has been described by Eriksson (1995) as part of the high-technology sector that "includes the airframe companies that are manufacturers of the basic structure and assemble for that structure components supplied by other branches of the aircraft industry, the engine builders and equipment manufacturers including aviation electronics (avionics).

In this study, the civil aircraft industry forms part of the broader aerospace industry, which is described as a technological sector covering elements such as research and development (R&D), design, manufacture, support, maintenance, conversion and upgrade of both rotary and fixed wing aircraft, as well as their relevant subsystems and components (CSIR, 2003).

The aerospace market is cyclical, with the cycles being closely linked to global economic performance. Prior to 2001, the civil aircraft industry was operating at full capacity with high production levels. Then, a global economic slowdown occurred. It was believed to have been aggravated by events such as the attacks of September 11, 2001; the uncertainty in the Middle East, including conflicts in Afghanistan and Iraq; and SARS outbreak in Asia. The resulting decline in passenger air-travel led, in turn, to a decrease in demand for civil aircraft products. From 2005, the civil aviation sector began to recover, with civil aircraft manufacturers planning increased production that year, with further increases planned for the following years (House of Commons Trade and Industry Committee, 2005).

The aircraft industry is broadly seen as an advanced, technologically complex and competitive sector that has a strong impact on other industries and on the national economy, and which is therefore strategically important for strengthening national competitiveness and international trade (Cho, 2000). This view is in line with that of the House of Commons Trade and Industry Committee (2005), which described aerospace as a high-technology manufacturing industry that provides high-value goods and services to a wide range of markets. Eriksson (2006) also supports the view when indicating that aerospace industry is the 'archetypical knowledge-intensive sector', 'characterised by complex, very high-value added products in relatively small quantities, produced by relatively few players', with potential for linkages and spillover to other sectors. Eriksson (2000) indicated that "in many industrialized countries the aerospace industry together with some high-tech industries is strongly regarded as a source of technology renewal and thus a strategic industry that will foster spin-off and economic development". This has recently been seen applying to a number of developing and newly industrializing countries, especially in East and Southeast Asia.

Advancements in technology have played a major role in the industrial development and economic growth of developed countries. It is acknowledged that the civil aircraft industry in these countries has kept pace with technological changes and has been innovative so as to remain competitive in the transport business market.

Most developed countries have promoted the aircraft industry as an engine for continuous economic growth and advancement in technology (Cho, 2000). This is true for countries such as the US and France, which have succeeded in facilitating economic growth through the development of the aircraft industry. Kleiner, Leonard and Pilarski (1999) state that the aircraft industry is of particular importance in the US economy as it has been one of the dominant export sectors of high value-added goods. It also recorded a trade surplus of $21,3 billion (on about 57% of total civil export volume) in 1995, and a trade surplus of $27 billion in 2000 (De Bruijn & Steenhuis 2004:382), which rose to a total of $32 billion in 2004 (Napier, 2005). During that period the industry was also the second largest provider of manufacturing jobs in the US behind automobile manufacturing, with an estimated annual average of 583 900 employees in 2004 (Napier, 2005).

The manufacture of large civil aircraft is currently the largest single component of Europe's aerospace sales, accounting for over €20 billion annually (Europa, 2005). In the EU, the aerospace industry contributed €1.9 billion to the EU trade balance (De Bruijn & Steenhuis 2004:382, 383). However, the aircraft market is cyclical as it is dependant on airline acquisition plans, which fluctuate considerably, especially during times of uncertain economic prospects and global security concerns. The industry is of critical importance in the areas of maintaining superior defence technology, promoting rapid-growth industries, and improving productivity (Cho, 2000). For defence aircraft, demand is dependent on the defence budgets and the procurement policies of governments, which in turn depend on geopolitical developments and the changing perception of threat (Europa, 2005). It is essential for the aircraft industry to have as much predictability and stability as possible in both the civil and defence segments as the products in both these segments have many commonalities. This increases the chances of making best use of the knowledge base to optimise technical, human and financial resources, and increases the likelihood of each segment complementing the other during demand fluctuations in either one.

1.1.1 The aircraft industry

The structure of the civil aircraft industry will be used to analyse the South African aircraft industry and its environment, including any existing capability gaps. The aim is to establish where the South African industry fits within the structure in terms of its technology and its current trade within the global value chain. The industry is usually structured in the form of a pyramid as illustrated in Figure 1.1.

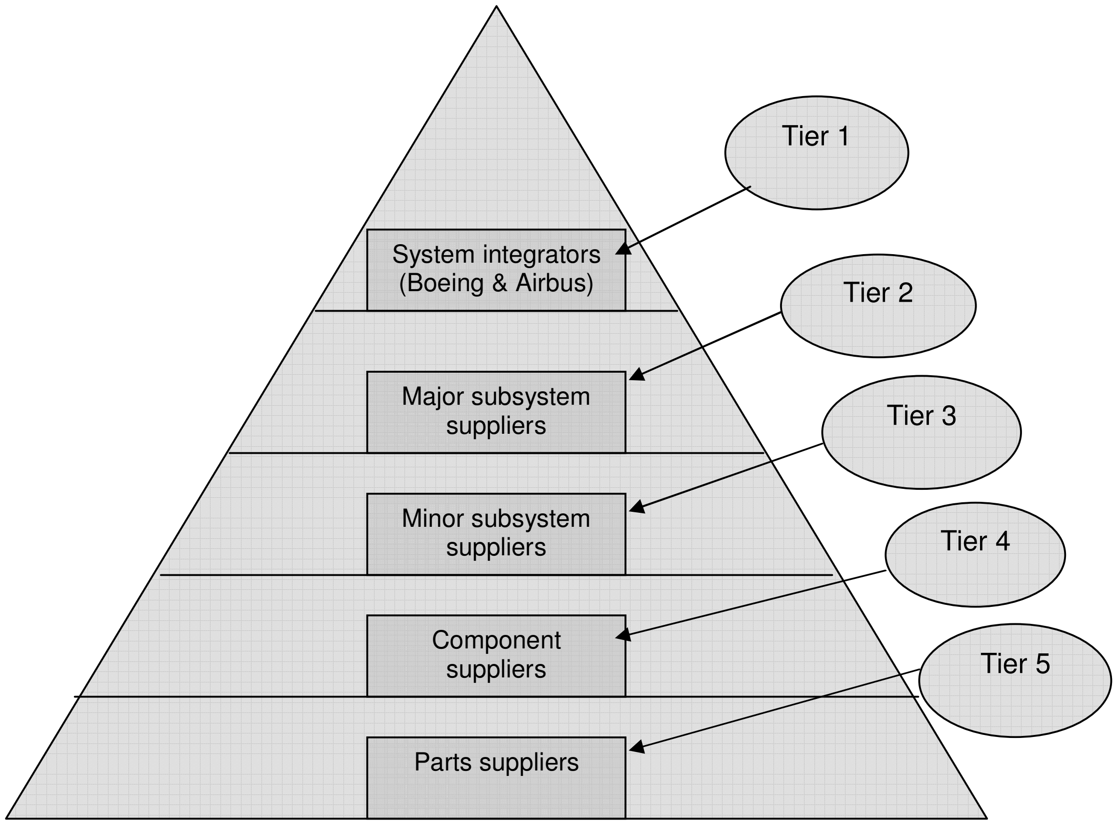

Figure 1.1 The aircraft industry structure

Source: Adapted from British Aerospace: Annual Report and Accounts (1998)

The **first tier**, at the top of the pyramid, consists of **system integrators** (airframe and engine) that have to manage a vast network of suppliers and subcontractors, and provide customer support for the 20–30 years of product life. Currently, two large oligopolistic groups, Airbus and Boeing, dominate systems design, manufacturing, and sales (Chiang, 1999:264). This excludes the regional or commuter aircraft industry, where Bombadier and Embraer have been the two dominating producers. The first tier has the highest value-added products. Most of the work in this area is assembling, with very little manufacturing. Upgrade and maintenance also fall into this category. Examples of the products include the A380 aeroplane, Rooivalk helicopter and Hercules C130. Examples of firms in this tier are Airbus, Boeing, Embraer, Lockheed-Martin and Denel.

Major subsystems suppliers form the **second tier**. They supply airframe structures, electronic components, engine accessories, landing gear, and hydraulic systems to the system integrators. This tier is characterised by high value-added products, and the main contributors are Rolls-Royce, General Electric (GE), Snecma, Advanced Technologies, engineering company ATE and Bombardier. Some assembling takes place in this category, and a small amount of manufacturing.

The **third tier** is made up of **minor subsystems suppliers**, and they supply medium value-added products such as navigation systems, computer systems, gearboxes and aerodynamic control surfaces. Denel and Aerosud are the main firms in this category. This is an assembly intensive area that includes some manufacturing as well.

Fourth tier firms are **component suppliers** that provide parts such as valves, pumps, electrical circuit boards, and machined engine parts. Medium value-added products are found in this category. The main firms here are Turbomeca Africa and Smiths. It is predominantly a manufacturing area and is assembly intensive.

The **fifth tier,** at the bottom of the pyramid, is made up of **parts suppliers** that provide items such as shafts, rivets, un-machined castings, and some electrical components. Only manufacturing occurs in this area, with no assembling at all. Firms in this tier focus on low value-added products.

Construction of a civil aircraft needs extensive systems integration skills of a level greater than computing, which is a skill of putting various pieces together (McGuire, 1999). This supports the fact that the aircraft industry is complex and that it is an aggregate system integrating almost all the nation's high-technology industry products (Cho, 2000). This statement is general for most nations, especially when considering the fact that currently most large aircraft built today form part of international co-operation projects where several nations' high-technology industries are aggregated into the assembly of aircraft, such as Airbus and Boeing. The system is composed of electronic, electrical, mechanical, and other subsystems, and the reliability of each subsystem's components is crucial. For the aircraft to be flown successfully, all subsystems have to function properly and reliably, while also interfacing with each other in a perfect manner. This means that all related industries have to be well developed, otherwise it becomes almost impossible to produce aircraft, and this is why aircraft industries occur mostly in developed countries.

The aircraft industry has a wide impact on various other sectors, as it requires a high level of investment and has long development times. Niosi & Zhegu (2005) described aerospace as a high value-added sector, strongly affected by scale and timing, with success depending on rapid technological progress and government support for corporate R&D becoming essential. This was further supported by Cho (2000) when he described the industry as a high value-added business sector, based on specialised and technology-intensive labour, hence to develop or produce an aircraft, large-scale production facilities supported by significant investment and specialised technological labour are essential. The persistent increase of R&D costs appears to be the major centrifugal force for the aircraft global decentralization: the industry has been gradually implementing strategies of international cooperation so as to reduce R&D costs (Niosi & Zhegu, 2005). This is something that could have a positive impact for South African aircraft industry if properly implemented.

1.1.2 Overview of the world market

Two market segments exist within the aircraft industry: military and civil aircraft. The Aerospace and defence industry profile (DTI (SA), 2001) indicates that the civil aircraft market accounts for about 40% of aerospace and defence industry spending, and is divided into four segments: large civil aircraft (aeroplanes of 100 seats or more); maintenance, repair and overhaul (MRO); jet engines; and business and regional aircraft (less than 100 seats). It further states that defence spending generates 86.4% of the global aerospace and defence market's value, with civil aerospace spending accounting for the remaining 13.6% of the market's revenues (Datamonitor, 2005).

Most of the world large aerospace companies are located in the advanced economies such as the US, UK, France, Germany, Canada, Japan, Italy, Sweden but also the former Soviet Union (Eriksson, 1995). Production-sharing and subcontracting have become the most significant features of world aerospace

production. This is because of the requirements to 'offset' costly purchases of aircraft and the pressure to find lower-cost sources of components to lower the production costs. This could result in technological capability being acquired by local forms in the purchasing country should some production take place within that country. The production network is denser and more valuable towards the North American aerospace industries than towards Europe, which could be due to various strategies used by the main aerospace firms such as Boeing and Airbus (Eriksson, 2003b). The US and European markets are dominant in the civil aircraft industry, with Boeing and Airbus Industrie being the leaders in large civil aircraft manufacturing/assembling. The largest regional aircraft makers are Bombardier, Embraer, and ATR, whereas Gulfstream and Textron's Cessna unit are manufacturers of business jets. Gulfstream has few models used as "corporate shuttles" with a maximum of 26 passengers (an example being Gulfstream III).
Pratt and Whitney, General Electric (USA), Rolls-Royce (UK), and Snecma (France), who together have more than 80% of the world jet engine-making market, dominate the aero-engine sector (Hwang, 2000). Most aircraft manufacturers also do maintenance, repair and overhaul (MRO). In South Africa, SAA Technical is the dominant organisation for maintenance, repair and overhaul work.

Currently, only the US, the UK and France (known as the world's 'Big Three') have the design and development capabilities to produce a complete range of aerospace products and related equipment. The US industry has greater economies of scale with more R&D, and the advantage of trading aircraft in US dollars (House of Commons Trade and Industry Committee, 2005). UK, France and Germany represent about 50% of the 429000 European aerospace employees (Niosi & Zhegu, 2005). The two main European aerospace industries (UK and France) are roughly similar in size in terms of sales.

Emerging economies such as Brazil, Taiwan and Indonesia have established their own aerospace industries that could have an impact on the international market in future should they become successful (House of Commons Trade and Industry Committee, 2005). Eriksson (2003b) indicated that several economies in East, Southeast Asia and South Asia (China, India, Indonesia, Singapore, South Korea and Taiwan), during the last decades, have targeted the aircraft industry for their future economic development, where they have explicit industrial policies to develop their industrial competence and technology. What appears to be important is fostering economic development and the creation of "spin-off" effects to other sectors leading to development of new technologies and job creation. Singapore's government has put more emphasis on the development of aircraft-related sectors of the economy. Another observation is the lack of 'internal' intra-regional subcontracting links within the Asian NIEs (Eriksson, 2003b).

Several other nations have varying degrees of capability in niche or specialised markets (Hayward, 1994). Table 1.1 shows the distribution of World Top 100 aerospace companies. The 'Big Three' can be differentiated from the rest by the scope of their national capabilities. However, drawing conclusions of the origin, impact and national capabilities in the aircraft industry could be difficult because of the increased cross-border acquisitions and mergers in recent years.

Table 1.1 Distribution of the World Top 100 aerospace companies

Country	Ownership of the World Top 100 aerospace companies
USA	47
UK	12
France	7
Japan	6
Germany	3
Canada	3
Sweden	3
Others (including South Korea and Brazil)	19

Source: Adapted from Flight International 13th August, 2002

The size of some of the national industries is indicated in Table 1.2.

Table 1.2 Estimates of aerospace industry sales and employment, 2003

Country	Sales (million pounds)	Employees (000s)
USA	91 000	475
France	17 000	106
UK	17 000	124
Germany	11 000	75
Canada	9 000	76
Italy	7 000	38
Japan	7 000	30
Spain	3 000	23

Source: Based on House of Commons Library estimates and Aerospace and Defence Industries Association of Europe, Facts & Figures 2003, 2004 (in House of Commons Trade and Industry Committee, 2005)

A strategy for an aerospace industry in South Africa indicates that the international aerospace market is growing and is expected to continue increasing (DTI (SA), 2003). Datamonitor (2005) indicates a growth of 5.4% in 2004 for the global aerospace and defence market. It further indicates that passenger traffic is expected to increase at about 4.7% per annum, whereas the number of aircraft is expected to increase at about 3.1% in the near future (DTI (SA), 2003). The total number of civil aeroplanes in the world is expected to double to about 28 400 over the next 20 years as a result of business demands associated with competitiveness and globalisation – increased business travel, the growing affordability of air travel, and the desire for time saving. This is supported by Figure 1.2, which shows the general growth in air traffic between 1970 and 2001, and the growth forecast beyond that period, to 2020. Boeing forecasts a growth for the African market from 641 aeroplanes to about 1 000 aeroplanes over a 20-year period (Reuters News, 2004). The increasing demand for new aeroplanes encompasses the need to replace old ones. The market demands increasing technical complexities associated with newer technologies and must build on aspects of safety and security in line with the current trends or society's expectations.

After a drop in civil aircraft orders in 2001 following the September 11 attack on the World Trade Centre (Boeing experienced a drop in orders of 45% and Airbus 28%), orders rose again in 2003 and 2004 (DTI (SA), 2001). Boeing developed the long-range, fuel-efficient, mid-sized, 7E7 Dreamliner (to be launched in 2008), while Airbus countered with its A380, a 550-passenger aircraft. Airbus also announced plans to build the A350 (due in 2010), which is intended to compete directly with Boeing's 7E7 Dreamliner.

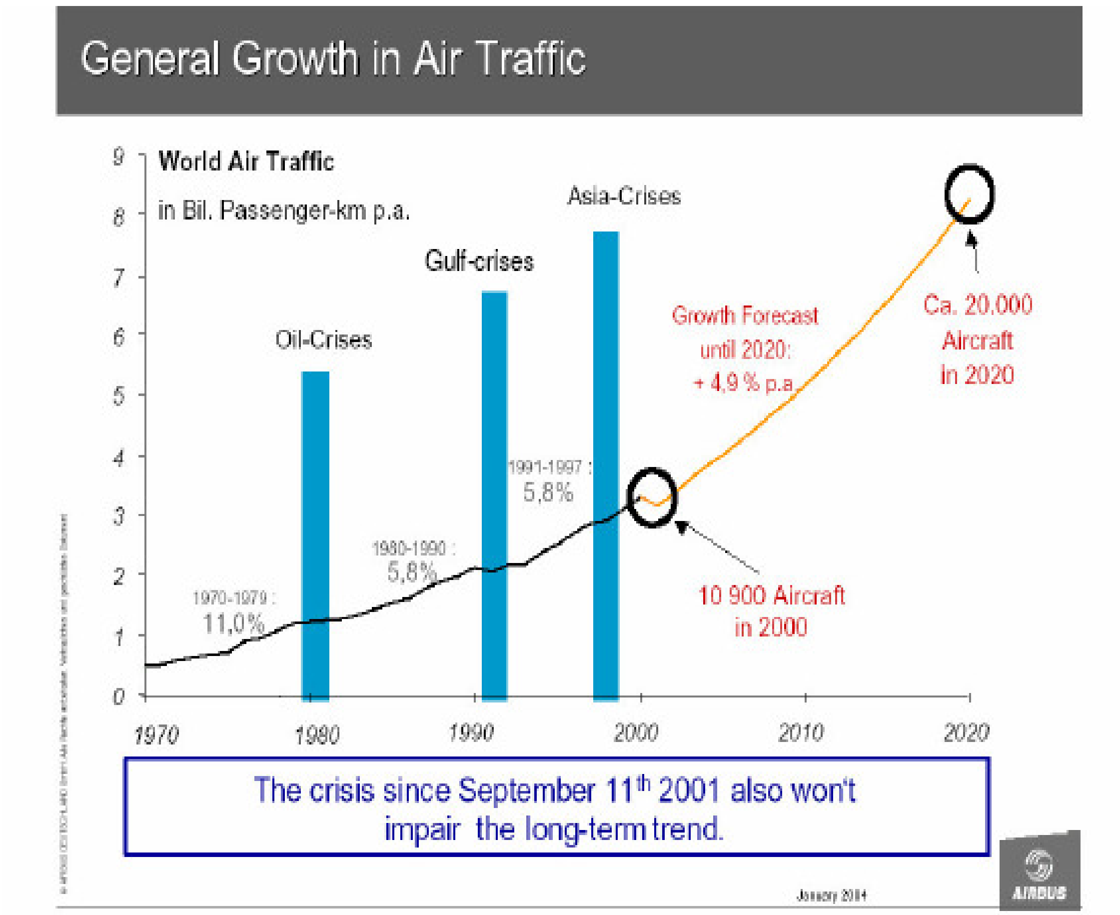

Figure 1.2 General growth in air traffic

Source: DTI (SA), 2005. Positioning the South African Aerospace Industry as a Priority Sector: Presentation July 2005.

Airbus (which is European) continues to increase its market share of aircraft manufacturing. Its global customers include Lufthansa (German) and Air France. Its strategy at the time when the three major US civil aircraft manufacturers (Boeing, McDonnell Douglas and Lockheed Martin) dominated the market, had been to find and exploit a niche market ignored by other manufacturers (Campos, 2001).

The overall development of the market for large civil aircraft and the competitiveness of Airbus are key elements in the future development of the European aircraft industry, which will possibly set trends for the global industry (Europa, 2005). Airbus was less affected by problems such as the general economic downturn, the threat of terrorism, the Iraq war and the SARS outbreak, compared to Boeing, its main international competitor, and that has resulted in increased market share for Airbus. It now has roughly of the same as Boeing. Its performance could continue to improve, if the development and market introduction of the new A380 super-jumbo is successful. Table 1.3 shows the annual sales figures of some of the leading international aerospace manufacturing companies with the two largest South African companies for comparison.

Table 1.3 Historical annual sales for selected aerospace companies

Company	Country	Annual Sales (RB)*	Military Sales (RB)*	% Military
Boeing	US	423	130	30%
Lockheed Martin	US	235	188	80%
EADS +	Germany, France, Spain, Italy	210	52	25%
BAE Systems	UK	174	139	80%
Raytheon	US	156	125	80%
Northrop	US	79	56	70%
Thompson CSF	France	62	43	70%
Finmeccanica	Italy	35	17	50%
Embraer	Brazil	15.8	2.5	16%
Denel Aviation	SA	1.6	1.4	88%
SAA Technical	SA	2.2	0	0%

* RB: Billion Rand
+ EADS: European Aeronautic, Defence and Space Company
Source: CSIR 2003. ASSEGAI (Hatty: International data circa 2000, Domestic data circa 2002)

A recent trend in the international aircraft industry has been the merging of firms in different countries as a strategy to increase the size of their business and to position themselves better within the global value chain. EADS is one such example. It was formed following a merger of Daimler Chrysler Aerospace (German), Aerospatiale Matra (French), CASA (Spanish) and Alenia (Italian). Boeing also undertook a merger, with McDonnel Douglas, also from the US.

A merger is undertaken for the following reasons (DTI (SA), 2003):

- The high cost of developing new technologies
- The high cost of designing, developing and producing a new aircraft
- The intense competition and high cost of marketing new products entering the global market.

It has become essential for firms, and even countries, to join forces, as the resources needed for designing, developing, producing and selling new aircraft are extensive.

The military aircraft market accounts for 60–80% of aircraft sales in most developing countries (Hwang, 2000). The remaining 20–40% forms the civil aircraft market in these developing or emerging economies, and it consists mainly of component or parts supplied to the developed nations under contract.

The immediate impact of the September 11, 2001 attack on the World Trade Center has reduced customer demand in the airline sector. This problem spilled over into the aircraft-manufacturing sector, resulting in severe cuts in civil aircraft production in the US market. Increases in military spending provided only a small-to-moderate counter balance to the decline in civil output. These events occurred at a time when production cuts were already planned due to a slowing economy and the gains made by non-US producers in most of the industry's market segments, such as Airbus in the European market (September 11 effects on aerospace industry, 2003). The US government provided large state subsidies to their airlines after the September 11 attack, as a way of compensating losses and assisting in stabilising the market. The US government further placed an order worth US$ 200 billion, which helped to generate growth in the industry. The military aircraft industry has been stimulated by the ongoing war in Iraq.

The September 11 attack had the effect of increasing the level of spending on aircraft security as never before. This has significant implications for civil aircraft manufacturing:

- There is an ongoing demand for components that relate to avionic security
- A larger demand now exists for air defence systems, for both military and civilian aircraft.

As a result of the attacks, airframe and power-plant manufacturers investigated various aspects such as technological security, which has had a tremendous impact on the aircraft business.

The US government has been very involved in this process since the September 11 incident. At defence companies, substantial additional security measures have been implemented, which might eventually lead to denying market entry to firms from other countries (September 11 effects on aerospace industry, 2003). The recent growth in aviation has been more of defence systems than of civilian systems. However, the experience gained from defence system processes should somehow be adapted for the development processes of civilian systems. Apart from pure national security concerns, other governments see the aerospace industry as a producer of a variety of leading edge technologies (McGuire, 1999). This leads to question regarding the extent to which government should tolerate technology transfer implied by the creation of strategic alliances among aerospace firms.

Aircraft manufacturers have begun redesigning security processes and technologies, such as the strengthening of cockpit doors. Additional methods of communication between crew members, ground stations and other aeroplanes are being investigated, and they might become a requirement for all aircraft. Attention is being paid to making aeroplanes more resistant to firearms, taking into account traditional concerns about adding more weight to the aircraft. More likely, critical systems will be modified to allow for greater hardened sheathing of critical nodes, cables and wires.

For firms to remain competitive in the global market, they require investment in new technology; a far-sighted, broad-spectrum design orientation; and the negotiation of trade agreements that make aircraft products competitive. At this stage, a greater government intervention in the entire aerospace industry is required. Recovery from the effects of the September 11 incident has depended on the ability of significant elements of the aerospace supply chain to absorb the full impact of the civil aircraft sector nose-dive. The recent concerns about aircraft security call for an investigation into whether the South African aircraft industry should start looking at avionic security and information communication technology in the industry as a possible niche markets in the near future.

1.1.3 The African aircraft market and investment

Africa Trade Issue Brief (1995) indicates that sales of US aircraft and aircraft parts to sub-Saharan Africa for the four years prior to 1995 were approximately US$ 289 million. US aircraft firms continue to see a lucrative market in Africa. This has been confirmed by Boeing which views the current market outlook for Africa as good, with a forecast growth from 641 aeroplanes over a 20 year period to about 1 000 aeroplanes (Reuters News, 2004). Boeing aims to increase market share across the African continent, where its aircraft currently make up 78 percent of the fleet. South African firms, with an excellent track record in both manufacturing of military aircraft and supply of civil aircraft components, have an opportunity to exploit the aircraft manufacturing market, even if it means supplying on behalf of other global firms (Reuters News, 2004).

South Africa is becoming increasingly important as a regional hub for maintenance repair organisations serving operators flying in sub-Saharan Africa. Turbomeca Africa, a joint venture between Denel and the French group Turbomeca, is an African investment in the area of engine manufacturing. It will focus on products from international firms such as Rolls-Royce and General Electric, as well as from domestic firms, and provide support for repairs and overhauls of civil and military helicopter engines (BuaNews, 2004). Turbomeca Africa is planning to export engines for the Swedish and Malaysian military aircraft markets, and to overhaul engines for the French and British ministries of defence from the year 2005. The Bedek Group, a division of Israel Aircraft Industries (IAI), started as a small workshop for the maintenance of military aircraft. It has since developed into the world's leading enterprise for overhauling and converting passenger aircraft (*The*

Israeli aircraft industries Quality Translations Job 31401). Civil aviation exports generate almost 90% of IAI's US$ 500 million annual sales.

For 2000–2005, capital expenditure by the Airports Company South Africa (ACSA), a state-owned corporation and the largest airport operator in South Africa, has been projected at US$ 234 million (Info Reporter, 2004a).

1.1.4 The South African civil aircraft industry and the national economy

South Africa has to develop a competitive, sustainable, fast-growing economy that creates national prosperity (Canta, 2003). The South African gross domestic product (GDP) for 2000 was R900 billion, compared to R500 billion for 1995, with 50% resulting from total sales of manufactured goods. The annual average real GDP growth increased slightly from 2.8% in 2001 to 3.6% in 2002. In 2003 the real GDP growth declined sharply to 1.9%. Some of the main contributors to the real economic growth rate were Manufacturing (0.7%), Agriculture (0.2%) and Transport and communication (0.6%) (Statistics South Africa, 2003). No official records were found regarding the aircraft sector's exact contribution to the total GDP, but the industry experts believe that the contribution is less than 5%, and that it is reflected in the manufacturing and transport industry contributions shown above (AMTS, 2003). The export figures of the South African aircraft industry in Table 1.4 indicate that this industry is making a contribution to the country's GDP and that it has the capability to expand, as it falls under the main contributors to the 1.9% real economic growth rate.

The mining industry sector, which historically played a major role in the economic development of South Africa, still accounted for 7% of the total GDP in the two years ending in 2002, although its importance later declined. Its contribution to the total GDP declined to an average of 3.4% in the first two quarters of 2004. However, the mining industry still remains a major employer, providing about 437 000 jobs. Energy contributes about 15% of the total GDP and employs about 250 000 people. Primary agriculture contributes about 3% of the country's GDP and provides almost 9% of formal employment. However, the agro-industrial sector is estimated to comprise 15% of the GDP (South African Embassy in Sweden, 2003). The entire manufacturing industry accounts for about 24% of the country's economic activity (Werksmans Attorneys, 2003).

Table 1.4 The size of the South African aircraft industry[1]

Aircraft (R million)[2]

Year	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
Exports	95	356	279	174	732	760	850	1 774
Imports	1 163	1 033	1 468	747	1 867	2 064	3 289	3 892

Aircraft components (R million)

Year	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*
Exports	45	69	120	146	217	200	380	344
Imports	268	309	315	312	528	677	744	751

Source: Trade and Investment SA trade statistics, 2002

Both the manufacturing and transport industries (including the aircraft industry) contribute an estimated 40% of the total GDP. As indicated previously, there are no formal records about the contribution of the aerospace industry to the total GDP, however industry experts believe that such contribution remains below 5%. The South African aircraft industry is believed to employ about 12 000 people (AMTS, 2003). The real investment for automotive and transport industry (aircraft included) was R21,084 billion in 2003, and was forecast to be R21,6 billion for 2004 (DTI (SA), 2004).

The challenge of facilitating growth depends on a dynamic and multi-disciplinary knowledge base capable of integrating technology, management and labour. Knowledge, innovation and productivity (important aspects in business sustainability) become key in building a competitive industrial base.

The South African aerospace industry in general and the civil aircraft sector in particular are high technology segments and very important to the national

[1] The export of aircraft is defined as exports of new aircraft to African countries or the sale of second-hand aircraft. Imports include purchases of new and second-hand aircraft.
[2] 1 US$ ≅ R7

economy. This industry can help produce a large amount of innovation – new products, processes and services, that will enhance firms' ability to gain global market share, create entirely new markets, or lead to a more productive use of resources (National Science Board, 2003).

1.2 General overview of the South African aircraft industry

1.2.1 The South African aircraft industry and its market

The South African aircraft industry has about 220 companies of which the majority are SMEs. The dominant South African aircraft companies are Denel; Aerosud; Aerospace; Maritime and Defence Association (AMD), SAA Technical (a subsidiary of South African Airways); Advanced Technologies and Engineering (ATE); Grintek; and International Aviation Support (IAS). In 1999 the Department of Trade and Industry (DTI) SA carried out a study to assess the aircraft industry's contribution to growing the South African economy. The study revealed that the aircraft industry produces annual sales of more than R5 billion, employs about 12 000 people and uses R2,520 billion in capital, while about 25% of the industry is very closely related to the defence industry (TISA, 2002). The South African government owns the largest companies in the industry, South African Airways (SAA) and Denel (made up of Denel Aviation, Denel Airmotive, Kentron and Denel Aviation Transport Aircraft Maintenance) which account for about two thirds of the industry's output. The industry is mainly concentrated in Gauteng near OR Tambo International Airport, although some companies are based in the Western Cape and Kwazulu-Natal.

The purchase of 21 Boeing 737 aircraft by South African Airways (SAA) to upgrade its fleet resulted in a number of opportunities for the development of the local aerospace sector. The first three Boeing 'Next-Generation' 737s were delivered to SAA in July 2000. The total investment of this purchase was estimated at US$ 1,8 billion. Boeing relocated some of its machining operations for the manufacture of aircraft components to local companies and committed to providing aircraft maintenance work to a South African company (NIPP, 2002). The subsequent contract for the supply of 41 aircraft to SAA by Airbus, further benefited the aerospace industry with approved projects including the development of a non-destructive testing centre in association with French multinationals. Opportunities for local companies to supply aircraft components to Airbus and to be involved in the development of the A400M transport aircraft, scheduled to be released in 2006, also arose from this contract (NIPP, 2002). The contract involved an investment of US$ 3,5 billion by Airbus to renew SAA's entire fleet of 41 aircraft over a period of ten years – three A340-600s were to be delivered in the fourth quarter of 2002 and another four by the third quarter of 2003. The remaining 34 aircraft – a combination of A340-600s, A340-300Es, A320-200s and A319-100s – were scheduled for delivery between 2005 and 2012. SAA later considered cancelling plans for buying 15 single-aisle Airbus A320-200 aeroplanes that were due for delivery in 2010, following a R8.7 billion trading loss following currency fluctuations. It considered leasing 11 single-aisle A319-100s and 5 twin-aisle A340-300s to avoid further losses (Brand, 2004).

The aircraft sector has been characterised by huge capital investments (such as the Boeing and Airbus purchases indicated above) associated with business development, substantial research and development associated with technology development, and long product development periods (sometimes more than a decade) from the inception of R&D to final product delivery. These are challenges that the country has to face given the inadequate resource base, in order to realise opportunities and facilitate growth.

1.2.1.1 Market focus prior to 1994: Military market development

In most developing countries, the military aircraft market is the major market with 60–80% of aircraft sales in the aircraft industry (Hwang, 2000). The South African government, prior to 1994, promoted the military sector of the aircraft industry by providing financial support, as part of a strategy for growth. Between 1989 and 1994, and up to 1997, the South African defence budget was cut by more than 50% in real terms, with most of the cuts coming from the procurement budget, which was cut by nearly 70% in real terms during the same period (Corporate performance and military production in SA, 2003). With the change of South African government in 1994, government spending priorities changed from defence to social upliftment.

By the end of 1997, the military budget had been reduced to about 1.6% of the gross domestic product. In anticipation of these changes, a plan was formulated, to convert the defence industry from a manufacturer of military products only, to a manufacturer of civilian products as well. Military aircraft sales still represent 60% of the total aircraft industry sales even with the decrease in military budget. In the military aircraft market, government appears to be the largest customer.

Prior to the changes of focus from a military to a civil market, South African firms had shown their skills in military aircraft development. One such example was Aerosud, a firm that was widely acknowledged for its track record on major developments such as the Rooivalk attack helicopter and the Cheetah fighter aircraft. It was highly successful in building systems integration capabilities for military aircraft, and executed refurbishment and upgrade programs as well. Such capabilities covered a broad area of aeronautical activities such as overall conceptualisation, system engineering management, and the integration of effort across organisational boundaries for complex multi-disciplinary programs. The company used these existing capabilities as the basis for further learning, which it had the advantage of applying in civil aircraft development. Aerosud was the main contractor and overall airframe and system design leader for the Mirage re-engining program, which involved the installation of the Russian Klimov RD33 engine as used in the Mig29 fighter. The Mirage F1, and the Cheetah D (Mirage III variant), which were the prototypes produced, were successfully flight-tested and both displayed excellent performance characteristics. Denel successfully assembled the Italian MB326 (Impala) trainer jet, under French license.

1.2.1.2 Market focus post 1994: Civil market development

The civil aircraft market in South Africa consists of civil transport, helicopters, business jets, commuter or regional aircraft and general aviation. With the move to a civil aircraft market, most firms that previously focused on military aircraft development, now tend to have capabilities in both military and civil aircraft development. In the civil and military industries Aerosud, Denel, and International Aviation Support (IAS) dominate the South African market. Table 1.5 shows some of the South African aircraft firms that contribute to the military and civil aircraft markets. IAS supplies aircraft engines, spares, components, tyres, oils, fluid, lubricants, tools, and maintenance for the South African market, while Aerosud and Denel have a global market.

Table 1.5 Some South African aircraft firms[3]

	Company name	Additional company information
Defence industry	1. Denel	1. Denel generates about US$ 536m sales per annum, and has about 10 500 employees. Most of its dealings are with BAE systems (30% share) and Turbomeca France (50% share).
	2. Aerosud	2. Aerosud has more than 200 employees and its major dealings are with the US (Boeing contracts). Sales are about US$ 25m per annum.
	3. Grintek and Avitronics	3. Saab (Swedish) owns about 49% of Grintek. Markets include Europe, the Middle East and Africa. It employs about 1 300 people, with a capital investment of US$ 2.4m.
	4. AMS (Aerospace Monitoring and Systems)	4. AMS, with about US$ 3.7m in capital investment, employs about 85 people. Most of its dealings are with BAE systems.
	5. Reunert	5. Reunert's major markets are Germany and the US with sales of about US$ 700m per year.
	6. International Aviation Support (IAS)	6. IAS supply local industry with aircraft engine and parts.
Civil industry	1. Denel	1. Same as 1 above.
	2. Aerosud	2. Same as 2 above.
	3. SAA Technical	3. SAA Technical employs about 3 200 people, and deals with France and the US on the Airbus and Boeing contracts respectively. Has recently invested US$ 1.9m for improving facilities, with sales of about US$ 30m.
	4. IAS	4. Same as 6 above.
	5. Aeromax	5. Aeromax is a SA-based US firm and also an approved US govt supplier (90% of its business).
	6. U-Play Hobbies	6. U-Play Hobbies supply private aircraft engines and radios.

Source: Mayindi and Kachienga (2008)

Since 1997, Denel's group sales have increased by 14,4%, from some R3 billion to R3,446 billion. In the same period, sales revenue from exports increased by 107%, from R613m to R1,269 billion in 2000. Exports account for 37% of Denel's sales, while in the case of Aerosud, 90% of its business is export orientated.

Table 1.4, shown previously, indicates the import and export sales figures of the

[3] Most firms don't give out sensitive, confidential company information. This table includes the only available information.

South African aircraft industry and demonstrates market size. Both Denel and Aerosud have strong aircraft structures capability on both the civil and the military side. There are several other aircraft firms in South Africa such as Aeromax and U-Play Hobbies that fall outside the civil transport market. Aeromax is a manufacturer and distributor of aircraft for training purposes, while U-Play Hobbies supplies engines and radios for private aircraft. The area of sub-contracting major international aircraft manufacturers or their suppliers has had major successes. The local companies have been successful in manufacturing auxiliary drive gearboxes, flaps, rudders, landing gear and pylons for aircraft.

About half of the companies in the industry are involved in the maintenance of aircraft. SAA Technical Division and Denel are the largest in this field, with high technical aircraft maintenance skills and facilities. SAA Technical has one of the best-equipped technical facilities in the world and performs third-party work for 47 airlines (TISA, 2002). One of its hangars is about 3600 square meters, which makes it the largest in the southern hemisphere. Figure 1.3 shows an SAA Technical hangar where maintenance takes place. In the past, prominent international airlines doubted the technological capabilities and competencies of firms from developing countries, but recently a record number have entrusted highly complex maintenance tasks to SAA Technical. SAA Technical offers its services at highly competitive rates. The sales for SAA Technical are over US$ 30 million per annum. SAA Technical has a staff complement of about 3 200.

Figure 1.3 An SAA Technical hangar
Source: SAA Technical: Presentation to SA aerospace industry contributors, 2003

The aircraft modifications section is the smallest portion of the industry. There are a large number of small and medium enterprise (SME) suppliers to this section of the industry.

Denel's Aerospace and Military Division specialises in the design and construction of helicopters and other military aircraft while Denel's Airmotive Division specialises in the maintenance and modification of aircraft engines. DATAM is another key firm for aircraft maintenance, upgrades, modification and aircraft refurbishment, and a number of smaller companies such as Aerosud and Execujet also specialise in some of these fields. Grintek is the major company for civil and defence avionics. In 2004, Grintek announced that it had secured two contracts worth approximately R134 million to supply 18 multi-sensor warning systems for the Malaysian government's new Sukhoi fighter aircraft (Info Reporter, 2004b). This is the kind of on-going exposure that is needed for the development of the civil aircraft industry. On the civilian side, Grintek would also supply and install instrument landing equipment to a civilian airport in Malaysia. This project would be carried out by Avitronics, the joint venture company formed by Grintek and Saab (Sweden).

The South African aircraft market has specific competitive advantages (TISA, 2002):

- The availability of aircraft maintenance skills and facilities
- The availability of modifications skills and facilities
- The availability of upgrade skills and facilities
- The availability of design and manufacturing skills in the area of helicopters
- Low labour costs
- Strong support from the avionics and information telecommunication industries
- An aviation hub for Southern Africa
- A number of existing aviation training centres
- A number of FAA and JAA certified companies
- Enough space for business premises.

The competitive advantages of the South African aircraft industry need to be exploited further to achieve higher levels of national growth. This study will explore ways in which such competitive advantages and capabilities can be fully exploited to achieve the intended growth through technology and business development. Appendix 1 highlights some of the capabilities of South African aircraft firms (TISA, 2004).

The business growth prospects for the South African aircraft industry appear to be in the following fields (AMTS, 2003; TISA, 2002):

- Aircraft maintenance
- Aircraft conversions, of military and civil aircraft
- Aircraft modifications, including aircraft upgrades, refurbishment and conversions
- The manufacture of components and sub-system levels
- Upgrading of existing skills for composites, rotor-wing propeller blades, avionics, gearboxes and interiors
- Sub-contracting and third-party work
- The Industrial Participation Program (IPP), offered by the South African government through the DTI in support of investment or trade in South African industries.

South Africa's global market includes Europe (France, Germany, Switzerland), the US, the UK and Africa. Most of the business comes from imports of new and second-hand aircraft and the export or supply of subsystems and components. When assessing the status of South African firms with regard to their international joint ventures and strategic alliances, Europe (UK, France, Germany) accounts for 40%, followed by the US with about 30%, and the rest of Africa making up the remaining 30%. South Africa has a bigger export market to African countries for the sale of second-hand aircraft, which accounts for about 90% of its entire export market in that field. Aircraft parts are mostly exported to Algeria (32.1%), the US (19.2%) and Nigeria (10.1%), whereas most aircraft parts for complete aircraft are imported from the US (60.6%), the UK (15.2%) and France (12.5%). Complete aircraft are mostly imported from the US (88.8%), the UK (3.2%) and Switzerland (2.9%) (DTI (SA), 2003).

The South African aircraft industry provides about 12 000 jobs (AMTS, 2003). A variety of excellent engineering skills exist in aviation and a number of aviation training schools and pilot academies, such as the Aerosud Academy, are in place. The world's major carriers hold the industry's technical proficiency in such high esteem in that maintenance service is conducted for most of the international airlines. Of the 3 200 employees at SAA Technical, about 1 300 are highly qualified technicians with skills in avionics, mechanical, structures, component overhaul, line-station checks and a host of other highly technical aviation activities (TISA, 2002).

Sports aviation forms part of the development of the aircraft industry in South Africa. An Aero Club has been established, which is involved in development programmes aimed at exposing the previously isolated communities to aviation. It liaises with the Department of Sport and Recreation (Thomas, 2002). The club has about 5 000 affiliated members, and a body that oversees the overall safety of the flying activities and liaises with the Civil Aviation Authority on sport aviation issues. Experience and learning from technology development within the ambit of sports aviation could have long-term benefits for the development of the civil aircraft industry, especially in experimental aircraft programmes and the promotion of safety.

1.2.2 The influence of the national environment on the South African aircraft industry

Porter (1990) examines the role played by national policies and the environment in shaping the capability building of key firms in the creation of national competitiveness. How the national environment shapes the South African aircraft industry can also be assessed.

1.2.2.1 Production factors

Production factors fall into a number of broad categories, such as human resources, physical resources, knowledge resources, capital resources and infra-structural resources. These factors can be further differentiated into two types – basic and advanced factors; and generalised and specialised factors.

Because of the large financial layout involved with aircraft maintenance, there are a number of funding institutions, government departments (ministries) and various levels of personnel that influence the selection process. Decisions within the decision-making chain can be quite political where large contracts are at stake, especially for a historically disadvantaged country like South Africa that is a relative latecomer to the international aircraft industry. It is very important to place the maintenance facility (infra-structural resources) at an easily accessible city: in South Africa, most aircraft firms are situated near OR Tambo International Airport. This kind of situation can play a decisive role in the customer's choice of supplier. The factors outlined above, and how they impact on the South African aircraft industry, will be explored further during the data collection section of this document.

1.2.2.2 Demand conditions

The South African aircraft industry is heavily driven by exports and in the relative absence of a local market, firms are less sensitive to domestic demand. The most active home market is aircraft maintenance, as international airline operators need the infrastructure available in the country during stop-overs. Most South African firms are diversifying into aircraft maintenance and service provision as part of their strategy to strengthen the market. The aircraft maintenance market has two main areas of competition: heavy maintenance and minor maintenance inspections (Denel SA, 2002). The South African industry falls within the large area of heavy maintenance.

National carriers such as South African Airways (SAA), Ethiopian Airlines and Royal Air Morocco have large common fleets and generally perform all their maintenance in-house. The second tier carriers tend to have smaller mixed fleets, and perform as much of their minor maintenance as possible in-house.

The maintenance market size for older generation aircraft in South Africa is based on flying hours/cycles and the willingness to do scheduled maintenance. Aircraft maintenance opportunities in South Africa tend to be influenced by global economic activity. High economic activity results in increased civil aviation activity, which results in an increased demand for aircraft maintenance.

National carriers use workshops in Europe for the overhaul and repair of major components, the sector which is traditionally the largest of the civil aviation maintenance market in Africa (South Africa included). The reason for this could be economies of scale. Most African operators do not have the through-put to justify the capital outlay of setting up workshops for major component overhaul and repair. African operators are offered favourable maintenance deals in Europe and Asia only when there is global over-capacity in the aircraft maintenance industry. SAA Technical is currently the major maintenance, overhaul and repair service provider in Africa.

Demand conditions trigger domestic rivalry when domestic buyers have a wider choice in the home market (Porter, 1990). The domestic market in South Africa is not large enough to support its civil aircraft sector; therefore firms are not building capabilities in the aircraft industry based on domestic demand but on global market demand. There are also very few firms in this industry, therefore domestic rivalry is limited.

1.2.2.3 Related and supporting industries

Firms in related industries tend to share complementary activities such as technology development, and facilitate the flow of information or knowledge exchange, thereby promoting international competitiveness. One example in South Africa is International Aviation Support (IAS), which supplies aircraft engines, spares, components, tyres, oils, fluid, lubricants and maintenance tools for the South African aircraft market. Large firms like Denel and Aerosud could subcontract some of their parts-manufacturing business to small firms, which can facilitate learning and capability building within the smaller organisations.

1.2.2.4 Strategy, structure and rivalry

Domestic rivalry within the aircraft industry is not a particularly favourable option as the really lucrative market is the highly competitive global industry. For a long-term process of catching-up, a national champion in the South African aircraft industry (rather than a strong rivalry) could better facilitate the large amount of learning that is still required. The market in South Africa is very small and it is not conducive to domestic rivalry. Denel and Aerosud work together as their expertise in engine component supply and airframe interior design respectively, complements each other in terms of aircraft development, and capacity building.

Porter (1990) indicates that government plays a large role in distorting competition in many of the prominent industries such as aerospace and telecommunications if there is only one national rival. This is the case in South Africa, where government previously funded the military aircraft sector (Denel). Both Denel and Aerosud are national champions of military aircraft, and are becoming national champions for civil aircraft. Their capabilities in both engines and airframes, which were built on the foundation of military aircraft experience, have grown significantly over the past years.

1.2.2.5 Chance and the role of government

Chance events[4] and government have an impact on the actual determinants of a national advantage, although they do not necessarily control them (Porter, 1990). However, nations with the most favourable determinants have a better opportunity to exploit chance events and convert them to a competitive advantage.

Government, through its policies such as those toward capital markets, education or the issuing of subsidies, can influence or shape national competitiveness. This can in turn affect factor conditions. The interest by the South African government in establishing a strategy for developing the civil aircraft industry, and also to provide funding in that regard, could have a major impact on the capability building and competitiveness of local firms. It is therefore the responsibility of the national government to impose standards and regulations, making business interaction more efficient, and to provide the communication infrastructure, the appropriate formal educational system and the supervision of property rights (Calliano and Carpano, 2000).

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[4] Occurrences not resulting from a nation's circumstances are outside a firm's control (Lall, 2000). Examples include pure invention, major technological discontinuities, wars and political decisions by foreign governments.

1.3 The research problem and research questions

1.3.1 Problem statement

The South African aircraft industry (military and civil combined) is believed to be contributing no more than 5% to the total GDP, although some local firms do supply components or parts to foreign manufacturers, and also do aircraft upgrades and maintenance service. Because 60–80% of aircraft sales in developing countries are military aircraft sales, the South African civil aircraft industry alone contributes no more than 2% to the country's total GDP. Nevertheless, the major efforts and contributions made by South African firms on military projects, provide evidence that South Africa has the potential to sustain its civil aircraft sector. Excellent performances were produced by firms such as Denel and Aerosud, with the production of the Rooivalk attack helicopter, the Cheetah fighter aircraft, the Mirage project, and the manufacture of the Italian MB 326 (Impala) trainer jet under French license.

The problem is that it is not known if the South African civil aircraft industry has proper support measures or if it follows a particular framework for technology development so as to gain global technological competitiveness. Some technological support programmes such as the Technology and Human Resources for Industry Programme (THRIP), the Support Programme for Industrial Innovation (SPII) and the Innovation Fund (IF), have been offered by government to improve industrial technological capabilities, but it is not known if these are enough to position local aircraft firms in the global value-chain system.

An investigative analysis was undertaken to establish if there were certain models or frameworks used internationally, that have helped improve the innovative and technological capabilities of the industry, and if similar models or frameworks do exist locally to strengthen current technological capabilities. It is also necessary to investigate if there were specific areas of intervention within such frameworks internationally that led to the development of industrial technological capabilities. It is believed that when key interventions or technological support measures for industrial development exist in a structured manner, firms have a more competitive edge and the ability to build technological capabilities (be it through technology transfer, imitation and adaptation, or even innovation), and are able to participate in the global market, contributing more towards the growth of the country.

It has been suggested that the South African government needs an aerospace development strategy aimed at strengthening technology development and business access to international aircraft markets (Engineering News, October 2003). At the official opening of the African Aerospace and Defence Trade Show in Pretoria, the Minister of Trade and Industry emphasised the need for introducing an aerospace industry support initiative to be used for unlocking potential, which is considered key in stimulating investment and economic growth (Engineering News, September 2004).

1.3.2 Research questions

The research seeks to address the following questions:

- Are there any specific successful models used for the development of technologically competitive civil aircraft industries internationally?
- What are the frameworks used for the development of technologically competitive civil aircraft industries internationally? Do they have any relation to technological capability building (technology transfer, skills development, infrastructure development, government support, and R&D investment)?
- Are there any commonalities (or even differences) among the frameworks that have been applied by different countries?
- How do the technological competencies of the South African civil aircraft industry compare with those of other successful countries?
- Was there a specific government policy aimed at civil aircraft technology development in all the successful countries studied?
- What are the known attributes that contribute to less developed technology bases in the civil aircraft industry?
- Are these attributes common in the South African case?
- Can the frameworks be adapted to suit the South African civil aircraft industry?
- What can be learned from the not so successful countries?

These questions are aimed at establishing the factors that would lead to the successful technology development of the civil aircraft industry, while considering the background of the South African aircraft industry and the lessons to be learned from other countries. If the questions can be well answered and properly analysed, they will be addressing the 'how scenario' of the research which is the main question of the study, i.e. "How can key lessons from international models or frameworks for the technological development of the civil aircraft industry be used to develop local frameworks for building a technological, competitive civil aircraft industry"?

1.3.3 Reasons for selecting this study

The South African government recognises the potential for the country's aircraft industry to contribute aggressively towards the growth of the national economy. It has clearly indicated its intention to transform the country's civil aircraft sector into a well-developed, sustainable, growing, empowered and globally recognised industry, like the successful automotive industry, by the year 2014. Aerospace development, and the aircraft sector specifically, has become a medium- to long-term project for the Department of Trade and Industry (DTI) SA (Engineering News, October 2003). Some South African aircraft firms are involved in maintenance, as well as component and parts supply to the global market, and thus South Africa has a comparative advantage over other African countries. Nevertheless, the South African government, through the DTI, believes that challenges do exist, in terms of improving the technological base of the South African civil aircraft industry. These have impacted on the national technological competitiveness of the industry in the past.

This study has therefore chosen to analyse the South African civil aircraft industry (civil aviation) and to propose models or frameworks for providing additional technological support mechanisms to improve the technological base of the industry, which is necessary for firms to become globally competitive. Government, as a major promoter of industrial development, is interested in strategies to reposition aircraft firms so that they can provide appropriate technologies (through technology transfer, imitation and adaptation) and participate in the global market, thereby contributing more towards the growth of the country.

The South African government and other role players need to be informed to be able to develop policies and growth strategies that will enhance and facilitate technology development within the industry, which will be of economic benefit to the country. This study includes discussion of the role that the South African Government could play as part of the solution. Private sector firms need to develop strategies to face the challenges stated in the problem statement, and this study could be beneficial to them.

The researcher looked at base models used by selected countries with World Top 100 aerospace companies, (listed in Table 1.1), to have a better understanding of how they developed their industries. These were used as a basis for the development of other models suitable to the South African situation. The countries used as base models within the civil aircraft industry are both developed and less developed countries, and they have produced some competitive companies that are among the World Top 100 aerospace companies. In this way, the study looked at international best practices for growing the civil aircraft industry and used those as a basis to establish what South Africa could do to develop its aircraft industry towards national technological competitiveness.

1.4 Expected contributions

The results of this study could benefit the South African private sector in identifying business and investment opportunities. Such results could be useful when making technology development, business development or strategic investment decisions to steer the sector in the right direction for bridging the identified gaps within the aircraft industry. This could enable the aircraft–business sector to strategise on enhancing competitiveness and to reposition itself within the value chain of the aircraft industry structure or the System Integration Hierarchy (pyramid). The results should also provide a basis for establishing the possible linkages or networks that could be set up to ensure that technological development and globalisation of the South African aircraft industry are facilitated. This would lead to the establishment of strategies to either exploit and fully develop the existing market (component supply market, aircraft maintenance service), or to move into other strategic areas by pursuing means appropriate for technology development.

Firms within the aircraft industry would be able to introduce or establish competitive strategies to be used in facing the low technology-base challenges for participating in the global aircraft market.
The SMEs within the aviation sector that are believed not to be benefiting from government support initiatives such as the Department of Trade and Industry's Industrial Participation's Offset Programme, could benefit as this study might propose strategic options for the entire industry, not only large businesses.

The public sector could benefit from the results, which could be used for developing long-term policies on aircraft development and required infrastructure, including the provision of the required support systems. The Department of Trade and Industry (DTI), the Department of Science and Technology (DST), the Department of Public Enterprise (DPE), the Department of Defence (DOD) and the Department of Transport (DOT) could derive the most benefit from this study. Lessons learnt from the various successful models used in other countries, could be further developed for a South African perspective. New models developed for the South African aircraft industry could assist in dealing with the issue of national technological competitiveness. The development of competitive civil transport could generate regional and international trade, thus stimulating national economic growth. New policies could be developed and implemented by government to address the issue of aircraft technology development, which could lead to local industrial competitiveness and better access to business opportunities in the global aircraft market.

The academic sector could also benefit from this study, especially in the area of research, where additional or new models could be developed to add to the existing knowledge of the aircraft industry, and science in general. Most existing theories place emphasis on the complexity of the global aircraft industry without outlining the empirical models or frameworks that catching-up economies should follow to develop civil aircraft industries that are part of the global value chain. The results of this study could contribute to bridging the existing gap by providing new or improved theories for a strategy to develop the civil aircraft industry towards national technological competitiveness.

CHAPTER II: THEORETICAL BACKGROUND: THE CIVIL AIRCRAFT INDUSTRY AND NATIONAL TECHNOLOGICAL COMPETENCIES

The aerospace industry has been described by the CSIR's ASSEGAI document (2003) as covering research and development (R&D), design, manufacture, support, maintenance, conversion and upgrade of both rotary and fixed wing aircraft, as well as their relevant subsystems and components. Aerospace markets fall into a number of different categories, ranging from fixed-wing and rotary-wing aircraft to satellites and both civilian and military applications of aerospace technology (Jackson 2004:521). This study looks at aircraft industry development within the aerospace industry context as described by ASSEGAI above, with special focus on the civil aircraft sector. Throughout this study, when referring to 'aerospace industry', the researcher will be referring specifically to the aircraft industry, covering all the aspects mentioned in the description of the aerospace industry above.

Delaware Aerospace Education Foundation (DASEF 2002:1) defined aerospace as follows: '*Aero* is air and atmosphere, and *Space* is the region beyond the earth's atmosphere or beyond the solar system'. Aerospace has also been defined as, 'of or relating to the Earth's atmosphere and the space beyond', or alternately, 'of or relating to the science or technology of flight' (Answers Corporation 2006:1). The first part of the definition by Answers Corporation (2006) is broad, as it does not specifically mention 'technology', whereas the second part clearly coincides with this researcher's area of study as it specifically refers to the 'technology of flight'. This often refers to the technology of aviation for spacecraft and aircraft. In line with the description mentioned above, the focus of this study will be on the analysis of the developmental approaches for the civil 'technology of flight', meaning civil aviation, and how they can be used to improve aircraft industry capabilities towards national technological competitiveness.

2.1 Technological competence and capacity building within firms

Some studies have highlighted the importance of firms developing capabilities in general, and the impact of the environment in which they are situated (Teece and Pisano 1994:538; Porter, 1990). This study utilises the existing twin concepts of dynamic capabilities and absorptive capacity, and attempts to adapt them to an investigation of a framework for the South African aircraft industry. This will be done to ascertain the strategies prevalent in the industry in order to generalise them and establish their wider applicability in innovation, technology development and the facilitation of growth within the industry.

The concept of competitiveness includes productivity, efficiency and viability. However, the competitiveness of a country, region or firm now depends predominantly on its capacity to invest in research, know-how, technology and the skills that allow maximum benefit to be derived in terms of new products or services (European Commission 1996). This theory is relevant to this study in that it indicates the dependence of national technological competitiveness on industrial capability, which could involve aspects such as investing in research, know-how, skills and technology as outlined above.

"Innovation is taken as being a synonym for the successful production, assimilation and exploitation of novelty in the economic and social spheres" (European Commission 1996). Research, development and the application of new technologies are key elements in innovation. Firms must adapt methods of production, management and distribution, in order to incorporate innovation elements. Government, through strategies such as technology-policy development, should propose mechanisms or frameworks for initiating new solutions to industrial competitiveness problems, and encourage the promotion of the culture of innovation, technology absorption, global collaboration and knowledge sharing.

"The quality of the educational system, the regulatory, legislative and fiscal framework, the competitive environment and the firm's partners, the legislation on patents and intellectual property, and the public infrastructure for research and innovation support services, are all examples of factors impeding or promoting innovation" (European Commission 1996).

Also relevant to this study is the theory of Tidd, Bessant and Pavitt (2001:15) that innovation is a powerful way of securing competitive advantage and a more secure approach to defending strategic positions, but success is not guaranteed. The uncertainty of success includes the economics of production, as well as technical, market, social and political forces, hence it is a trial and error situation. It is essential that experiments are well-designed and controlled so as to minimise the incidence of failure and, where it occurs, lessons are learned to avoid similar problems in future.

Bell and Pavitt (1993:195) argue that in Africa, in particular, performance has frequently declined over time, implying that an industry falls behind ever more rapidly. If this is true, then for firms in Africa, catching-up must form part of the plan for technological change. With a low reputation for production efficiency or product quality/performance, technology transfer and alliances are strategies that most firms could use to strengthen capabilities.

Lall (1990:26) argues that national technological competence cannot be assessed 'in the abstract', but only with reference to its manifestation in the manufacturing sector. The concern appears to be more about productive deployment of capabilities rather than the potential existing in things such as stocks of underutilised capital, engineering manpower or academic knowledge.

The new theories of growth stress that development of know-how and technological change – rather than the mere accumulation of capital – are the driving forces behind lasting growth (European Commission 1996). These theories indicate that authorities can influence the foundations of economic growth by playing a part in the development of know-how, one of the principal mainsprings of innovation. Authorities can also influence the distribution of know-how and skills throughout the economy and society by facilitating the mobility of persons; by encouraging interaction between firms as well as between firms and outside sources of skills, in particular universities; and also by ensuring that competition is given free rein.

Kim (1980:255) emphasises the importance of technological change, which is a major determinant of national development. Goldsmith (in Kim 1980:255) points out that many studies have shown that in industrialised economies, more than 50 % of long term economic growth stems from technological changes which improve productivity or lead to new products, processes or industries. However, it remains a challenge for less developed regions of the world to effectively use science and technology for their economic and social development.

Technology is changing at a much faster pace in process and manufacturing industries than in others (Sajid 1995:119). It therefore becomes important for management at higher levels to include reshaping of human resources as part of strategic decisions when building or maintaining technological competencies. With technology changing so fast, it has sometimes become difficult for firms to work alone. It has therefore become important for firms to enter into strategic alliances to share technology, as such alliances may be critical to the continued technology development of many industries. Sajid (1995:120) further indicates the importance of networking and flexibility for continuous technological innovation, which becomes critical for an organisation's competitive success.

Speed is important when planning technological change. Teece and Pisano (1994:538), argue that "winners in the global marketplace have been firms demonstrating timely responsiveness and rapid and flexible product innovation, along with the management capability to effectively coordinate and re-deploy internal and external competencies". This indicates the importance of a firm's dynamic capabilities when planning for technological change, as the firm will have to look at various aspects:

- Its competitive advantage in the shifting character of the environment
- How it will appropriately adapt, integrate, and reconfigure internal and external organisational skills, resources, and functional competencies towards the changing environment.

The theories outlined by the EU White paper on Innovation (1996); Tidd, Bessant and Pavitt (2001); Bell and Pavitt (1993); Lall (1990) and Teece and Pisano (1994), all coincide with the area of study. They show the importance of organisational or structural arrangements when dealing with innovation. Where possible, the environment could also be shaped through such structural arrangements. Innovation could lead to technological change, which requires planning for aspects such as adaptation, capacity, core competencies, resources, competition, market, environmental changes and structural changes. The researcher found it necessary to follow a particular framework for technology development so as to explore industrial technological capabilities from innovation to technology application and national technological competitiveness. The link between the involvement of the private and public sectors had not yet been determined when structural frameworks were developed.

Technological capacity in firms is particularly relevant during planning. Pavitt (1999) indicates that the central importance of technological knowledge and activities embedded within firms goes beyond the necessity to generate new ideas and innovations. It should enable the effective assimilation of technological and scientific knowledge from outside. R&D expenditures and other indicators of technological activity in a business reflect not only the firm's ability to get ahead but also its capacity to keep up. Firms need to establish the extent of this when planning for change.

Kim and Seong (1997:383-384) argue that although South Korea's rapid industrialisation can be attributed to many economic, social, and technical factors, the most important one for industry may be technological change stemming from the accumulation of technological capability over time. Technological capability is the combined outcome of various economic, social, and technical inputs (Kim & Seong 1997:384). Technological capability has been broadly defined as the entire range of human skills (entrepreneurial, managerial and technical) needed to set up and operate industries efficiently over time (Lall 1990:17). This is the ability to make effective use of technological knowledge in production, investment (including duplication and expansion), and innovation, in order to sustain competitiveness in price and quality. It is this technological capability that enables one to assimilate, use, adapt, and change existing technologies. Technological capability also enables one to create new technologies and to develop new products and processes in response to a changing economic environment. The acquisition of technological capabilities is a skill, thus it is a learning process that proceeds at a certain pace dependent on the complexity of the knowledge involved and the initial capabilities of a learner. Stiglitz (in Lall, 1990) mentions that there are inherent differences in the pace of technological development depending on the nature of technology and the technological capabilities available, and so the technological development process gives an additional advantage to those with a favourable endowment of capabilities.

It appears that the technological capability of a country and the levels of its skills development go hand in hand. A country cannot enhance its technological capability if its labour force does not have the absorptive capacity to exploit new technologies to the benefit of its industries (DTI (SA), 2007).

A study by Mani (in DTI (SA), 2007) on the role of government in promoting innovation, compared South Africa, India, Malaysia and Singapore and indicated that the Technology and Human Resources for Industry Programme (THRIP) was unique in that it sought to address one of the most fundamental weaknesses of the National System of Innovation (NSI), namely the shortage of technically trained personnel. According to Mani, none of the instruments has effectively addressed the severe shortage of skilled manpower, not only in manufacturing, but also in research. Only Singapore has an effective innovation policy in the sense that it has been continually fostering its research industry. It has a growing number of patents granted to local enterprises and has one of the highest high-technology export intensities in the world.

Lowe (1995:72,77,115) indicates that the enhancement of the relative competence of industrial personnel in key sectors, at all levels, is an important requisite for human resource levels to sustain growth and international competitiveness. Otherwise, if there is no appropriate education and training policy, there will be insufficient skills and expertise to create, design and manufacture world-class products. For the support and development of the competitive position of particular industries, government support could be function-specific (for example, the specific training of design engineers could be subsidised where there is a shortage of such personnel) as well as task-specific (for example decision skills in the field of technology management could be improved).

Antoniou and Ansoff (2004) believe that the creation, development and application of technology are major forces that make firms or organisations successful, and that those firms that remain in the forefront of technological innovations are the ones that are most successful and technologically competent. They argue that new technologies can be obtained through long-term investment in R&D and capacity building, to ensure that the necessary technological expertise exists within the firm to develop the technological products or services dictated by the market. Firms need to guard against obsolete technologists who could fail to forsee the next technological wave. Capacity building, therefore, is crucial within high-technology fields such as the aircraft industry. Technological obsolescence of technologists can become an obstacle to technological innovation. When a new technology evolves, the existing expertise in firms could become obsolete, so increased capacity and retraining is required to maintain the balance between innovation and competitiveness

Burgelman, Maidique and Wheelwright (1996:34) emphasize the importance of firms building strong technological competencies and strategic capabilities, as these are most likely to generate innovation. Firms that develop distinctive or core technological competencies, through which differential skills, complementary assets, and unique routines are built to create sustainable a competitive advantage, still need to guard against core rigidity. Maintaining technological leadership through the command of a body of technological competencies and capabilities can give firms a global competitive edge, and enable them to remain successful for a long time as a result of their distinct competencies and capabilities that are difficult to replicate. This is quite common in the complex aircraft industry where technological competence impacts on most areas of the value chain.

Pelc (2002) argues that new technologies and their impact on economies accelerate the evolution of the technology management paradigm, which complements two other paradigms – engineering management and technological entrepreneurship. Technology advances and their association with success in many companies, together with their impact on national competitiveness, show that managing technology is essential for building a competitive advantage, and it should form an integral part of business processes, organisations and strategies. The success of technology-based firms can be attributed to their ability to match technology to customer needs, to develop markets, to attract venture capital, and to apply sound business practices. This is where a technological entrepreneurship capability becomes critical, in order to support the expansion of new technology through new business start-ups.

Most of the authors mentioned above outline the meaning of technological capabilities and emphasize the importance of firms accumulating such technological capabilities, as these appear to be linked to the human ability to learn, develop, and apply technological knowledge in the competitiveness of industry. The theory is relevant to this study as it showed the importance of countries accumulating and investing in technological capabilities over time, to become technologically competitive. A critical aspect still lacking in this theory is how firms or industry attain the level where they could accumulate technological capabilities. The researcher believes that the accumulation of technological capabilities should be done in a structured manner, by means of a framework outlining all the key aspects that contribute to the process. Some information was given on how authorities could influence development of know-how, but there was no emphasis on how the framework for technology development should be structured so as to facilitate industrial technological capabilities.

The influence of authorities on the development of know-how was investigated by Parker (2004:294,295), who emphasized the importance of the state's contribution in building competencies in science, technology and industry infrastructure, as part of promoting industrial competitiveness. The strength of the state is usually associated with its ability to develop and implement industry policies, including technology development strategies, independently of major political interests. The state–industry relationship is critical in explaining the ability of some nations to adapt rapidly to international economic change by conquering new export markets or upgrading technological capabilities. The existence of policy linkages between the state and industry allows for the coordination of investment decisions for industry. The state provides an 'encompassing organisational complex' that should be able to assist industry in meeting long-term objectives and lessen the high risk associated with the development and diffusion of new technologies and production processes (Parker 2004:295). Lessons from East Asian economies such as Japan have shown institutions of the state developing formal and informal links with the private sector to enable the gathering of information and coordination activities across a range of sectors and industries. Such lessons are relevant to the South African aircraft industry where there is an urgent need to put in place a framework for all the key structures linked to the process of technology development.

2.1.1 The theory of dynamic capabilities

Most firms could be understood to be using their core competencies and capabilities as a basis for building or developing their competitive advantage (Prencipe 2000:895). Design is one of the core competencies within the aircraft industry that is key to airframe manufacturing's technological performance. A good manufacturing technological performance goes hand in hand with the development of the capabilities required for producing good technology. "Technology is understood here as the body of knowledge underlying the design, development, and manufacture of product" (Prencipe 2001:304). Design is a core competency, and as such should be difficult to imitate. It should be something that differentiates a firm. Some of the capabilities that need to be developed in-house include developing product specifications, evaluating market requirements, integrating component compatibility, and the application of technological advancements. It is important that firms maintain and develop their core capabilities, so as to be technologically competitive. This links to the area under study in that the development of technological capabilities could lead to the development of core capabilities, thereby resulting in technological competitiveness.

Developing countries import foreign technology. However, in order to absorb such technologies effectively, they need some technological capabilities as a base. Fransman (in Costa & de Queiroz 2001:3) has one of the most usual definitions of technological capabilities. It is defined as the "*skills, knowledge and experience* required for firms to pursue certain goals:

- Search for available technological alternatives and select the most appropriate ones
- Dominate the selected technologies, successfully using them for transforming inputs into outputs
- Adapt those technologies to specific conditions of production and local demand
- Achieve subsequent improvements through incremental innovations
- Institutionalise research and development (R&D) activities
- Carry out more basic technological activities, including basic research".

These skills, knowledge and experience form part of technological capabilities, and are acquired and accumulated mainly through technological efforts. This accumulation (or learning) process is known as the technological capability building process. Technological capability building is path dependent and it can consolidate different technological trajectories. These are given direction by technology efforts that depend on technology-, firm-, industry-, and country-specific aspects (Costa & de Queiroz 2001:3). This particular theory supports the area of study in that a structural framework for technology development could depend on various aspects that are linked to the firm, industry, country and availability of technology. These could, however, go deeper into elements of skills, knowledge, and experience and how these elements could be applied in building technological capabilities.

Teece and Pisano (1994:541) developed the dynamic capabilities framework using resource-based theories to assess the competitive advantage of a firm. These theories indicate system integration capability building within firms. The framework distinguishes the following three elements of corporate innovation strategy:

- Competitive and national positions
- Technological paths
- Organisational and managerial processes.

Although their argument emphasizes timely responsiveness for firms in the changing environment of product innovation, along with the management capability to effectively co-ordinate and re-deploy internal and external competencies, the accumulation of resources seems to be the departure point for firms in catching-up economies. However, the biggest problem facing such firms is that before they can acquire the resources needed to face the market challenges, the environment changes. This is a problem that many South African firms face. When planning for change, firms are often faced with the problems of deciding how much to spend (invest) and how to develop difficult-to-imitate processes and paths for new products or processes (Teece & Pisano 1994:552). Following certain trajectories or paths of competence development is critical to central planning, and this is where the concept of a structural framework becomes relevant to facilitate the development of new technologies (be it in the form of new products or processes).

The paths define the choices currently available to the firm, and also delineate what its core competence is likely to be in the future. As a result, firms assess the considerable changes that take place over the years. For example, the tremendous growth in pharmaceutical products led to an improvement in the chemical-based sectors. Another example would be the relative decline in mechanical, electrical and electronic engineering. Firms have to decide which long-term paths to commit to and when to change such paths in terms of existing capabilities in order to develop their core competences.

When building strategies for discontinuous conditions, these are the number of things that should be taken into account (Tidd, Bessant & Pavitt 2001:23):

- Knowledge is becoming central to competitiveness
- Impacts vary, from niches through to sectors and the economy (strong future orientation)
- Change may not affect the entire business: firms need to establish which parts of the organisation will be affected, and react accordingly. The availability of a structural framework would be critical for industry to predict change and impact, and would make it easier to take the necessary measures.

Hwang (2000) argues that the dynamic capabilities framework proposed by Teece and Pisano (1994:539,540,541) has a weakness in not fitting well with catching-up economies. This is because it was designed for the world frontier firms in a rapidly shifting market with changing technologies. However, the aircraft industry has firms from various countries contributing towards the systems integration supply

chain, and therefore this framework becomes relevant to this study as it would have an impact on catching-up economies.
Da Silveira (2002:229) explains dynamic capability as the ability to continuously adapt and integrate the set of skills, resources, and competencies of the firm to an ever-shifting competitive environment. Such dynamic capabilities have been labelled 'high order' capabilities as they provide firms with the capacity to develop other capabilities. Furthermore, dynamic capabilities enable firms to adapt to resources and other capabilities to create new sources of competitive advantage and explore market opportunities. Freeman and Soete (in Da Silveira 2002:229) indicate this dynamic capabilities theory as translating practically into improved products and processes to incorporate new ideas, technical knowledge, and working methods. The theory goes beyond the resource-based strategy view in that it indicates the need for coordinating and redeploying competencies rather than the mere accumulation of assets.

Da Silveira (2002:229) specifies three types of dynamic capabilities:

- Knowledge management to acquire, disseminate, and make use of new learning across the organisation
- Organisational flexibility to reconfigure the organisation rapidly to deliver new products and services and work with new process technologies
- Innovation capabilities, mainly R&D and new product development methods, to constantly adapt products and processes to new technologies and customer requirements.

One major challenge to dynamic capability development, as indicated by Da Silveira (2002:229), arises from the evolutionary nature of dynamic capabilities, which are always 'built' and not 'bought', and so development mostly takes an incremental rather than a radical form. For this reason, successful innovative firms have often been characterised by strong in-house, professional R&D, and heavy R&D expenditure over long periods.

According to Lall (2000), the dynamic capabilities perspective, when applied to a country would "suggest that comparative advantage depends more on the national ability to master and use technology than other factor endowments". Dosi, Pavitt and Soete (1990), believe that the path a country has taken to its present level of development has a crucial role in the determination of future growth, having shaped its dynamic assets. Lall (2001) indicates that countries should try to change from purely comparative advantages to competitive advantages when these do not coincide. The comparative advantages of most developed economies have largely been in dynamic sectors with high value-added production of goods and services, while developing economies have mostly followed a different pattern that relies on commodity production with a very low content of technology. Although firms in developing countries historically lacked technological experience or the organisational capabilities needed to enter global markets, they need not remain in traditionally low-technology industries. They are gradually becoming more involved in dynamic and high technology industries.

Prencipe (2001:305,306) argues that besides R&D, design, and manufacturing capabilities, firms producing multi-technology products should develop four main types of technological capabilities to compete successfully over time:

- *Absorptive capabilities* are necessary for monitoring, identifying, and evaluating new opportunities emerging from general advances in science and technology. This is in line with the concept of absorptive capacity proposed by Cohen and Levinthal (1990:128).
- *Integrative capabilities* are necessary to set the requirements, specify source equipment, materials, and components, which can be designed and manufactured either internally or externally, and integrate them into the architectures of existing products. These enable firms to gain a better understanding of the underlying technologies of outsourced components so as to control and integrate changes and improvements.
- *Coordinative capabilities* are needed to coordinate the development of new and emerging bodies of technological knowledge. Such capabilities need to be developed for the coordination of change across different bodies of technological knowledge, and also across organisational boundaries. It is important for firms that develop multi-technology products to keep pace with and, more importantly, coordinate uneven technological developments to incorporate them into new products and processes. Where firms lack in-house capabilities for certain technology areas, the management of the relationships

with, and coordination of, external sources becomes crucial.

- *Generative capabilities* are key to innovation both at the component level and the architecture level, independently of external sources. This involves exploratory research programmes which play a fundamental role in the introduction of new component technologies as well as new product architectures.

Costa and de Queiroz (2001:11) introduce an essential element of the learning or technology capability-building process, where a distinction is made between *meta-technological capabilities* and *functional-technological capabilities*. Three types of functional-technological capabilities are proposed: *operational*, *improvement*, and *generation* capabilities. Operational capabilities are the technology capabilities related to efficient performance and productivity. They encompass the skills, knowledge and experience to search, acquire, assimilate, use, dominate, and make technology adaptations. Improvement capabilities are related to the skills and knowledge needed for improvement, imitation, creativity and the adoption of acquired technologies. Generation capabilities are the technological capabilities characterised by technologically creative skills and the knowledge needed for generating own innovations.

The literature discussed above corresponds to the area of study. It shows the importance of linking dynamic capability-building theory to resource-based strategy and how these compliment one another. In the theories discussed above, there is convergence of dynamic capabilities through to technological capabilities. These lead to the aspect of incorporating a range of issues around technology development from structural organisation to key elements of efficiency and productivity such as skills, resources and innovation. The effective use of existing capacity to develop other capabilities, be they skills, knowledge, or innovation capabilities, could eventually lead to technological capabilities. Accumulating a wide range of technological capabilities, such as the absorptive, integrative, coordinative and generative capabilities mentioned above, would require the proper support structures that this study identifies as constituting a framework for technology development. Based on the available literature, it can be determined that the South African civil aircraft industry needs to strengthen its capabilities to capitalise on the business growth prospects of the industry. The South African aircraft industry has already built a core competence in Africa for aircraft maintenance and aircraft conversions of military and civil aircraft, which it can use as a competitive advantage to be the main aviation hub in Africa. This was achieved as a result of the dynamic capabilities that were built around skills and knowledge of aircraft maintenance, and the well-established training centres that facilitate skills development and transfer. The generative capabilities of the South African aircraft industry were built around the design and manufacture of helicopters, and the manufacture and supply of components and sub-systems.

Although some capabilities have been built in the area of skills and technology development, more are needed by the South African aircraft industry. This therefore calls for the skilled people present in the labour force of the industry to be utilised in strategic areas where their skills could be fully exploited and transferred accordingly, now and in the future. Although very limited in number, these skilled people exist right across the aerospace sector, from artisans undergoing workplace learning for production purposes, through to the scientists working on innovative future technologies in academia and the science councils.

The literature indicates that the South African civil aircraft industry needs to build capabilities around the development of the following technologies:

- Composite materials
- Alloy technologies
- Ultra-light materials.

This study was aimed at proposing an empirical framework that would fully exploit and further develop existing technological capabilities to create more competitive advantages and the crucial core competence to develop a national technologically competitive civil aircraft industry.

2.1.2 Technological knowledge, learning and absorptive capacity

The study by Patel and Pavitt (1993) discusses the concept or theory of National Systems of Innovation (NSI) and the importance of interactive learning processes in shaping the capability building of firms. National Systems of Innovation are defined as the national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning in a country (Patel & Pavitt, 1993). Four sets of institutions exist within the National Systems of Innovation:

- Business firms
- Universities and similar institutions offering basic research and related training
- Both public and private institutions, offering general education and vocational training
- Governments, promoting technical change through the provision of finance and regulation.

These four types of institutions are applicable to the South African situation within a framework to enhance the rate, and shape the direction, of learning within the aircraft industry.

Government needs to facilitate technological learning at individual firms to keep pace with the dynamically changing global technology environment. Kim (1998b) supports the theory by stating that government should provide a technology policy framework that can address three perspectives, a *market mechanism perspective*, a *technology flow perspective* and a *time perspective*, as part of the facilitation of technological learning.

With the *market mechanism perspective*, the focus is on both the demand side and the supply side of technology development. Support should be provided for technological development in three major ways:

- To strengthen the demand side, thereby assisting in creating market demand for technology
- To strengthen the supply side, thereby increasing science and technology capabilities
- To provide effective linkages between the demand and supply sides, in an attempt to ensure that innovation activities are both technically and commercially successful.

Irrespective of the presence of both demand for innovation and supply of capabilities, few innovations can be expected to take place unless there is good management of the R&D system, effectively linking demand to supply.

The *technology flow perspective* focuses mainly on three key sequences in the flow of technology from abroad to developing countries:

- The transfer of foreign technology
- The diffusion of imported technology
- The indigenous R&D to assimilate and improve imported technology and to generate own technology.

The first sequence involves technology transfer from abroad through such formal mechanisms as foreign direct investment (FDI); the purchase of turnkey plants and machinery; foreign licenses (FLs); and technical services. The effective diffusion of imported technology within an industry and across industries is the second sequence in upgrading the technological capability of an economy. The third sequence involves local efforts to assimilate, adapt and improve imported technology and eventually to develop one's own technology. These efforts are crucial to augmenting technology transfer and expediting the acquisition of technological capability. Technology may be transferred to a firm from abroad or through local diffusion, but the ability to make effective use of it cannot be achieved automatically. Such ability can only be acquired through indigenous technological effort; therefore government support becomes crucial in that regard.

The *time perspective* indicates the impact of technology flow and market mechanisms, which will change over time as industries in developing countries advance through different stages of development.

Architectural knowledge is needed to inform designers about other component specifications, such as interfaces (Brusoni & Prencipe 2001:181). This is important in that during technological change, architectural innovation alters interfaces. Knowledge management becomes a crucial area with regard to the enhancement of learning and capability building within firms. This becomes relevant even in cases of technology transfer, from the use of imported technology to the stage where firms could generate own-technology after learning. The theories above outline the importance of knowledge (and its management), learning, and absorptive capacity when building technological capabilities. The National

Systems of Innovation (NSI) theory by Patel and Pavitt (1993) highlights the types of institutions that could shape technological learning, whereas the theory by Kim (1998a) provides, in addition, a perspective on technological learning that touches on technology flow, market, and time. In both instances, external factors could impact on technological learning; therefore the availability of a structural framework for technological capability building could supply additional interfaces and the way in which various institutions could contribute towards the entire process.

Technological learning is connected to the availability of infrastructural resources. For example, it could be that there are not enough aircraft available for training purposes due to reduced investment in aircraft, or the associated high costs. As a result, aircraft mechanics may have to acquire some of their knowledge from study manuals, which don't always provide comprehensive coverage or the necessary hands-on experience. Smrcka (2003) explains the importance of the Advanced Integrated Training in Aeronautics Maintenance (Aitram) program for virtual aircraft maintenance. The program offers advantages such as 'learning by doing', reduced training time, reduced costs and risks, and the teaching of complex learning material in an easy, comprehensive manner. This virtual training program has been designed to assist engineers in becoming better equipped for routine work, and to avoid 'human error' – if a mistake is made, the session ends immediately. Boeing and Airbus are interested in the Aitram program for their staff training.

Various sources evaluate the potential of laggard economic units (countries or firms) to catch up and converge with economic units at the frontier. Amongst these are Dahlman and Nelson (1995), who define national absorptive capacity as "the ability to learn and implement the technologies and associated practices of already developed countries". At the industrial level of analysis, Cohen and Levinthal (1990:128) provide the most robust seminal work on absorptive capacity. Their definition of a firm's absorptive capacity highlights three aspects:

- The ability to value knowledge
- The ability to assimilate knowledge
- The ability to apply knowledge.

It is often asserted that many small and medium enterprises (SMEs) fail to exploit the information, knowledge and skills in the knowledge base embodied by higher education, research institutes, and large companies (Iles & Yolles, 2002). The existing technology gap between SMEs and the knowledge base needs to be bridged by a technology translation process whereby knowledge migration from the knowledge base (source) to the knowledge sink (SMEs) occurs. The same model applies when technology is transferred from one country to another. Apart from South Africa being less technologically competent than most developed countries, the South African aircraft industry also faces the challenge of bridging the technology gap between SMEs and the technology base, as most SMEs suffer from a lack of support from large South African firms.

Other researchers expound on this definition of absorptive capacity as follows:

- A firm's ability to *value* knowledge depends on its prior experiences and investments (Kim, 1997 and 1998a)
- The ability to *assimilate* knowledge depends on a firm's ability to comprehend and understand that particular knowledge and its characteristics (Gilbert & Cordey-Hayes, 1996)
- The capacity to *apply* this new knowledge depends on a firm's ability to see innovative uses for that knowledge (Teece, 1997; Van den Bosch, Volberda & de Boer, 1999).

"The growth and nurturing of core technological capabilities require constant fertilizing by streams of information" (Leonard-Barton 1995:177,178). Receiving knowledge from the market is important to a technology-based firm. Figure 2.1 shows knowledge-creating activities where knowledge is imported from the market. Core technological capabilities can become sustainable when there is constant information flow from the market, and that imported knowledge can be used in other knowledge-creating activities such as problem solving, implementation and integration, and experimentation (R&D). This theory confirms the need for a proper structural framework that exhibits a flow in the building of technological capabilities.

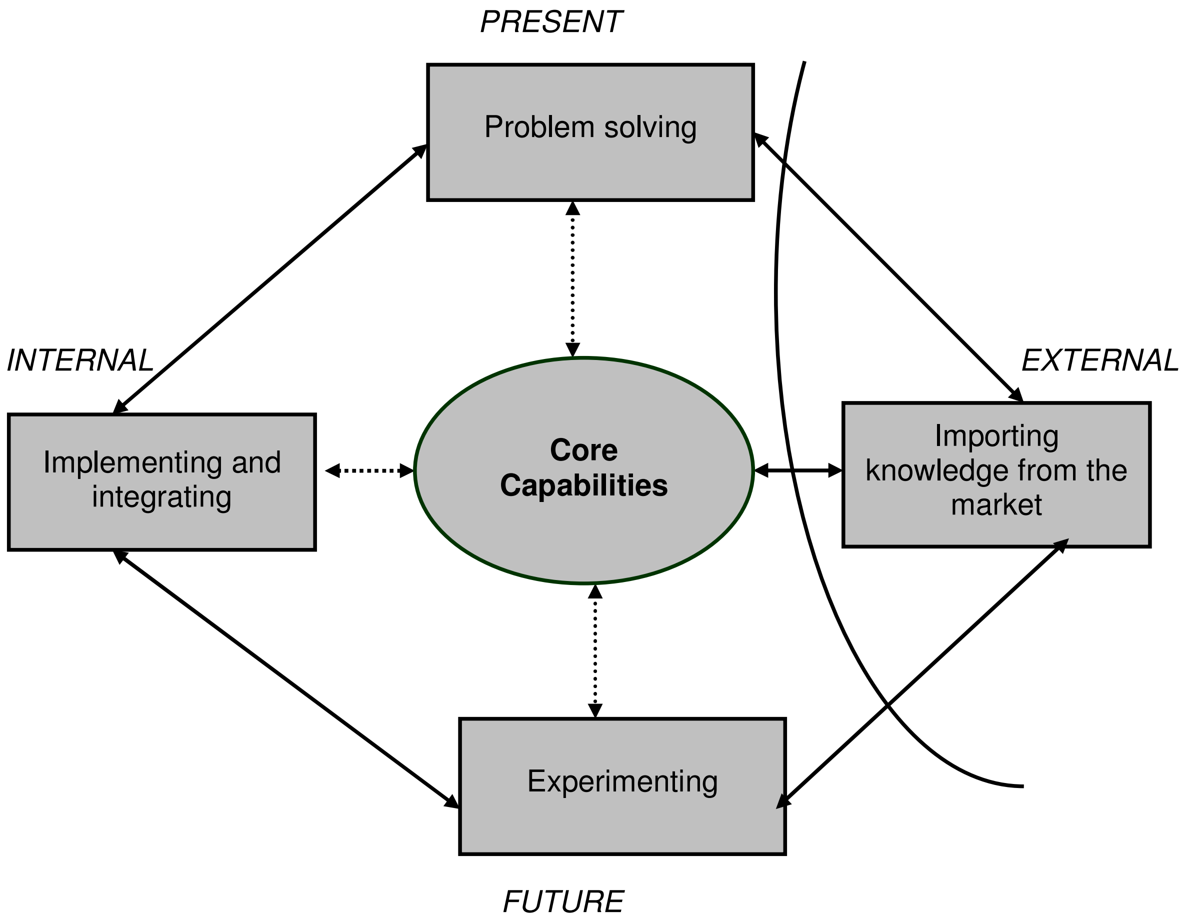

Figure 2.1 Knowledge-creating activities: Importing knowledge from the market
Source: Adapted from Leonard-Barton (1995)

2.1.3 National environmental factors and a firm's competitive advantage

Parker (2004:294,295) proposes that technology development and innovation are related to national and local competencies. Elements of the domestic science, technology and industry infrastructure, such as the capacity for learning and generation of new ideas, stock of knowledge and competency in the economy, vary cross-nationally and tend to be related to the level of participation of a nation in knowledge-intensive activities. A study by Porter (1990) provides a framework (Figure 2.2) for the determinants of national advantage, which explains the role played by national policies and the environment in the capability building of firms within nations. This framework shows four aspects of a nation that shape the environment in which local firms compete, leading to the creation or impediment of a competitive advantage. These attributes are factor conditions; demand conditions; related and supporting industries; and firm strategy, structure and rivalry. These aspects are related to each other; therefore advantages in one might create advantages for another, thereby making the system favourable.

The study further indicates that favourable factors have to be created and upgraded continuously because of rapid shifts in the market, in order to sustain competitiveness (Porter, 1990). These determinants tend to be influenced by two other variables, 'chance' and 'government'. This framework is relevant to the study, but its applicability, with or without modifications, to the facilitation of technology development in the South African aircraft industry needs to be assessed. What is interesting in this framework is the influence that government seems to have on all aspects of the nation in the field of capability building.

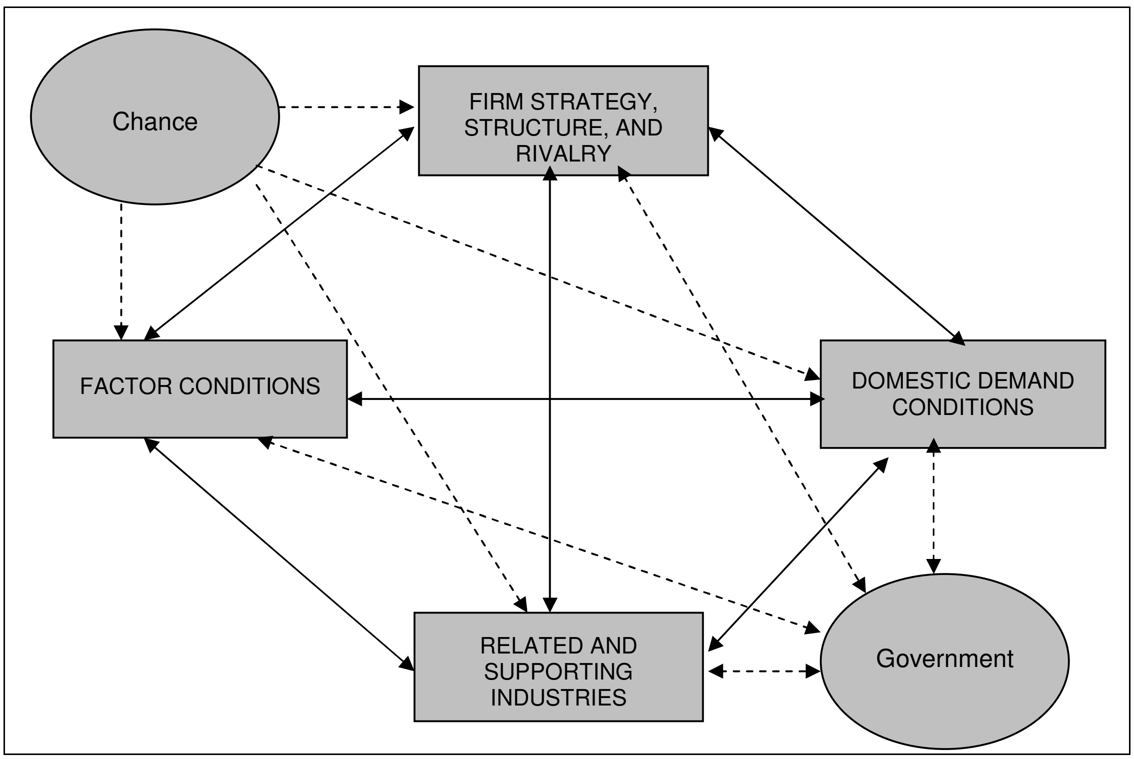

Figure 2.2 Determinants of national advantage
Source: Porter (1990)

Hwang (2000) qualifies Porter's framework of national factors for capability building to suit the South Korean aircraft industry (Figure 2.3). This framework revises the four main elements of national environmental factors and the role of government in promoting competitiveness. It excludes 'chance', because chance events can not be controlled in the way they influence capability building. It is only after they have taken place that they can be manipulated.

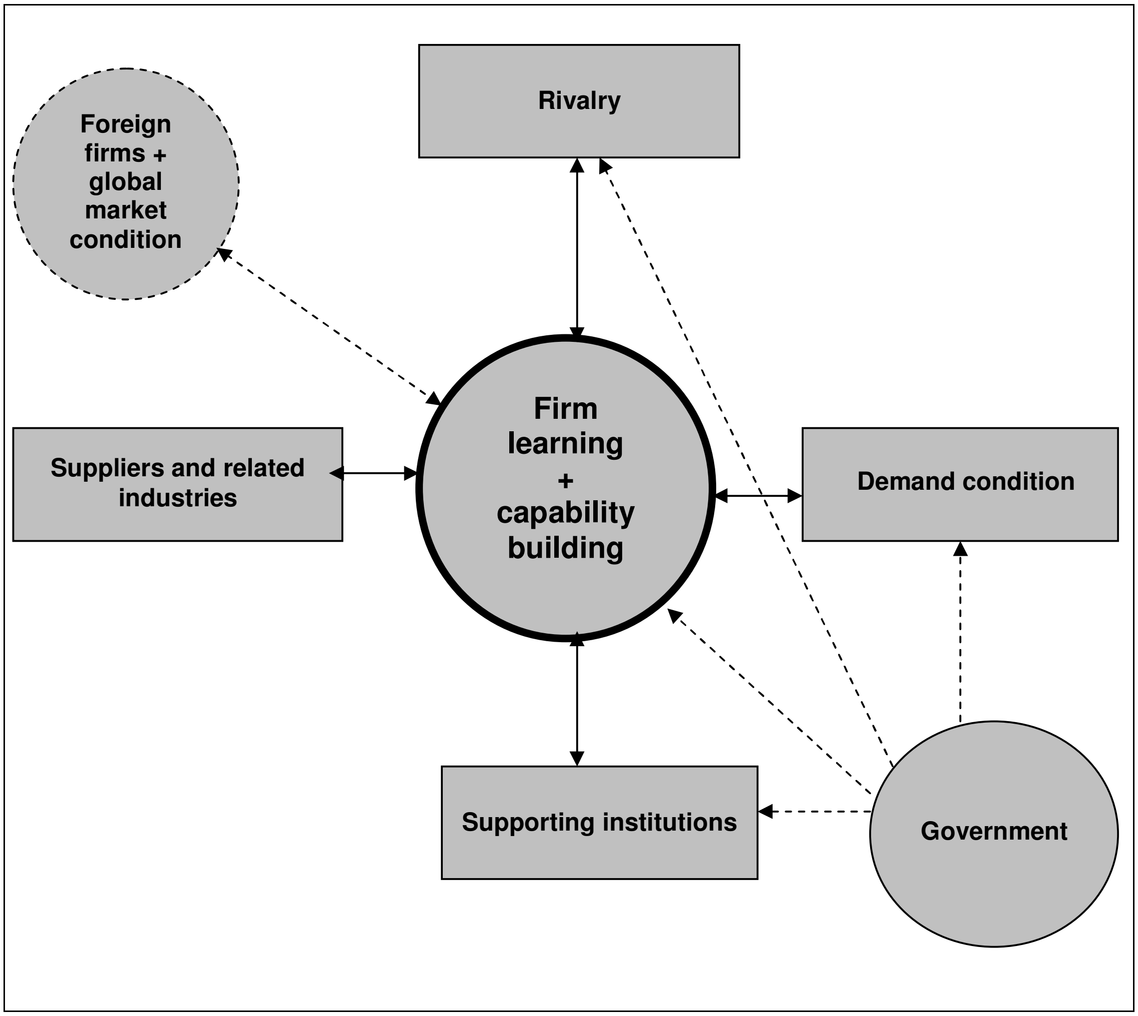

Figure 2.3 National factors in capability building
Source: Hwang (2000)

Davies and Brady (1998:293), indicate how patterns of technological innovation in complex product systems (CoPS) may be influenced by policies of direct and indirect government control to promote industrial leadership. An example is the cellular mobile communications system infrastructure, (classified under CoPS) where it is believed that European manufacturers have taken the lead over North America and East Asia because of government involvement in the shaping of domestic market structures by such means as regulation, licensing, and spectrum allocation policies. In addition they are supporting domestic manufacturing interests in foreign markets by promoting national technologies as global standards.

As previously indicated under the theory of Dynamic Capabilities, most firms use their core competencies and capabilities as the basis for building or developing their competitive advantage (Prencipe 2000:895). Design is one of the core competencies in airframe manufacturing.

Davies and Brady (2000:931) explain how the suppliers of CoPS build the required capabilities to expand and compete successfully with new products or services. Firms can achieve 'economies of repetition' by putting in place organisational changes, routines and learning processes to execute a growing number of similar projects at lower cost, more effectively. Burns and Stalker (in Davies & Brady 2000:934) argue that firms adjusting to changing technology and markets may adopt two ideal types of management organisation: 'mechanistic' and 'organic' organisation. In mechanistic organisation, tasks are broken down into specialisms, with a clear hierarchy of control. For organic organisation, new and unexpected problems continue to arise and they cannot be broken down among existing specialist roles. Knowledge at lower levels of the organisation is utilised to achieve the overall goals of the organisation, with communication taking place in a more informal, less hierarchical manner. The ability of a firm to adapt to changing business requirements partly depends on 'absorptive capacity', which is based on a firm's prior knowledge and experiences in relation to new technologies. Changes in the environment can force firms to renew their capabilities and organisation.

Cohen and Levinthal (1990:128,129,130,131) argue that without developing, acquiring or adapting the competencies needed for new markets, it is not easy for firms to provide services that were previously not their core competency. It becomes important for firms to recognise the value of new external knowledge and information, and to be able to assimilate and apply it to meet new civil objectives.

Capability building in latecomer firms involves catching-up strategies within an unfavourable environment with regard to technology, knowledge, skilled personnel, finance, market conditions, and infrastructure. For such firms to succeed, they have to acquire the necessary capabilities from advanced economies, make adaptations and implement incremental innovation where possible.

In aircraft manufacturing, firms now provide finance and maintenance throughout the product lifecycle. This includes providing other services by means of exploiting the down-streaming opportunities. This explains the shift in focus from operational excellence to customer allegiance. The capabilities firms need in order to move successfully into the provision of integrated solutions include system integration, operational services, business consulting, and financing (Davies with Tang, Brady, Hobday, Rush & Gann, 2001).

Systems integration is one other crucial area having an impact on increasing competitiveness in the aerospace industry. Systems integration is described as the ability to design, produce, test, and implement large-scale complex systems whose individual elements often utilise advanced technology components (US Technology Policy and Trend Report, 1995). The development of technological competencies and capabilities is critically important because of the complexity of the component technologies involved and of the entire systems integration process. Systems integration can be heavily affected by national environmental factors and a firm's competitive capabilities. The primary focus of systems integration is to ensure that components and subsystems are conceived and developed as integrated packages to meet an overall system design so that they work effectively with other contributors in the supply chain to the desired outcome (Davies et al, 2001). This is not an easy task, as the entire development process involves coordination of the innovation activities in the supply chain.

Success in the aircraft industry also depends on design and manufacturing strength, the price and operational costs of aircraft, and the after-sale services available to customers. Although the number of customers may be relatively low, they are frequently spread throughout the world (Goldstein, 2001). It is therefore imperative for firms to capacitate themselves in line with competitive trends, and to overcome barriers associated with national environmental factors that impact on global technological competitiveness. The reduction costs over time from 'learning by doing' are known to be unusually high. In addition, the launch and R&D costs, including survival risk, are also high. The aircraft industry is therefore a global oligopolistic sector, where most of the developed economies that are currently offering world-class aeroplanes had established aviation industries by the end of World War I.

An aircraft ceases to be a science project and becomes a costly machine that needs to earn its investment back once it is certified and enters production (Engineering News, October 2003). It becomes the responsibility of the aircraft maintenance organisation whose maintenance engineer has to maintain it in accordance with the requirements laid down by the manufacturer. Wise and Baumgartner (1999) state that the downstream chain, which includes financing and leasing; maintenance; scheduling and capacity planning; catering and servicing; parts-depot operations; refurbishment and resale; as well as aircraft operation, is much more complex in the aircraft market than other markets.

The theory in this section discusses the influence of the national environment on the building of technological capabilities. Government is critical in shaping this environment. The importance of firms continually building technological capabilities because of the changing environment influenced by the changing technologies and markets, has also been highlighted. It becomes evident that firms must be able to adapt to the changing environment and develop competencies for new markets, especially latecomer firms that may exist in an unfavourable environment. Systems integration within the development of an aircraft industry is heavily affected by national environmental factors because of the long chain of activities that may involve other nations. The theory indicates the importance of building technological capabilities beyond manufacturing, so that maintenance and the management of the value chain system become significant. The facts above show that the availability of an empirical framework for technological capability building is key in linking all the various aspects needed for technology development.

2.1.3.1 The role of government in building national technological capabilities and competencies

Where technology policy is deemed a necessity, it is the role of government to provide support to effectively promote, coordinate and encourage technology development and intake, so as to provide inputs into the overall industrial policy (DTI (SA), 2007). It is crucial that government provides a technology policy framework that caters for the establishment of adequate and appropriate mechanisms and/or systems to coordinate effectively all technology development activities within the sectors believed to be key in industrial development and competitiveness. These activities include technology awareness, acquisition, diffusion, as well as the monitoring of global technology development trends. One of the mechanisms used is the provision of incentive programmes to facilitate the development, promotion and implementation of technological innovations and ideas aimed at industrial development and competitiveness across all the sectors. With a well-structured technology policy framework in place, it becomes easier for a nation to identify positive and negative factors impacting on technology enhancement, as well as mechanisms that allow for an increased innovation capacity and technology transfer and diffusion. This leads to improved national technological competitiveness.

International trends in technology policy indicate the following main objectives (DTI (SA), 2007):

- To identify, promote and encourage the development of technologies relevant to the needs of the country
- To develop a technology infrastructure to meet existing and future needs of industrial development and global competitiveness
- To develop mechanisms for collecting, analysing, evaluating, selecting and disseminating technology information, thereby ensuring there is a regular flow of vital technology information to key sectors of the economy
- To employ technology for the efficient utilisation of a nation's resources
- To provide standardisation and quality systems in the production of goods and services for the enhancement of competitiveness in local and foreign trade
- To promote the educational and professional development of human resources

to support the needs of the scientific technology community

- To improve the quality of life of citizens and to protect and conserve the natural environment
- To support the integration of technology in macro-economic planning
- To promote the inclusion and advancement of all social groups in the technology application
- To increase the public awareness and acceptance of technology.

Of these objectives, the need to develop a technology infrastructure to meet existing and future needs of industrial development and global competitiveness is the most applicable to this study. The development of a technology infrastructure could be guided by a framework that highlights the key elements required in technological capability building.

Until the 1980s, government exercised direct control over the supply of CoPS through state ownership, purchasing decisions, subsidies and protection policies (Davies & Brady 1998:296,297). Before that, many European governments encouraged the consolidation of strategic industries in cases where CoPS suppliers faced strong foreign competition, where national champions were formed from a number of existing firms in areas such as aerospace, defence and telecommunications. To prepare them for foreign competition, these national champions benefited in their home markets from direct government intervention through protectionist policies such as public procurement programmes, R&D subsidies and exclusive rights for home-based companies. During the 1990s, government strategy changed from direct control towards market competition, where new forms of indirect control were initiated to promote competitiveness. The current trend in innovation and industrial competitiveness is to expose domestic CoPS suppliers to the disciplines of foreign competition, in order to enhance technological competitiveness. Governments continue to be directly involved in promoting CoPS by providing subsidies (for example the EU's fifth and sixth framework programme) and also by being state-owned suppliers or purchasers of equipment.

Mowery and Rosenberg (1982:171) allude to the importance of government intervention and its support in enhancing the supply of potential innovations in the aircraft industry. Government policies were found to have an impact on the demand for innovation by the civil aircraft industry, and an influence on the structure and conduct of the air transportation industry, by providing substantial incentives for rapid adoption of innovations.

The basic requirement for the continued growth and development of national economies is the acquisition and creation of technological capabilities (Focus group progress report, 2003). However, a nation's specific economic situation and overall social environment will shape the patterns of technological development. Government and other sources are required to play a complementary role, since catching-up economies lack some of the prerequisite conditions for economic growth. Catching-up economies are characteristically faced with two tasks: firstly, to utilise latecomer advantages fully, to enable themselves to catch up with advanced economies, and secondly, to build up indigenous science and technology bases for supporting economic performances.

The study on Airbus versus Boeing examines international competition in the civil aircraft industry, with an emphasis on the market requirements, dynamic capabilities and competencies of firms (Irwin & Pavcnik, 2001). It focuses on the differentiated-products demand system for wide-bodied aircraft and examines the international rivalry of firms using various assumptions about firm conduct. The study also looks at the limiting of aircraft subsidies in the 1992 US–EU agreement on trade in civil aircraft, which is believed to have had a significant impact on pricing in the aircraft market. The presence of multi-product firms makes it more challenging for aircraft companies to introduce new aircraft successfully without detracting from existing product lines. The study did not, however, address the issues of strategic trade policies that are more dynamic in nature, such as the role of government subsidies in assisting firms to develop capabilities to facilitate growth and entry into the aircraft market.

Neven and Seabright (1995) provide an analysis of the impact of Airbus on the market for large jet aircraft. They characterise various stages in the development of the large civil airline market, which is dominated by three companies, Boeing, Airbus and McDonnel Douglas. The large civil airline market has four market segments:

- Short range, narrow bodied
- Medium range, medium bodied
- Long range, medium bodied
- Long range, wide bodied.

The study provides two justifications for government subsidies of activities that could be expected to be profitable:

- The perception exists that private capital markets often fail to fund activities that have a profitable expectation, but happen to have a long investment horizon.
- The knowledge of government's involvement in, or support for, activities may add credibility to a producer's presence in the market. As a result, it may deter either predation by an established rival or entry by new one.

The involvement of government in the industry could affect the success of entry, if not the credibility of the venture (Neven & Seabright, 1995).

The study also highlights the consequences for Airbus of European public support, without which it would probably have been difficult, if not impossible, to enter the market successfully, as government support was absent initially. Government support for the Airbus A-320 programme is believed to have induced Boeing to produce a new version of the 737 in the narrow-bodied segment of the small range aircraft market. Bonaccorsi and Giuri (2001) provide a novel contribution to the role of demand for technological competition, with an emphasis on the analysis of the mechanisms of technological learning and the spillovers that occur in different structures of networks of vertically related industries. Such analysis highlights the issue of technological competition among suppliers, and the structure of the network of two vertically related industries, namely the civil jet and turboprop aero-engine and aircraft industries. This could influence the facilitation of technology development within the aircraft industry.

The theories discussed above conclude that government can play a key role in influencing the facilitation of technology development, through support mechanisms in the form of incentive programmes or policy guidelines. For developing economies, government support has been shown to be critical as firms acting alone find it difficult to provide the necessary infrastructure required for technology development.

2.2 Innovation and technology challenges for civil aircraft development

The Department of Trade and Industry (DTI) SA has identified the South African aircraft industry as an important sector of the country's manufacturing capability. It is an important cluster that should be promoted and developed further (Campbell, 2003). In the past, the South African industry developed competitive technologies for the military aircraft sector, which can be used as a basis for future development of technologies for the civil aircraft sector. According to De Bruijn and Steenhuis (2004:383), there is a linkage between civil aircraft technologies and military aircraft technologies. Nevertheless, it remains a challenge for South African firms to develop the civil aircraft industry to higher levels of technological competence, as have other developing or latecomer economies.

Military and civilian aircraft industry needs are very different in terms of design demands, economies of scale, economies of scope, and the experience curve (Chiang 1999:263). In high-tech fields, little civil–military integration exists because of the dual structure or segregation of the defence and civil technology and industrial bases. The existing differences do not necessarily hinder learning from one another. Some of the benefits that aircraft firms have exploited in the civil aircraft market draw on their military experience. Although Chiang (1999:263) suggests that civil benefit from military experience is minimal, this does not mean that such experience cannot be fully exploited when it comes to building technological capabilities.

In emerging economies (Chiang 1999:264), the domestic capabilities for a military system usually evolve in a specific sequence. They begin with maintenance and repair, followed by licensed production and modification; independent production of subsystems; and lastly indigenous design, development and production of the whole system (which may still require supplies of critical parts and subsystems from advanced countries). It would be possible for firms with military experience to convert their defence capacity into civil capacity. The assumption is that spin-offs would be more intense if military and civilian technologies were more similar or the military and civilian communities were more closely interactive (Chiang 1999:267). The facilitation of spin-offs could be through such mechanisms as personal contact, R&D cooperation, technical consultation, technology demonstration, technical data provision, publications, conferences, and the mobility of personnel from mission-oriented programs to civilian industry.

The large civil aircraft manufacturing industry is characterised by the following factors (De Bruijn & Steenhuis 2004:383):

- *Huge investment* – Investment in a new aircraft design is usually very high; for example, the estimated development costs for the Airbus A380 were approximately US$11–12 billion.
- *High risk* – Because it takes several years to develop a new aircraft, the new product demand is uncertain.
- *Political context* – Aircraft production and sales are heavily influenced or controlled by government activities; for example, governments in industrially developing countries might require aircraft manufacturing companies to produce in their own countries.
- *Cyclical demand* – The demand for customer travel is cyclical, and therefore so is aircraft demand. In 1999, Boeing delivered 573 aircraft, its highest total, whereas the production for 2003 was expected to be only 380 aircraft.

Chiang (1999:269) further highlights some of the challenges faced by newly industrialised countries in relation to aircraft industry development, using Taiwan as an example. The challenges are the following:

- "A limited domestic base of human resources and infrastructure in the aircraft industry
- Limited suppliers and related industries that are internationally competitive
- The lack of home demand for civil products and thus the existence of two-edged direct pressures on firms to compete globally

- Little acquaintance with global civil practices, coupled with inexperience in integrating the military and civilian sides of the industry".

Some authors referred to above highlight the challenges faced by developing economies in the development of the civil aircraft industry. The existence of such challenges can obviously impact negatively on the technological development of the industry. The authors also discuss how civil aircraft development could benefit from the technological capabilities built as a result of military aircraft development, including the spin-offs thereof. How the facilitation of spin-offs from military to civil technologies, through mechanisms such as R&D co-operation and mobility of staff, could be structured, is not discussed, however.

Few studies exist on catching-up theories, in relation to complex systems such as an aircraft. However, literature exists on the complexity of the aircraft industry, which explains the challenges faced by firms or nations with regard to technological and innovation capabilities as directed by the international trends or trajectories of the aircraft market.

South African aircraft firms are regarded as latecomer firms because they lag behind in terms of innovation and technology development, as well as integration into the global value chain system. Hobday (1995) defines a latecomer firm as a manufacturing company that faces two competitive disadvantages in attempting to compete in export markets. The first is a technological disadvantage, where firms are dislocated from the main international sources of technology and R&D. The second is a market disadvantage, where firms are dislocated from the mainstream international markets and demanding users they wish to supply.

Catching-up firms, in South Africa's case, have insufficient in-house technological capability, poor external environment, and underdeveloped national systems of innovation. Latecomer firms have to overcome their technological disadvantages, devise ways of overcoming market barriers to entry, and forge the user–producer linkages that stimulate technological advancement, so as to succeed in catching up. The challenge facing latecomer firms is how to successfully design and implement the corporate strategies that could enable them to overcome barriers related to international markets, and to acquire the necessary technology.

Hobday (1998) classifies the aircraft system (including jet fighters and civil aircraft) as complex. This system has several significant differences compared with mass production in terms of production process, system hierarchy, complexity, customisation, and market structure.

Davies and Brady (1998:295) differentiate between high value added complex product systems (CoPS) and mass production products by explaining that CoPS are developed and produced as single items or in small tailored batches for large business users. Table 2.1 shows a range of CoPS and mass-produced products supplied by a number of strategic European countries. It is difficult to explain the pattern of innovation and industrial competitiveness of CoPS because they tend to remain in a fluid phase of product innovation and follow a different cycle of innovation and industrial competition. Davies and Brady (1998:295,296) indentify the following major characteristics of CoPS, as opposed to mass-produced products:

- CoPS involve a high degree of customisation in the final product and its key components, therefore close attention has to be paid to the criteria of component and interface compatibility with existing and future component technologies and standards
- CoPS are produced as units or in small batches rather than in high volumes, and are designed by project organisations. Production starts after an order has been obtained, with modification of the design to suit customer requirements, unlike in mass production where product development occurs first, followed by the actual production, then the marketing of the final product to the clients
- Industries supplying CoPS are usually bilateral oligopolies with a few large suppliers facing a few large customers in each country
- Users such as air traffic controllers, airlines, etc, tend to be heavily involved in CoPS since their competitive survival often depends on the technical quality and performance of the final product.

Table 2.1 Selected examples of Complex Product Systems (CoPS) and mass-production products by sector

Sectors	CoPS	Mass production
Aerospace	*Airports, airtraffic control systems, baggage handling systems, aircraft, ground support vehicles.*	*Aircraft components (eg tyres) and consumables (eg de-icing fluid).*
Rail and tramway	Stations, tunnels and viaducts, locomotives, carriages and wagons. Electrical signalling equipment.	Brake blocks, wheels, sleepers, lighting equipment.
Telecommunications	Mobile phone systems, digital exchanges, broadband networks, military central command and control systems.	Telephone handsets, fax machines, pocket pagers.
Electronics	Semiconductor fabrication plant, banking automation systems, business information networks.	Personal computers, electronic calculators, printers, consumer durables.
Heavy engineering	Offshore drilling rigs, dams, steelwork plant, chemical plant, hydro-electric plant, machine tools, industrial turbines, cranes.	Hand tools and implements, jigs and dies

Source: Adapted from Davies and Brady (1998)

According to Tidd, Bessant and Pavitt (2001:41), complex product systems (CoPS) represent an interesting case, involving the kind of technological systems which bring together a number of different elements into an integrated whole, often involving different firms, long timescales and high levels of technological risk. All the variations within a complex system make it very difficult for firms to innovate or advance technology development. Therefore strong strategic and technology management capabilities are required to guide the process towards technological competitiveness.

Henderson and Clark (1990) define the aircraft system as a complex system, consisting of numerous parts and subsystems. The interaction between many functional subsystems makes it extremely difficult to predict overall performance, hence linkage and interface technology between components and subsystems is critical in the performance and safety of the aircraft. Furthermore, Prencipe (1997) indicates that the high degree of interdependence among components and subsystems requires close configuration of their performances in order to achieve an optimal match. One of the challenges facing airframe manufacturers and component suppliers is having the necessary multi-skills, including component knowledge and how such components link and operate together as a system. Innovation and technology play a pivotal role in such a challenge being met.

The Department of Trade and Industry (UK)'s independent report by the Aerospace Innovation and Growth Team (AeIGT) also alludes to the complexity of the aircraft system ((DTI) UK, 2003). It described aerospace, which includes aircraft, as being composed of an unusual combination of industrial characteristics that tend to differentiate it from other areas of manufacturing as follows:

- High levels of technological and scientific intensity
- High cost and high risk programmes
- Long development and payback cycles
- Low volume, high value products
- Civil–military linkages
- International collaboration in design and development
- Central role of government as sponsor, customer, regulatory and market gatekeeper
- High barriers to entry
- Highly safety critical
- Long service life.

Various authors referred to above emphasize the complexity of the civil aircraft system and the importance of giving attention to interface compatibility to ensure the success of final products. It is evident that developing economies need to build technological capabilities to be able to deal with the complexity challenges of the civil aircraft system. However, how firms in developing economies should deal with the technological capability challenges that have resulted in their being dislocated from international markets and international sources of technology and R&D, was not discussed.

2.2.1 The need for technology advancement and sustainable development

Firms should be organisationally and culturally flexible enough to meet the massive changes associated with technology advancement (Sajid, 1995). Long-term planning becomes crucial in an age of global markets that offer both challenges and opportunities for dynamic management.

Okamoto and Sjöholm (2001) discuss four lessons that could be learned from Indonesia's technology development and advancement:

- External sources of technology become very important in the early stages of industrial development when technological requirements are still relatively low. New technology and know-how may be acquired through the channels of foreign experts, trading companies and foreign buyers, which means that openness to trade, investment and skilled labour enhances industrial technology development.
- It remains the responsibility of the public sector to make greater efforts to acquire, upgrade, and disseminate technology and know-how as the country moves up the technology ladder.
- Foreign Direct Investment (FDI) is crucial for technology development. It can be used as a tool for new technology introduction, employment generation, product expansion and exports. It can be used to complement government funding where there are constraints, but it does not necessarily lead to technological upgrading.
- Technological, managerial and institutional infrastructure needs to be developed before a micro-level intervention for promoting technological development becomes effective.

In technology advancement and sustainability, one major challenge for a firm's competencies within the aircraft industry is the ability to showcase its technological capability in a way that enhances aircraft performance. That has been true from as early as the 1950s, where the focus was on speed, through the 1980s when the development of aircraft 'stealth' began (Klesius, 2004). Today, aeroplanes have become even more complex, with technology evolving most dramatically with respect to interiors. An example is the 555-seater A380, which offer passengers extra comfort, without compromising technological performance. Many technologies are being adapted from military aircraft for civil applications. Computer automation has resulted in a new generation of military aeroplanes, unmanned aerial vehicles (UAVs), that fly without pilots. This technology has been adapted for civil aviation to some extent, where computer automation is being used to fly a plane immediately after take-off until landing, thereby transforming pilots into flight-systems managers. The current discussion regarding UAVs for civil aircraft is whether cargo planes and passenger aircraft could be flown without pilots.

It is believed that technology development in the aircraft industry will lead to the enhancement of the technological development potentialities of airframe/engine manufacturers and related industries such as component or material makers (IADF, 2004). For example, General Electric (GE) is executing a wide-ranging technology development and maturation effort to acquire and bank technologies that would be needed for wide-body transport engines that will enter into service between 2008 and 2015 (Kandebo 2002:1). Two programs, known as Generation X and Generation Y, have been initiated to look at the development of engine technologies needed by 2008. Also, a longer term endeavour is aimed at power plants to be in service by 2015. Generation X engines should provide a 15% improvement in specific fuel consumption (Kandebo 2002:1).

Technology development should provide growth in other related industries (IADF, 2004). The aviation industry is perceived to be a leader in technology development because it pioneers new technologies and techniques that become readily available to the industry at large (Engineering News, October 2003). Aircraft are designed and built with a multitude of science and mechanics concerns. These include the analysis of vibrations induced in the airframe, principally by the power plants and other rotating parts, such as propellers.

Technology advancement is regarded as an important factor when assessing sustainability in the aerospace industry. For this reason, the Advisory Council for Aeronautical Research in Europe (ACARE) has proposed an agenda for sustainable development, to be achieved by 2020, based on four objectives (ATAG, 2002):

- A 50% reduction in CO_2 emissions per passenger-kilometre
- An 80% cut in nitrogen oxide (NO_x) emissions
- A 50% noise reduction at source, including noise abatement operational procedures
- An 80% reduction of air transport accidents.

The main environmental challenge facing aviation is the maintenance of an acceptable balance between growing consumer demand and technological progress (ATAG, 2002). Such a balance appears to have been achieved for noise, whilst global greenhouse gas emissions are becoming more of a challenge. Currently, the aviation emissions represent about 3,5% of the total climate-change effect from all human activities. This figure could rise to 6% in the next 50 years, in spite of further technological advances.

It appears that the challenge over the next decade will be to meet the increased demand for safety, environmental compatibility and capacity, while enhancing performance and reducing costs, through the use of new technologies. A profound shift in behaviour, delivery and control disciplines is required, not just a better understanding of physics and new technologies in the traditional performance disciplines of aerodynamics, propulsion, structures, materials and manufacturing. These revision should include aerospace system engineering; integration of customer specifications; design concepts; functional architecture; physical architecture; design analysis and synthesis; trade studies and multidisciplinary optimisation; risk analysis; manufacturing; supply-chain management; logistics; testing; verification and validation; and life cycle cost

General Electric (GE), in association with the National Aeronautics and Space Administration (NASA), has already started to develop the technology to cut oxides of nitrogen emissions (Kandebo 2002:1). In line with ACARE's proposed agenda for sustainable development, GE plans to develop technologies that would result in an ultra-clean, ultra-quiet and ultra-reliable power plant, which would have a number of positive engine-operation consequences:

- Oxides of nitrogen emissions would be reduced by 85%

- Carbon dioxide emissions would be reduced by 20% compared to the old GE90 engine
- Operation noise levels would be 33 EPNdB (cumulative) lower than stage 3 regulations
- Engine-caused flight delays and cancellations would be reduced by 50%, compared to current generation power plants
- In-flight shutdowns would be reduced by 50%, compared to current power plants
- Fuel burn would be reduced by 20%, compared to the old GE90 (Kandebo 2002:2).

Another technological challenge in the aviation sector is vibration, which shortens the life of the aircraft and increases its operation costs as a result of loss of service life of many of the components, from sensitive avionics and instrumentation, to fatigue and damage in the airframe (Engineering News, October 2003). Vibrations experienced as noise lead to fatigue and discomfort for the occupants of an aeroplane, both crew and passengers.

The technology-development cycle within the aircraft industry is constrained by regulation and certification. Aircraft technology has to be tested before being incorporated into products, and customers expect a level of technology demonstration sufficient to meet regulatory requirements before inviting a potential service provider to bid. Another constraint is that new technologies may take up to 15 years to progress from basic science to product application (DTI (UK), 2003). Ineffective technologies developed today could severely impede long-term industry competitiveness and growth, therefore research and development (R&D) is crucial for the successful development of technologies.

Various authors highlight the contributions made and the lessons learnt within the aircraft industry with regard to technological advancement and sustainability. Technological advancement and sustainability can be facilitated if technological capabilities exist. Various expectations of technological advancement for the aircraft market were highlighted, without indications of how the required technological capabilities could be achieved. Some theories discuss expected achievements as part of overcoming technological challenges. These could be complemented by a technology-development framework to prepare for such desired outcomes.

2.2.2 Technology transfer and its impact on technology development

There is a general acceptance that the level of technological development has a major influence on the level of economic development (Steenhuis & De Bruijn 2001:552). Technology transfer has, therefore, been considered by developing countries as a vehicle for economic growth. Some developing countries give special attention to certain industries, which are then stimulated to develop their technology. A country can only enhance its technological capability in two ways: by developing new technologies itself or by acquiring them by means of technology transfer (DTI (SA), 2007). As no country in the world is in a position to develop competitively all the technologies that are required for its industries, technology transfer will always be an important form of upgrading a country's technological base. Technology transfer can happen in a number of ways such as through outright purchase or through some form of contractual agreement (which may include the transfer of personnel), strategic alliances, patents and licensing agreements.

Government has a significant role to play in the facilitation and encouragement of technology transfer (Paras Report, 1998). International experience indicates that technology transfer is most successful when people are the carriers of the technology and are involved in the transfer. Technology transfer in the form of licences on Intellectual Property Rights (IPR) know-how agreements, without the involvement of personnel skills transfer, often fails because technology cannot be reduced in its entirety to words-on-paper or computer software.

The following areas of technology transfer were identified as opportunities (Paras report, 1998):

- Co-operative R&D is seen to be the most important mechanism for technology transfer, and should be encouraged by government grants.
- Collaboration between Higher education institutions (HEIs), industry, and

Science, engineering and technology institutions (SETIs) are underdeveloped in South Africa, and Small and medium enterprises (SMEs) are not adequately involved.

- Supply chain management, which is an effective process for technology transfer, is underdeveloped in South Africa.
- Collaboration is seen as an effective way for technology diffusion, and the Technology and Human Resources for Industry Programme (THRIP) is playing a meaningful role. The scale of division through collaboration is limited, however, and government has an additional role to play in assimilating information and diffusing it broadly.

It is not only the transfer of technology across borders that is important, the rate of technology transfer/diffusion within a country also determines a country's technological capability (DTI (SA), 2007). This is especially true for the so-called pervasive technologies (e.g. ICT or management technologies) that determine the competitiveness of an industry.

Technology transfer has frequently been used by developing countries with limited financial and human resources as the most efficient and cost effective approach for selecting/acquiring appropriate technology. The Draft technology policy framework for South Africa (DTI (SA), 2007) recommends that government offer more support for technology transfer in South African industry, which can be used to the country's advantage in a number of ways:

- To select technology appropriate to the country's needs
- To evaluate local as well as imported technologies and decide on their utilisation to ensure maximum benefit
- To modify and adapt technologies to suit the local environment
- To transfer technological developments through science and technology institutional linkages
- To ensure that technology transfer assists communities in developing or enhancing their own technologies
- To monitor and evaluate the effectiveness of technologies being transferred and implemented

- To protect intellectual property

The aircraft industry has attracted special attention from various governments such as China, Indonesia, Brazil, India, and Romania (Steenhuis & De Bruijn 2001:552). The Indonesian government started Industri Pesawat Terbang Nusantara (IPTN), the aircraft manufacturing firm that has been the largest and most ambitious investment made by the Indonesian government to promote technology development in the country (Eriksson, 2003a). IPTN has core competence in aircraft design, development and manufacturing of commuter aircraft. It has had poor financial performance although it has been heavily subsidised and also managed to develop various technologies. It is believed that underdeveloped managerial capacity could have led to the limited commercial success of the firm although huge investments have been made in engineering and production facilities.

From as early as 1975, Indonesia was involved in indigenous aircraft design through technology transfer, and the development of that aircraft manufacturing industry has been monitored to understand how technology transfer contributes to technology development. By 1990, Indonesia was still not established in the international aircraft industry, and the two aircraft designs that resulted from technology transfer projects were produced in limited numbers, with few exports. The reasons for such limited success included: infrastructural restraints; cultural restraints; general bureaucracy and import difficulties; and credibility problems following uncertified products. This shows that the success of technology transfer is not always guaranteed, but is to a large extent determined by the process at the operational level. Even if the technology is transferred successfully, with the receiving company being technically able to produce the aircraft (product), production might not always be viable. The success of technology transfer is determined by both the successful installation of a technology at the destination site, and the successful utilisation of that technology after transfer. This could be the reason why Indonesia has been slow in establishing a successful aircraft industry even with technology transfer because their technology development and advancement in general has been successful according to Okamoto and Sjöholm (2001), who previously discussed lessons learned from the country's technology development and advancement.

It appears that the establishment of IPTN by Indonesian government was the factor of national prestige (Eriksson, 2003a). The Progressive Manufacturing Programme was used as a four-phase scheme for technology transfer development and manufacturing. Phase 1 (Licence program) was used as a learning process and for establishing appropriate technology during early stages of development, which involved transfer of technology for a specific type of aircraft made by IPTN and the manufacturing process starting from end to beginning. Phase 2 (Joint venture program) involved the integration of existing technology through realisation of the co-design and manufacturing programmes with CASA of Spain. This was for the transfer and build-up of aircraft technology, where they lacked an internationally recognised certificate of airworthiness which resulted in limited exports. They also lacked experience in sales and marketing of such products. What appears to be critical in the success of the product is by focusing not only on the technology itself but also the business side, which includes management and marketing.

Phase 3 (Development of new technology) involved the application of the acquired technology for the indigenous design and manufacture of new products. IPTN entered this phase before securing customers and without proper certification, which led to problems in entering the international market. Another constrain was that they decided to go alone instead of following the international aerospace industry trend of increased cooperation in the development of aircraft.

Phase 4 (Large-scale research and development program) was aimed at the implementation of research and development of future technology, where a transonic 130 seater (N-2130) was supposed to be launched. This phase of technology development has never been successful following the failure of phase 3.

The Taiwanese government embarked on the development of the commercial aerospace industry as well as an internationally competitive supplier system as aprt of upgrading the country's industrial and technology capabilities (Eriksson, 2006). During the beginning of the process a huge gap existed between Taiwan's military aircraft capability and the nearly non-existent civil aerospace competence.

Part of their strategy for developing a successful civil aerospace industry was by taking equity stakes and risk-sharing deals with foreign firms. Taiwan's aerospace industry long-term competitive advantages depend on factors such as (Eriksson, 2006):

- Further development of Science and Technology policies thus strengthening the innovation capability
- Specialisation in further development of integrated subsystems in fields such as airframe parts, avionics or advanced material technology
- A need to join large international aerospace design and manufacturing networks to be able to act as a supplier to the large system integrators such as Airbus and Boeing so as to gain access to product and manufacturing knowledge and innovation
- Long-term view opportunities for East and Southeast Asian economies to pull their technological resources together in the aerospace field, to challenge the leading European and US companies.

Taiwan also has strengths as follows (Eriksson, 2006):

- It has many years of experience from the aerospace sector, with Aero Industry Development Centre (AIDC) which is the main source of knowledge within the domestic industry and few others like Center for Aviation and Space Technology (CAST) as a new source of technology spillover
- It masters a general level of technology, which is superior to many other emerging economies
- It pursues dedicated technology policies with a strong determination to climb the ladder of science and technology
- A dedicated, although limited, supplier system being under development
- Taiwanese companies gathering experience from international business arena, although not from the aerospace sector
- Taiwan in a fortunate situation in terms of capital resources.

Antoniou and Ansoff (2004) highlight the importance of technologists doing environmental assessments constantly to determine whether to transfer or develop new technologies. They indicate the following as major areas to consider when managing a firm's technology:

- The identification of future technologies and their impact on their organisation's environment
- The assessment of the firm's internal technology capability
- The integration of technology into the organisation's strategy.

Steenhuis and de Boer (in Iles & Yolles 2002:32) mention the importance of maintaining balance, during technology transfer, between source and destination, to avoid a potential imbalance in the destination company. It is essential to distinguish between two types of technology transfer when analysing the success of technology transfer in the aircraft industry: sharing a technology, and trading a technology (Steenhuis & De Bruijn 2001:557). In technology sharing, the source company shares its technology freely with the destination company, and purchases the resulting products. Technology sharing does not significantly contribute to the development of technological capabilities, either in the destination company, or in the country in which it is found. This is supported by Mowery and Rosenberg (1984) and Steenhuis & De Bruijn (2001:557), who observed that technology transfer does not always contribute to technological development.

For technology trading, the destination company purchases a new technology under license from the source company, learns to use it, adapts it and applies it in its own applications. This type of technology transfer is known to increase the technological capabilities of firms, although payment is required to acquire such technological capabilities. What has not been established is the extent to which these technological capabilities contribute towards a sustainable position in the industry, and consequently, towards national technological competitiveness. The age of the technology being transferred and the market size could both have a negative effect on the ability to sustain technological competitiveness.

Another major characteristic of the aircraft industry is the large R&D investment required (Steenhuis & De Bruijn 2001:558). Technologies within this industry need to be improved frequently for firms to remain competitive. However, the requisite R&D capabilities are crucial when developing technologies, or upgrading technology after technology transfer. Embraer, a Brazilian aircraft manufacturer, became a serious global competitor in the aircraft industry after it focused technology transfer efforts on acquiring R&D capabilities (Steenhuis & De Bruijn 2001:559). Most authors agree that R&D capabilities are a prerequisite for successful technology development in the aircraft industry, which is needed for achieving technological competitiveness and for adapting the transferred technology for local circumstances. It is highly unlikely, therefore, that destination firms could compete successfully only through production technology transfer, unless they have their own R&D capabilities.

Steenhuis and De Bruijn (2001:559) highlight some of the factors that impact on utilisation effectiveness, even where technology has been successfully installed:

- Limited financial resources – leading to procurement problems
- Difficulties in importing tools, materials and parts – causing delays in production activities
- Local industries characterised by high price, low quality, long lead times – causing problems with procurement, production delays, and poor quality work
- Difficulties in obtaining certification – affecting the usability of the produced products, resulting in considerable delays
- Cultural characteristics, adverse working conditions and limited technical organisational knowledge levels – affecting productivity and quality
- Poorly developed communication infrastructures – hampering communication, leading to production delays.

The factors described above are related to the environment of the aircraft-manufacturing firm, and are typical characteristics of industrially developing countries. This means that aircraft production technology requires a specific environment for it to be efficient.

A number of authors discuss the concept of technology transfer and its contribution towards building technological capabilities, especially in developing economies. Acquiring R&D capabilities appears to be critical, even for technology upgrading following technology transfer. The link between the development of R&D capabilities, national environment and the entire technology development system is not very clearly demonstrated by the authors discussed above.

2.2.3 R&D investment and its impact on performance in the global technology trade

R&D Investment has been key in triggering innovation within the aircraft industry irrespective of the complexities embedded within the aircraft systems. It also appears that investment in technology development by firms and countries through R&D has an impact on technology trade performance.

Oerlemans, Pretorius, Buys and Rooks (2005) indicate that a typical South African firm spends less on innovation than the average European company. Furthermore, about 44% of South African firms overall had introduced technological innovations within the 1998–2000 period, whereas 70% of firms within the sector for the manufacturing of transport equipment claimed to have introduced own-innovations. Both the automotive and the aircraft industries fall within the transport equipment-manufacturing sector. The automotive industry probably makes up more than 50% of the sector.

Steenhuis and De Bruijn (2001:559) acknowledge the history of US federal research investment in industry, and suggest that public R&D programs can exert a powerful and positive influence on the innovative performance of an industry.
Table 2.2 shows a summary of the general science, space and technology spending that has occurred within the US, which has escalated with time. AISI (2005) also supports this theory of R&D investment (See Figure 2.4).

Table 2.2 Support and funding in the US

Federal support of general science, space and technology (in millions of Dollars)							
Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Spend	19,203*	20,861°	21,191°	21,892°	22,441°	22,910°	23,488°

Key: * Actual, ° Estimate

Source: Steenhuis and De Bruijn (2001)

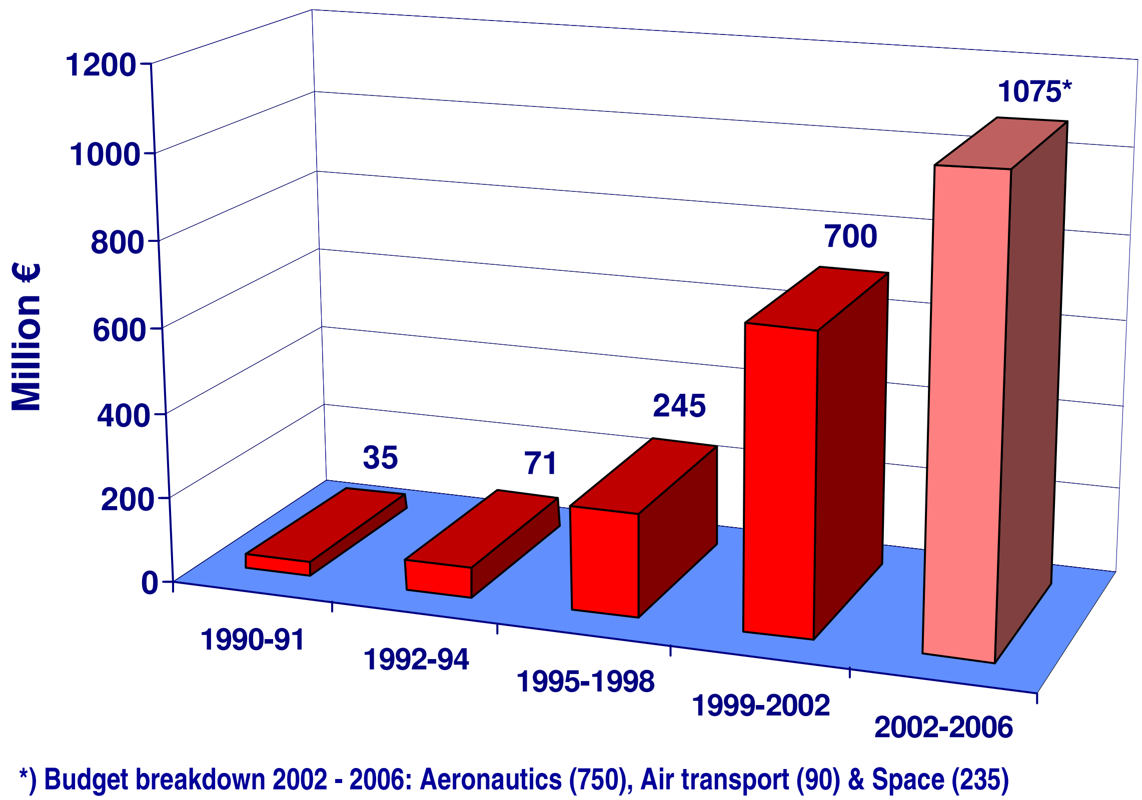

Figure 2.4 Research and technology development funding for specific aeronautics research on EU level (1990–2006) in million Euro
Source: DTI (SA), 2005. Positioning the South African aerospace industry as a priority sector: Presentation

South African exports have underachieved relative to the world across most of the technology spectrum over the last decade (Trade & Industry Monitor, 2004:2). The country's trade performance in relation to developing countries, both in aggregate and in every technology category, has also been poorly rated. The challenge for South Africa is to upgrade to more technologically complex, dynamic sectors that undoubtedly provide the most growth potential. South Africa has an insignificant share of global trade in dynamic products, which are technology- and/or knowledge-intensive. For firms to be competitive in their production it will require high levels of innovation, and good research and development platforms. Technological classifications are shown in table 2.3.

Table 2.3 The technological classification of exports

Classification	Examples
Primary products	Fresh fruit, meat, rice, cocoa, wood, coal, crude petroleum, gas
Manufactured products	
Resource-based manufactures	
RB1: Agro/forest-based products	Prepared meats/fruits, beverages, wood products, vegetable oils
RB2: Other resource-based products	Ore concentrates, petroleum/rubber products, cement, cut gems, glass
Low-technology manufactures	
LT1: 'Fashion cluster'	Textiles fabrics, clothing, headgear, footwear, leather manufactures, travel goods
LT2: Other low technology	Pottery, simple metal parts/structures, furniture, jewellery, toys, plastic products
Medium-technology manufactures	
MT1: Automotive products	Passenger vehicles and parts, commercial vehicles, motorcycles and parts
MT2: Process industries	Synthetic fibres, chemicals and paints, fertilizers, plastics, iron, pipes/tubes
MT3: Engineering industries	Engines, motors, industrial machinery, pumps, switchgear, ships, watches
High-technology manufactures	
HT1: Electronic and electrical products	Office/data processing/telecommunications equipment, TVs, transistors, turbines, power
HT2: Other high technology	Pharmaceuticals, aerospace, optical/measuring instruments, cameras
Other transitions	Electricity, cinema film, printed matter, 'special' transactions, gold, art, coins, pets

Source: Lall 2000a, in Trade and Industry Monitor (2004:2)

When looking further at comparative performance (1992–2002), exports from South Africa grew less rapidly than world exports in aggregate and in most technological categories, with two exceptions: medium-technology products (MT), where South Africa's exports grew twice as fast, and high-technology products (HT), where the country's export growth rate marginally exceeded the global growth rate. When compared to developing countries, South Africa's performance has been particularly weak, as, on aggregate, its exports grew at less than half the rate of developing countries (see Figure 2.5).

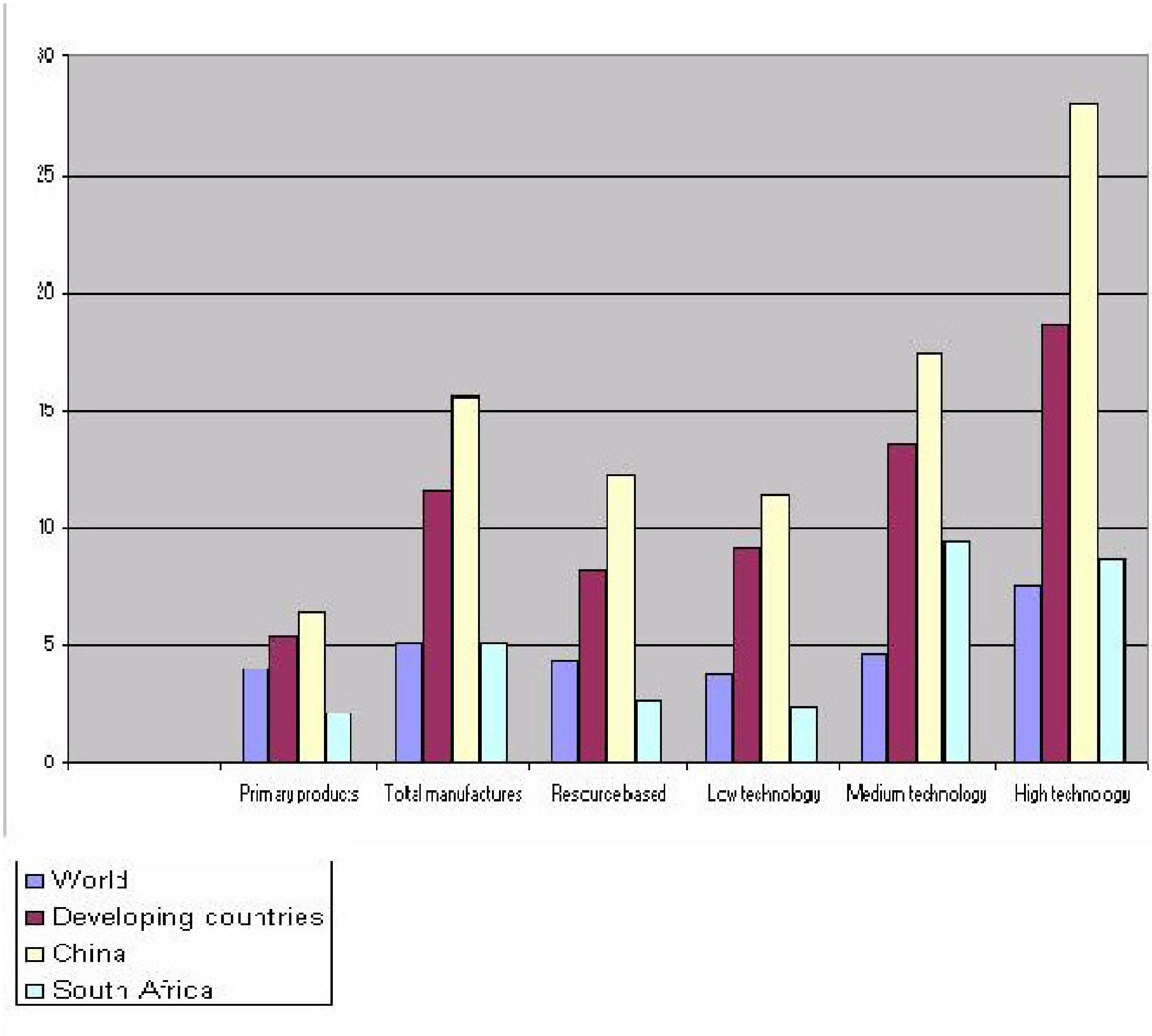

Figure 2.5 Growth rates by technology category (1992–2002)
Source: Trade and Industry Monitor (2004:3)

South Africa's share of global exports has eroded, with better performing developing countries taking over. Table 2.4 shows South Africa's share in world and developing country exports (1992–2002), with declines of 43% and 45%.

Table 2.4 South Africa's share in world and developing-country exports (1992–2002) (%)

	World		Developing countries	
Product	**1992**	**2002**	**1992**	**2002**
All sectors	0.44	0.42	3.33	1.89
Primary products	0.82	0.68	4.02	2.93
Total Manufactures	0.38	0.38	3.14	1.72
Resource based	1	0.85	5.6	3.3
Low technology	0.34	0.31	1.58	0.84
Medium technology	0.27	0.41	3.77	2.59
High technology	0.07	0.07	0.9	0.36

Source: Trade and Industry Monitor (2004:4)

When focusing on manufacturing, judging from the tables above, South Africa has significantly increased its global presence in medium-technology products, but this has not counteracted the losses in all other technology categories. South Africa shows signs of struggling to upgrade into more technologically complex, dynamic innovative products, such as aerospace (classified under high technology). It appears that South Africa's comparative success has been in scale- and capital-intensive medium-technology products with low incremental output/labour ratios. This is supported by the statistics shown in Table 2.5.

Table 2.5 South African trade with the world: Top 10 products (HS2; Q1 2004)

Products	Total Exports (Rbn)	% of Total Exports	Products	Total Imports (Rbn)	% of Total Imports
Precious metals and stones	19.54	30.30	Machinery and boilers	12.03	19.61
Iron and steel	7.56	11.71	Electric machinery	6.32	10.31
Vehicles	4.86	7.53	Special motor parts	5.79	9.45
Machinery and boilers	3.87	6.00	Vehicles	4.94	8.05
Minerals and fuel oils	3.42	5.30	Minerals and fuel oils	3.96	6.46
Aluminum	2.42	3.75	Aircraft	2.89	4.71
Ores, slag and ash	2.40	3.72	Medical & surgical equipment	2.16	3.51
Citrus fruit	1.97	3.06	Pharmaceutical products	1.80	2.93
Inorganic chemicals	1.37	2.13	Precious metals and stones	1.58	2.58
Electric machinery	1.26	1.96	Plastics	1.56	2.54
Total	48.67	75.5	Total	43.03	70.2

Source: Trade and Industry Monitor (2004:11)

Global technological advances have increased the skill and technological intensity of production, thereby requiring that firms master increasingly sophisticated production techniques in order to remain competitive. The technological advances, unequally distributed growth in global income and the splitting-up of production chains across countries, have meant that high-technology products such as aerospace, have shown the fastest growth in manufactured exports, with medium-technology products retaining a high but steady share, and low technology and resource-based products declining in world trade (see Figure 2.6).

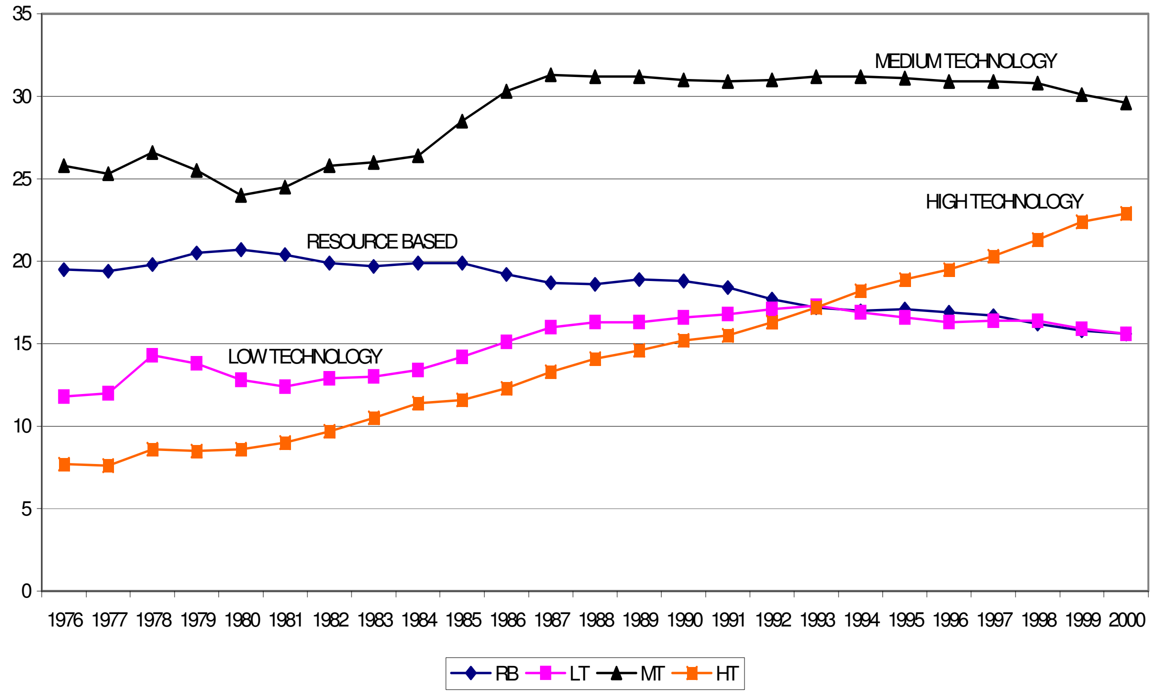

Figure 2.6 Shares of manufactured products in world exports by technology levels (1976–2000) (%)
Source: Lall 2003

In order for South Africa to stay competitive with respect to its main trading partners, it is important that it does not fall behind in developing new products and processes. Table 2.6 from the DTI's Draft technology policy framework (DTI (SA) 2007) gives an indication of South Africa's position regarding R&D expenditure.

South Africa's performance in international trade, in terms of the different levels of technology classification, indicates the need to develop new technologies in all categories. Only in the medium-technology category has South Africa performed well. This could be an indication that government needs to increase the support for new product and process development technologies substantially, in line with government policy to increase the national expenditure on R&D from the current 0,91% to 1% of GDP, to bring it closer to those of its most important trading partners.

Table 2.6 R&D expenditure as % of GDP per country

Country	**R&D expenditure as % of GDP**
Finland	3,46
Japan	3,12
USA	2,60
Australia	1,54
China	1,22
OECD Average	2,26
EU Average	1,86
South Africa	**0,91**

Source: DTI (SA), 2007 Draft technology policy framework for SA

New technology often creates excitement, which may result in poor investment decisions (Sajid 1995:117). Managers tend to conclude that their organisations will gain a competitive edge by acquiring the best and most advanced technology available, without examining the environment in which they operate first, so as to determine what would provide the best combination for optimisation.

The literature emphasises the importance of nations investing in R&D to achieve higher technology trade performance or returns. What is not clear is whether developing nations should invest in low, medium or high technology, and whether the technology classification category where R&D investment is being made has an impact on the economic status of the nation. It was stated that South African firms have introduced technological innovations but whether such innovations were related to production or management within firms, was not discussed.

2.2.4 Adoption theory of innovation

Tidd, Bessant and Pavitt (2001:182) explain the development and adoption process for complex products such as aircraft, where they identify the processes and services as being very difficult. The benefits to potential users may be difficult to identify and value, and with few direct substitutes available, the market might not be able to provide any technology benchmarks. Furthermore, the relationship between users and developers changes throughout the development and adoption process, where three distinct processes, development, adoption and interfacing, each demanding different linkages, need to be managed. Frameworks have been formulated to help manage the development process of innovation, whereas little guidance is available for managing the interface between developers and adopters of innovation.

Davies and Brady (1998:297,298) argue that the decision to adopt a new component or an interface technology entails a commitment to a standard. Each new systemic innovation that is introduced, where there is a change in design or functioning of one component that cannot be introduced without significant readjustment in the design or functioning of other components, must be backwards compatible with the existing system. Therefore future investments have to be compatible with the chosen standard. When a new technology is developed, governments, regulatory bodies, system suppliers and users have a limited opportunity to intervene at the early stages to promote a technical standard and influence the future pattern of innovation and demand for such a technology. As soon as a particular standard becomes widely adopted, it becomes difficult for alternative technologies to gain acceptance, because buyers of CoPS have made large investments in the technologies and these usually have long operating life cycles.

Firms make decisions about the adoption of technological innovations in the context of their own economic environment. Adoption of new technologies enables firms to reduce production costs and improve competitiveness (Goel & Rich 1997:513). Not all firms choose to adopt an innovation as it is not a costless exercise, and the adopter is unsure at the time of adoption about the technical reliability and financial feasibility of that particular technology. There are risks of the newly adopted technology being superseded by another innovation even before all the adoption benefits have been realised. This has led to some firms delaying the adoption of an innovation if its profitability remains uncertain. The market structure can also have an influence on a firm's behaviour with regard to technology adoption. Regardless of the fact that a monopolist might have the resources, it might not have the incentive to adopt early. On the other hand, competitive firms do have the incentive, but may not have the means to adopt new technologies, especially those that are risky and expensive (Goel & Rich 1997:514).

Goel and Rich (1997:514) further indicate that firm- and market-specific factors like technology adoption costs, number of prior adoptions and profitability of the existing technology have a bearing on the decision by a firm to adopt a new technology. Other factors influencing the diffusion rates are absolute capital requirements, durability of the adopting industry's capital stock, the industry's rate of sales growth, the complexity of the new technology, the cost of information dissemination, and the stage of the overall business cycle. The extent of the firm's technology adoption is dependant on the nature of innovation. Innovations associated with large economies of scale are more likely to be adopted by most firms. The costs of adoption and potential profitability are more likely to be determined by the operating environment of the individual firm and its current existing technologies.

The effective diffusion of imported technology across firms within an industry and across industries within an economy is as important as foreign technology acquisition for upgrading overall technological capability in the economy (Kim & Seong 1997:390). Tacitness of technology requires individuals and firms to exert their efforts to acquire, assimilate, and improve foreign technology and to generate their own innovations. Kim (1980:268) indicates that although specific 'unpacked' technologies may be imported from abroad, local research, development and engineering (RD&E) efforts have also become a necessary course of action for local industry not only to improve imported technology, but also to implement their own novel ideas.

Kim (1980:268,269) also argues that successful assimilation of foreign technology through accumulated experience in production and product design, and limited efforts in local R&D activity, would lead to the application of imported technologies to different product lines. Furthermore, such assimilation of various foreign technologies, which would increase capability of local scientific and technical personnel and local R&D efforts, would in turn provide the basis for general technology development in the industry, and for further introductions of more sophisticated product lines, without necessarily requiring the transfer of foreign technology.

The general pattern of the development of industrial technology that proceeds from implementation of imported technology, to assimilation, and eventually to improvement thereof in order to strengthen competitiveness, is evident in the history of manufacturing industries in various countries (Kim 1980:271).

Tidd, Bessant and Pavitt (2001:185-187) identify some characteristics that affect technology and innovation diffusion, which in-turn impacts on adoption:

- Relative advantage
- Compatibility
- Complexity
- Trialability
- Observability

Relative advantage has to do with the degree to which an innovation is perceived to be better than the product it supersedes. Aspects such as cost, financial payback, convenience, satisfaction and social prestige have been used as typical measures. It is believed that the greater the perceived advantage, the faster the rate of adoption. For a country such as South Africa, the main constraint for adopting an innovation within the aircraft industry is cost. Incentives could be used to promote the adoption of an innovation, whether by subsidising trials or reducing the cost of incompatibilities (Tidd et al 2001:186).

Compatibility is the degree to which an innovation is perceived to be consistent with the existing values, experience and needs of potential adopters. Existing skills and practices, and values and norms, are found to be the key aspects. The extent to which the innovation fits the existing skills, equipment, procedures and performance criteria of the potential adopter is crucial. The adoption process (Tidd et al 2001:187) can be affected by 'network externalities', where the cost of adoption and use, as distinct from the cost of purchase, may be influenced by a number of factors:

- Information about the technology from other users
- Trained skilled users
- Technical assistance and maintenance
- Complementary innovations, both technical and organisational.

Misalignments between an innovation and an adopting organisation require changes to be made in the innovation or the organisation, or both. The mutual adaptation of the innovation and the organisation is believed to take place in most cases of successful implementation.

Complexity, which is the degree to which an innovation is perceived as being complex to understand or apply, impacts on the adoption process. Innovations that are simpler for potential adopters to understand are more likely to be adopted, more rapidly, than those that require the adopter to develop new skills and knowledge.

Trialability, is the degree to which an innovation can be experimented with on a limited basis. When an innovation is trialable, it represents more certainty to potential adopters, thereby providing opportunities for learning by doing. Such trialable innovations tend to be adopted more quickly than those that seem difficult. When there are more benefits from the functional effects of an innovation, the rate of adoption increases even further.

Observability is the degree to which the results of an innovation are visible to others. It is easier for an innovation to be adopted if the benefits can be easily seen or observed. The simple epidemic model of diffusion assumes that innovations spread as potential adopters come into contact with the existing users of an innovation (Tidd et al 2001:187).

Tidd et al (2001:188) present some models that explain diffusion and adoption of innovation. The ***epidemic model***, which is said to be the earliest and most commonly used, assumes that innovation is spread by information transmitted through personal contact, and the geographic proximity of existing and potential adopters. This model emphasizes communication and the provision of clear technical information. The weakness of this model is that it assumes that all potential adopters are the same, with similar needs.

The ***Bass model*** of diffusion improves on the epidemic model by including two different groups of potential adopters: innovators; and imitators, where the diffusion takes the epidemic form. Innovators adopt the innovation quite early, with imitators following very late.

The ***Probit model*** assumes that potential adopters have different threshold values for costs or benefits. Differences in threshold values, therefore, can be used to explain different rates of adoption. This model suggests that the more similar the potential adopters are, the faster the diffusion. Adopters in this model delay the adoption process until they are convinced that the benefits will be sufficient.

The ***Bayesian model*** of diffusion identifies lack of information as the main constraint to diffusion. Potential adopters may have different perceptions regarding the value of the innovation, which they may revise according to the results of trials to test the innovation. If trials become private, imitation is unlikely, and potential adopters cannot learn from the trials. This model suggests that even potential adopters that are better informed, may not necessarily adopt innovation earlier than the less informed.

Goel and Rich (1997:516) expand on the concept of adoption, indicating that time-dependent and time-independent factors will influence a firm's decision to adopt or forego adoption of an available technology. When looking at the empirical representation of the firm's adoption decision, Goel and Rich (1997:516) found the rate of diffusion for new aircraft technologies, measured as a percentage of total industry aircraft, to serve as the pre-eminent time-dependent explanatory variable. Figure 2.7 shows an overview of aircraft group diffusion rates, where industry-wide diffusion of aircraft innovations considered in the study by Goel and Rich (1997:516) exceeded 25% by the end of the sample period ending in 1986.

Diffusion rates for relatively early aircraft innovations (Group I) taper off as new aircraft design innovations emerge, and by the end of the period Group III, innovations are still in the process of diffusion.

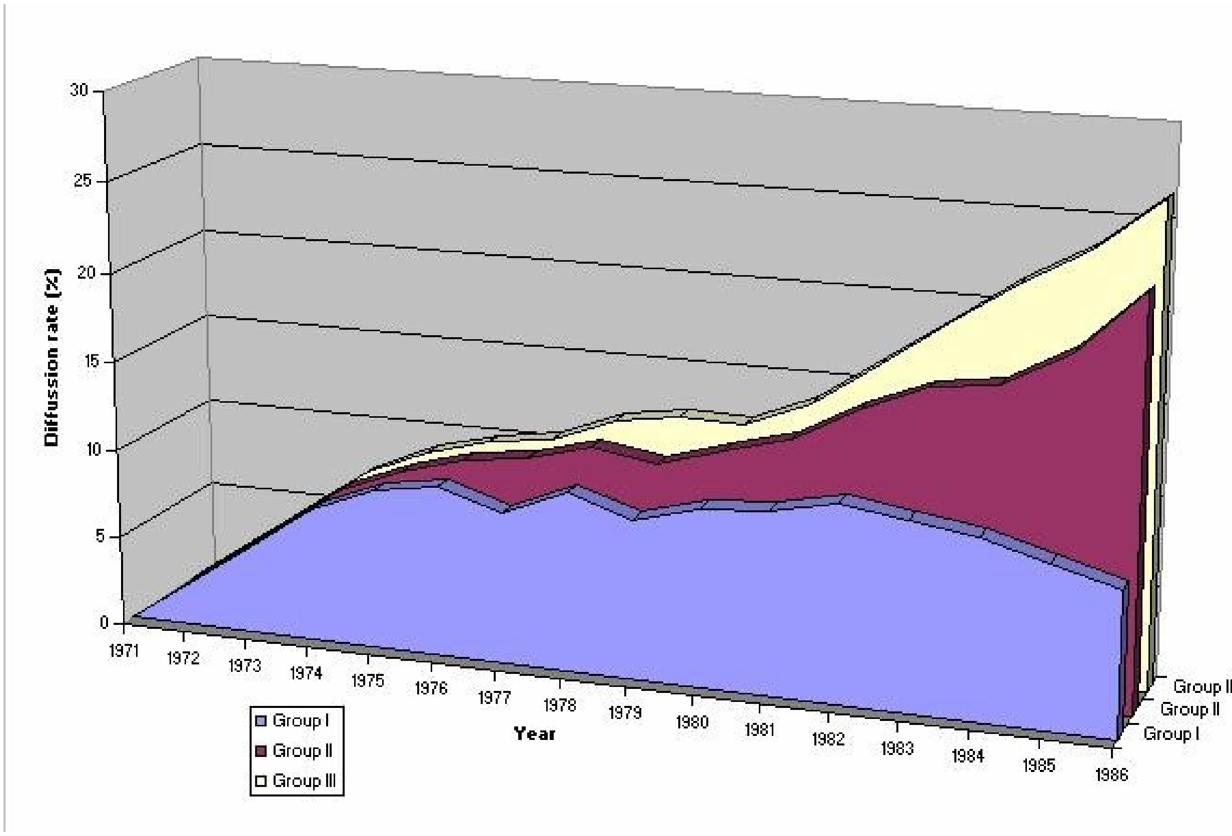

Figure 2.7 Diffusion of aircraft innovations (as % of total industry fleet)
Source: Goel and Rich (1997)

Greater industry-wide diffusion should put firms at ease and reduce their uncertainty about adoption by providing valuable information and diminishing the probability of unanticipated obsolescence. With a widespread industry acceptance of new technology, there could be improvements in the complementarity of ground equipment, availability of spare parts, and quality of training for flight crew and maintenance workers. The diffusion rates will also determine the extent of rival precedence in innovation adoption (Goel & Rich 1997:516,517). Product market competition and prior adoptions were found to be key determinants of technology adoption in the airline service sector. The distribution of an airline firm's characteristics is represented by the variations in route system (stage, hub, trunk) and aircraft fleet measures (fuel efficiency, seat capacity) across firms. For example, Group I (DC-10 and L-1011) technology could be meaningful for firms serving non-stop transcontinental routes, with Group III (A300 and B767) new aircraft providing greater complementarity with the high density, short-to-medium stage length hauls associated with hub-and-spoke route systems. These tend to support the hypothesis that firm-specific production characteristics could play a role in technology-adoption decisions.

The performance attributes of existing fleets of aircraft are of interest when assessing new technologies. The adoption of aircraft innovations could be delayed due to the availability of relatively large numbers of seats per craft. Also, prior adoption of aircraft providing similar attributes (such as seating capacity) could reduce the probability of integrating the latest wide-body or stretch-body technology into the firm's fleet. Further to the empirical analysis by Goel and Rich (1997:517), while fuel price shocks tended to enhance the incentives for adoption of other fuel-saving aircraft innovations in Groups II (DC9-50, DC9-80, B737-300, B757) and III, fuel efficiency of the existing fleet has shown to be a deterrent to adoption of Groups II and III aircraft.

Very rapid rates of adoption of new aircraft designs by major carriers also occurred based upon their belief that rapid introduction of state-of-the-art aircraft would be an effective marketing strategy when price competition becomes impossible (Mowery and Rosenberg 1982:173). Major airlines became strongly motivated by the drive to be first with a new design, so as to make early purchase commitments to airframe manufacturers as a strategy to achieve the earliest possible delivery. The competition for service quality fosters rapid diffusion and adoption of innovations drawing upon government supported research, and supports strong competition amongst manufacturers.

The institutions through which technology is diffused in East Asia are chosen as vehicles of leverage, rather than instruments of innovation. Such institutions have a number of identifying characteristics (Mathews, 2001):

- They tend to be large established firms in the industrially upgrading country

- They may be public sector laboratories and institutions linked to consortia of small firms
- They may have external leverage via multinational corporations.

The authors referred to above emphasize that, even with the available models, the adoption of new technologies has to be done correctly the first time, therefore the necessary preparations need to be taken to avoid misalignment. Such preparations include establishing the need, value, challenges, costs and availability of various resources; the feasibility of implementation, and the benefits of the adoption of innovation. It is evident that the link between developers and adopters of technology has to be maintained. The availability of a framework for technological capability building is relevant to this theory as it could provide management of the interface between developers and adopters of innovation.

2.2.5 The theory of innovation networks

In recent years, the concept of innovation networks has become popular as they offer many benefits for technology development in firms (Tidd, Bessant & Pavitt 2001:214). Networks are appropriate where the benefits of co-specialisation, sharing of joint infrastructure and standards, and other network externalities outweigh the costs of network governance and maintenance. A network approach is most beneficial where the costs of purchasing a technology are too high, and where uncertainties exist.

Networks of collaborative relationships amongst firms and other institutions are widely recognised as an important organisational form of innovative activity (Orsenigo, Pammolli, & Riccaboni 2001:485). The literature has widely different interpretations of the nature, structure, motivations and functions of networks. Most approaches agree, in principle, that networks of collaborative relationships, especially in high-growth, technology-intensive industries, should be considered and analysed as organisational devices for the coordination of heterogeneous learning processes by agents characterised by different skills, competencies, access to information, and assets (Orsenigo et al 2001:485). Fostering cooperation between the educational system, firms, and research institutes can improve the quality of labour, thereby giving a country an advantage (Calliano &

Carpano, 2000).

Strategic alliances happen in the form of voluntary arrangements between firms involving exchange, sharing, or co-development of products, technologies or services (Gulati 1998:293,296). The importance of networks of contact between actors is that they can become sources of information for all participants. Those actors that have direct connections with each other are likely to possess more common knowledge or information, on innovations and their organisations. Networks can also promote behavioural conformity by serving as conduits for both technological and social information about organisational activities, which in turn have the ability to influence the extent to which new innovations are adopted.

Kogut (in Gulati 1998:298), highlights three main motivations that are broadly applicable to other types of alliances:

- Transaction costs resulting from small numbers of bargaining
- Strategic behaviour that leads firms to enhance their competitive positioning
- A quest for organisational knowledge or learning that results when one or both partners want to acquire some critical knowledge from the other, or one partner wants to maintain its capability while seeking another firm's knowledge.

Of paramount importance to the efficiency of the R&D process is the ability of aerospace engineers and scientists to identify, acquire and utilise scientific and technical information related to aerospace and aerospace-related activities (Blados, Cotter & Ryan 2001:54). Therefore greater awareness and exchange of scientific and technical aerospace information is necessary to ensure the success of the innovation process in general. It is on this basis that the Advisory Group for Aerospace Research and Development (AGARD) proposed the establishment of the International Aerospace Information Network (IAIN), to serve as a self-sustaining worldwide network of partner organisations committed to sharing their data and information resources. With recent advances in information technology and information management, increased participation in the aerospace field, and the realities of scarce resources for every nation, the strategies and benefits of international cooperation and resource sharing have become apparent (Blados et al 2001:54). The purpose of IAIN would be to provide a technical infrastructure that services aerospace research scientists and engineers, and the community of policy analysts, resource managers and educators as well as the general public, thereby promoting innovation and diffusion.

Developing economies tend to experience resource-related problems with regard to innovation and implementation of technologies. The innovation networks theory outlined above emphasizes the potential benefits of such collaborative relationships, such as sharing infrastructure, information, skills, and technologies. Such collaborative relationships could be critical in technological capability building and the creation of national technological competence.

2.3 Technological competence and the capacity-building paths followed by various countries

This section outlines information collected from various literature sources about the paths followed by various countries in building technological capacity in the aircraft industry for national technological competence. The successes and problems encountered during such a process will be related to the South African industry to establish if there are any commonalities, and if the lessons from other countries could be used in developing models suitable for building local technological competitiveness in the civil aircraft industry. The countries studied appear in the distribution of the World Top 100 aerospace companies list (Table 1.1), and the estimates of aerospace industry sales and employment, 2003 (Table 1.2), where in both instances, the United States leads the performance list. The United Kingdom was second in both instances, although it has the same value of sales as France (Table 1.2). It is assumed that, by virtue of these countries heading the list, they have displayed national technological competence and high technology trade performance.

2.3.1 The United States aircraft industry

US leadership in aircraft manufacturing has been a major part of the nation's economic strength and national security for more than 50 years (NRC, 1994). Lately, its leadership has begun to be challenged as major US aircraft manufacturers and their suppliers face declining sales and intense international competition.

Other countries such as Japan, and other global companies, are relevant to the US aircraft industry as partners, customers, and competitors. Although most of these global companies are not competing directly in civil airframes and major subsystems, they already possess or could acquire the capabilities needed to do so. The Japanese companies are a good example as they are displacing US suppliers in areas such as fuselage structures, and they dominate trade in several critical component technologies. Firms that emphasise high quality, low-cost manufacturing would obviously have an advantage in global leadership (NRC, 1994). Many US aircraft companies are no longer making the investments necessary to stay on the cutting edge of manufacturing, largely as a result of declining sales of military and civil aircraft. Japanese companies are doing the opposite.

The forces shaping competition in the 21st century – growing but price-sensitive markets, industry restructuring, and fewer new programs to build aircraft and engines – continue to pressurise major US aircraft manufacturers and their suppliers to deliver more value at lower cost.

US companies and government need to work together to develop a long-term strategy to meet the challenges posed by other industrialised nations that view aviation as an important part of economic growth (NRC, 1994). Although responsibility rests with the aircraft companies themselves, government still has a role to play in creating a favourable overall environment for the industry. A coherent policy or institutional mechanism is required.

The National Research Council (NRC) reports on what government and industry can do towards maintaining US technological leadership and manufacturing capabilities while encouraging mutually beneficial interactions with countries such as Japan. One of its recommendations is for a 35% increase in National Aeronautics and Space Administration (NASA) aeronautics funding for three years, with an expansion of applied research programs in subsonic aircraft and propulsion systems. NASA should increase significantly the share of research contracted to industry to ensure that this kind of work will be civilly viable. The report also calls for the elimination of obstacles to greater synergy between military and civil aircraft production, and for new approaches for identifying and managing critical technologies (NRC, 1994).

The major advantage for US aerospace companies is that they have a strong civil business base, which do not necessarily rely on military business although there has been a close connection between civil and military businesses (Crawford, 2000). The huge government funding of military projects has been a basis for spill-overs into the civil business base for both technology and economic development. US aerospace companies also have a consolidation of aerospace companies, which is lacking in most developing countries. Although consolidation and partnerships are good drivers of growth, they can also create monopolies that affect costs, and may limit competition in the generation of new ideas.

2.3.1.1 Collaboration in America

US economic development strategy suggests that to compete effectively in the international marketplace, US corporations need to collaborate with their domestic competitors (The US report on aerospace, 2003). This kind of cooperation should enhance and increase competitiveness, both domestically and internationally. Collaboration becomes extremely important with regard to R&D, as increased competitiveness results in increased industry standards, which provide a base for competition at higher levels of product quality, price, and performance.

For the collaboration to be successful, government and industry have to view each other as strategic partners who mutually advance each other's strategic position, share higher risks for higher rewards, and leverage financial and human resources for these gains.

2.3.1.2 Lessons learned from US collaborations

- Joint public–private R&D collaboration strengthens the nation's technology strategy
- In joint R&D collaboration, all parties share in the resource commitments. As industry commits resources from within its strategic R&D investment plans, the

entire process aligns such investment plans using government and private sector resources (i.e. personnel, facilities, funds) towards the achievement of the national goals

- Strategic alliances should be long-term commitments
- Collaboration increases competitiveness.

2.3.2 The United Kingdom aircraft industry

Aerospace was one of the most vibrant and successful sectors of the UK industry in 2003 (DTI (UK), 2003). At this time, more than 3 000 companies existed in this industry, which employed approximately 180 000 people directly and 350 000 indirectly. The UK aerospace industry is the second largest worldwide behind the US, making up about 15% of world trade with contributions from high-technology field such as engineering, electronics and software, among others. It has been adding approximately £3 billion annually to the UK balance of trade, and provides over 10% of UK exports (Farnborough Aerospace Consortium, 2005).

According to Jackson (2004:522), in terms of the civilian–military mix in the UK aerospace industry there has been a move away from defence (as a percentage of sales) in favour of civilian production. This is highlighted in Figure 2.8, where it is indicated that in 1980, over 65% of aerospace sales were in the defence sector, whereas by 2002, the percentage sales for the defence aerospace sector had fallen to 56%.

The UK aerospace industry is described by Jackson (2004:523) as being heavily involved in developing technologies on a variety fronts through its R&D programmes, mainly in fixed-wing airframes, helicopters, aero-engines, avionics equipment, guided weapons and satellites. The firms are known for their competencies in manufacture or assembly of complete aircraft, aircraft overhaul and rebuilding, developing and making prototypes, and in producing aircraft engine propulsion and auxiliary apparatus.

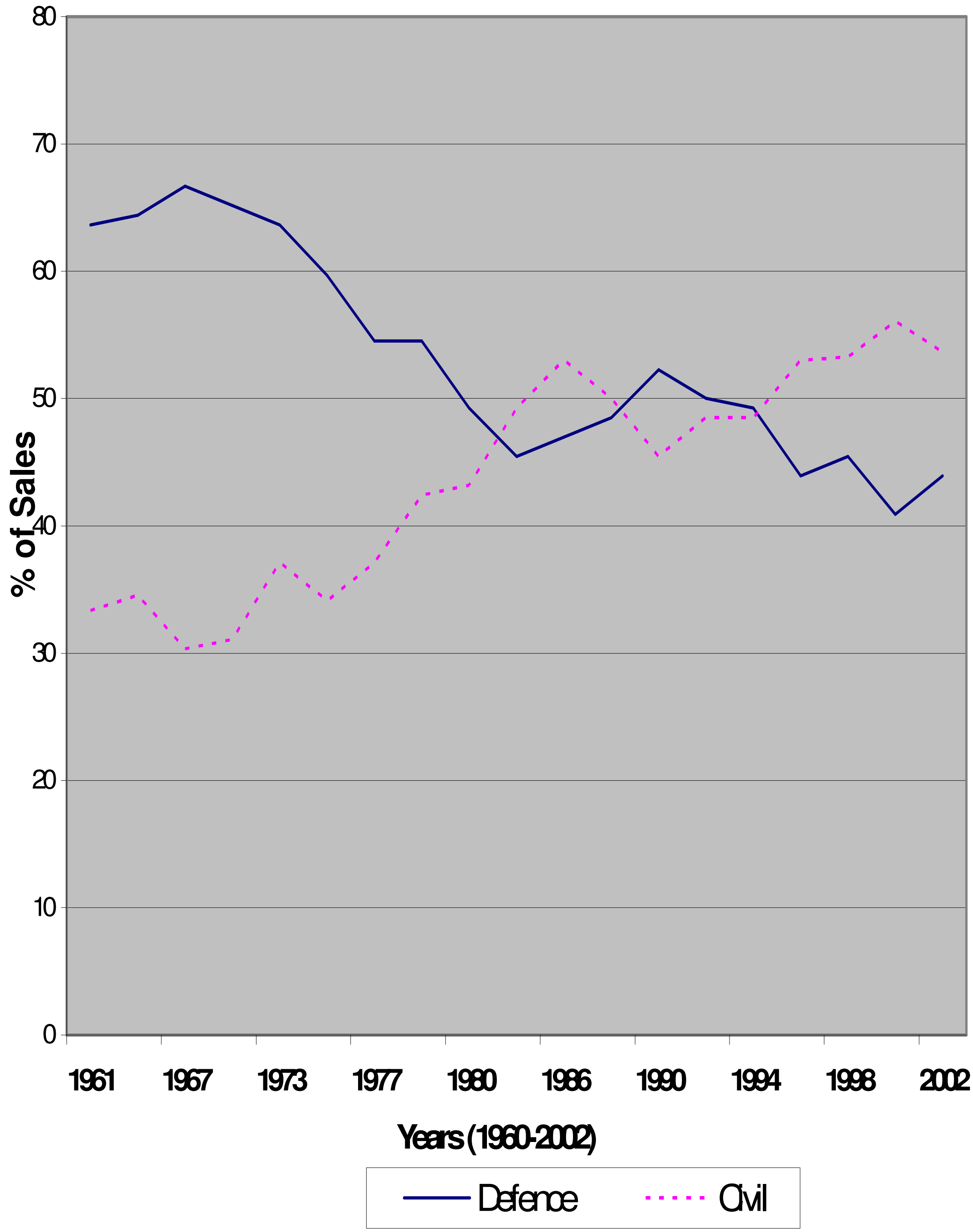

Figure 2.8 The civil and defence aerospace mix as a percentage of sales
Source: SBAC in Jackson (2004:522)

According to the DTI (UK)'s independent report by AeIGT (2003), the UK aerospace industry's global competitive edge is a result of three factors:

- Excellent innovative products derived from applied research, demonstration and product development strategies in the 1970s and 1980s
- World-class productivity within key UK companies, derived from sustained process improvement programmes and world-class skilled people
- A positive socio-economic environment in which government policy, trade associations, trade unions and academic institutions have underpinned and encouraged investment in aerospace (DTI (UK), 2003).

It is apparent that the British aerospace industry relies on its technology base to remain competitive. The UK government set out its plans for the future development of air transport in a White Paper (European Commission, 1996). Some of the UK government's efforts in growing the aerospace industry are described in ATAG's report on 'The future development of air transport in the United Kingdom'. ATAG is an "independent coalition of organisations and companies that have united to support aviation infrastructure developments and capacity improvements in an environmentally responsible manner" (ATAG, 2002). ATAG's funding members include Airbus, Boeing, Rolls-Royce, International Air Transport Association (IATA) and CFM. Amongst other things, ATAG provides advice to public authorities and governments on behalf of the international air transport industry.

The ATAG report recommends that the UK government work in partnerships with other governments, industry, NGOs and the civil aviation industry, as such approaches would ensure long-term development of sustainable aviation (ATAG, 2002).

The UK government is regarded as an important partner for sustainable aviation in the following respects:

- Infrastructure development
- Political and financial framework
- Economic and environmental regulations.

The UK government should therefore be able to play a number of important roles:

- Stimulating partnerships at the local level, supporting R&D programmes, promoting air intermodality
- Promoting the implementation of modern air traffic management and communications, navigation and surveillance systems
- Contributing to the work of the International Civil Aviation Organization (ICAO) on environmental standards and emission trading schemes
- Encouraging voluntary initiatives towards environmental benefits (ATAG, 2002).

The UK government provides policy guidelines to find optimum ways of stimulating innovation and growth within the UK aerospace industry It has established, through its Department of Trade and Industry, a body called the Aerospace Innovation and Growth Team (AeIGT). This team consists of over 140 senior executives from the aerospace sector's major stakeholders, which include industry, government, academia, research bodies and the unions. Four subgroups, including a focus group on finance, conducted a study on the key challenges facing the aerospace industry and how they could be addressed. The four subgroups were tasked to look at various aspects impacting on industry development, such as technology, capability and skills; engineering, manufacturing and supply; market structure and market access; and regulation environment and safety. A final report was presented to the AeIGT executive, with recommendations regarding stimulating innovation and growth within their specific areas of focus. (DTI (UK), 2003).

The success of the UK aerospace industry with international ventures is based on a partnership between industry and government (DTI (UK), 2003). Their output has focused on international collaborative programmes, primarily with European firms. This international collaboration led to a major improvement in economies of scale for UK aircraft production, giving it the advantage to compete with big companies such as Boeing. This enabled the UK to establish one of the best world centres for large civil aero-engine systems integration.

The aerospace and defence centre for excellence in the UK, the Farnborough Aerospace Consortium (FAC), covers South East England and London. FAC is basically a large aerospace and defence trade association with national and international membership. Its main focus is on assisting UK firms in acquiring business in a global market, and directing the development of sectors targeted for growth within the aerospace industry. It is deeply involved with the UK AeIGT programme.

FAC has formed alliances with other associations such as the Society of British Aerospace Companies (SBAC) and the Defence Manufacturers Association (DMA), along with 8 other regional trade associations. FAC has specific aims:

- Delivering improved access to market
- Promoting competitiveness for meeting current and future market requirements
- Facilitating technology development and exploitation (including access to knowledge of research and technology availability)
- Acting as a forum to interact with and influence public and private sector organisations for support
- Providing networking opportunities

2.3.3 The Japanese aircraft industry

Mowery and Rosenberg (1984), in their study on catching-up in the aircraft industry, predicted that catching-up in the area of large civil transport would not be feasible for Japan before the 21st century. They stress the importance of having an established domestic market with its research and engineering infrastructure, and appropriate government policy.

Japan used to be the world's second largest market for aircraft, most of which were purchased from US firms (NRC, 1994). Japan's participation in the global aircraft industry is more extensive than is generally recognised, and has been achieved largely through alliances with US industry. The Japanese civil aircraft industries participated in the development and production of the YX/767, a large-scale international joint collaboration on the V2500 engine, CF34-8/10 engine and B777 aircraft (IADF, 2004). This followed the development and production of the

YS-11, the first civil aircraft developed in Japan, a project that was a failure in the market. Japan is between stages 3 and 4 of the SIH model discussed by Hwang (2000) as it has been involved in subassembly development, low level aircraft system development and full system integration. Japan partnered with Boeing on the B767 and B777 programmes, in a 15%~21% risk sharing agreement. The Japanese have maintained an international reputation as a result of these collaborations.

The Japanese continue to accumulate experience in the field of component development, sales and product support, and to participate in international joint development and production, since that affords them more learning and skills transfer. To achieve optimum investment of financial resources, as the development of aircraft and related components involves a great amount of risk, the Japanese established an organisation for promoting international collaboration between aircraft industries, where financial support is offered for international collaborative joint projects. The organisation is called the International Aircraft Development Fund (IADF), a non-profit organisation.

Apart from financial support for the Japanese facilitators who execute the international collaborations on civil aircraft and engines, the IADF aims to promote the Japanese aircraft industry internationally. Collaboration on international projects is designed to enhance industrial technology, and sponsor international personnel exchange and the transfer of technological know-how or skills.

With government assistance, the Japan Aircraft Development Corporation (JADC), a consortium of Japanese aircraft industry organisations, was established for the development of civil airplanes (JADC, 2004). The main purpose of the JADC, a non-profit foundation, is to oversee the enhancement of the Japanese aircraft industry. Its objective is to advance the development of civil aircraft through research, studies and other appropriate means capable of promoting the improvement and development of the aircraft industry, and eventually, to make a contribution to the prosperity of whole industries, and the country as a whole.

JADC carries out a number of activities to achieve its objectives (JADC, 2004):

- Research and studies necessary or appropriate for the development of civil aircraft
- Tests and experiments relating to the above research and studies
- Analyses of the results of the research, studies, tests and experiments
- Facilitation and promotion of the manufacture and sale of civil aircraft resulting from or otherwise relating to the above activities
- Any activity incidental to each of the above activities
- Any other activities necessary or appropriate to achieve the objectives of the JADC.

The JADC plays a role by coordinating and consolidating resources, and also by cooperating with foreign manufacturers, as the need arises, in cases where a single manufacturer cannot afford to undertake an aircraft development program due to resource constraints.

2.3.4 The South Korean aircraft industry

South Korea is a latecomer in the aircraft-manufacturing sector. Nevertheless, it has shown improvements over the course of its successive production of military aircraft such as the MD-500, the UH-60, and the KF-16. There has, however, been limited spread of technology to other areas of manufacturing and areas of research and development (Cho, 2003).

In the past, four main South Korean firms shared a small domestic market, which, despite strong rivalry, did not create favourable conditions for competing in world markets. This situation resulted in production inefficiencies and insufficient learning and, for this reason, in October 1999 South Korean aircraft firms merged to form the Korean Aerospace Industries Company Ltd (KAI). KAI was made up of the four firms – Korean Air, Samsung, Daewoo, and Hyundai. Since this merge, KAI has become the prime contractor for all domestic aircraft projects and the national aircraft champion in South Korea (Cho, 2003). This represented a fundamental policy shift from domestic rivalry to a national champion. In the process, the government streamlined aircraft industry policy. "In many of the prominent industries in which there is only one national rival, such as aerospace and telecommunications, government has played a large role in distorting competition" (Porter, 1990). It should also be noted that a national champion policy might bring negative effects such as inefficiency arising from a rigid bureaucracy, and lack of competition amongst local firms.

The rationale behind the establishment of KAI resulted from the South Korean aircraft industry having suffered huge unprofitabilities, high debt and over capacity. The new strategy for consolidation into KAI was aimed at achieving economies of scale and creating opportunities for sufficient strength to compete in the global economy (Hwang, 2000).

Another interesting point is the fact that Korean Air, a partner in KAI, started as an airline and later diversified into producing aircraft and airframe parts. It had the advantage of having operated civil transport aircraft, by which means it acquired knowledge about aircraft and related technologies. From its experience in aeroplane operation, it became a successful aircraft manufacturer. Korean Air is currently the only airline in the world that also produces aircraft. The kind of diversification undertaken by Korean Air is not easy, as airframe manufacturing requires state-of-the-art technologies such as aerodynamics, structural analysis, avionics, new materials etc, all of which were outside its core business before.

South Korea has three aircraft related government research institutes (GRIs): the Korea Aerospace Research Institute (KARI), the Korea Research Institute of Machinery and Metals (KIMM), and the Advanced Agency for Defence Development (ADD). Whereas KARI and KIMM operate under the Ministry of Science and Technology (MOST), ADD operates under the Ministry of Defence (MOD). KARI conducts civil aerospace technology development, with one area of focus being aircraft and aero-engine technology development. It is also responsible for the performance and quality evaluation of aerospace products. Its research funds come from MOST and the Ministry of Commerce, Industry and Energy (MOCIE). KIMM is responsible for small amounts of R&D for aircraft parts and materials, mostly precision casting of aero-engine parts. ADD is responsible for the development of military or defence technologies, which include aircraft and missiles. In addition to the three GRIs, the Korea Institute of Aerospace Technology (KIAT) also exists (Hwang, 2000).

Prior to the formation of KAI in 1999, Korean Air initiated several aircraft development projects through KIAT as part of system integration capability development. The Chang Gong-91, which first flew in 1991, was the first full-scale system development project resulting from Korean Air's initiatives, and also the first civil South Korean-model aircraft to be officially certified by the South Korean Government (Hwang, 2000).

The South Korean aircraft industry took into consideration the new trend of forming strategic alliances with foreign partners, not just with the US, but also with states from the European Union. This is a good way of sustaining an aircraft business in the world market and it provides opportunities for the acquisition of systems integration capabilities. By working with Boeing, KAI has the opportunity to acquire state-of-the-art technology, although the success of the co-operation depends on its capability for effective usage of the offset package committed by Boeing. KAI's competitive edge should be not just in project management and financial capabilities, but also in core technologies and the creation of the niche sector required for its survival in the highly competitive global aircraft industry.

2.3.4.1 Some of the lessons learned by South Korea

South Korean aircraft firms learned that forming strategic alliances with foreign partners from developed economies could equip them to develop technology capabilities including the systems integration capabilities required for sustainable technological competitiveness within the industry. An example is the strategic alliance that was formed between KAI and Boeing, where KAI was able to learn and acquire technologies from Boeing, thereby putting itself in a better position eventually to develop its own distinctive core technologies to give it a competitive edge.

In-house research and development (R&D) becomes a crucial factor when a nation needs to enhance design technology within the aircraft industry. For the revitalisation of R&D in the aircraft industry of South Korea, certain factors that appear to be secondary to technology management aspects but that are fundamental to the issues of building national technological competence, had to be taken into consideration (Cho, 2000):

- The approach to the promotion of the aircraft industry should not only have economic value in mind, but should also recognise the national security aspect of civil aircraft, which is why government's direct action is required. This calls for national investment in the development of technological capabilities that would address civil aircraft safety aspects. The Advisory Council for Aeronautical Research in Europe (ACARE) considers aircraft safety to be one of the objectives on the agenda for sustainable development. It has been proposed that an 80% reduction of air transport accidents should be achieved by the year 2020.
- South Korea recognised that the aircraft industry has some beneficial externalities such as enhancing national prestige; therefore an overall evaluation of the industry cannot be limited to a quantitative judgment alone. However, it learned about the importance of the aircraft sector by improving industrial growth and national technological competitiveness. This was realized through technological competence that followed from the strategies for acquiring, assimilating, and improving foreign technology, which achieved success through collaboration with developed countries. It also noted that the competition expected in the 21st century has to be taken into account with regard to returns on investment and the assumption of substantial risks. Therefore, preparation for the expected competition would not be enough without building technological capacity aimed at enhancing national technological competence within the civil aircraft industry.
- South Korea took cognisance of the fact that government support should promote the aircraft industry with a view to attaining fundamental capabilities for aircraft development. Government policy and continued substantial investment are crucial in the advancement of aircraft development. This is a very important fact as such advancement in aircraft development requires investment in technology development capabilities, which could be better facilitated with government support on issues such as R&D, technology transfer, skills development as well as the broader development of a technological infrastructure.

2.3.5 The Brazilian aircraft industry

Brazil is one of the most successful latecomer countries in the international aircraft industry. There are about 500 companies in the Brazilian aviation industry that employs approximately 50 000 people. The development of aircraft suitable for regional passenger transport has been a key factor in the success of the Brazilian aircraft industry (Science and Technology, 2003). Its previous experience includes the development of the Bandeirante (19-seater) aircraft and the Ipanema small transport. The Bandeirante satisfied regional aviation demands and received orders from both domestic and foreign markets, resulting in a production of approximately 500 units.

Embraer, the Brazilian aircraft company, has been successful in the regional/commuter market, where it developed the 30-seater EMB-120 (Brasilia), which sold more than 400 units worldwide in 1985, most being exported to the United States (Hwang, 2000). It became a major international supplier in the aviation field. It also successfully developed a 48-seater EMB-145 jet transport, and the jet fighter AMX with Alenia and Aermacchi, which are Italian-based companies. The sale of about 200 of Embraer's new EMB-145 regional jets led to its control of about 40% of the market by 1999. It became responsible for about 6,5% of Brazil's manufacturing exports (Freeman, 2002). Embraer drew its strength from the regional aviation and military training sectors and applied that to mastering the latest designs and production technologies. These ranged from composite materials design and production, to systems integration, development of real-time airborne software, digital mock-up, and flight-data acquisition with real-time telemetry (Science and Technology, 2003). Embraer concentrated on key technologies such as fuselage and systems integration, as a means of gaining mastery and autonomy over its business, importing and integrating components as required (Freeman, 2002). Rapid nationalisation of components would have led to technological decline as a result of high costs.

In the Brazilian aircraft industry, technology transfer became central to the creation of jobs or balance of trade, and as a result, became a key requirement for procurement in the development of military aircraft (Freeman, 2002). The approach is similar to the one followed by countries such as South Korea and Taiwan. The acquired knowledge and lessons learned within the military context were important for the Brazilians when it came to the development of the civil aircraft industry. Brazilian engineers received training from countries transferring technology, and specialists from such countries went to Brazil to assist in setting up production lines. One such example is the production of the EMB326 Xavante aircraft under license from Italy, where 70 Brazilian engineers were trained in Italy.

Exploring niche markets and regional/commuter markets had a successful outcome for the Brazilian aircraft industry. The existing aircraft-related training colleges and research institutes supply the Brazilian industry with highly qualified personnel, whose employment in a thriving aeronautical industry is guaranteed.

2.3.6 Summary of other countries: Successes and problem areas

2.3.6.1 The United States

Successes:

- Emphasized high quality/low-cost manufacturing, which has given it the advantage of increased global leadership
- Has a strong civil business base and does not rely on military business
- Has an extraordinary consolidation of aerospace companies, which is something that is still lacking in most developing countries
- Has joint public–private R&D collaboration that strengthens the nation's technology strategy
- In joint R&D collaboration, all parties share in the resource commitments. As industry commits resources from their strategic R&D investment plans, the entire process aligns such investment plans with government and private sector resources (i.e. personnel, facilities, funds) towards the achievement of national goals
- Uses strategic alliances to build long term and sustainable technology leadership
- Uses collaboration to increase technology competitiveness within firms.

Some problem areas:

US aircraft manufacturers and their suppliers are constantly under pressure to deliver more value at lower costs for the following reasons:

- Price-sensitive markets

- Industry restructuring
- Fewer new programs to build aircraft and engines.

2.3.6.2 The United Kingdom

Successes:

The UK aircraft industry is competitive because of the emphasis placed on developing the following crucial factors:

- Excellent innovative products resulting from applied research, demonstration and product development strategies as early as the 1970s and 1980s
- World-class productivity within key UK companies, derived from sustained process improvement programmes and world-class skilled people
- A positive socio-economic environment in which government policy, trade associations, trade unions and academic institutions have underpinned and encouraged investment in aerospace.

The UK aerospace industry has maintained its competitiveness because of having developed a good technology base. The UK government is an important partner for sustainable aviation with regard to infrastructure development, political and financial frameworks, and economic and environmental regulations. The UK aerospace industry’s success in international ventures is based on the partnership between UK industry and government, with special focus on international collaborative programmes, primarily with European firms. The UK has one of the best world centres for large civil aero-engine systems integration.

Some problem areas:

UK aircraft industry has focused on establishing partnerships with other European countries, with minimal efforts to consider most developing countries, which has resulted in few problems with regard to competing on price from low cost products.

2.3.6.3 Japan

Successes:

Japan has become the world's second-largest market for aircraft, most of them purchased from US firms. This can be attributed to its participation in global aircraft development projects, and also largely to developing global alliances, mostly with the US.

It has been successfully involved in subassembly development, low level aircraft system development, and full system integration, as well as in aircraft development projects as risk sharing partners.
It has used participation in international joint development and production strategically, for greater benefit from learning and skills transfer.

The Japanese established an organisation called the International Aircraft Development Fund (IADF), to make financial support available for promoting international collaboration between aircraft industries. The IADF also helps to promote the Japanese aircraft industry internationally, by promoting the enhancement of industrial technology and the evolution of international personnel exchange, and transfer of technological know-how or skills, through the execution of international collaborative projects.

With government assistance, the Japan Aircraft Development Corporation (JADC) was established to oversee the enhancement of the Japanese aircraft industry. Its objectives are to advance and further the development of civil aircraft through research, studies and other appropriate means capable of promoting the improvement and development of the aircraft industry, and eventually, to make a contribution to the prosperity of whole industries, and the country as a whole.

Some problem areas:
The Japanese aircraft industry still has an under established domestic market, too little research and engineering infrastructure, and insufficient government policy on the development of the industry.

2.3.6.4 South Korea

Successes:
The South Korean aircraft industry has successfully moved from domestic rivalry to national championship, so as to position firms for global competitiveness. Major firms merged to form a single supplier known as Korean Aircraft Industry (KAI).

Government has been successful in streamlining aircraft industry policy, achieving economies of scale and creating opportunities for sufficient strength to compete in the global economy. Diversification by firms has been one of the key successes where, for example, an airline firm has been able to diversify into aircraft and airframe parts manufacturing.

South Korea has successfully established aircraft-related research institutes that have focused on aircraft technology development, R&D and the performance and quality evaluation of aerospace products.

The South Korean aircraft industry formed strategic alliances with foreign partners, not just with the US, but also with European states. It also successfully developed system integration capabilities through various programs resulting from such strategic alliances. By working with Boeing, KAI had the opportunity to acquire state-of-the-art technology.

Some problem areas:

Although the South Korean aircraft industry has improved aircraft technology development through its successive production of military aircraft such as the MD-500, the UH-60, and the KF-16, there has been limited spread of technology and research and development to civil aircraft manufacturing.

Korean Aircraft Industry (KAI)'s competitive edge has been more in project management and financial engineering and less in core technologies, whereas the creation of a niche sector could be key to long-term survival in the highly competitive global aircraft industry.

2.3.6.5 Brazil

Successes:

Brazil is one of the most successful latecomer countries in the aircraft industry. The development of aircraft suitable for regional passenger transport has been a key factor in its success. Its previous experience includes the development of the Bandeirante (19-seater) aircraft, which satisfied regional aviation demands, and for which orders from both domestic and foreign markets were received.

Embraer, a prominent Brazilian aircraft company, has become a major international supplier in the aviation field with the 48-seater EMB-145 and the EMB-145 jets. Firms such as Embraer have drawn successfully on regional aviation and the military training sector in mastering the latest designs and production technologies, which range from composite materials design and production, to systems integration, development of real-time airborne software, digital mock-up, and flight-data acquisition with real-time telemetry.

The industry focused on key technologies such as fuselage and systems integration, as a means of gaining mastery and autonomy over its business, importing and integrating components as required. Exploring niche markets and regional/commuter markets has contributed to its success. Technology transfer, including skills transfer, is central to Brazil's successes. Aircraft technology development was a requirement for procurement, where foreign experts were invited to assist in setting up production lines. Aircraft-related training colleges and research institutes supply the Brazilian industry with highly qualified personnel, whose employment in the country's thriving aeronautical industry is guaranteed.

Some problem areas:

Skills shortage remains a challenge for the Brazilian aircraft industry, as it does for South Africa.

2.3.6.6 Theoretical relevance to the research area

Information on the successes of various countries was used to complement the research findings that were applied to the recommendation of a framework for technological development. Collectively, developed economies appear to have focussed on joint public–private national R&D collaborations; R&D investments; strategic alliances and collaborations (both national and international); government policy that guides technology development; networks; and infrastructure development. These elements, including those that were based on the findings of the study, formed part of the framework proposed by the researcher. Developing economies should exploit some of the strengths of developed economies, such as competing on price (more value at lower costs), whereby technologies developed or adapted become affordable. A remaining challenge for developing economies is the reluctance to enter into strategic alliances with developing economies for fear of a lack of technological capabilities and national competence. The success of developing economies can be attributed to national championships, with key firms merging to form large corporations, with technological capabilities gathered from various backgrounds. For developing economies, technology transfer is a focal area for acquiring technological capabilities. The lack of infrastructure and resources, skills shortages, and the failure to access international (and/or domestic) markets are areas of concern. These elements should be taken into consideration when recommending a structural framework for the development of technological capabilities

2.3.7 Some highlights of the South African aircraft industry

Some technological competencies and capability building paths followed by the South African aircraft industry were indicated in Chapter 1, section 1.2 in 'overview of the South African aircraft industry'. A number of key highlights will be discussed in this section. The focus in this section will be on the challenges facing the South African aircraft industry in comparison to other countries. The intentions of both industry and government in developing industrial capabilities towards improved national technological competitiveness will be discussed, and some initiatives within technological development will be highlighted.

In the study done by the Department of Trade and Industry (DTI) SA to assess the contribution of the industry in growing the South African economy, it was found that the industry produces annual sales of more than R5 billion, employing approximately 12 000 people and using R2,520 billion in capital. About 25% of the industry is very closely related to the defence industry (TISA, 2002). The civil aircraft market in South Africa consists of civil transport, helicopters, business jets, commuter or regional aircraft and general aviation. Major successes in manufacturing have occurred in the area of sub-contracting to major international aircraft manufacturers or their suppliers. Local companies have been successful in manufacturing auxiliary drive gearboxes, flaps, rudders, landing gear and pylons for aircraft. About half of the companies in the industry are involved in maintenance of aircraft, and have high technical aircraft maintenance skills and facilities.

The domestic market in South Africa is not large enough to support its civil aircraft sector, therefore firms are not building capabilities in the aircraft industry based on domestic demand but rather on global market demand.

Some aircraft firms share complementary activities such as technology development, and facilitate the flow of information or knowledge exchange, thereby promoting international competitiveness. More learning is required, and it could be easily coordinated within a national championing infrastructure support system. As the market in South Africa is very small, it does not allow domestic rivalry to happen effectively. Denel and Aerosud work together as they have expertise in engine component supply and airframe interior designing, respectively, hence they complement each other in terms of aircraft development and capacity building.

In the past, government played a large role in distorting competition by funding the military aircraft sector, Denel being the main beneficiary. Both Denel and Aerosud are national champions of military aircraft, with the capability of becoming national champions for civil aircraft. Their capabilities in both engines and airframes, based on a foundation of military aircraft experience, have grown significantly over the years.

Government, through its policies on capital markets, education or issuing of subsidies, can influence or shape national competitiveness. This can in turn affect factor conditions. The interest by the South African government in establishing a strategy for developing the civil aircraft industry, and also in providing funding in that regard, could have a major impact on the capability building and competitiveness of local firms. It is the responsibility of national government to impose standards and regulations, make business interaction more efficient, provide communication infrastructure, create an appropriate formal educational system, and supervise property rights (Calliano & Carpano, 2000).

2.3.7.1 Some challenges and problem areas

As highlighted earlier in this document, the aircraft sector is characterised by huge capital investments (required for business development), substantial research and development (R&D) (associated with technology development), and long product development periods (sometimes more than a decade from inception to final product). These are challenges that the local South African aircraft industry has to face, given the current inadequate resource-base, in order for the sector to make the most of opportunities and realise capabilities for facilitating growth.

There are a number of problem areas in the South African aircraft industry:

- A poorly developed technology base
- An inadequate resource base (skills, R&D, funds)
- Insufficient experience for certain levels of aircraft development, e.g. assembly of civil aircraft
- Very little collaboration between firms and few strategic alliances with foreign partners
- Insufficient government support for R&D, technology transfer and skills development
- A poorly developed technological infrastructure.

These elements appear to be similar to the ones identified as problematic in the literature on developing economies.

The South African aircraft industry is aware of global trends in aerospace, and these could be used to address some of the problem areas indicated above. The Aerospace Industry Support Initiative document highlights a number of global trends in the international aerospace sector (AISI, 2005):

- Consolidation, such as the merger of Boeing and McDonnel Douglas, and those within the European aerospace industry
- Moves towards single source suppliers
- Development of technological innovation to address global events such as the September 11 attack on the Twin Towers
- A drive towards risk and revenue sharing partnerships.

These global trends are challenges for the South African aircraft industry in that if they are not considered when local technology development strategies are formulated, the current innovation inefficiencies in the industry might continue. These challenges are currently being considered by the South African aircraft industry, together with government, in the proposal of a strategy that will see the development of improved competitiveness for the local industry.

As is the case of similar environments, such as Australia and New Zealand, general aviation (GA) is a significant part of the total South African aviation landscape (AISI, 2005). A key problem for the South African aircraft industry is that its GA has been declining in the past few years, with few new successful manufacturing entrants and an ageing countrywide fleet. The reason for such a decline remains to be determined. However, in the case of Australia, the downward trend has been attributed to rising costs (both operating and purchase), the lack of government policy, and the lack of financial incentives such as tax and other rebates. It must be noted that there are fairly onerous regulatory and certification issues pertaining to this sector, so the involvement of the relevant civil aviation authorities is paramount in any shift in the sector (AISI, 2005).

2.3.7.2 Highlights of current initiatives by government and industry

The South African aircraft industry has learned from other successful countries, such as New Zealand (which in comparison to Australia has an extremely vibrant general aviation sector), that in order to develop improved national technological competitiveness, appropriate measures have to be taken to nurture, protect and promote the industry.

It has been noted earlier in this document that South Africa is becoming important as a regional hub for maintenance repair organisations serving operators flying in sub-Saharan Africa. This is one area that can be fully exploited by the South African aircraft industry, where technology development is a necessity for competitiveness to be realised. Turbomeca Africa, a joint venture company formed by Denel and the French group Turbomeca, is an African investment in the area of engine manufacture, focusing on domestic firms as well as international firms such as Rolls-Royce and General Electric. It also provides support for repairs and overhauls of civil and military helicopter engines in sub-Saharan Africa. This form of partnership can enhance the learning and skills development necessary for the technology development of South African aircraft firms in the area of aircraft maintenance.

The South African aircraft market has certain competitive advantages (TISA, 2002):

- Availability of aircraft maintenance skills and facilities
- Availability of modifications skills and facilities
- Availability of upgrade skills and facilities
- Availability of design and manufacturing skills in the area of helicopters
- Low labour costs
- Strong support from avionics and the information telecommunication industries
- An aviation hub for Southern Africa
- Existing aviation training centres
- Various FAA and JAA certified companies
- Sufficient space for business operations.

Some of the capabilities of South African aircraft firms have been highlighted in Annexure 1. Business growth prospects for the South African aircraft industry, based on existing capabilities, appear to be in the following fields (AMTS, 2003; TISA, 2002):

- Aircraft maintenance
- Aircraft conversions of military and civil aircraft
- Aircraft modifications, including aircraft upgrades, refurbishment and conversions
- Manufacture of components and sub-system levels
- Upgrading existing skills for composites, rotor wing propeller blades, avionics, gearboxes and interiors.
- Sub-contracting and third-party work.
- The Industrial Participation Program (IPP), offered by the South African government through the DTI in support of investment or trade in South African industries.

The competitive advantages of the South African aircraft industry highlighted above need to be exploited further to achieve higher levels of national growth. Therefore, this study aims to propose frameworks that enable the competitive advantages and capabilities to be fully exploited in developing a national, technologically competitive civil aircraft industry, taking into consideration proposed growth prospects for the SA aircraft industry. Government and industry could initiate technology development strategies for the South African aircraft industry using existing capabilities and competencies, in line with global technology development trends.

The AISI document (2005) suggests that the local general aviation (GA) sector would benefit from the following initiatives:

- A detailed study on GA in South Africa, both civil and recreational
- The development of models for increasing investment in GA, encompassing:
    - Manufacturing under license
    - Design of new aircraft types for local manufacture, and local and international sale
    - Flight safety and GA security benchmarks
- Appropriate measures related to:
    - Tax incentives
    - Manufacturing allowances
- The promotion of GA manufacturing companies both domestically and internationally though mechanisms such as Africa Aerospace and Defense (AAD) exhibitions.

The strategy developed by the Department of Trade and Industry (DTI) SA indicated in the Aerospace Industry Support Initiative document (AISI, 2005), states that "technological and business agenda for innovation must be created" so as to afford partnerships the opportunity to collectively generate long-term strategies around certain issues:

- The generation of a suitable business and technology infrastructure that will last until well beyond 2014
- A human capital base agenda that will nurture the country's future experts while retaining the present expertise
- The facilitation of mechanisms for:
    - Communicating industry needs and expectations to government, whilst achieving the same for government
    - Collective manufacturing and marketing (clustering and integration)

- Supply chain management
- Supplier base assistance:
  - ✓ Funding mechanisms
  - ✓ Active small, medium and micro enterprises (SMMEs), black economic empowerment (BEE) development
- Suitable business climate creation (partnerships and clustering amongst domestic and international industry organisations)
- R&D re-focus and expenditure increase.

The government initiative '*A strategy for a sustainable, economical and growing aerospace industry*' (ASSEGAI) was produced during the development of the Advanced Manufacturing Technology Strategy for the Department of Science and Technology (DST) in 2003. This followed a consultation process with local large aircraft firms (Denel, Aerosud, SAA Technical, AMS, AMD, Grintek, IAS and ATE) and government departments or ministries (DTI, DST, DPE, DOD and DOT) that started in November 2003. Figure 2.9 is a graphic representation of the outcomes of the ASSEGAI process, where it was determined that the industry should move away from a prescriptive industrial mindset, in which the international partners expect the local industry to manufacture according to a fixed design or recipe, towards a more beneficial future in which the domestic aircraft industry owns not only the intellectual design and rights but also the actual manufacturing process itself (AISI, 2005). Figure 2.9 also illustrated those areas in which the AISI needs to develop and engender the correct processes and frameworks.

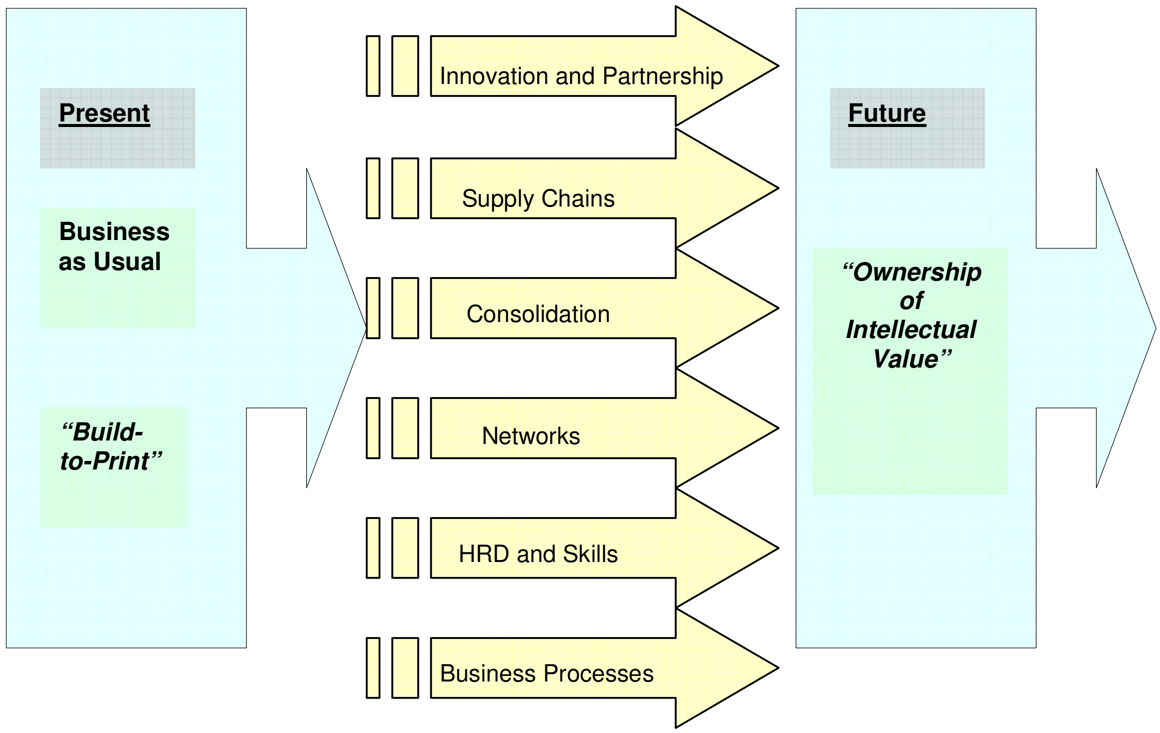

Figure 2.9 Graphic representation of the outcomes of the ASSEGAI process
Source: AISI Aerospace Industry Support Initiative 2005. Implementation Strategy for the Department of Trade and Industry, SA

With regard to skills and technology development, which appears to be a problem area for the South African aircraft industry, there is an immediate and future need to move the skilled people who make up the labour force of the industry to strategic areas where their skills could be fully exploited and transferred accordingly. Although very limited in number, these skilled people exist right across the aerospace sector, from artisans undergoing workplace learning for production purposes, through to the scientists working on innovative future technologies in academia and the science councils.

The AISI document (2005) proposes the following initiatives be undertaken by government, as part of skills and technology development:

- The development, implementation, monitoring and evaluation of a skills strategy for the industry
- The identification of current and future skills needs of the domestic aerospace industry by, amongst other initiatives, monitoring general and industry labour market trends

- The improvement of linkages between the aerospace industry and education, including joint curricula development
- Monitoring of technological trends and their potential impact on the global and local industry, and implementation of a research and development strategy
- Facilitation of specific capacity-building projects, including internships, learnerships and bursaries
- Fostering of collaborations with skills and education training authorities (SETAs) and provision of advice to aerospace companies on skills development matters
- Facilitation of engagement with government on skills, human resource development (HRD) and education policy, strategy and programmes.

Furthermore, some key technology areas that need to be developed for the local aircraft industry have been identified through the study done by the DTI (SA) on Technology Development Trends (DTI (SA), 2004b), and the work done through the ASSEGAI process (CSIR, 2003) mentioned earlier in the document. Certain key technologies have been identified:

- Composite materials
- ICT
- Alloy technologies
- Ultra light materials

2.3.8 Situational analysis of various countries in comparison to South Africa

Situational analysis was done to compare the South African aircraft industry to those of other countries and to identify the gaps existing in that regard. This would be used when conducting interviews aimed at resolving industry problems and in developing frameworks for South Africa for civil aircraft technology development.

2.3.8.1 Common paths and trends followed by various countries in developing technological competence and capacity building

Table 2.7 highlights some of the important aspects considered by countries growing their aerospace industry. This was to be compared to data collected during the case study research and interviews in certain instances.

Table 2.7 Situational analysis of various countries

Competency area	South Korea	Japan	Brazil	USA	UK	EU	SA
Technology development	X	X	X	X	X	X	
R&D programme (public or private)	X	X		X	X		
Other incentive programmes		X					X
Government support	X	X	X	X	X	X	X
Market acquisition assistance	X			X	X	X	
Firm collaboration and strategic alliances	X	X	X	X	X	X	
Aircraft-related research institutes	X		X				
Skills transfer/development	X	X	X			X	
Technology transfer	X	X	X				X

From the literature review, it emerged that most countries have used the paths and trends discussed below to achieve their successes within the aircraft industry.

2.3.8.1.1 Strategic alliances and collaboration

Many countries believe that collaboration is crucial for an aircraft industry to develop. For such collaboration to be successful, government and industry have to view each other as strategic partners who mutually advance each other's strategic position, share higher risks for higher rewards, and leverage financial and human resources for these gains. These were some of the lessons learnt under such collaborations:

- Joint public–private R&D collaboration strengthens a nation's technology strategy
- In joint R&D collaboration, all parties share in the resource commitments. As industry commits resources from within their strategic R&D investment plans, the entire process aligns such investment plans with government and private sector resources (i.e. personnel, facilities, funds) towards the achievement of national goals

- Strategic alliances are important in building the long-term sustainability of an aircraft industry
- Collaboration increases competitiveness.

The formation of strategic alliances with foreign partners from developed economies can equip firms for developing technology capabilities, including the systems integration capabilities required for sustainable technological competitiveness within the industry. An example is the strategic alliance that was formed between Korean Aerospace Industries (KAI) and Boeing, where KAI was able to learn and acquire technologies from Boeing, thereby putting it in a better position to develop its own distinctive core technologies eventually, for a competitive edge.

2.3.8.1.2 Research and development (R&D)

In-house research and development (R&D) is a crucial factor in enhancing design technology within an aircraft industry. Most governments in the countries studied in this project offered support for technology development by funding R&D, where global technology development trends were followed, in line with the agenda for sustainable development proposed by the Advisory Council for Aeronautical Research in Europe (ACARE), to be achieved by the year 2020 (ATAG 2002). Government should promote the aircraft industry with a view to attaining fundamental capabilities for aircraft development.

2.3.8.1.3 Government policy in support of technology development

Government policy and continued substantial investment could be crucial in the advancement of aircraft development. Such advancement requires investment in technology development capabilities, which are better facilitated with government support for issues such as R&D, technology transfer, and skills development, as well as the broader development of technological infrastructure. Incentive programmes have been offered in certain instances by most governments to support technology development, although in other countries these are not specifically designed for the aircraft industry.

Government has been seen to be offering guidelines with regard to consolidation and coordination of efforts towards technology development in the aircraft industry. A number of areas are crucial for government intervention as part of supporting technological development in the aircraft industry:

- Infrastructure development
- Human resource development
- Political and financial frameworks
- Economic and environmental regulations.

2.3.8.2 Conclusion: What the common paths and trends mean for the South African aircraft industry

Based on the items in Table 2.7 above, and the factors common to the success of many countries, it is clear that South Africa has some challenges that need to be addressed in order to develop a sustainable well-developed aircraft industry. The common aspects in the success of many aircraft firms in developing technological competitiveness in the countries discussed (South Korea, Japan, the UK, EU, Brazil, and the USA) were: Government involvement, collaboration between firms, strategic alliances (local and international), and large investments in research and development to enhance technology development. Developing countries focused more on skills development and transfer, where they relied mostly on technology transfer and exchange programmes to improve skills.

It is not known if the current government support in South Africa is enough to position the industry to build more technological capabilities, and whether it is comparable to that provided by governments in other countries to their civil aircraft industry.

It is evident from the literature studied that skills shortage is a major problem in the South African aircraft industry, in which many scientists are reaching retirement age in the absence of a ready pool of graduate replacements, and where technology development expertise continues to decline. An analysis based on the available literature suggests that technological capability challenges could improve if the South African aircraft industry had more collaboration and strategic alliances, both local and international, instead of relying just on technology transfer.

2.4 The existing gap in theory and literature

A gap appears to exist in the literature on technology development frameworks for civil aircraft industry in that many studies discussed in the theoretical background of this document focused on the complexity of the global aircraft industry, and partly on capacity-building frameworks, although mostly not specifically for the aircraft industry. Little is said regarding empirically successful models or frameworks that developing economies should follow to build a civil aircraft industry towards national technological competitiveness, thereby integrating firms into the global value chain. It is also not very clear how a technology base necessary for the industry to gain global technological competence, as well as support mechanisms for building technological capabilities, could be provided as means for building the civil aircraft industry. Such a gap calls for a new or improved theory to provide a strategy for developing the civil aircraft industry towards national technological competitiveness. Although some information is provided on elements that could influence development of technological know-how, there is no discussion on how the framework for technology development should be structured so as to facilitate industrial technological capabilities.

New theories are needed to provide frameworks that show the correlation between attributes such as government policy and support, skills development programmes, infrastructure development, the organisational structure of industry, and the level of development of the technology base of the civil aircraft industry.

CHAPTER III: ANALYTICAL FRAMEWORK: DEVELOPMENT STRATEGIES WITHIN THE CIVIL AIRCRAFT INDUSTRY

3.1 Current theories, models or methods applicable in the study

Hwang (2000) argues that an understanding of a firm's capabilities, inside a firm, is a prerequisite for catching-up in the aircraft industry. On this basis, he suggests a theory to explain a firm's capabilities in terms of two aspects:

- How technological capabilities are developed in the aircraft industry, moving up a system hierarchy to complex systems integration activities
- How organisational capabilities are required to achieve efficiencies on repetition of projects for both national and international markets.

The Systems Integration Hierarchy (SIH) model, as presented by Hwang, describes how firms move up the hierarchy from airframe parts manufacturing and subassembly, through subassembly development, to system integration. This is a capability building process model, occurring in four stages:

1) Knock-down system assembly

This is the first stage of catching up where latecomer firms start with simple assembly work.

2) Parts manufacturing and subassembly

This stage is applicable to airframe parts manufacturing, but it could be modified to include engine-parts manufacturing. The levels of assembly range from small subassembly to that of the main wing. Aircraft manufacturers and participants in development programmes usually provide tooling designs. Nonetheless, subcontractors sometimes copy master tools using manufacturers' drawings.

3) Subassembly development (and low level aircraft system development)

This is the stage where firms start sharing development costs and sales returns with contractors. Latecomer firms have to pay the contracting company for license fees, know-how, and technical data. Contracts for development work range from conceptual design, basic design, and detailed design, to actual production. Some of the South African firms such as Denel SA have been involved in actual production under their previous contracts for civil aircraft.

4) System integration

At this stage, firms emerge as major contributors to the international aircraft market, including becoming international joint-development partners. Here, latecomer firms become involved in every area of the aircraft business, such as design and development, production, market surveys, marketing, product support, after sales, and financing. Although South African firms could not be regarded as system integrators, they have started getting involved in some of the business aspects of this level, such as aircraft maintenance (product support) and producing on license. They do not have to be fully involved at once, as the learning process usually takes time.

The SIH model described above is applicable to the study area of technological capability building as it was based on developing economies.

Holmes (1996) indicates that alliances and partnerships are crucial in enhancing the rate of learning within a nation. He proposes an *alliance design and implementation* model for the aerospace industry, where the following steps were regarded as being useful:

- **Establish commitment** by industry and government partners to shared vision and goals. This is about engaging individuals from government, industry, and academia with the authority to commit their organisation to the collaboration. Industry and government representatives are usually drawn from senior management.
- **Negotiate specific objectives.** Strategic objectives of common interest leading to partnership goals have to be assessed.
- **Negotiate specific tasks, resources and performing organisations.** Industry partners have to define the tasks (statements of work) required to accomplish the partnership objectives, allocate resources to such tasks, and make a recommendation to government partners on the suitable performing organisations.
- **Sign agreements and establish governance.** Government representatives are established, and issues such as Intellectual Property Rights are negotiated.

This model by Holmes (1996) is also applicable to the study as it outlines the flow of events on how alliances can be managed during learning, forming technological capability-building paths.

Countries whose manufacturing industries are dependent on foreign technology are described by De Wet (in Buys, 2001:7) as 'technological colonies'. These depend on foreign technologies because their national systems of innovation are deficient or poorly developed. The fact that South Africa, as a nation, is also a technological colony, has influenced the technological innovation within the aircraft industry.

The level of innovation activity in developing countries tends to be low compared to that of developed countries. Sull, Ruelas-Gossi and Escobari (in Buys, 2004:1) indicate that the difference can be attributed to the lack of a solid technological base of scientists and research facilities; customers with low disposable income; and small R&D budgets. This results in innovation becoming focused more on marketing and building customer relations, rather than on technology.

Buys (2001) describes the simplest model of innovation (Figure 3.1), as a one-directional linear flow process whereby one sub-system transfers goods, services or information to the next sub-system within the entire system. The model proposes six subsystems within a National System of Innovation (NSI):

- Research
- Technology development
- New product or process development
- Product or process improvement
- Production and manufacturing
- Distribution, marketing, sales and services.

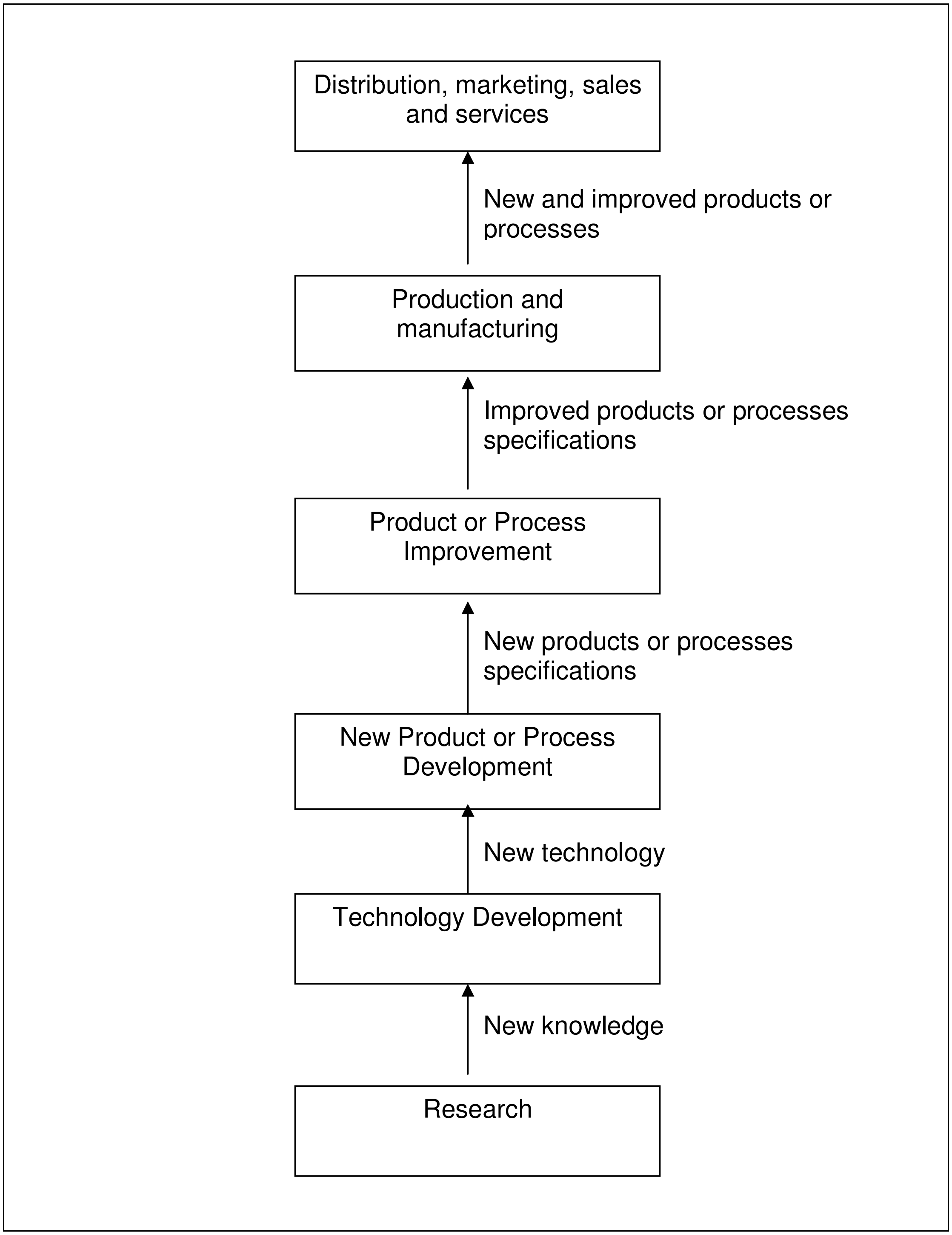

Figure 3.1 The one-directional linear model of the innovation process
Source: Buys (2001; 2002)

Ideally, the South African aircraft industry should be positioned within this linear flow process model, from the generation of new knowledge to the stage where it could produce and improve new products or processes for distribution to the global market. Practically, this linear flow process could not be easily implemented in its existing form, given the current innovation levels of South African civil aircraft firms.

Within the National Systems of Innovation (NSI) innovation is defined broadly to include the development and uptake of technology, the introduction of new products or processes, the different forms of work organisation or management structures and approaches, and the utilisation of new market opportunities (Parker, 2004). These forms of innovation appear to be key for growth, productivity and technological competitiveness.

Innovation is, however, not necessarily as simple as the linear flow process model, because it involves a cyclical, multi-dimensional, complex process with many feedback loops. The complexity of the innovation process is been described by Buys (2001), who proposes a five-stage process of backward integration of the NSI (Figure 3.2) as one method of technological decolonisation.

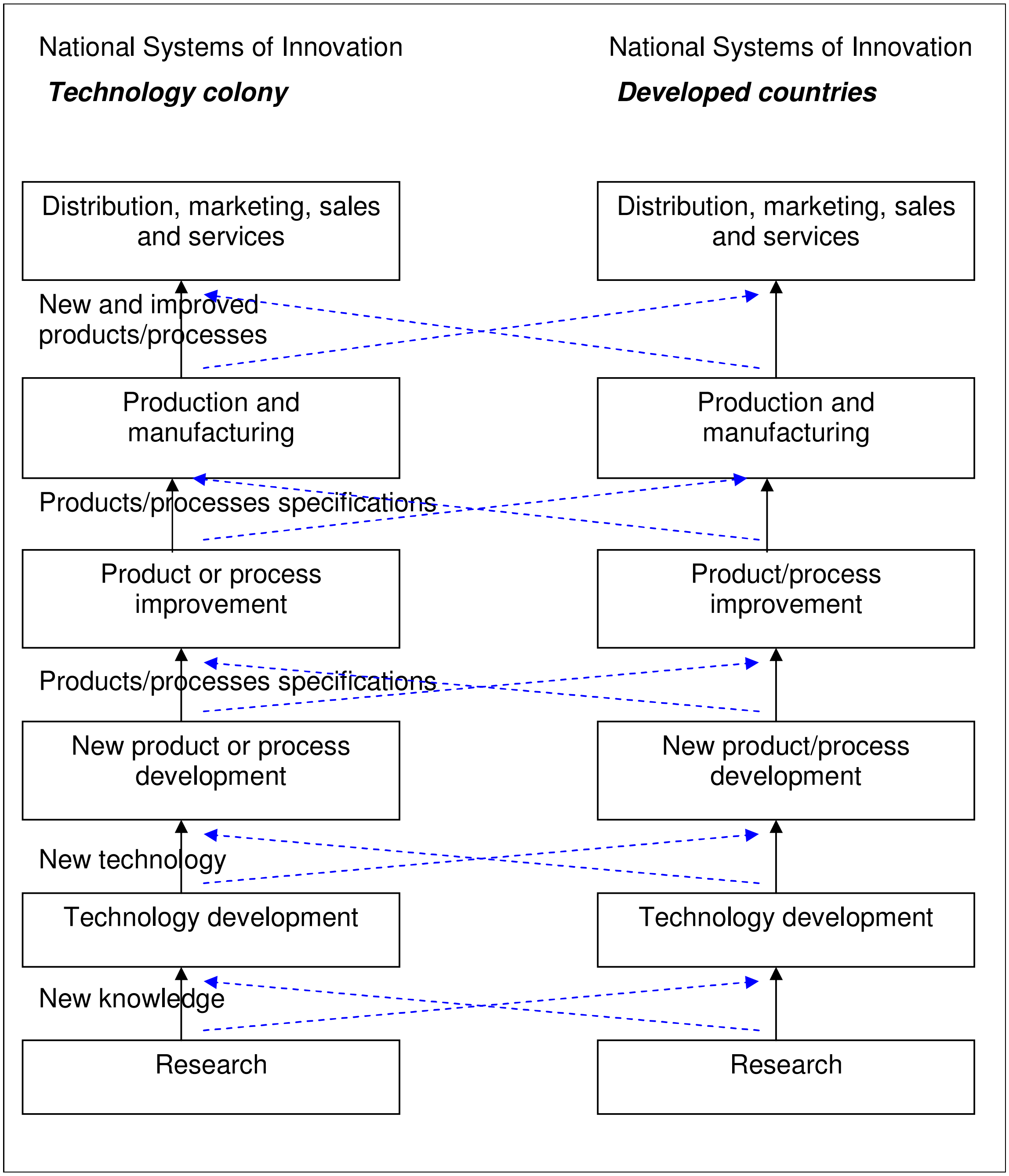

Figure 3.2 Five-stage backwards integration process of national systems of innovation
Source: Adapted from Buys (2001)

The backward integration model of industrial development could be applied to the advancement of the underdeveloped aircraft industry. The *initial stage* of the backward integration model is about establishing the local distribution, marketing, sales and after-sales services of foreign products or services. This involves the transfer of products or processes from foreign NSI to local NSI. The *second stage* requires the establishment of local production and manufacturing facilities for foreign products and services. Production know-how would be transferred from foreign NSI to local NSI where production licenses would be granted. Furthermore, a local applied research sub-system could be established during this stage. The *third stage* involves the local improvement (adaptation and modification) of foreign products or processes in line with local raw materials, skills and market needs. An innovative environment and strategy for the local industry would be necessary at this stage. *Stage four* is about local development of new products or processes for both local and global markets. The necessary technologies could still be sourced from foreign NSI. *Stage five* is about local technology development whereby the gap between the research sub-system and the development sub-system would finally be bridged.

According to Buys (2004) and analysis of the backward integration model,the South African manufacturing industry is currently at Stage 3 (Figure 3.3), which is about the improvement of products and processes using foreign technology. Based on the explanation above, the backward integration model could be applicable to the South African civil aircraft industry.

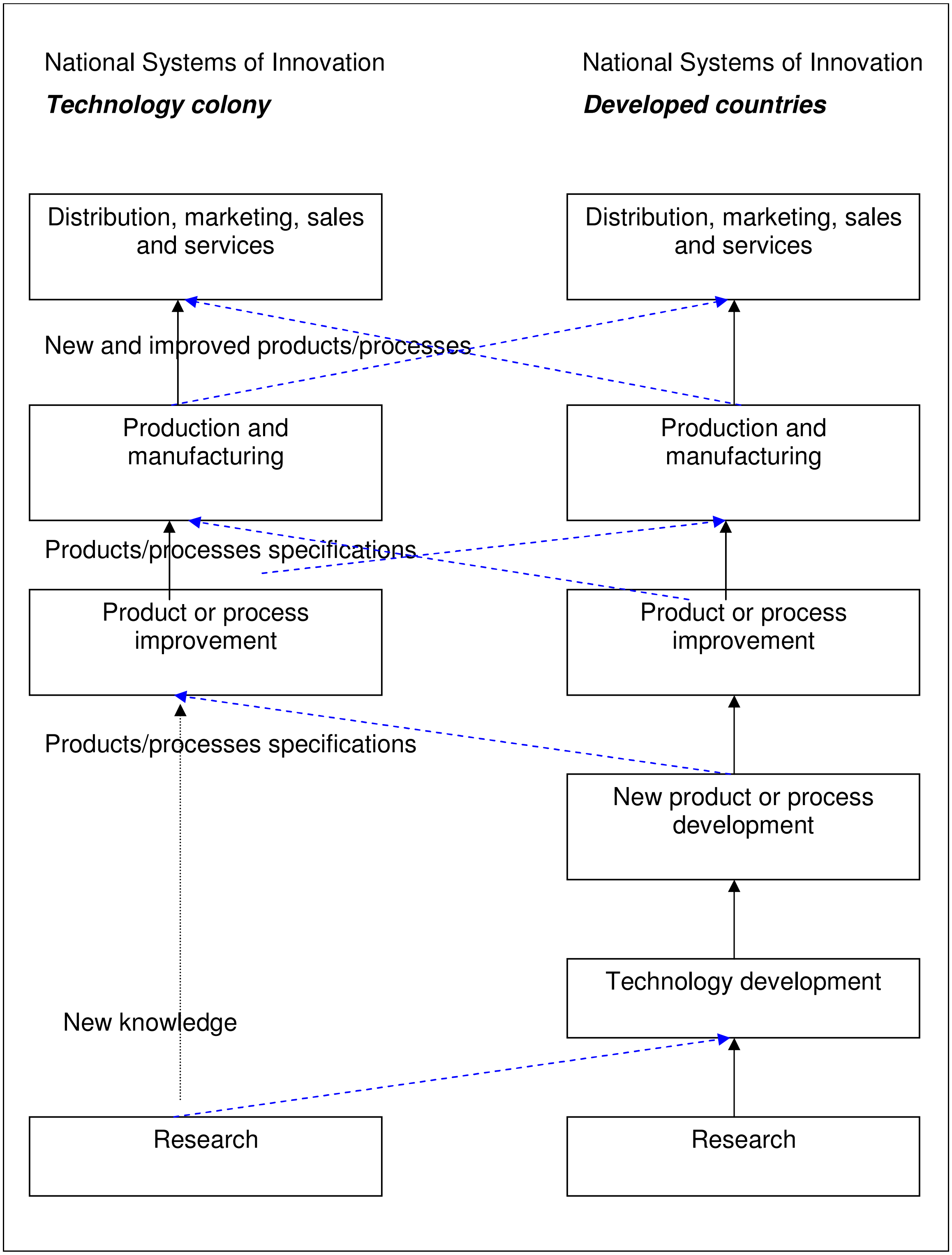

Figure 3.3 Stage III backwards integration of national systems of innovation
Source: Adapted from Buys (2001)

Costa and de Queiroz (2001:8-11) propose an analytical framework that could provide the base for the methodology needed to operationalise concepts of technological capabilities, and to compute Technological Capabilities proxies (TCs-proxies). The main elements, the basic dynamics of the learning process, and the technical change at the firm level are summarised in Figure 3.4. The elements are technological capabilities stock, technological efforts, internal and external determinants of these efforts, technical change, and time. Time is included to demonstrate the cumulative and path-dependent aspect of the learning process. Technological events in t_n would exert influence on $t_{n+1,}$ with the direction and rate of the process shaping the technological trajectory. This model could also be applicable in the area of study where the equation indicates that technological capabilities could be accumulated when technological efforts become evident. This is influenced by both internal and external factors, as well as technical changes that determine the rate and period it would take to accumulate technological capabilities stock, thereby shaping the technological path to be followed.

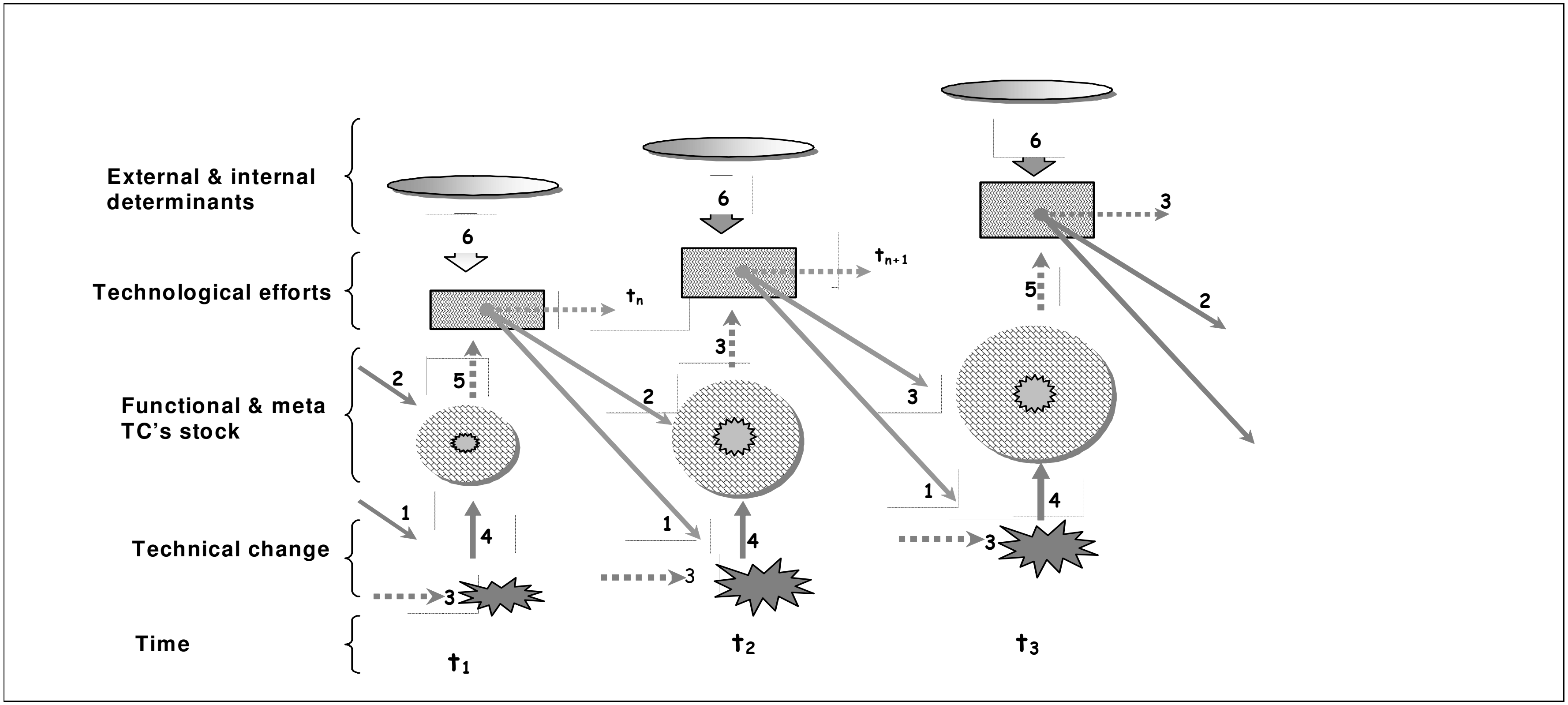

Figure 3.4 Learning process and technical change: Elements and dynamics

Source: Costa and de Queiroz (2001)

Technological diffusion should be managed in terms of two dimensions: enhancement of technological capabilities (deepening, broadening); and enhancement of access to or linkage with customers in advanced markets (Mathews, 2001). During technological learning, latecomer firms and countries tend to look at each of these dimensions in great detail independently without trying to tie the two together. Van de Ven and Garud (in Mathews 2001:17) present a model on the emergence of high technology industries, which they see unfolding over four distinct phases:

- Phase 1: Creation of resource endowment. This could be by basic R&D in public sector research institutes
- Phase 2: Appropriation of public knowledge by private firms. This could involve the formation of new firms, or diversification by existing firms
- Phase 3: Industry expansion. This could include the technical and economic activities of firms; institutional regulation; financial structuring and reimbursement; development of industry standards; and formation of pools of competencies
- Phase 4: Industry stabilisation. A dominant design might emerge, ushering in a period of consolidation.

The theory above was found to be applicable to this study as it highlights ways of managing technological capability building. The model that is discussed could help the South African aircraft industry realise the manner in which technological capability building could be structured, and the system in which related operations could unfold.

Another model applicable to the study is on the dynamics of diffusion, which focuses on the sequence of steps associated with a resource leverage approach. The sequence is argued to be followed by all high technology industries created successfully in East Asia, and it occurs logically as follows (Mathews, 2001):

- Step 1: Preparing the ground, ensuring that skills, knowledge, contacts, and companies are all in place
- Step 2: Seeding/implantation, which involves technology acquisition and resource leverage, leading to adaptation and improvement

- Step 3: Propagation, which involves providing financial resources, enterprise development, product development, and infrastructure support to encourage firms to take up new technologies
- Step 4: Sustainability, which involves deepening industry structures, establishing R&D capabilities and social structures of innovation.

Again, the model could help the South African aircraft industry realise the manner in which technological capability building could be structured.

3.2 Technological capability-building frameworks/models used by other countries: Case studies

3.2.1 The United Kingdom

The Aerospace Innovation and Growth Team (AeIGT) established by the UK government through its Department of Trade and Industry, looked at the optimum way of stimulating innovation and growth within the UK aerospace industry (DTI (UK), 2003). As mentioned in the previous chapter, the AeIGT consisted of over 140 senior executives from the aerospace sector's major stakeholders, including industry, government, academia, research bodies and the unions. Four subgroups including a focus group on finance conducted a study on the key challenges facing the aerospace industry and how they could be addressed. Figure 3.5 shows the organisational framework of the AeIGT. The four subgroups were tasked to look at various aspects within the following classified areas:

- Technology, capability and skills
- Engineering, manufacturing and supply
- Market structure and market access
- Regulation environment and safety.

On a regular basis, the various subgroups reported to the AeIGT executive, with recommendations for stimulating innovation and growth in their specific areas of focus. This framework was one of the strategies used by the UK aerospace industry, with the involvement of government, to build technological capabilities and knowledge accumulation.

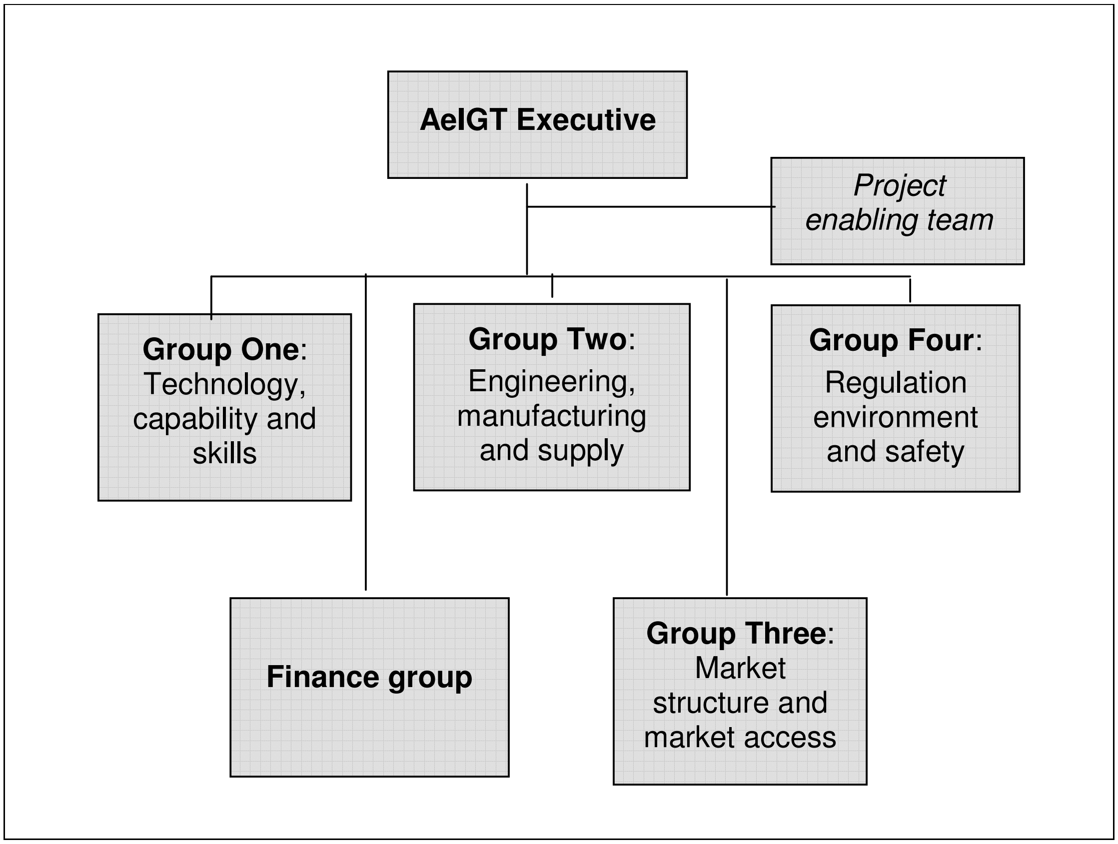

Figure 3.5 Aerospace Innovation and Growth Team (AeIGT) organisation
Source: DTI (UK), 2003. Independent report by Aerospace Innovation and Growth Team (AeIGT) on the future of the UK aerospace industry (June 2003)

3.2.2 South Korea

Bennett and Vaidya (2001) indicate that firms in the Asian newly industrialised countries (NICs) have acquired technological capabilities by making judicious use of foreign technology sourcing. In order to gain the required knowledge quickly they relied on customer firms to provide specifications and concentrated on developing capacity to produce to such specifications at low cost. South Korean and Taiwanese firms used original equipment manufacturer (OEM) agreements, whilst Singapore and second tier NICs relied largely on foreign direct investment (FDI) as means of entry into world markets. It was considered important for firms to combine foreign technology elements effectively with their own experience and knowledge, to strengthen their internal capabilities. This provided firms with valuable experience in mass production methods and most of them were successfully able to learn from such experience, and to upgrade product quality, improve production processes and efficiency, move into higher value added segments and develop own brands (Bennett & Vaidya 2001). The process of learning or building technological capability is indicated as a model in Table 3.1. The model is most applicable in primarily consumer products.

Table 3.1 A typical technological capability building process: the South Korean model

The process of development		Technology imports	Production and R&D
1960s-1970s	*Goal:* establishment of production base. *Characteristics*: heavy dependence on imported technologies.	Packaged technology: turnkey based plants. Assembly technology.	Knock down production (SKD/CKD). OEM-dominated. Almost no in-house R&D.
Early 1980s	*Goal*: promotion of self-reliance. *Characteristics*: import substitution, localisation of parts/components production	Unpacked technology: parts/components technology. Operation technology.	OEM/own brand: high ratio. Product development.
Late 1980s-1990s	*Goal*: export promotion by means of expansion of domestic market. *Characteristics*: beginning of plant exports, learning advanced and core technologies.	Materials-related technology. Control technology. Design technology. High-quality product technology.	OEM/own brand: low ratio. Product innovation. Process improvement.

Source: Adapted from OECD. 1996. *Review of National Science and Technology Policy: Republic of Korea,* OECD, Paris.

The four main South Korean firms, as discussed in the previous chapter, merged to form Korean Aerospace Industries Company Ltd (KAI). This was one of the solutions to address the South Korean aircraft industry's failure to compete effectively in the global market. KAI was used to promote learning, to build technological capabilities, and to improve on production inefficiencies. Following this restructuring, KAI became a prime contractor for all domestic aircraft projects, and a national aircraft champion in South Korea (Cho, 2003). This move represented a fundamental policy shift from domestic rivalry to a national champion, which helped the South Korean government streamline aircraft industry policy.

As mentioned in the previous chapter, for technology development and capability-building, South Korea has three aircraft related government research institutes (GRIs): the Korea Aerospace Research Institute (KARI), Korea Research Institute of Machinery and Metals (KIMM), and the Advanced Agency for Defence Development (ADD). In addition, the Korea Institute of Aerospace Technology (KIAT) also exists (Hwang, 2000). Figure 3.6 indicates the framework of the national R&D mechanism in the South Korean aircraft industry, which was used to build technological capabilities and competencies.

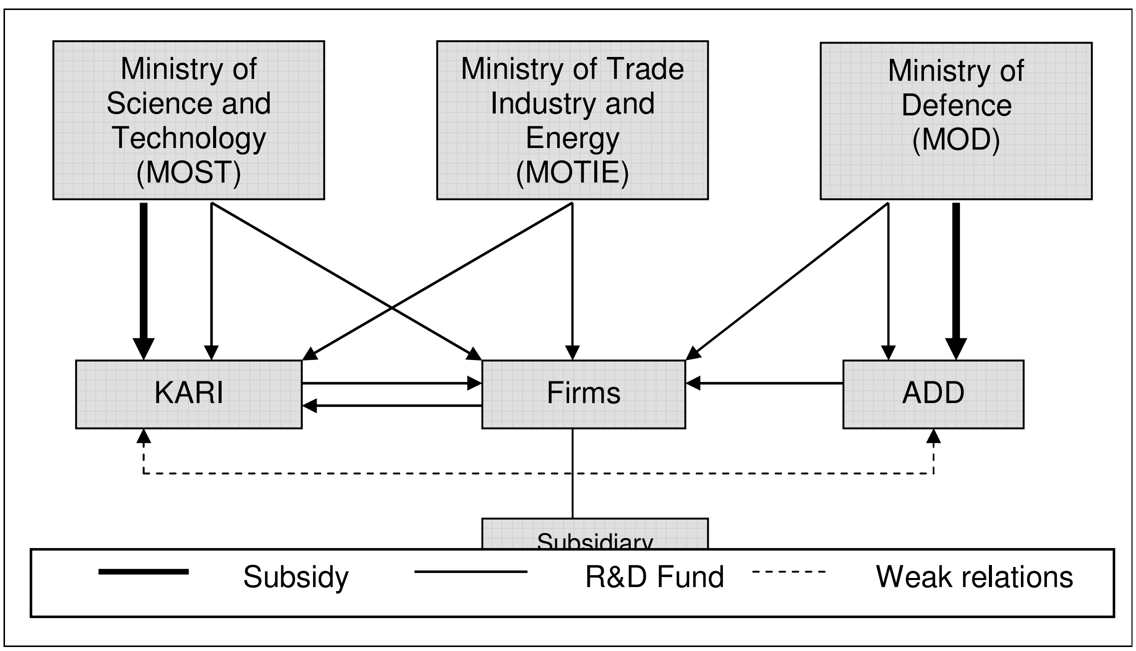

Figure 3.6 The national R&D mechanism on the South Korean aircraft industry
Source: Hwang, 2000 (adapted from Lee and Hwang, 1992)

Both KARI and KIMM operate under the Ministry of Science and Technology

(MOST) whereas ADD falls under the Ministry of Defence (MOD). KARI conducts civil aerospace technology development, where one of the areas of focus is aircraft and aero-engine technology development. It is also responsible for the performance and quality evaluation of aerospace products. Most of its research funds come from MOST and the Ministry of Trade, Industry and Energy (MOTIE). KIMM is responsible for small amount of R&D for aircraft parts and materials, mostly precision casting of aero-engine parts. ADD is responsible for the development of military or defence technologies, including aircraft and missiles.

Korean Air initiated several aircraft development projects prior to the formation of KAI in 1999, which were done through KIAT as part of system integration capability development. The first full-scale system development project that resulted from Korean Air's initiatives was Chang Gong-91, the first civil South Korean-model aircraft to be officially certified by the South Korean government (Hwang, 2000). Figure 3.7 indicates the institutional framework of how the Chang Gong-91 aircraft project was conducted as part of learning or technology capability building.

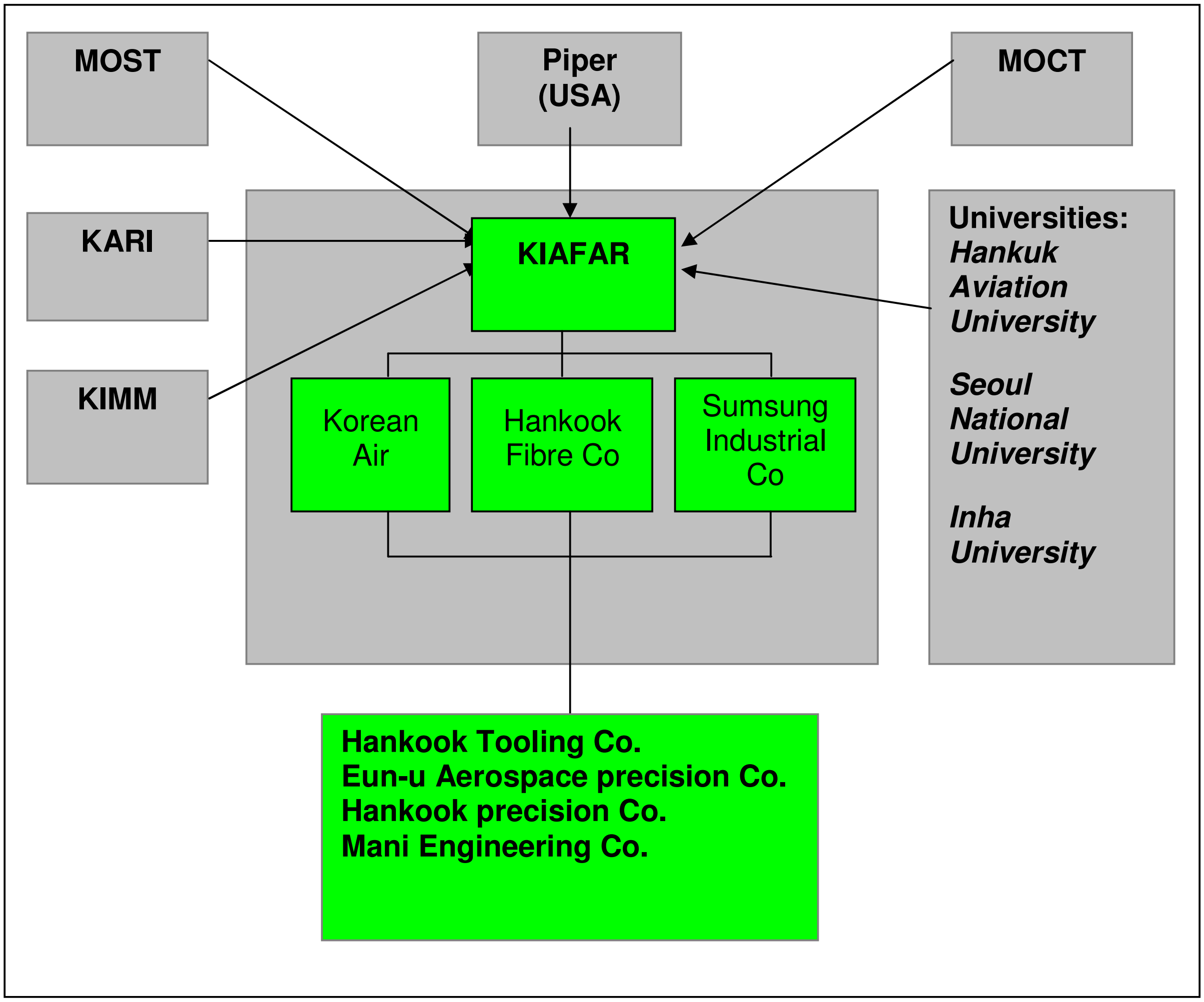

Figure 3.7 Institutional structure (framework) of the Chang Gong-91 project
Source: Hwang (2000)

For this particular project (Chang Gong-91), Korean Air joined forces with Hankook Fibre Company (HFC) and Samsung Industrial Company (SIC) to form Korean Industrial Association for Aerospace Research (KIAFAR). Korean Air remained responsible for the overall development of the aircraft within the consortium. Government supported KIAFAR both technologically, through GRIs (KARI and KIMM), and financially, through MOST and the Ministry of Construction and Transport (MOCT). MOST contributed approximately 40% of the project's technology development costs. Several universities were highly involved in carrying out flight tests and aerodynamic characteristics analyses. Subsidiary companies were involved in tooling and jig production. KIMM was responsible for airframe structures tests and wing fatigue tests, whereas KARI took the lead in airworthiness assessment and the development of type certification procedures. A

Memorandum of Agreement (MoA) for technology cooperation was established with Piper (US) for Piper aircraft development. The purpose of this was to train South Korean engineers and acquire technologies. As a result, 85 engineers were involved in the technology development process over a period of 4 years and 6 months. Korean Air accumulated aircraft design and development experience through the Chang Gong-91 project, although it was not successful in using the project to move into civil production (Hwang, 2000). Korean Air was also involved in the B717 Nosecone risk-sharing development project, where it was responsible for design, development and FAA certification. It successfully completed the project in 1998 and became a supplier of the B717 Nosecone after that.

3.3 Development of new or improved models

From the paths followed by the countries studied (e.g. South Korea, Japan, UK, EU, Brazil, USA), it emerged that common methods were used for enhancing technology development leading to national technological competitiveness. These were government involvement (support for technology development); collaboration and strategic alliances between firms (local and international), and large investments in research and development. The importance of government in providing support and guidelines for the creation of technology development mechanisms is evident, with areas of specific intervention:

- Infrastructure development
- Human resource development
- Political and financial frameworks
- Economic and environmental regulations.

Developing countries focused more on skills development and transfer, relying mostly on technology transfer and exchange programmes as strategies to improve skills. Skills shortage remains a major problem in the South African aircraft industry, in which many scientists are reaching retirement age in the absence of a ready pool of graduate replacements, and where technology development expertise continues to decline. From the analysis of the literature, South African aircraft firms appear to have few strategic alliances or exchange programmes for skills improvement or technology transfer purposes. These are areas that need serious interventions. It could be that current government support is not enough, or initially, not forceful enough, when compared to other countries studied.

Most of the technology capability frameworks or models from the literature discussed above could be applicable to the area of study. The SIH model by Hwang (2000), which indicates the capability building process of the aircraft industry, emphasised technology transfer and adoption. It showed how technological capabilities could be accumulated through various stages, from knock-down system assembly to system integration. The model indicated that as processes unfold, they require skills development, innovation networks, infrastructure development and R&D investment.

The NSI backward integration model by Buys (2001) shows how industries develop through technology transfer and adoption, and touches on skill needs and development during improvement of foreign technologies.

The analytical framework by Costa and de Queiroz (2001) emphasizes the dynamics of technological learning, and indicates the importance of developing technological capabilities, where analysis shows that technological efforts could involve skills and infrastructure development.

The technological diffusion model by Mathews (2001) indicates the importance of R&D investment, infrastructure development, as well as financial and other resources, during the accumulation of technological capabilities. The dynamics of diffusion model, also by Mathews (2001), emphasizes the need for skills development, human resources (HR) and knowledge, innovation networks, R&D investment, infrastructure and innovation adoption.

The literature-based technological capability-building frameworks for the aircraft industry used by UK and South Korea were found to be applicable to the area of study. The UK had an Aerospace Innovation and Growth Team (AeIGT) organisational framework (Figure 3.5), which emphasised learning and skills development through various working groups, thereby promoting innovation networks and infra-structural development.

For South Korea, the technological capability building process was presented in the form of a table (Table 3.1), which indicates how technological capabilities were developed over the years through technology imports and adaptation. An analysis of the national R&D mechanism of the South Korean aircraft industry (Figure 3.6) indicates R&D investment and infra-structural development; the availability of labs and research institutes (such as ADD and KARI); and government interventions, where various government ministries formed part of the framework. An analysis of the institutional framework (Figure 3.7) that was used by the South Korean industry during projects indicates key elements such as skills development and technology; innovation networks involving universities, the aerospace research associations and other research institutes (KARI and KIMM); and government (MOST) involvment with KIAFAR. Technology transfer and adaptation was also evident, where major South Korean firms in conjunction with the aerospace research associations, conveyed information to small companies. Other elements were infra-structural development and government intervention, as indicated above. Based on the analysis of literature, and the models or frameworks used by other countries to build reputable technologically competitive industries, the researcher can propose a conceptual framework to be used for developing empirical frameworks for the South African civil aircraft industry. These could be based on the patterns and commonalities identified, as well as specific attributes that were areas of focus in developing capability-building strategies. These could be compared to the South African civil aircraft industry situation and its existing challenges.

3.3.1 Proposed conceptual framework

The problem, as highlighted in Chapter 1, is whether the South African civil aircraft industry has adequate technological support measures, and whether it should follow a particular framework for technology development to gain global technological competitiveness. It was not known if the existing government support measures to improve industrial technological capabilities were enough to position the aircraft firms in the global value chain system.

From the literature analysis, it appears that the aircraft sector, in general, requires huge capital investment in research and development (R&D) for technology development, and it frequently has long product development periods (sometimes more than a decade from inception to final product). This is equally a challenge for the South African aircraft industry, where there seems to be an inadequate resource-base, making it difficult for firms to exploit existing opportunities. Other problem areas in the South African aircraft industry have been highlighted as follows:

- A poorly developed technology base
- An inadequate resource base (skills, R&D, funds)
- Insufficient experience for certain levels of aircraft development, e.g. assembly of civil aircraft
- Very little collaboration between firms and few strategic alliances with foreign partners
- Insufficient government support for R&D, technology transfer and skills development
- Poorly developed technological infrastructure.

The proposed new models/frameworks should provide a clear strategy on how such challenges could be addressed.

It was noted previously that general aviation (GA) in South Africa has been declining in recent years, with few successful new manufacturing entrants and an ageing countrywide fleet. Although the reasons for such a decline are yet to be fully determined, it could be attributed, in some measure, to rising costs (both operating and purchase), lack of government policy, and lack of financial incentives such as tax and other rebates.

It is clear, from the literature discussed above, that challenges exist with regard to frameworks to guide the civil aircraft industry, especially in developing economies. Frameworks on how to develop a competitive technological base are required, and support mechanisms are needed for building a national technological competitive industry. The researcher proposes a conceptual framework to highlight important information and insights about the problem area, incorporating literature review, previous work done on the subject, and information gathered through other sources of information. The conceptual framework focuses on literature analysis, where patterns and commonalities, as well as specific attributes that were areas of focus in developing capability-building frameworks, were considered. Based on the researcher's analysis, the conceptual framework incorporates support mechanisms in various areas: technological capability building in relation to resource-based theories; innovation networks; technology transfer and adoption; and R&D resource capability development. Whether issues such as skills development; institutional and infrastructure development (include strategic alliances and collaboration); sustainability and dynamic capabilities of firms (including government interventions) have contributed towards shaping the success of the countries studied in building national technological, competitive civil aircraft industries, were also taken into account. A questionnaire (for South African and international experts) was designed as part of testing the proposed conceptual framework, to gather more information for theory building in addressing the research problem.

The proposed conceptual framework could then be assessed for possible incorporation into proposed new empirical frameworks for successful technology development in the civil aircraft industry. The background of the South African aircraft industry could then be looked at and related to lessons learned from the literature and the other countries studied. Such proposed empirical frameworks should address the main research question, summarised as follows: "How can key lessons from international frameworks for the technological development of civil aircraft industries be used to develop local frameworks for a technological, competitive civil aircraft industry"?

CHAPTER IV: RESEARCH DESIGN AND METHODOLOGY

4.1 Research design

4.1.1 Type of research

The objective of the research was to develop strategies and frameworks aimed at assisting South Africa in developing a technologically competitive civil aircraft industry, thereby improving industrial capabilities, leading to economic growth and national competitiveness through the enhancement of technology development. Many studies focus on the complexity of the global aircraft industry without specifying the empirical models that catching-up economies should follow to develop their technology base and become part of the global value chain. Technology is regarded as an important requirement for sustainability in the aircraft industry.

The research was aimed at providing frameworks or models that could be applied to facilitate technology development in the South African aircraft industry, therefore it took the form of theory-building through a qualitative research design, where case studies were used. Theories from existing literature were tested and modified to develop new models suitable for the South African environment. The research logic followed, as indicated in Figure 4.1, was in line with theory-based empirical research, as proposed in *Research guide for post-graduate students* (Buys 2005:62).

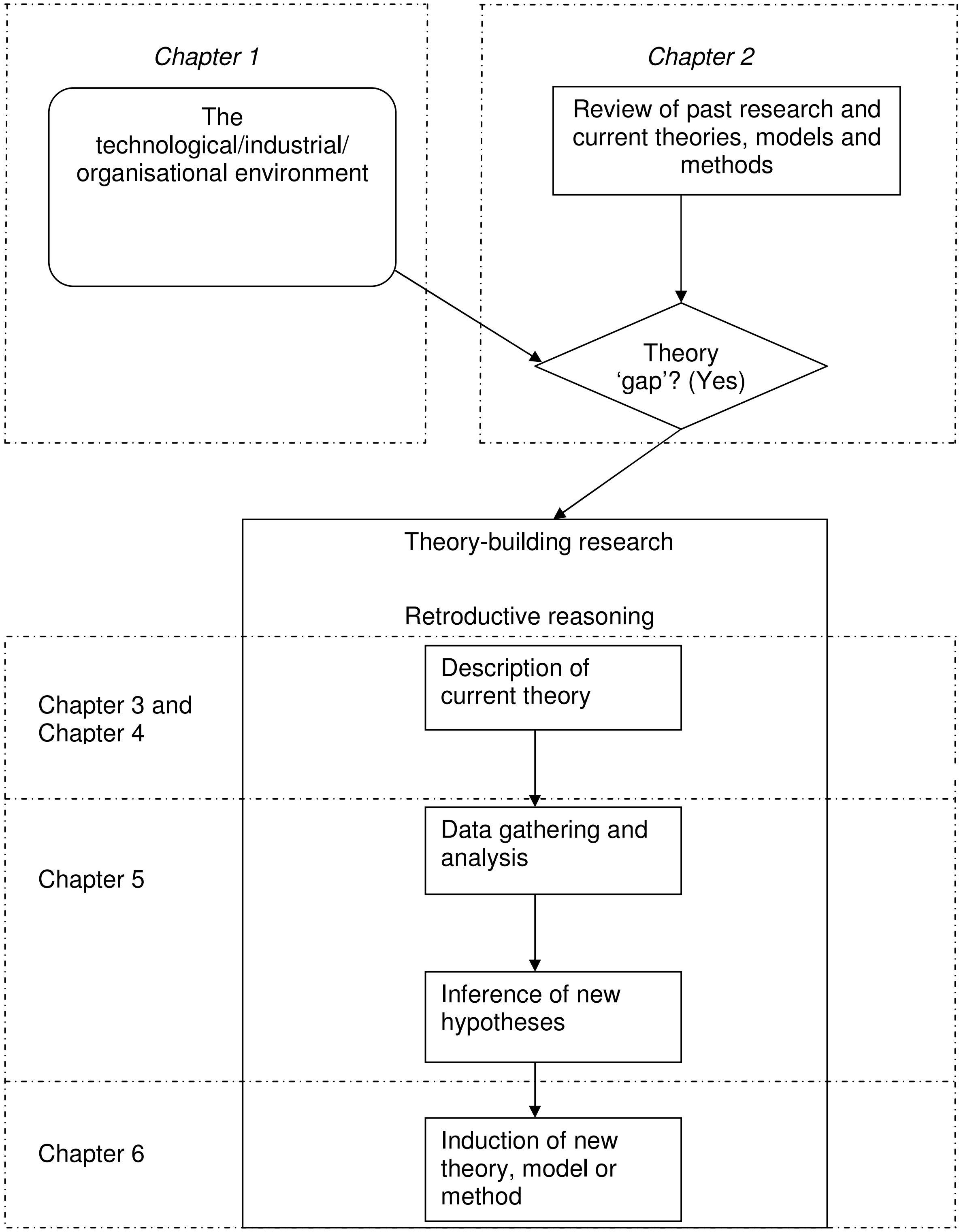

Figure 4.1 Research logic for theory-based research
Source: Adapted from Buys (2005: 62)

4.2 Research strategy and methodology

4.2.1 Approach and strategy for performing the research

The aircraft industry is a very broad area, therefore, for the purpose of this study it was the focus was narrowed to the civilian aircraft sector, with emphasis on the technology development (through innovation, technology transfer, adaptation) of the South African aircraft market. The study took the form of multiple case studies, where various countries were studied, and the results compared, so as to arrive at the proposed generalisations for building theory. Multiple case studies should follow a replication logic, rather than sampling, with a view to similar results being found (Yin 1993:34).

The researcher chose to conduct case studies, as part of both a quantitative and a qualitative research design, in that they (case studies) illuminate a decision or set of decisions, the reasons why such decisions were taken, how they were implemented and the kind of results obtained (Yin 2003:12). The research design took the form of a 2x2 matrix based on a type 3 multiple case study (holistic), where each country studied was used as the subject of an individual case, whilst the study as a whole covered several countries, using a multiple-case design (Yin 2003:39, 46).

According to Leedy and Ormrod (2005:135), a case study may be suitable when wanting to learn more about a little known or poorly understood situation. It can also be used for investigating how a situation changed over time, perhaps as a result of certain circumstances or interventions that took place. It is also known to be useful in providing preliminary support for hypotheses. Yin (1993:31) states that "case studies are an appropriate research method when trying to attribute causal relationships and not just describe a situation", which is the case with this particular study. A case study research method was therefore used in this study as a research technique to analyse the strategic models or aspects that were considered by various countries in developing their technologically competitive civil aircraft industry, thereby establishing the underpinning causal relationships in all the countries studied.

The case study research technique was found to be relevant in that the researcher aimed at finding out how other countries successfully established and implemented their strategies for developing their aircraft industry through technology development, and what the results were in all the countries studied. Of particular importance was the identification of attributes that led to the successful technology development of each country's civil aircraft industry, what worked in a given situation and why such results were attained. The results were then used by the researcher in bridging the gap that exists in the South African industry. By comparison with other countries, but by means of adapting not repeating their strategies, the researcher attempted to develop new models or theories applicable to the South African aircraft industry.

The 'case study tactics for design tests' model (Table 4.1) proposed by Yin (1994:33) was applied in this study to increase its reliability and validity.

To construct validity, the researcher used multiple sources of evidence as part of data collection. Documents (such as books, newspapers, articles, journals, newsletters, databases, firms' business records, past records), the internet (where information was further investigated for validity), key informants and interviews with relevant personnel were used.

Pattern matching between the countries studied was used during data analysis, as part of ensuring internal validity. The initial, proposed models were matched to the data collected in order to be able to draw certain conclusions.

Replication logic was used when designing questionnaires for both local and international experts, where similar sets of questions were used for local interviewees, while another, slightly modified set of similar questions, was used for all international interviewees. The researcher therefore provided a set of questions that were common for all local interviewees, and another set of questions that were common for all international interviewees, thus ensuring external validity.

Table 4.1 Case study tactics for design tests

Tests	Case study tactic	Phase of research in which it occurs
Construct validity	Use multiple sources of evidence Establish chain of events Have key informants review draft report	Data collection Data collection Composition
Internal validity	Do pattern-matching Do explanation-building Do time-series analysis	Data analysis Data analysis Data analysis
External validity	Use replication logic in multiple case studies	Research design
Reliability	Use case study protocol Develop case study database	Data collection Data collection

Source: Yin (1994:33)

To ensure reliability, both a case study protocol and a case study database were designed, with Microsoft Excel being used for the latter.

The process of conducting case studies was reinforced through the application of the Monitoring Technique described by Burgelman, Maidique and Wheelwright (1996:151-152). It focuses on making a well-informed judgement or decision by having a good insight into the issue that is being researched. Judgement should be based upon good and comprehensive information, therefore the gathering of such information needs to be highly organised. Usually, the gathering of information by means of this monitoring technique includes a search through documentation (reading), discussions, conferences and other relevant sources. This is in line with the use of multiple sources of evidence that Yin (1993:32) considers to be an important aspect of case study data collection.

Interviews were conducted in the case studies, as this form of data collection is valuable when using multiple sources of evidence, as proposed in Table 4.1. Information gathered through interviews was reviewed in various phases using the Grounded Theory Technique for research. This type of technique can be trusted in that it has a number of follow-up processes and verification during the data collection phase (Leedy & Ormrod 2005:108,140-142). The technique is relevant in this study as it is applicable to theory-building research. According to Saunders, Lewis and Thornhill (2003:398), "Grounded theory procedures are designed to build an explanation or to generate a theory around the core or central theme that emerges from your data".

4.2.2 Methodology

4.2.2.1 Case study research

The multiple case study research method was used, where the researcher looked at the lessons learnt, the paths followed, the sequence of events that unfolded, and analysed the strategies or models that had been followed by various countries in the past, to facilitate technology development and a successful and competitive civil aircraft industry. This was done by means of comparison with the gaps that exist in the South African civil aircraft industry. A well-known difference that exists between South Africa and countries that have been successful in the aircraft industry is in the broad area of aircraft manufacturing, specifically technology development and technological capability-building strategies. In comparing South Africa to other countries, the areas of focus were: the technological competencies of firms; capability-building processes (with specific focus on technology transfer and adoption); innovation networks and alliances; R&D; skills development; infrastructure development, and government support or interventions.

The South Korean aircraft industry was used as the main case study, as it is currently one of the leading emerging economies. How it dealt with the challenges of reaching the level of systems integration through technology development, made it a suitable base model. South Korean firms are at advanced levels, carrying out full assembly, and manufacturing entire aircraft, because of their gained capabilities in the area of technology and specialised skills. The researcher intended to visit South Korea to observe 3 to 5 firms in the aircraft industry directly, but this was not possible due to a lack of resources.

Other countries used as case studies for the aircraft industry were Brazil (developing country) and France (developed country). The US was initially chosen as a case study country but the researcher only managed to access the relevant participants during the final stages of the analysis. Some of their views, acquired during the researcher's visit to US, are included in the discussions. These countries were selected from the world top 100 aerospace companies (Table 1.1), and they appear in the international aerospace industry's sales and employment figures listed in Table 1.2. In both instances, the United States headed the list. The United Kingdom followed in both instances, while being equal to France in sales. It was assumed that by virtue of these countries heading the list, they are good examples of national technological competence and high technology trade performance.

When designing the case studies, a case study protocol was developed for use during investigations, based on that proposed by Yin (2003:67-68). Yin states that the case study protocol is intended to guide the researcher in successfully carrying out the data collection process, and it increases the reliability of case study research. Yin (2003:3-4) describes some important case study strategies, of which two were applicable to this study:

- **Descriptive** – This is about tracing and analysing a sequence of events in a descriptive manner to determine whether they followed a similar or different course to the others.
- **Explanatory** – The objective is to pose competing explanations for the same set of events and to indicate how such explanations may apply to other situations.

4.2.3 Research instruments and methods of data collection

This research focused on the civil aircraft industry, which is believed to be capable of influencing growth in the industry through the development of technologically competitive manufacturing capabilities within the industry. Literature review and case studies were used as the main tools for collecting data. At the same time the theory on a country's strategies for facilitating growth and globalisation, as well as the general overview of the aircraft industry and its complexity with regard to technological innovation and capability building, were investigated. Also considered were: lessons learnt, paths followed, the sequence of events that unfolded, and the strategies or models that were followed by various countries to facilitate the technology development that subsequently led to successful and competitive civil aircraft industries. Issues around the technological competencies of firms and the technological capability-building process (with specific focus on technology transfer and adoption, innovation networks and alliances, R&D, skills development, infrastructure development, and government support or interventions), were the areas of focus within technology development in the civil aircraft industry.

During the case study, the researcher collected extensive data by two main methods: Interviews and the Monitoring Technique. With the Monitoring Technique, data was collected through direct observation (including on-site visits), literature sources (including documents such as books, newspapers, articles, journals, newsletters, databases), the internet (where information was further investigated for validity) and past records. Some statistical quantitative data relevant to the aircraft industry was collected in the process, such as figures for exports and imports, levels of innovation, technology transfer, job creation and investment, to support the assertion that such countries be regarded as successful. Some of this information has been included in the theoretical background of the report. Qualitative data collected included processes or factors embedded within the strategies or models applied by various successful countries, which was used for pattern matching and for establishing commonalities amongst the sample countries.

The main research instruments used during interviews were structured questionnaires (refer to Appendix II and III), which were designed to seek answers in relation to the problem of the South African civil aircraft industry, where it was not known if proper support mechanisms or a particular framework for technology development existed to build a technological base for firms to gain global competitiveness and growth. Such interviews were conducted via e-mail, telephone, fax, and in certain instances, one-on-one interviews on site. The researcher established contact with the proposed interviewees to make the data collection process easier. Where information was needed from international experts, the economic representatives of the ministry or Department of Trade and Industry (DTI) SA in various countries were requested to expedite the process of disseminating and collecting questionnaires as required. Saunders, Lewis and Thornhill (2003:284) depict a table (reproduced here as Table 4.2) showing the main attributes of questionnaires, and the best way of acquiring reliable data during delivery and collection of questionnaires, depending on the type of scenario. The researcher followed their proposal when selecting the collection tool. Although most attributes were relevant, a special focus was on those highlighted in the table.

A case study protocol was also designed for use during investigations or interviews. This was aimed at increasing the reliability of the case study research, and was intended to guide the researcher in successfully carrying out the data collection process. As many of the interviewees had busy schedules, time taken to complete collection initially was 12 weeks, with another period of 12 weeks for 'follow ups'. The initial plan had been for the completion of collection to be not more than 6 weeks as indicated on Table 4.2.

Table 4.2 The main attributes of questionnaires

Attribute	On line	Postal	Delivery and collection	Telephone	Structured interview
Population's characteristics for which suitable	Computer-literate individuals who can be contacted by e-mail or internet	Literate individuals who can be contacted by post, selected by name, household, organisation etc		Individuals who can be telephoned, selected by name, household, organisation etc	Any; selected by name, household, organisation, in the street etc
Confidence that right person has responded	High if using e-mail	Low	Low but can be checked at collection	High	
Likely response rate	Variable, 30% reasonable within organisations Internet 10% or lower	Variable, 30% reasonable	Moderately high, 30-50% reasonable	High 50%-70% reasonable	
Suitable types of questions	Closed questions but not too complex, complicated sequencing fine if uses IT; must be of interest to respondents.	Closed questions but not too complex, simple sequencing only, must be of interest to the respondent		Open and closed questions, but only simple questions, complicated sequencing fine	Open and closed questions, including complicated questions, complicated sequencing fine.
Time taken to complete collection	2-6 weeks from distribution (dependent on number of follow-ups)	4-8 weeks from posting (dependent on number of follow-ups)	Dependent on sample size, number of field workers etc.	Dependent on sample size, number of interviewers etc but lower than self-administered for same sample size	

Source: Adapted from Saunders, Lewis, and Thornhill (2003:284)

After obtaining the initial responses from interviews, the data collection process was followed by a series of rounds or phases where the gathered information was reviewed based on initial responses and the Monitoring Technique (all relevant sources), so as to reach certain conclusions. The Grounded Theory Technique was then used to refine the collected data. The Grounded Theory Technique is used for academic research, and is aimed at deriving theory through the use of multiple stages of data collection and interpretation (Leedy & Ormrod 2005:108). This technique can be applied in the later stages of the data collection process, following the review of initial responses acquired through other techniques. This was not the main data collection tool in this study as its primary use is to increase the validity or reliability of the collected data.

The combination of these data collection instruments equipped the researcher to gather the necessary information relating to the problem area and the various national environments that influence the technological development of the civil aircraft industry. The researcher was then able to make theoretical conclusions to assist in developing theoretical models to address the research problem.

The quantitative data was analysed using the STATA statistical program, where frequencies and Pearson's Chi-square tests were used for interpretation of the results. This form of analysis is easier when comparing several sets of data: in this case various groups were studied (interviewed) in South Africa and in three other countries (South Korea, Brazil and France). Responses from local experts were compared to test significant dependence of groups on various factors or aspects. This was also done on responses from international experts where significant tests were done to compare developing and developed countries' views. Data was also analysed based on Creswell and Stake (in Leedy 2005:136), where data analysis in a case study is shown to involve certain steps:

- Organisation of details about the case
- Categorisation of data
- Interpretation of single instances
- Identification of patterns
- Synthesis and generalisations.

This was used to derive meaning and insight from the frequency pattern found in the data.

4.2.3.1 Research interviews

As indicated earlier in the document, interviews were conducted during the case study research. A questionnaire was designed as part of testing the proposed conceptual framework and to gather more information for theory building. The questionnaire was aimed at establishing whether countries applied the proposed conceptual framework on technological capability building, which focused on aspects such as innovation networks, technology transfer and adoption, and R&D investment. It also looked at whether issues such as skills development, infrastructure development and the dynamic capabilities of firms, including government interventions, have contributed towards shaping the outcomes of the countries studied in building national technological competitive civil aircraft industries.

For South Africa, the questionnaire also looked at the technological challenges to be faced by the civil aircraft industry, as indicated by the background literature review, and also partly by the testing of the conceptual framework proposed by the researcher for building technological capabilities.

4.2.3.1.1. South African interviews

Interviews were conducted, using the questionnaire, with relevant experts (such as senior managers and engineers) in South African aircraft firms, various research and higher education institutions that are relevant to the aircraft industry, and government officials involved in developing government policies that impact on the development of the aircraft industry. The research institutions that participated were the National Research Foundation (NRF), and the Council for Scientific and Industrial Research (CSIR), where one (1) expert engineer and four (4) senior engineers/experts were interviewed from these institutions respectively. The initial proposed sample was three (3) experts per institution, but in some cases, like the NRF, only one expert was available to be interviewed because of limited numbers of experts in research institutions in this sector. The interviewees were role players who focus on technology development and capability building strategies that shape the growth of the aircraft industry.

The higher education institutions that participated were the Universities of the Witwatersrand (Wits) and Cape Town (UCT). These institutions have academic expertise in the fields of civil aviation and aeronautics, with special focus on technology development competencies. Six (6) experts were interviewed in total.

Four (4) experts from South African government departments (ministries) were interviewed – senior management officials from the Department of Trade and Industry (DTI), and the Department of Science and Technology (DST), who contribute to national civil aircraft technology development. Officials from other relevant government departments (ministries) such as the Department of Public Enterprise (DPE), the Department of Transport (DOT) and the Department of Defence (DOD) were not directly involved in interviews as their focus is more on business acquisition rather than civil aircraft technology development (focus of study).

In the South African civil aircraft industry, eight (8) engineers/experts at senior management level from three highly successful firms, were interviewed. The firms Denel, Aerospace Monitoring Systems (AMS) and Aerosud have all made a direct or indirect contribution to both the local and the global market, through manufacturing or supply of subsystems and components of aircraft. The high sales figures of these three firms are the reason they were used as the research sample. The South African aircraft industry is very small and very few firms supply the global market. Table 4.3 is a summary of the number of participants in the South African interviews.

Table 4.3 Summary of participation: South African interviews

Organisation		**No of participants**
Research institutions	NRF	1
	CSIR	4
Higher education institutions	WITS	5
	UCT	1
Government	DTI	3
	DST	1
Industry (Denel, AMS, Aerosud)		8
Total		**23**

The questionnaire was aimed at examining the firms' strategies for building technological capabilities; their core-competencies; their impact on the growth of the industry; their involvement with international firms (research collaboration, joint ventures, manufacturing contracts); their record for developing own innovations, technology transfer and imitation; the feasibility of their becoming global contributors through technology development; technologically related obstacles for market entry and growth of the industry; and the impact and availability of resources (infrastructure, technology-related skills).

On the *Research questionnaire for South African experts,* question construction was based on the following:

Part I:

Questions 1-6 were aimed at establishing technological innovation related background in the form of both current and previous activities that firms had embarked upon, to enable the researcher to make an analytical comparison of the successful countries' patterns of technology development. This is in line with the theory on technological competence and capability building paths followed by most of the successful countries studied (Chapter 2, Section 2.3).

Questions 7-8 had a similar objective to that of Questions 1-6, but here the researcher needed to further establish the positioning of firms (current and future) based on the aircraft industry structure that has been shown in Chapter 1, Section 1.1.1 (Figure 1.1).

Part II:

Question 9 was aimed at establishing the factors that impact on the technological capability-building process for the South African civil aircraft industry, and was constructed using Steenhuis and de Bruijn (2001), who indicate the factors that impact on utilisation effectiveness. The question was also aimed at validating the theory in Chapter 2, Section 2.3.7.1, which highlighted some gaps that are impacting on the South African technological capability-building process.

Questions 10-11 were aimed at testing the models proposed by the researcher, shown as Figures 3.8 and 3.9. They were in line with the theory on technological competence and capability building paths followed by most of the successful countries studied (Chapter 2, Section 2.3).

Question 12 was based on South African aircraft capabilities and comparative advantages as indicated in Chapter 2, Section 2.3.7.2. The question was therefore aimed at testing market feasibility for doing business with certain countries based on existing technological capabilities for South Africa.

Questions 13-14 had a similar objective to that of *Questions 10-11*. They were aimed at testing the models proposed by the researcher, shown as Figures 3.8 and 3.9. They were also constructed based on the theory of technological competence and capability building paths followed by most of the successful countries studied (Chapter 2, Section 2.3).

Question 15 was based on Chapter 2, Section 2.3.7.1 that highlights gaps impacting on the technological capability-building process.

Questions 16-17 were structured in line with the theoretical argument of Antoniou and Ansoff (2004) that emphasizes the importance of assessing firms' internal technological capabilities in order to establish the technological capabilities to be developed or transferred. The questions were also constructed based on South African aircraft capabilities and comparative advantages as indicated in Chapter 2, Section 2.3.7.2.

Question 18 was aimed at testing the theory in Chapter 2, Section 2.2.3, described by Oerlemans, Pretorius, Buys and Rooks (2005), that a typical South African firm spends less on innovation than the average European company. Furthermore, it was stated that about 44% of South African firms overall had introduced technological innovations within the 1998–2000 period, whereas 70% of firms in the sector for the manufacturing of transport equipment claimed to have introduced own innovations. Both automotive and aircraft fall in the sector for manufacturing of transport equipment, with probably more than 50% being specifically in the automotive industry. This was done to compare the spending on civil aircraft innovations in South Africa to that of the other countries being studied.

4.2.3.1.2 International interviews

For information gathering from international experts, the economic representatives of the Department of Trade and Industry (DTI) SA based in various countries (South Korea, Brazil, and France) were requested to expedite the process of disseminating and collecting questionnaires as required via email. This information was in addition to the secondary data acquired through various sources (reports, journal papers, conference proceedings) on the various case study countries.

Twenty-one (21) international experts were interviewed on issues of aircraft technology development and strategy. These experts were from aircraft-related firms (such as Airbus, Embraer, Korean Aircraft Industries) and institutions, including government departments (ministries). The selected countries included South Korea and Brazil (developing countries), and France (developed countries). A total of twelve (12) experts were interviewed from the South Korean aircraft industry (government, as well as aircraft-related firms and institutions), because South Korea was being used as the main case study for developing economies after having displayed successful technological capability building and competencies with regard to technology development in the industry. Table 4.4 shows a summary of the participation by the three countries studied.

Table 4.4 Summary of participation: International interviews

Country		No of participants
France (Firms)		7
Brazil (Firms)		2
South Korea	Research institutes	5
	Government	1
	Firms	6
Total		**21**

The questionnaire was aimed at examining international countries' technological capability building and technology development strategies for the aircraft industry, and also at determining whether building technological capabilities and competencies followed a particular pattern that encompassed the following: technology transfer and adoption, innovation networks and alliances, R&D investment, skills development, infrastructure development, and government support.

On the *Research questionnaire for international experts* the question construction was based on the following:

Part I:

Questions 1-6 and *Questions 7-8* were the same as for South African experts.

Part II:

Questions 9-11 were aimed at testing the conceptual framework proposed by the researcher, as shown in Figures 3.8 and 3.9. They were also constructed based on the theory of technological competence and capability building paths followed by most of the successful countries studied (Chapter 2, Section 2.3).

Question 12 was aimed at validating the factors that impact on the technological capability-building process as highlighted by the gaps in the South African civil aircraft industry (Chapter 2, Section 2.3.7.1). It was constructed based on Steenhuis and de Bruijn (2001), who describe the factors that impact on utilisation effectiveness.

Question 13 was aimed at testing the models proposed by the researcher, shown in Figures 3.8 and 3.9. Data collected by means of this question was used for pattern matching for South Africa and the case countries studied, based on the theory on technological competence and capability building paths followed by most of the successful countries studied (Chapter 2, Section 2.3).

Question 14 was based on the theory in Chapter 2, Section 2.3.7.1, which describes gaps and factors that are impacting on technological the capability-building process for the South African civil aircraft industry. This theory was to be validated and compared to other theories from other countries for pattern matching and use when developing models in line with the research problem.

Question 15 was in line with the theoretical argument of Antoniou and Ansoff (2004) that emphasizes the importance of assessing firms' internal technological capabilities in order to establish the technological capabilities that still have to be developed or transferred. The question was also constructed based on South African aircraft capabilities and comparative advantages indicated in Chapter 2, Section 2.3.7.2, for comparison with other countries' capabilities and comparative advantages so as to undertake a pattern-matching analysis.

Question 16 was aimed at comparing the information gathered from various sources of data to what the firms believe to be the spending on civil aircraft innovations (Chapter 2, Section 2.3). Such information was then compared to local firms' information to establish a pattern in line with technological capability building paths followed by other countries.

CHAPTER V: DATA GATHERING AND ANALYSIS

5.1 The data gathering process

Although this was a case study research project, primary data was gathered using structured questionnaires (Appendices II and III) as the main research instrument, where both South African and international experts were interviewed. As highlighted earlier in Chapter IV, interviews were performed one-on-one on site in certain instances (e.g. Denel) and by means of e-mail, telephone and fax in others. Secondary data was also gathered through conferences attended in Europe, visits to relevant institutions in the United States and Canada, journal papers, newsletters and reports.

Both questionnaires had various questions about firms' strategies for building technological capabilities, their core competencies, their impact on the growth of the industry, their involvement with international firms (research collaboration, joint ventures, manufacturing contracts), technologically related obstacles for market entry and growth of the industry, impact and availability of resources (infrastructure, technology-related skills), feasibility of becoming global players through technology development, and their record for developing own innovations, technology transfer and imitation.

For the interviews with international experts, the questionnaire was structured in such a manner that the final analysis of responses could provide information on whether countries had built technological capabilities following the conceptual framework indicated by the researcher. As indicated earlier in Chapter III, the framework highlighted technological capabilities built through strategies such as innovation networks, technology transfer and adoption, and R&D investment. These would incorporate skills development, infrastructure development and dynamic capabilities of firms, and the issue of whether government interventions make a contribution towards shaping the success of the countries studied in building national technological competitive civil aircraft industry. For South Africa, specifically, the questionnaire was aimed at identifying the technological challenges facing the local civil aircraft industry, and partly at testing the conceptual framework proposed by the researcher for building technological competencies.

Tables 4.3 and 4.4 shown in Chapter IV indicate the summary of the number of participants for the South African interviews and international interviews respectively.

5.2 Analysis and discussion of findings

5.2.1 South African responses

Tests were performed to determine the significant dependence of group responses (*Firms, Government, Research institutions* and *Academia*) on various elements, which could be part of the technology capability-building process needed to enable firms to contribute towards national technological competence. Pearson's Chi-square was used because it is an effective form of analysis when testing the degree of significant dependence of group responses or when comparing several sets of data to test the degree of association between them. For the basis of this research a very low probability would mean that there was very high significant dependence of group responses or that there was a high degree of association within the groups that respondents belonged to. The degree of significant dependence or association should preferably be in the range of 0.05 and below. In this case, various groups were studied (interviewed) in South Africa and in three other countries (South Korea, Brazil and France). Responses from local experts were compared to test significant dependence of groups on various factors or aspects, and the level of agreement for various areas tested.

On the professional background of respondents, most of the areas tested displayed no significant dependence of group responses with regard to their professional background elements such as field of work and work experience. This was shown by means of computed probabilities that were found to be high. However, distribution of field of expertise showed a significant dependence of group response, or there was a degree of association with the group that respondents belonged to. Engineering was found to be more prevalent with *Firms* (100%) and *Academia* (100%) than with *Government*. While no respondents of engineering origin were found in *Government*, they were observed in other groups. In *Firms* 100% of respondents were in engineering whereas in *Government* 50% were in management science. Analysis of results showed a significant dependence of group responses on the probability for the field of expertise as described above. This was computed as follows: *Probability = 0.022*

Part I looked at the technological innovation related background in the form of activities (both current and previous) that firms had embarked on, so as to be able to make a comparison to the successful countries' pattern of technology development. This was in line with the theory of technological competence and capability building paths followed by most of the successful countries studied (Chapter 2). It also looked at the current and future positioning of firms in relation to the aircraft industry structure. For Part I, *Questions 1-8* were clustered to determine if there was significant dependence of groups or degree of association with a group that a respondent belonged to. Tests were done on the level of agreement to the firms' technological innovation activities, including its position within the aircraft industry structure and the capability to contribute towards national technological competence.

The results indicated that significant dependence of group responses existed with regard to the availability of a firm's technological innovation activities. The questions were asked to determine if such activities do play a role in fast-tracking the technology capability building process of firms to enable them to contribute towards national technological competence.

The firms' technological innovation activities that displayed such significant dependence or degree of association within certain groups were indicated as follows:

Have joint ventures with international aircraft institutions

Probability = 0.05

Occurrence of previous or current joint ventures with international aircraft institutions was found to be slightly dependent or associated with a group. Of those that responded 'YES', 67% belonged to the *Research* groups and 33%

belonged to *Firms*. The computed probability therefore means that there was a slight significant dependence of group response or level of association with the groups that respondents belonged to on the level of involvement on having joint ventures with international aircraft institutions.

Involved in aircraft projects for an international contractor

Probability = 0.043

For this particular activity the analysis (probability) showed that there was some significant dependence of group response on the level of agreement about being involved in aircraft projects for an international contractor. 57% of the responses belonged to *Firms* with 29% belonging to *Research*.

The percentage contribution for such projects also intensified the degree of association on further analysis, which was computed as: *Probability = 0.025*

Furthermore, there was also significant dependence of group response or level of association with the group that a respondent belonged to with regard to the percentage contribution of such projects to the turnover of the institutions. However, it needs to be noted that only 5 out of 23 respondents were able to indicate the percentage contribution, which might have led to such result.

South African firms making a major contribution on the 3rd tier

Probability = 0.019

The analysis of South African firms making a major contribution on the third tier of the aircraft industry structure was associated with a group that a respondent belonged to, therefore it showed a high significant dependence of group response in this particular instance. *Firms* had a 100% agreement that this is where they are making a major contribution whereas the others had different responses (*Government* and *Academia* with 100% disagreement).

For the following element, there was no significant dependence of group response displayed, meaning that responses were not influenced by the origins of the groups that respondents belonged to:

Involved in collaboration with local institutions

There was a 100% agreement therefore an obvious conclusion would be that all respondents agree to having been involved in collaboration activities with local institutions.

Part II looked at technological competencies, factors that impact on the technological capability-building process for the South African civil aircraft industry, market feasibility of South African firms, and testing the conceptual framework proposed by the researcher. This was based on the theory of technological competence and capability building paths followed by most of the successful countries. In short, the section was aimed at identifying the technological challenges faced by the local civil aircraft industry, and whether the framework proposed by the researcher on building technological competencies could be useful in resolving such challenges.

Part II was therefore designed to test the degree of association with the groups that respondents belonged to and their level of agreement, availability and/or ranking for some of the commonly-known factors impacting (positively or negatively) on the technology capability building process and the required competencies for enabling firms to contribute towards national technological competence. Pearson's Chi-square was also used to test such significance.

On the current gaps that affect the technology capability building process of South African firms, there was, overall, an insignificant dependence of group responses received for almost all the factors. The analysis therefore meant that respondents agreed, without being influenced by their groups of origin, that the elements indicated were the gaps that impact negatively on the technology capability building process of the South African civil aircraft firms, and their ability to contribute towards national technological competence. The only slightly significant dependence of group response was shown on *'poor external environment'*, meaning that for this specific element there was some degree of association with the group that respondents belonged to with regard to their perception of the impact of the element on technology capability building. The result in that regard was computed as: *Probability = 0.041*

Also, for the factors that hamper business acquisition and the technology capability building process for South African firms, no significant dependence of group response was realised on the level of agreement. The analysis meant that, overall, respondents agreed without being influenced by their groups of origin that such factors hamper business acquisition and technology capability building for South African firms and their ability to contribute towards national technological competence. The only slightly significant dependence of group response was realised on *'insufficient experience in global supply'* as a factor impacting negatively on the technology capability building process. Its result was computed as: *Probability = 0.040*

Another analysis was done to determine if there was a significant dependence of group response with regard to the rankings of the proposed frameworks for successful capability building and the specific factors required to enable firms to contribute towards national technological competence.

When specifically looking at the area where South Africa firms should be playing a bigger role in building national technological competencies, there was overall agreement by respondents, with no degree of association with the groups that respondents belonged to, regarding the prioritisation of the proposed areas of focus. However, a degree of association with the respondents' groups of origin became slightly significant when ranking of *'research and technology development'* as an area of focus. Highest priority was given by respondents belonging to *Government* (100%), whereas respondents belonging to *Firms* (100%) found this element to be of medium priority. The level of significant dependence was computed as: *Probability = 0.049*

There was also a slightly significant dependence of group response on level of agreement for *'firm collaboration – international'* as an aspect for improving technology development within the civil aircraft industry and an improved capability of firms to contribute towards national technological competence. The respondents generally agreed, without being influenced by their groups of origin, to the other listed elements regarded as important for improving technology development within the civil aircraft industry. The level of significant dependence of group response for *'firm collaboration – international'* was computed as: *Probability =*

0.048

There was some significant dependence of group response realised on the statement that *'government interventions are necessary for business and market access'*, meaning that respondents were slightly influenced by their group category on this. The result was: *Probability = 0.05*

Respondents generally agreed, without being influenced by their groups of origin, to having done some interventions for human resource development, to enhance in-house technological capabilities.

On the existing competencies or skills available within the South African aircraft industry, there was also a general agreement, without being influenced by their groups of origin, regarding what the skills existing locally within the aircraft industry were.

There was a significant level of association with the groups that respondents belonged to with regard to the level of agreement for one ideal competency area (manufacture of composites, rotor wing propeller blades, gear-boxes) needed for technology development in the South African civil aircraft industry. The result was computed as: *Probability = 0.046*

The other ideal competency areas researched did not display any significant dependence of group responses.

With regard to countries that South African firms should focus on for developing their markets, a slightly significant dependence of group response was displayed only for the UK. For the other countries (Europe excluding the UK, the United States, Asia, Latin America) there was no level of association with the respondents origin of group, therefore there was general agreement without any dependence of group. Firms and Government had 100% agreement for the UK as highest priority, but the significant difference could have resulted from the fact that Research only found it as high priority (50%) and medium priority (50%). The result for the UK as a priority market for South Africa was computed as: *Probability = 0.043*

There was no significant dependence of group response with regard to respondents' perception of the current level of innovation in South Africa. The analysis could mean that respondents were not influenced by their belonging to certain groups on the results shown of the perception for the current level of innovation when compared to other successful countries.

5.2.2 International responses (South Korea, Brazil and France)

Statistical tests were designed to establish the degree of significant dependence or association between developing (South Korea/Brazil) and developed (France) countries, on various elements which could be part of the technology capability-building process needed to enable firms to contribute towards national technological competence. Pearson's Chi-square was also used to test the level of significance.

On the personal background of respondents, almost all the areas displayed no significant level of association between developed and developing economies with regard to professional background aspects (field of work, field of expertise and work experience).

Part I looked at technological innovation related background in the form of activities (both current and previous) that firms had embarked on, so as to compare the successful countries' pattern of technology development to that existing in South African. This was in line with the theory on technological competence and capability building paths followed by most of the successful countries studied (Chapter 2). It also looked at the current and future positioning of firms in relation to the structure of the aircraft industry.

For Part I, *Questions 1-8* were clustered to determine if there was significant dependence of group responses (South Korea/Brazil and France) with the level of involvement of firms' technological innovation activities, including their contribution within the aircraft industry structure. The results indicated some significant dependence of group response in half of the responses, with the other half showing no significant dependence on the level of involvement with regard to the specified technology-related activities.

The firms' technological innovation activities that displayed a significant dependence of groups between responses by France and South Korea/Brazil were as follows:

Have joint ventures with international aircraft institutions

Probability = 0.001

The probability indicated that there was a very high significant dependence in the responses received. The analysis indicated that France displayed a 100% involvement in joint ventures with international aircraft organisations when the combined response of South Korea and Brazil showed only a 23% involvement.

Involved in sub-contracting to international institutions

Probability = 0.032

The analysis showed evidence of a high significant dependence on group response for the responses received. There was 100% involvement (YES) by France compared to 54% involvement by South Korea/Brazil.

Involved in aircraft projects for an international contractor

Probability = 0.000

The probability indicated a very high significant dependence on group response therefore there was a significant dependence on the responses received, with South Korea/Brazil showing a 100% involvement in aircraft projects compared to France, which indicated only a 14% involvement.

Making a major contribution on 2nd tier

There were differences shown in the responses, which indicated a significant dependence of group response. South Korea/Brazil were almost twice as involved (64%) with second tier as France (36%).

Making a major contribution on 3rd tier

There were also differences shown in the responses, indicating significant dependence of group response. South Korea/Brazil had 9 out of 14 responses indicating involvement, compared to France with only 1 out of 7 responses in that regard.

It was quite interesting to note that for the following activities (half of the responses) there was no evidence of significant dependence of group responses on the results, which were as follows:

Involved in collaboration with local institutions

Probability = 0.452

No evidence of significant dependence of group response displayed.

Involved in technological innovation or improvement

In both instances (France and South Korea/Brazil) there was 100% agreement that they are involved in technological innovation within the aircraft industry. This also displayed non-significant dependence of group response on the results.

Acquired contracts through government assistance

Probability = 0.279

No evidence of significant dependence of group response displayed.

Involved in technology transfer with global institutions

Probability = 0.639

No evidence of significant dependence of group response displayed.

Making a major contribution on 1st tier

In both instances similar involvement in making a contribution on the first tier of the aircraft industry structure was indicated.

Part II looked at the trends of the factors and interventions believed to be key in building technological competencies within the aircraft industry. Data would be compared to that gathered from local respondents to establish if a pattern exists on the technological capability building paths followed by various countries.

For Part II, tests were done to determine if there was significant dependence between developing (South Korea/Brazil) and developed (France) countries on the level of agreement, availability and/or rankings of some of the commonly known factors impacting (positively or negatively) on the technology capability building process and the required competencies for enabling firms to contribute towards national technological competence. In essence, the study needed to establish if there was a level of association between the success of international firms, and the technological capacity building process (technology transfer, skills development, infrastructure development, government support, and R&D investment).

On the aspect of government promoting national technological competence through specific interventions, significant dependence of group response was displayed on two elements as follows:

Support R&D programmes

Probability = 0.008

The probability indicated a very high significant dependence of group response. South Korea/Brazil (100% strongly agree) indicated the need for government support of R&D programmes, whereas France (57% strongly agree) saw less need, probably because it is already well positioned and independent.

Support infrastructure development

Probability = 0.000

Again, the probability indicated a very high significant dependence of group response. South Korea/Brazil (100% strongly agree) indicated the need for government support of infrastructure development, whereas France (57% agree) did not see as much need, probably because it is already well positioned and independent.

Regarding essential interventions for successful technology capability building within the aircraft industry, significant differences were displayed on four statements as follows:

"Large investment on R&D could improve technology competence within firms thereby enhancing technological competitiveness of the national aircraft industry".

Probability = 0.000

The computed probability indicated a very high significant dependence of group response. South Korea/Brazil (93% strongly agree) supported the statement on the need for large R&D investments, whereas France (100% agree) merely agreed without strongly supporting the statement.

"Technology transfer would be key towards development of technology capabilities, improved innovation and competitiveness of the aircraft industry".

Probability = 0.000

The probability here also indicated a very high significant dependence of group response. France (86% disagree) did not support the statement about technology transfer contributing to technology capability building, whereas the developing countries (South Korea/Brazil, 79% agree) believed that technology transfer was crucial in that regard.

"Government should collaborate with governments from other countries on major projects so as to improve technology competence and global market access for aircraft firms".

Probability = 0.000

A highly significant dependence probability of group response was computed. France (71% disagree) did not support the statement about government collaborating with governments from other countries, whereas the developing countries (South Korea/Brazil, 64% agree, 36% strongly agree) believed that government-to-government collaboration could improve technology competence and global market access.

"Collaborative efforts from academia, research institutions, firms and government are essential for enhancing innovation and technology development within the aircraft industry".

Probability = 0.049

The probability indicated a significant dependence of group response. South Korea/Brazil (93% strongly agree) indicated the need for collaboration by all relevant stakeholders, with France (57% strongly agree) agreeing much less than South Korea/Brazil, probably not seeing as much need because it is already well positioned and independent.

On the aspect of growing the aircraft industry towards the development of national technological competence, significant differences were displayed on five elements as follows:

Firm collaboration (national)

Probability = 0.000

A very high significant dependence of group response was witnessed as a result of the probability computed. South Korea/Brazil saw this element as a priority area (83% high priority, 17% highest priority) for developing national technological competence, with France seeing it as of medium priority (100% medium priority).

Aircraft-related research institutes

Probability = 0.001

The above probability indicated a very high significant dependence of group response. South Korea/Brazil saw this element as a priority area (75% highest priority, 17% high priority) for developing national technological competence, with France seeing it as of medium priority (100% medium priority).

Government support for technological innovation

Probability = 0.002

The probability indicated a high significant dependence of group response. South Korea/Brazil saw this element as a priority area (57% highest priority, 36% high priority) for developing national technological competence, with France seeing it as of least priority (80% least priority).

Technology transfer

Probability = 0.032

The probability indicated a significant dependence of group response. South Korea/Brazil saw this element as a priority area (91% high priority) for developing national technological competence, while France was divided in response (50% high priority, and 50% less priority).

Well-supported higher education & research institutions

Probability = 0.004

The probability indicated a high significant dependence of group response. South Korea/Brazil saw this element as a priority area (100% highest priority) for developing national technological competence, with France seeing it as of medium priority (75% medium priority).

For the most well-known aspects impacting on the technological competitiveness of firms within the civil aircraft industry, significant dependence of group response was displayed on the following elements:

Insufficient in-house technological capability

Probability = 0.000

The resulting probability indicated a very high significant dependence of group response. Developing countries (South Korea/Brazil) agreed (93% strongly agree) that this element has a negative impact on the technological competitiveness of firms, whereas the developed country (France) agreed to a lesser extent (86% agree).

Poorly developed aircraft infrastructure

Probability = 0.001

The probability indicated a very high significant dependence of group response. Developing countries (South Korea/Brazil) agreed (64% agree, 36% strongly agree) that this element has a negative impact on technological competitiveness of firms, whereas the developed country (France) hardly agreed (14% strongly agree).

Under-developed technological capabilities

Probability = 0.000

Here, again, the probability indicated a very high significant dependence of group response. Developing countries (South Korea/Brazil) agreed (86% strongly agree) that this element has a negative impact on the technological competitiveness of firms, whereas the developed country (France) merely agreed but not strongly (100% agree).

Insufficient R&D investment

Probability = 0.010

The probability here indicated a significant dependence of group response. Developing countries (South Korea/Brazil) agreed (79% strongly agree, 21% agree) that this element has a negative impact on the technological competitiveness of firms, whereas the developed country (France) agreed at a different level (83% agree, 17% strongly agree).

Insufficient skills development programme

Probability = 0.001

For this particular element, the probability indicated a very high significant dependence of group response. The developed country (France) strongly agreed (86% strongly agree, 14% agree) that this element has a negative impact on the technological competitiveness of firms, whereas the developing countries (South Korea/Brazil) merely agreed (14% strongly agree, 86% agree).

For the factors assumed to be hampering global business acquisition and technology capability building needed for enhancing technology development within civil aircraft firms, significant dependence of group response were displayed on the following elements:

Highly regulated environment (global & local)

Probability = 0.026

The probability indicated a significant dependence of group response. Developing countries (South Korea/Brazil) agreed to a certain extent (54% agree) that this factor hampers global business acquisition and technology capability building, whereas the developed country (France) strongly disagreed (33% strongly disagree) in this regard.

Insufficient financial resources

Probability = 0.029

Here, the probability indicated a significant dependence of group response. Developing countries (South Korea/Brazil) agreed (57% strongly agree, 36% agree) that this factor hampers global business acquisition and technology capability building, whereas the developed country (France) had a split response, agreeing (57% strongly agree) but also disagreeing to a certain extent (43% disagree).

Projects too costly

Probability = 0.001

The above probability indicated a high significant dependence of group response. Developing countries (South Korea/Brazil) agreed (79% strongly agree) that this factor hampers global business acquisition and technology capability building, whereas the developed country (France) disagreed (71% strongly disagree).

Poor strategic alliances or networks

Probability = 0.001

Judging from the above probability, there was a high significant dependence of group response. Developing countries (South Korea/Brazil) agreed (36% strongly agree, 57% agree) that this factor hampers global business acquisition and technology capability building, whereas the developed country (France) disagreed (83% disagree).

Insufficient government support

Probability = 0.001

Here, again, the probability indicated a high significant dependence of group response. Developing countries (South Korea/Brazil) agreed (64% agree, 29% strongly agree) that this factor hampers global business acquisition and technology capability building, whereas the developed country (France) disagreed (43% disagree).

Insufficient experience in global supply

Probability = 0.030

The probability indicated a significant dependence of group response. Developing countries (South Korea/Brazil) agreed to a certain extent (29% strongly agree, 14% agree) that this factor hampers global business acquisition and technology capability building, whereas the developed country (France) had mixed responses (50% agree, 50% disagree).

On the issue of ideal key competencies, capabilities, skills and technologies needed for civil aircraft technology development by developing economies, significant differences were displayed on the following elements:

Aircraft maintenance skills

Probability = 0.0000

The probability indicated a very high significant dependence of group response. South Korea/Brazil saw this element as an ideal skill with the highest priority (79% highest priority, 7% high priority) for civil aircraft technology development in developing economies, with France seeing such skill as of high priority (100% high priority).

Manufacture of composites, rotor wing propeller blades, gearboxes

Probability = 0.009

The probability indicated a high significant dependence of group response. South Korea/Brazil saw this element as ideal competency with highest priority (62% highest priority, 15% high priority) for civil aircraft technology development in developing economies, with France seeing such skill as of least priority (50% least priority, 50% less priority).

Design and manufacturing skills for passenger aircraft

Probability = 0.035

A high significant dependence of group response was witnessed based on the result of the probability. South Korea/Brazil saw this element as ideal skills with medium priority (100% medium priority) for civil aircraft technology development in developing economies, with France seeing such skill as of high priority (83% high priority).

With regard to the rating of the current level of innovation, there was a very high level of significant dependence of responses received when comparing the developing countries (South Korea and Brazil) with the developed country (France). This could be because France already regards itself as very strong on innovation, whereas the developing countries still regard themselves as having a medium level. The computed probability showed a very high significant dependence of group response as indicated. *Probability = 0.0000*

5.2.3 Comparative analysis of South African and international findings

This comparative analysis was done to investigate whether the technological innovation activities of nations could be associated with the capability-building pattern of successful firms. This would actually determine if South African firms are doing the same things that successful firms from both developing and developed nations have done, or something different. Also, could certain aspects be considered common in the technological capacity building process (technology transfer, skills development, infrastructure development, government support, and R&D investment).

The comparative analysis was done as follows:

Have joint ventures with international aircraft institutions

South African responses showed a 60% non-involvement, but *Firms* respondents from South Africa showing a 50% involvement. South Korea/Brazil (emerging economies) had a 77% non-involvement, which is close to what South Africa indicated. However, France (developed nations) showed a 100% involvement. South Korea/Brazil are regarded as successful in terms of international technological trade impact, as is France. The analysis reveals that it is a firm's own choice whether to form joint ventures with international aircraft institutions or not, as this does not really impact much on the technological capacity building process.

Involved in aircraft projects for an international contractor

South African total responses showed a 47% involvement, with responses by *Firms*, specifically, showing a 100% involvement where 95% of the work contributes to their turnover. South Korea/Brazil displayed a 100% involvement, which was similar to that of South African *Firms*, specifically. France showed only a 14% involvement, which was not surprising from a developed economy's view point. 60% of the total responses from both France and South Korea/Brazil indicated that 20% of such work contributed to their turnover. It is crucial that South Africa organisations increase their involvement in projects for international contractors, although South African *Firms*, specifically, were shown to be doing it already. The success of the developing economies (South Korea/Brazil) could be attributed to this aspect as well.

Involved in collaboration with local institutions

South Africa showed a 100% involvement by all respondents. France also showed a 100% involvement, whereas South Korea/Brazil displayed 92% involvement. For these successful nations to have such a high percentage of collaboration nationally indicates that this aspect is very important. South Africa should continue to foster collaboration with local institutions.

Involved in technological innovation or improvement

South Africa showed a 93% involvement, with *Firms*, *Government* and *Research* showing a 100% involvement. Both developing and developed economies showed a 100% involvement in technological innovation within the aircraft industry. For these successful nations to have such a high percentage on this aspect showed that it is a critical area. South Africa should continue to do more in this area of technological innovation or improvement.

Acquired contracts through government assistance

South Africa showed a 73% agreement, with *Firms* specifically showing a 100% agreement to having acquired contracts through government interventions. South Korea/Brazil displayed a 46% agreement. France showed a 71% agreement, almost similar to that of South Africa. The analysis showed that government played a critical role in assisting firms in acquiring contracts, even in developed economies such as France. The recommendation would therefore be that the South African government continue to support firms but in a structured manner so that the support has a positive impact on the technological capacity building process.

Involved in technology transfer with global institutions

South Africa showed a 53% agreement with *Firms,* specifically, showing a 100% agreement to having been involved in technology transfer. South Korea/Brazil displayed a 54% agreement, very similar to South Africa. France showed a 43% agreement, which was lower than developing nations had shown. That France is less involved in technology transfer could be an indication that it has enough technological innovation capability, whereas the developing nations still need to learn from the developed nations. South Africa should continue to engage in appropriate technology transfer, while still trying to innovate.

Tier level contribution

South Africa indicated that it makes a major contribution on the fourth tier (47%) and the third tier (40%). *Firms*, specifically, indicated where their contribution is on the fourth tier (100%), the third tier (100%), the second tier (75%) and the first tier (75%).

Both developing and developed nations indicated a 100% contribution on the first tier. The analysis showed that South Africa is still lagging when compared to successful firms in developed and developing nations. The South Africa aircraft industry further indicated that, ideally, it should be doing more work to support the second (87%) and the third tiers (80%), but it definitely should not be contributing much to the fourth tier. The findings in relation to where South African firms are contributing on the tier levels, and the ideal aspirations, conform to the Systems Integration Hierarchy (SIH) model, as presented by Hwang (2000), described in Chapter III. The SIH model was tested for its applicability to the South African situation, as it was based on developing economies. This capability-building model described the four-stage process of how firms move up the hierarchy from airframe parts manufacturing and subassembly, through subassembly development, to system integration.

The model has been proven to be applicable to the South African aircraft industry as follows:

1) Knock-down system assembly

During this first stage of catching up, latecomer firms undertake simple assembly work.

The majority of South African firms have been doing much of their work at this level, which matches the fourth tier level of the aircraft industry structure. The findings indicated a 100% contribution by South African firms to the fourth tier. A 47% contribution by the entire South African aircraft industry (research institutions included) was shown.

2) Parts manufacturing and subassembly

The model indicates this stage (which matches third tier) to be applicable for airframe parts manufacturing, but it could be modified to include engine parts manufacturing.

This is also an area where most of the South African firms are contributing. The levels of assembly range from small subassembly to that of the main wing. The findings indicated a 100% contribution by South African firms for the third tier, but a 40% contribution by the entire South African aircraft industry (research institutions included) was shown.

3) Subassembly development (and low level aircraft system development)

This is the stage where firms start sharing development costs and sales returns with contractors. Contracts for development work range from conceptual design work, basic design, and detailed design, to actual production. Few South African firms contribute at this second tier level other than Denel, which was involved in the actual production of its previous contracts for civil aircraft. The findings indicated a 75% contribution by South African firms compared to the higher contribution for both the fourth and the third tiers. A 33% contribution by the entire South African aircraft industry was noted (research institutions included).

4) System integration

This is the stage where firms emerge as major participants in the international aircraft market, including becoming international joint development partners. It is at this stage that latecomer firms become involved in every area of the aircraft business, including design and development, production, market survey, marketing, product support, after sales, and financing. Although South African firms could not be regarded as system integrators, they have been partly involved in some of the business aspects of this level, such as aircraft maintenance (product support) and producing on license. They do not have to be fully involved from the beginning, as the learning process usually takes time. Surprisingly, the findings indicated a 40% average contribution by the entire aircraft industry (research institutions included) on the first tier level, with *Firms*, specifically, indicating a 75% contribution.

Both developing and developed nations indicated a 100% contribution on the first tier. The analysis showed that South Africa is still lagging when compared to successful firms in developed and developing nations. The South African aircraft industry further indicated that, ideally, it should be doing more work to support the second (87%) and the third tiers (80%), but it definitely should not be contributing much to the fourth tier.

The comparative analysis was also done on the following:

Essential interventions for successful technology capability building

In both local and international findings, there were coinciding outcomes when the statement on collaboration was the first priority. The statement specifically mentioned that *"Collaborative efforts from Academia, Research institutions, Firms and Government are essential for enhancing innovation and technology development within the aircraft industry".* Furthermore, on issues for ***building national technological competencies***, "Research and technology development programme" was the first priority for international experts. This coincided with the findings from local experts where the following statement on an R&D programme was the first priority: "*R&D programme, in line with applied technology development could improve the technology base of the South African aircraft industry*".

When comparing responses on the question relating to ***growing or improving national technological competencies*** for the civil aircraft industry, specifically, "Research and technology development programme" was the first priority for international experts. For local experts "Research and technology development programme", and "Skills development" were rated second after "Government support". This reaffirms the conclusion that a research and technology development programme is critical. However, from a developing economy's' point of view, government intervention would be needed to support such a programme. On the same question, international respondents rated "Aircraft-related research institutes" second, followed by "Research collaboration – government, research institutes, academia, firms" and "Government support for technological innovation". There were commonalities in that for local responses, "Aircraft-related research institutes" and "Research collaboration – government, research institutes, academia, firms) had equal ranking after "Research and technology development programme".

On the question of ***aspects impacting negatively on the technology capability-building*** process, there were common findings from both international and local experts who rated "Inadequate skilled resources", and "Insufficient skilled resources", respectively, as the first priority. International respondents rated "Insufficient in-house technological capability" second, followed by "Insufficient R&D investments" and "Under-developed technological capabilities", both third in priority. However, when looking at a related question for local experts, on current gaps in the South African civil aircraft industry affecting the technology capability-building process, the findings indicated "Insufficient R&D investment" as the first priority, followed by "Under-developed national systems of innovation". Third in priority was "Insufficient skilled resources". The analysis of these choices would mean that appropriate skills need to be sought or developed, and once the appropriate skills exist in-house, it would be easier for R&D to be carried out, thereby also resolving the issue of lack of in-house technological capabilities, and the broader issue of under-developed technological capabilities. Again, all of the role players need to be involved to strengthen the process, therefore a well-structured national system of innovation would need to be developed.

A comparative analysis was also done on the issue of interventions needed or done in relation to ***human resources development*** to enhance in-house technological capabilities. What was common for both local and international findings was that an "In-house skills development programme" was the first priority. This again supported the analysis, above, that experts saw the development of skills as critical to be able to develop in-house technological capabilities. International experts ranked "Inter-firm research collaboration – international" second in priority, whereas local experts ranked "Inter-firm skills exchange program – international" second. This showed that the local industry is already involved in skills-exchange programs with international institutions as part of developing skills, because that is the quickest way of learning from the developed economies. International experts only viewed collaboration as a critical aspect because they already have resources and other ways of developing skills, so they ranked a skills-exchange program as last priority.

Comparative analysis of ***competencies, skills or technologies needed for the South African civil aircraft industry***, or for developing economies, showed the common outcome was "Aircraft maintenance skills", which was rated second in both local and international findings. It was quite interesting to see that international experts perceived aircraft maintenance skills as critical for developing economies, when South Africa is already specialising in this area of aircraft maintenance, even for international clients. What also emerged as close to common was the skill for "Manufacture of components and sub-system levels" which was fourth in priority for international experts and third for local experts. Local experts rated "Design and manufacturing skills for passenger aircraft" as first priority, probably because they are constrained by the lack of this skill, which affects technological capabilities and business acquisition. Surprisingly, international experts ranked this element sixth, having "Civil–military linkages" ranked as first priority. This could mean that they are aware of previous developments or achievements by South Africa in military aircraft design and manufacture, which could be used on civil aircraft. "Civil-military linkages" would therefore play a key role in translating acquired skills into technological applications for the design and manufacture of civil or passenger aircraft.

When comparing the rating of the ***current level of innovation***, international experts regarded themselves as "Very strong" on average, with the developed country experts indicating a 100% rating on "Very strong". The developing country experts, specifically, had "Moderate" as the highest ranking (46%), not much higher than "Poor", the second ranking (38%). South Africa had "Poor" as the highest ranking (57%) and "Moderate" at 35%. South African findings are not very far from those of the other developing countries (South Korea/Brazil), which showed that it has the capability of having a successful civil aircraft industry if it learns from the models that come from these successful countries. The common aspect from the perception of the developing country experts, both local and international, was that these developing countries still regard themselves as somewhere between Poor and Moderate with regard to their current level of innovation.

5.3 Inference of new theories and propositions

New facts to be considered for a framework for technological capability building will be proposed in this section, based on the results and analysis of findings.

Involved in collaboration with local institutions

South African aircraft industry role players have been involved in collaboration activities with local institutions as part of building local technological capabilities or competencies within the sector. This was shown in the research where the responses indicated 100% involvement. For France there was 100% involvement, whereas for South Korea/Brazil the responses indicated 92% involvement. The South African civil aircraft industry should take into consideration, as part of the new strategy, that successful firms have been involved in collaboration activities with their local institutions or counterparts as part of building local technology capabilities or competencies within the sector. This is something that could be included in a framework for technological capability building.

Factors impacting on the technology capability process

In the findings, respondents generally agree (non-significance dependence) that they are doing some interventions for human resource development to enhance in-house technological capabilities. Therefore, the South African aircraft industry role players find that it is necessary to invest in human resource development, which will in-turn support the local technology capability building process within the sector. This is in line with the views of the international aircraft industry experts, who found HRD to impact on the technological capability building process. Their response on the issue of insufficient skilled resources, rating it first, as impacting strongly on the technological competitiveness of firms. A fact to be considered in a new framework for the South African civil aircraft industry is that large investment in Human Resource Development could facilitate the technology capability building process of local aircraft firms.

At another level of responses, insufficient R&D investment ranked first as a major gap that impacts negatively on the technological capability building process of the South African aircraft industry. International experts ranked this element third, after under-developed technological capabilities. However, for under-developed technological capabilities to be resolved, an investment in R&D would be required. A new strategy for the South African civil aircraft industry, to be included in the framework for technological capability building, would be that South Africa invest more in R&D to be able to develop national technological competencies within the civil aircraft industry.

The analysis showed that South African role players mostly agreed on the perception of the current level of innovation, which was regarded as poor (57%)

when compared to other successful countries. There was no significant dependence of group responses shown in the responses, although *Firms* indicated a 75% poor compared to others (50% poor). Another fact to be noted by the South African civil aircraft industry in relation to the level of innovation is that the current level of innovation within the South African aircraft industry was perceived as poor compared to other developing countries like South Korea and Brazil. The final framework on technological capability building proposed by the researcher could help improve the level of innovation within the South African civil aircraft industry.

Involved in technological innovation or improvement

The findings showed that in both instances of the case study countries (France and South Korea/Brazil) there was 100% agreement that they are involved in technological innovation or improvement in the aircraft industry. Another new strategy to be considered by the South African civil aircraft industry would be to increase its level of involvement in technological innovation or improvement, especially technological improvement, where it could build technological capabilities to be in a position eventually to develop new technologies. This would be in line with the finding that successful aircraft firms from both developing and developed economies, are, or have been, involved in technological innovation or improvement within the aircraft industry, and that this has contributed to the technology capability building of their firms.

Making a major contribution on tier levels

The findings also showed that in both instances, South Korea/Brazil and France were making a contribution on the first tier, but South Korea was almost twice as involved on the second tier as Brazil. On the third tier, France's involvement was hardly visible. A fact that arose from the findings, to be considered when developing a strategy for the South African civil aircraft industry, was that although the successful aircraft firms from both developing and developed economies make a contribution on the first tier, only those from developing economies continue to make a major contribution on second and third tiers of the aircraft industry structure. This could mean that South Africa needs to make a vast contribution, especially on the second tier.

Subcontracting by international firms

Another strategy fact for consideration by the South African civil aircraft industry that arose from the findings, was that developed nations within the aircraft industry subcontract some of their work to developing nations, and developing nations that are successful subcontract some of their work to peer countries that are not necessarily as successful. This is evident from France's indication of 100% for subcontracting of work to organisations outside their country. South Korea/Brazil indicated a 54% for subcontracting to organisations outside their country. In this way, South Africa could exploit the African market, where there could be technological capability building opportunities, with work being subcontracted to technologically capable countries in Africa, but again South Africa assembling final products for supply to the African market.

Interventions for the successful building of technological capabilities and national technological competencies

The findings indicated coinciding outcomes (ranked first) by both local and international experts on the importance of collaboration on required interventions for successful technology capability building. The findings also showed a research and technology development programme to be a top priority for international experts. For local experts, it ranked as second priority together with skills development, with the top priority being government support. The conclusion on this aspect is that a research and technology development programme is critical, although from a developing economy's point of view, government intervention is needed to support such a programme, which should be coupled with skills development.

A fact to be considered for the new technological capability framework for the South African civil aircraft industry is that developing economies require government support for technological innovation. It should be in the form of R&D support programmes, skills development, and support for collaboration by various relevant participants, to improve the technological base of the South African aircraft industry. In addition, collaborative efforts by academia, research institutions, firms and government are deemed essential for enhancing innovation and technology development within the aircraft industry in developing economies.

Furthermore, developing economies need a well-structured national system of innovation, to develop appropriate skills for efficient R&D programmes. This would lead to the development of the in-house and broader technological capabilities needed by the civil aircraft industry. This is based on the common findings for both local and international experts that indicated inadequate skills resources as an element impacting negatively on the technology capability building process. For local experts, further findings indicated insufficient R&D investment, and under-developed national systems of innovation as highly ranked elements that also hamper the technology capability building process.

Competencies, skills or technologies needed by the South African aircraft industry

A logical strategy for South Africa would be to strengthen its core competency of aircraft maintenance skills, which are perceived to be critical for developing economies. This is based on the common outcome of aircraft maintenance skills that ranked second for both local and international findings. Furthermore, civil–military technological linkages could play a key role in translating acquired skills into technological applications for the design and manufacture of civil or passenger aircraft in South Africa. This conclusion was based on the first ranking of civil–military technological linkages by international experts, which could mean that they are aware of previous developments or achievements by South Africa in military aircraft design and manufacture. Meanwhile, local experts rated design and manufacturing skills for passenger aircraft first in their priorities, as a skill needed by the South African aircraft industry.

5.4 Finalising new theory and frameworks

In the previous section the research problem stated that it is not known if the South African civil aircraft industry has proper support measures or if it follows a particular framework for technology development to gain global technological competitiveness.

The investigative analysis of the study indicated certain models and frameworks, used internationally, which have helped improve the innovative and technological capabilities of the industry. Within these frameworks, specific elements or areas of intervention that have been used internationally were identified. Some of these appear to exist to a certain extent locally, and they contribute to the development of industrial technological capabilities.

The researcher proposed a conceptual framework in line with the problem area, incorporating literature review, including literature on related subjects, and information gathered from other sources of information. The conceptual framework indicated key elements of technological capability building, such as innovation networks, technology transfer and adoption, and R&D investment. It also looked at whether issues such as skills development, infrastructure development and the dynamic capabilities of firms, including government interventions, contributed towards shaping the building of national technological capabilities within the civil aircraft industry.

Based on the findings, it appears that successful nations, especially developing nations (represented by South Korea and Brazil), and, to some extent, developed nations (represented by France), show evidence of the following:

- Involved in aircraft projects for an international contractor (100% involvement for South Korea/Brazil)
- Involved in collaboration with local institutions (92% involvement for South Korea/Brazil, 100% involvement for France)
- Involved in technological innovation or improvement (100% involvement for South Korea/Brazil, 100% involvement for France)
- Involved in technology transfer with global institutions (54% involvement for South Korea/Brazil)

Elements that had similar responses from both developing and developed economy experts, ranking as first priority with regard to successful technology capability building or national technological competencies, were the following:

- Investing in R& D
- Developing aircraft-related research institutes
- Research collaboration (government, research institutes, academia, firms)

- Skills development
- Government support for technological innovation

These elements were in line with the findings from local experts and would seem to be key in curbing factors hampering the technology capability building process as indicated in the findings.

The findings of this research indicated that the current level of innovation in the South African aircraft industry is regarded as poor (57% from findings) compared to other developing nations like South Korea and Brazil. For the level of innovation to improve, a framework applicable to the South African aircraft industry needs to be developed. The key elements indicated by the findings of this study could be incorporated into the framework, outlining the support structure required for the development of industrial technological capabilities.

The researcher proposed three frameworks aimed at improving the technological capabilities of the South African civil aircraft industry. The three frameworks are linked to the Adoption Theory on innovation, the Networks Theory, technological competence, capacity building models and paths followed by some successful countries. Other models and frameworks considered when developing the three frameworks included:

- Holmes (1996) on fostering alliances and partnerships
- The backward integration model on industrial development, by Buys (2001), where the use of foreign technology in improving products and processes becomes critical
- The model on the emergence of high technology industries by Van de Garud (in Mathews 2001), which indicates the importance of creating resource endowment through to industry stabilisation
- The model on dynamics of diffusion for high technology industries by Mathews (2001), which emphasizes a resource-leverage approach from skills, knowledge, technology acquisition and adaptation through to establishment of R&D capabilities and social structures for innovation
- The UK's organisational structure (Aerospace Innovation and Growth team), showing the key areas considered during technological capability building (DTI

(UK) 2003)

- The framework on national R&D mechanisms in the South Korean aircraft industry, which showed how government and other role players worked together to build technological capabilities
- South Korea's institutional structure, showing the involvement of all key participants when working on certain projects.

5.4.1 Framework for technology capability building through public–private partnership

This is a framework for technology capability building through public–private partnership interventions (Figure 5.1).

It suggests the creation of a more developed **technology and business environment for the South African civil aircraft industry**, which would allow for development of more technological capabilities and competencies, leading to higher growth and an increased contribution to the global market. The framework emphasizes aggressive government interventions, which encourage collaboration between firms within industry, and with research and higher education institutions, followed by major investment in research and development. This framework is supported by the findings where it became evident that successful firms have been involved in collaboration activities with local institutions as part of building local technology capabilities or competencies within the sector. The findings also indicated that local firms (100%) viewed government intervention as critical in assisting the technological development of the industry and for business acquisition support. Government intervention was also a priority as an element needed to support the technology development of the industry. The developing nations agreed (71%) to having been assisted by government in acquiring business.

What the framework suggest is that government, through the relevant government departments (ministries) such as the Department of Trade and Industry (DTI), the Department of Science and Technology (DST), the Department of Public Enterprise (DPE), the Department of Defence (DOD) and the Department of Transport (DOT), establish a coordinating body to oversee the needs of the South African aircraft industry in terms of policy and strategy, which should focus on R&D

requirements (technology development & acquisition), skills development, funding requirements, development of local markets and international market access.

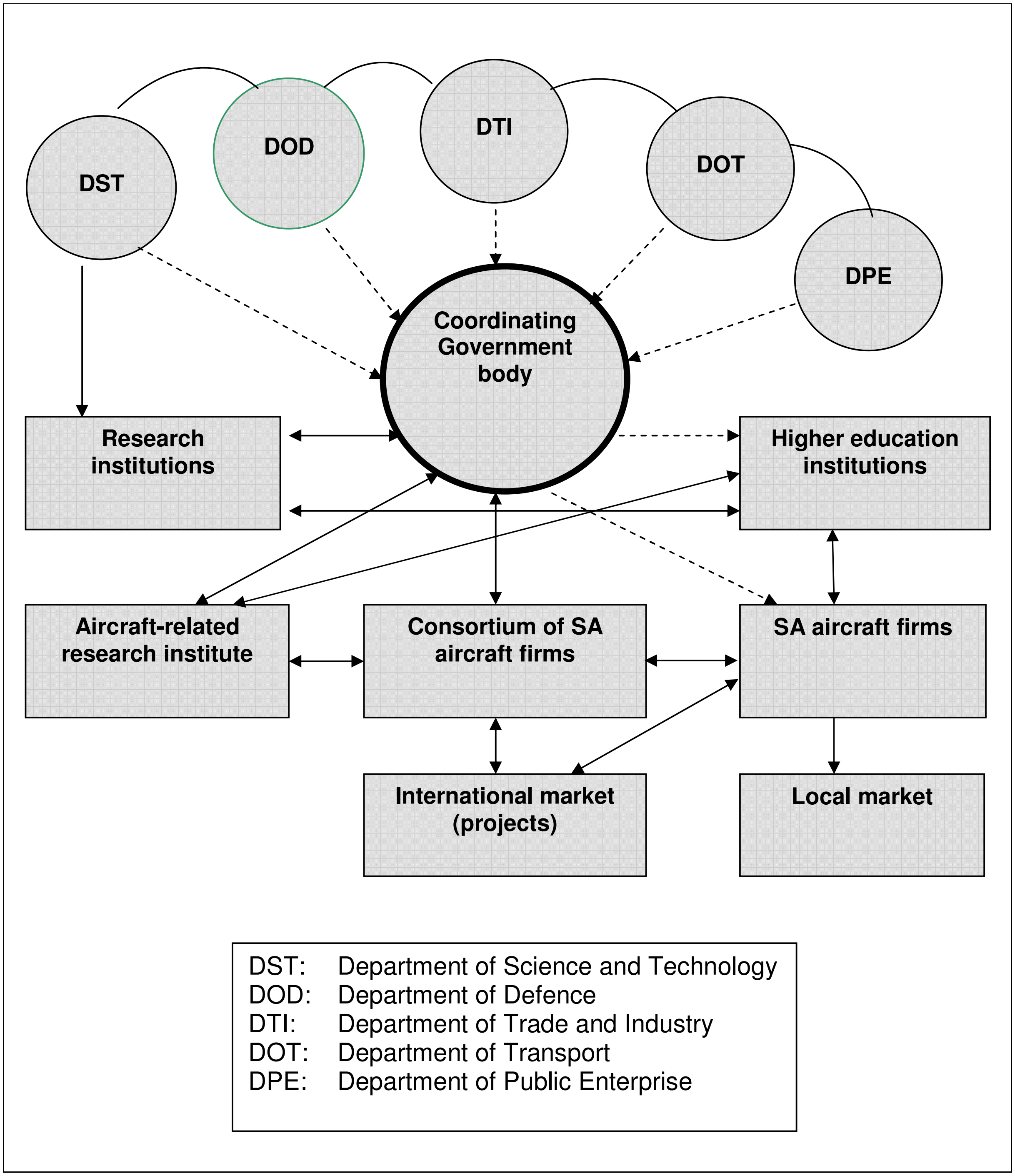

Figure 5.1 Technology capability building through public–private partnerships

The coordinating body shall work jointly to look at the development of the South African aircraft industry where members representing the respective departments (ministries) shall have a clear mandate in line with their objectives as follows:

- DTI shall be responsible for:
  - Monitoring of technological trends and their impact on global and local industry
  - Creating a suitable business climate including short-term industrial innovation, technology transfer, supply chain management and facilitating market acquisition by local firms
  - Facilitating skills and human resource development including strengthening of local and global networks
  - Promoting collective manufacturing and marketing through the creation of clusters
- DST shall be responsible for:
  - Research and development support
  - Directing the areas of long-term research and development in industry, relevant research institutions and higher education institutions
  - Facilitating innovation and technology development including the creation of local and international networks and partnerships on innovation
- DOD shall be responsible for skills transfer of defence technologies to be applied in the development of the civil aircraft industry
- DPE shall be responsible for infrastructure development that would create a better environment for technological development of the civil aircraft industry
- DOT shall be responsible for aligning transportation needs and policy to the technological development of the civil aircraft industry

The government coordinating body should consist of both private and public sector role players from upper management, and should be headed by the government's highest official who has an understanding of the aircraft industry. Government should channel funding through such a coordinating government body, which in turn should establish a consortium of aircraft firms with which to work closely, especially on the issues of international markets. The consortium should be independent in its operations, with the majority of private sector members being involved in the entire operation (related to project implementation) although government could still monitor efficiency and funding.

5.4.2 Institutional structure for the development of national aircraft technology

The framework indicates an institutional structure for the development of national aircraft technology (Figure 5.2). It is aimed at strengthening the technology development arena of the South African aircraft industry, through acquired projects, but with less emphasis on business acquisition. This is more applicable to existing national projects. The framework is supported by the findings that indicated the importance of interventions as systems for improving skills and national technological competencies for the civil aircraft industry. Suitable interventions would be aircraft-related research institutes, research collaboration (government, research institutes, academia, firms) and government support for technological innovation. These findings were drawn from responses of both local and international experts. The framework was based on the theory of Okamoto & Sjöholm (2001), who emphasize the importance of developing technological, managerial, and institutional infrastructure prior to micro-level interventions, for the promotion of technological development to become effective.

The framework suggests the establishment of a coordinating government body, as indicated in the previous model (Figure 5.1), to oversee the needs of the aircraft industry. However, in this case, it is suggested that a national Agency for Aircraft Development (AAD) be established to work closely with the coordinating government body and to report directly to such a body. The area of interest in this framework revolves around the coordinating government body and the AAD being tasked with facilitating technology development for the national aircraft industry. The AAD would focus mainly on R&D for the aircraft industry, specifically, but would work closely with other research institutions, Higher education institutions and other supporting institutions relevant to the industry. The AAD could establish the technology development needs of the aircraft industry, and evaluate global market requirements, to facilitate R&D in line with such findings. This agency could also look at the technology transfer requirements of the aircraft industry. The outcomes could be disseminated to the major national aircraft organisations such as Denel, SAA Technical, Aerosud, AMD and others. It is suggested that these large companies have small companies as subsidiaries.

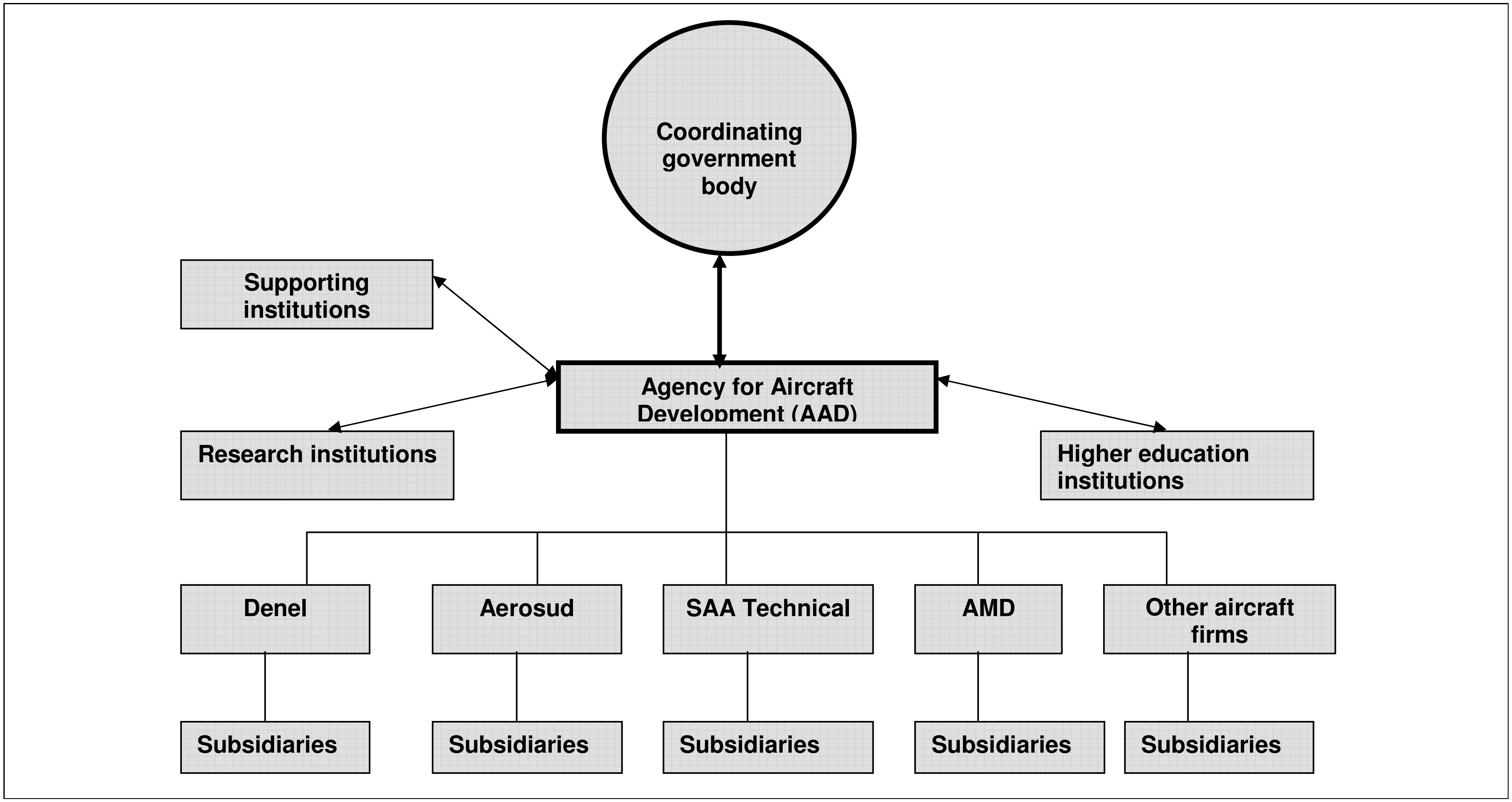

Figure 5.2 Institutional structure for the development of national aircraft technology

5.4.3 The South African Aircraft Industry Corporation (SAAIC)

An area of concern in the South African aircraft industry is the number of scientists in the field of research reaching retirement age, without there being sufficient available replacements. South Africa needs to develop strategies to stimulate interest among younger scientists in joining research professions, especially in the aircraft industry. The establishment of a major technology development and skills-transfer programme could be a solution to the problem. What is proposed is the establishment of a government-funded South African Aircraft Industry Corporation (SAAIC) whereby older and retired experts from the aircraft industry could be tasked with various roles including technology or skills transfer to, and mentoring of, newly-recruited graduates.

This corporation could also be used as a centre of excellence for the aircraft industry. The private sector could support this kind of facility as it could draw newly-trained personnel from the corporation into employment within its own ranks, and it would also have the opportunity of consulting these retired experts where necessary.

This conclusion is based on the common findings of both local and international experts, where inadequate skilled resources were found to be an aspect hampering the technology capability-building process. The aspect of inadequate skilled resources was of prime importance in both local and international findings.

CHAPTER VI: CONCLUSION AND RECOMMENDATIONS

6.1 Interpretation of findings

The research problem was that it is not known whether the South African civil aircraft industry has proper support measures or if it follows a particular framework for technology development so as to gain global technological competitiveness. At the beginning of the study, the researcher pointed out that the literature shows that the South African civil aircraft industry is lagging behind on issues of innovation and technology, as well as human capital. This was confirmed by the findings, which indicated the current level of innovation within the South African aircraft industry as poor compared to other emerging economies such as South Korea and Brazil. The poor state of innovation could have led to the current problem of a less-developed technology base that impacts on the national technological competence of South African aircraft firms. This was confirmed by the findings that revealed under-developed technological capabilities and insufficient in-house technological capabilities as highly ranked aspects impacting on the technological competence of firms in the civil aircraft industry.

The findings further indicated that successful nations, especially the emerging economies represented by South Korea and Brazil, have specific areas of involvement:

- Aircraft projects for global contractors or institutions
- Collaboration with their own local institutions
- Technological innovation or improvement
- Technology transfer with global institutions.

What was interesting was that South African firms, specifically, showed an almost 100% level of involvement in all the indicated aspects, but not sufficiently to be competitive. This is surprising. If South African firms have been involved in the above aspects, just like South Korea, which is ahead of South Africa in technological innovation, then perhaps South African firms are doing something wrong, not doing enough, or lack the correct strategy required to building technological capabilities.

A number of elements were ranked the highest priorities for successful technology capability building or developing national technological competencies:

- Investing in R&D
- Developing aircraft-related research institutes
- Research collaboration (government, research institutes, academia, firms)
- Skills development
- Government support for technological innovation.

These elements were found to be useful in addressing the constraints of factors that impact on the technology capability building process. It appears that South African firms have not been doing enough in these areas.

Based on the findings of this study and other sources, certain key factors that impact on technology capability building in the civil aircraft industry were found:

- Inadequate or insufficient skilled resources
- Insufficient in-house technological capability
- Insufficient R&D investment
- Under-developed technological capabilities
- Under-developed national systems of innovation.

As previously highlighted in Chapter V, the researcher developed three new frameworks aimed at improving the technological base of the South African aircraft industry:

- A framework for technology capability building through public–private partnerships. It emphasizes aggressive government interventions to encourage collaboration between firms within the industry and with research institutions and higher education institutions, followed by major investment in research and development.
- An institutional structure for the development of national aircraft technology. This is aimed at strengthening the technology development arena of the South African aircraft industry, through acquired projects, but with less emphasis on business acquisition.
- The South African Aircraft Industry Corporation (SAAIC), a technology development and skills-transfer programme.

The three frameworks proposed by the researcher are linked to the Adoption Theory on innovation, the Networks Theory, technological competence, capacity building models and paths followed by some successful countries. The new proposed frameworks coincide with the previously proposed conceptual framework.

The analysis showed that the South African civil aircraft industry has the capability of contributing to building national technological competence when compared to what successful countries have done regarding technological capability-building interventions. The proposed frameworks are aimed at facilitating the processes required to achieve national technological competence of the industry.

The findings indicate that the South African civil aircraft industry is making a major contribution on the fourth tier, less on the third tier, with a minimal contribution on the second and the first tier. The findings for South African firms, specifically (excluding other institutions), showed that their major contribution was equally on the third and fourth tiers, with less on the first and second tiers (equal contribution).

It came as a surprise to note that both the developing and developed nations studied indicated that they both contribute more to the first tier. The analysis showed that South Africa was still lagging when compared to the successful firms in emerging economies. This was not a surprise at all, as South Korea and Brazil are known to be technologically competitive in the civil aircraft industry. The South African aircraft industry further indicated that, ideally, it should be doing more to support second and third tier initiatives, with more emphasis on the second tier. It also felt that it definitely should not be contributing much to the fourth tier and fifth tier. These results are an indication that the South African aircraft industry is already moving up the value chain supply system (pyramid) of the aircraft industry structure. This did not necessarily mean that it could not have technologies for contributing on the first tier, but the market could be the determining factor.

It became evident that technological capacity building in successful aircraft firms from emerging economies could be associated with technology transfer, skills development, infrastructure development, government support, and R&D investment. This was in line with generally-known theories, not necessarily for the aircraft industry, but for other sectors, such as the automotive.

The findings indicated that Europe should be the main area of focus in terms of market development for South African aircraft firms. UK followed with a 2% difference, meaning that it can be considered to be the second priority area of focus. This would mean subcontracting for work, which does not take place currently as South Africa lags in technological development. The findings further identified Africa as the third priority area for South Africa with regard to market developments. This could be a good opportunity for South Africa, based on the perception that it has a stronger technological base compared to the rest of Africa, so work could be subcontracted to countries in Africa with less-successful aircraft industries.

6.1.1 Answering the research questions

The objective of the research was achieved in that the main research question was addressed. The research question is summarised as follows: "*How can key lessons from international models for the technological development of the civil aircraft industry be successfully used to develop local models for a technologically-competitive civil aircraft industry*"?

Key elements that were common to successful countries studied, with regard to the technology capability building process, were taken into consideration when developing local models for a technologically-competitive civil aircraft industry. Such elements included: investing in R&D, developing aircraft-related research institutes, encouraging research collaboration, investing in skills development, and government support of technological innovation. The models were aimed at addressing constraints by existing factors that impact on the technology capability building process of the South African aircraft industry.

The main question, as summarised above, was broken down into specific questions (some similar but asked in various forms) that were aimed at establishing specific aspects or key elements for building a technologically-competitive civil aircraft industry.

The questions were as follows:

Are there any specific successful models used for the development of a technologically-competitive civil aircraft industry internationally?

Countries used various models but these were quite similar to each other. Most countries have structural or organisational models aimed at promoting the elements known to be key in the technology capability building process, which give rise to national technological competences. For most countries, it was not clear if there were any specific models followed, except that specific elements became evident as having been taken into consideration when developing technological capabilities. Such elements were common for most countries. South Korea had a specific model that showed how it acquired technological capabilities over the years, and also how the organisational models were used to promote the key elements known for building a technological competitive civil aircraft industry. These were confirmed during interviews.

What are the successful models used for the development of technologically-competitive civil aircraft industries internationally? Do they have any relation to technological capacity building (technology transfer, skills development, infrastructure development, government support, and R&D investment)?

The key elements that were common for developing a technologically-competitive civil aircraft industry in successful countries studied, formed part of the technology capability building process. They included: investing in R&D, developing aircraft-related research institutes, encouraging research collaboration, investing in skills development, and government support for technological innovation.

Are there any commonalities (or even differences) amongst these models that have been applied by various countries?

As previously indicated, the common elements included: investing in R&D, developing aircraft-related research institutes, encouraging research collaboration, investing in skills development, and government support for technological innovation. What was also common was the involvement of successful nations, especially developing nations represented by South Korea and Brazil, in certain areas that contribute towards building technological capabilities:

- Aircraft projects for an international contractor
- Collaboration with their local institutions
- Technological innovation or improvement
- Technology transfer with global institutions.

How do the technological competencies of the South African civil aircraft industry compare with those of other, successful, countries?

The level of innovation for the South African civil aircraft industry was rated as poor compared to that of developing nations studied (South Korea and Brazil), which were in-turn rated as moderate in comparison to developed nations.

Was there a specific government policy aimed at civil aircraft technology development in all the successful countries studied?

Government in certain countries such as South Korea was found to encourage collaboration by using structural organisations that indirectly enforce conformity on firms and institutions if they need to benefit. The South African government could also support collaboration through the use of structural organisations that enforce collaboration and knowledge transfer. This study proposed frameworks that could address some of the main gaps in the South African civil aircraft industry, as indicated in this section, which could become government policy.

What are the known attributes that contribute to a less-developed technology base for a civil aircraft industry?

Based on the findings, key factors impact on the technology capability building of the civil aircraft industry:

- Inadequate or insufficient skilled resources
- Insufficient in-house technological capability
- Insufficient R&D investments
- Under-developed technological capabilities
- Under-developed national systems of innovation.

Are these attributes common to the South African case?

All the attributes identified as impacting on the technology capability building of a civil aircraft industry were found to be common to South Africa. These are known to contribute to a less-developed technology base for a civil aircraft industry.

Can the successful models be adapted to suit the South African civil aircraft industry?

Based on the priority elements that were indicated to be key in the findings on successful technology capability building or national technological competencies, the researcher was able to develop new frameworks to be used in improving the technological base of the South African aircraft industry:

- A framework for technology capability building through public–private partnerships.
- An institutional structure for the development of national aircraft technology.
- The South African Aircraft Industry Corporation (SAAIC).

What can be learned from the not so successful countries?

Not all countries were successful in developing an aircraft industry. Indonesia was one such example. The findings indicate that the country lacked an internationally recognised certificate of airworthiness which resulted in limited exports of final products. They also lacked experience in sales and marketing of such products. What appears to be critical in the success of the aircraft development is to focus not only on the technology development itself but also the business side, which includes management and marketing. Another key issue that lacked from the not so successful countries was that of not following the international aerospace industry trend of increased cooperation in the development of aircraft.

6.2 Contribution to theory and applicability

The proposed empirical framework (Fig 5.2) on institutional structure for the development of national aircraft technology added to the theory by Okamoto & Sjöholm (2001) that emphasizes the importance of developing technological, managerial and institutional infrastructure prior to micro-level interventions, for the promotion of technological development to become effective. This proposed framework could form part of a new strategy for the South African civil aircraft industry. It emphasizes the importance of providing institutional structures that coordinate the work of aircraft-related research institutes, research collaboration networks (government, research institutes, academia, firms) and government, through its support for technological innovation. This could provide a system for improving skills and national technological competencies for the civil aircraft industry.

The contributions made by South African firms to the aircraft industry structure (Fig 1.1) that was discussed earlier, match the model of Systems Integration Hierarchy (SIH) described by Hwang (2000). In addition, it is noted that firms do not necessarily have to move through the stages categorically: they can be in various stages at the same time. This is evident in South African aircraft firms that are contributing to all stages, with a greater contribution in the first tier than the second tier.

In the previous section, it was shown in Figure 2.3 how Hwang (2000) qualified Porter's (1990) framework to suit the South Korean aircraft industry in indicating the national factors for capability building. The new framework reviews the four main elements of national environmental factors, and the role of government in promoting competitiveness. This framework is applicable to the South African environment as it clearly shows that government should direct and support firms in promoting technological capability building, although it does not show the level of government involvement.

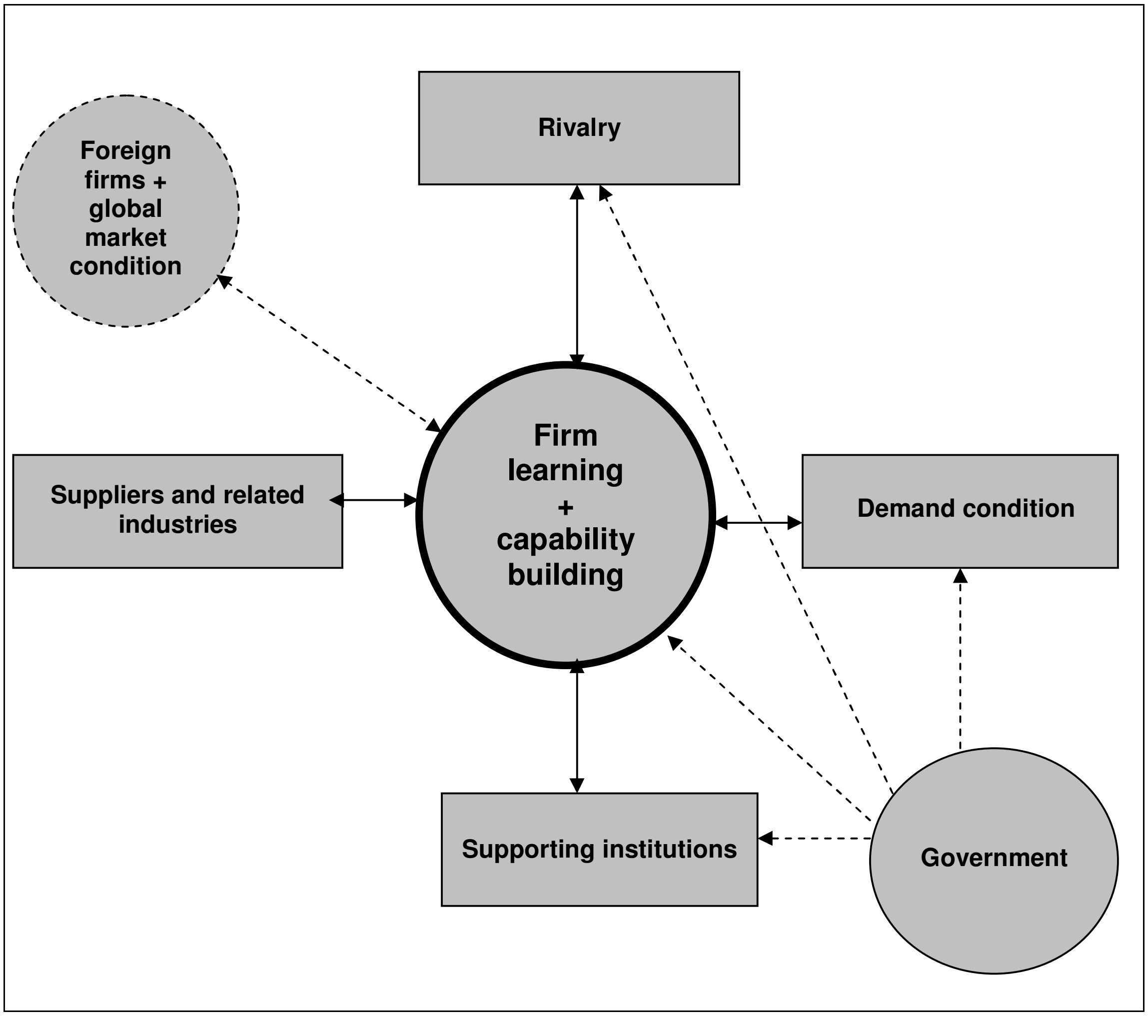

Figure 2.3 National factors in capability building
Source: Hwang (2000)

The new framework for technology capability building through public–private partnerships developed by the researcher (Fig 5.1) has extended Hwang's theory by specifically indicating how government should be guiding technological capability building within firms. It emphasizes aggressive government interventions, working with the private sector, to promote collaboration between firms in the industry, as well as with research and higher education institutions, followed by major investment in research and development. The theory is supported by the findings where it became evident that successful firms have been involved in collaboration activities with their local institutions as part of building local technological capabilities or competencies within the sector.

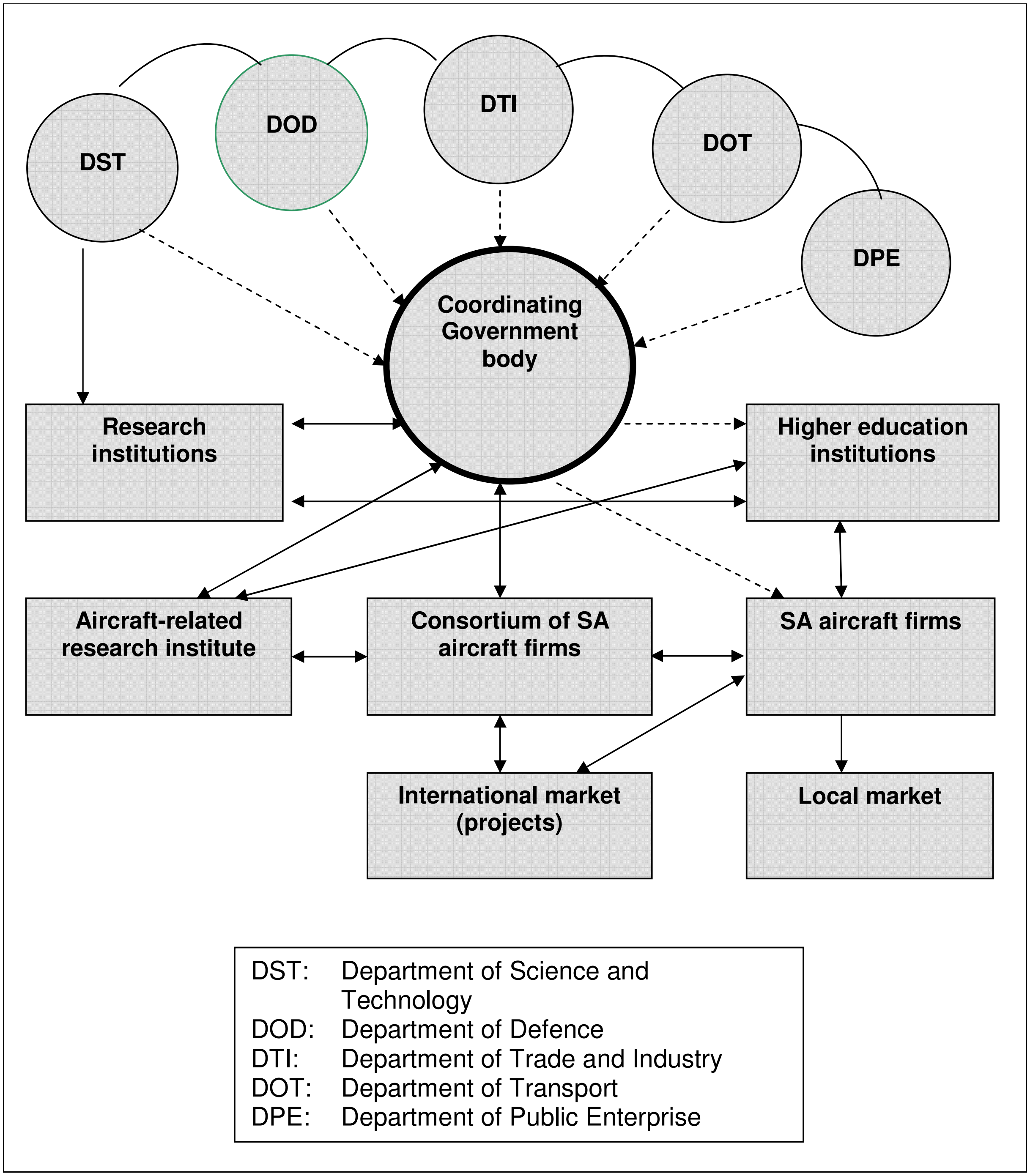

Figure 5.1 Technology capability building through public–private partnerships

6.3 Research achievements

The entire study was directed towards providing frameworks for building and improving technological competencies for the civil aircraft industry, with a focus on strategies for technological capability building (e.g. technology transfer and adoption, innovation networks and alliances, R&D investment, skills development, infrastructure development and government support).

It was quite interesting that local research institutions, government and academia were highly cooperative and committed to assisting the researcher. International experts were also much more easily accessible than anticipated, especially those from South Korea and France, and to a lesser extent those from Brazil. Twenty-one (21) international experts were interviewed in total, mainly by email and fax, which the researcher initially thought would be difficult. Locally a total of twenty-three (23) experts were interviewed.

For the United States it was problematic to make contact with the correct experts during the time the interviews were conducted. This led to the country being excluded for the purpose of interviews. Discussions were later held with Canadian and US aerospace experts when the researcher visited the two countries to discuss industrial sector technology-related strategies. These did not form part of the structured questionnaires as they happened after the analysis of statistical results had been completed. The analysis of data from interviews was a challenge, therefore, as a result of the skewed sample of developed nations (only France was used as the US had been excluded) in comparison to developing nations (South Korea and Brazil were used). However, the discussions that were later held with Canada and the United States were considered during the final analysis of findings to establish conformity. The outcome of the discussions conformed with the findings of French experts in most areas, for example on the highest priority elements in relation to successful technology capability building (i.e. investing in R&D; developing aircraft-related research institutes; research collaboration (government, research institutes, academia, firms); skills development; and government support for technological innovation.

The objective of proposing frameworks to be used in offering a strategy for improving the technology base of the South African aircraft industry was achieved.

The researcher made use of the data obtained from a literature review, which equipped her to achieve the objectives of the study. It was possible to analyse the capability of the South African civil aircraft industry for improving national technological competence in comparison to what successful countries have done with technological capability-building interventions. Analysis was done, which included the following aspects: Technology transfer and adoption, innovation networks and alliances (collaboration), R&D investment, skills development, infrastructure development and government support.

The main challenge experienced by the researcher was the lack of studies or information published regarding the South African civil aircraft industry. This was a major limitation for the researcher in the gathering and analysis of data for comparison with other nations. Most of the existing literature in the study area focused only on developed economies where the aircraft industry is already successful. It also emphasized the complexity of the global aircraft industry without specifying the empirical models or frameworks that catching-up economies should follow to develop a civil aircraft industry successfully. It was therefore difficult to apply previous findings to the South African situation without major adaptations.

The researcher anticipated that experts, especially locally, would be easily accessible for interviews, and this was the case with research institutions, academia and government. Local experts from the private sector, however, were hesitant to participate because of a reluctance to reveal confidential information that might become available to competitors. This resulted in delays in finalising the study, and a very small sample size for local firms, which made it difficult for the researcher to come to concrete conclusions in line with the statistical outcomes. There were also very few experts within the public service, therefore that sample size was also very small.

6.4 Recommendations for policy and further research

South Africa could learn from the pockets of knowledge existing in the countries studied on how they have build technological capabilities within the civil aircraft industry, the key areas of focus that led to their successes, government's involvement in supporting international co-operation, mergers and attracting investment.

A conclusion has been drawn that successful nations within the aircraft industry subcontract some of their work to other nations that are less successful. The findings indicated that Europe should be the market focus for South Africa, meaning that work from there could be subcontracted to South African firms. Some of the South African aircraft firms have already been doing work for the European firms under contract. However, the author recommends that the market focus should not be on successful countries from developed economies such as Europe and USA only, but that South Africa start looking at successful countries from emerging economies such as the East, Southeast and South Asia (e.g. South Korea, China) who have in the last decades targeted aircraft industry for their economic and technological development. It also makes business sense for South Africa to initiate special programmes for civil aviation collaboration with South Korea and Brazil because as emerging economies, they have similar economic structures, thus providing high probability for win-win collaborations in aviation industry business. There is a bilateral trade agreement between South Africa and Brazil, which should be expanded to include collaboration in aviation components, avionic systems and subsystems manufacturing.

Of the common elements that appear to have been applied by various successful nations in building technological capabilities (investing in R&D, developing aircraft-related research institutes, encouraging research collaboration and networks, investing in skills development, and government support for technological innovation), it is recommended that South Africa include them in aircraft-related government policies aimed at building competencies within the entire aerospace sector. It is critical that South Africa becomes part of the international aerospace network, which has been observed as a global trend for most successful countries studied. An increased co-operation in aircraft development could benefit South African civil aircraft industry in:

- Learning more on technology development, manufacturing, R&D, business aspects; and
- Gaining from knowledge & resources that exist in both developed & developing economies

Government support for technological innovation and improvement should be strengthened: all the technological innovation support programmes such as the Technology and Human Resource for Industry Programme (THRIP), the Support Programme for Industrial Innovation (SPII) and the Innovation Fund (IF) should be improved and offered on a large scale. The existing support for technology transfer should also be strengthened and provided on a wider scale to facilitate skills transfer and learning from technology providers. The newly established Aerospace Industry Support Initiative (AISI) should be rolled out to industry as quickly as possible to allow firms to start addressing the challenges related to skills and technological capacity within the sector.

The results also indicated that Africa is the third priority, after the UK, in terms of developing markets for South Africa. The recommendation in line with these findings is to establish the possibility of South Africa exploiting the African civil aircraft market, where it could subcontract some of its business to countries with less technological capability, in the process building or improving national technological competence. This is based on the perception that South Africa is further ahead in terms of technological development than the rest of Africa. If the proposal for South Africa to exploit the African civil aircraft market turns out to be feasible following a study in that regard, the actual strategy for the implementation would need to be established before a policy could be formally adopted. The recommendation will also be in line with the global aerospace industry trend of increased international subcontracting, mergers and acquisitions. Further to that, another area of study could be to look at the short-term and long-term technological solutions that South Africa could consider to facilitate the development of the African civil aircraft market, which could in turn benefit South Africa and the technological capability building process. The study could also look at the possibility of South Africa becoming an aircraft technology development hub for the entire African region, including looking at the specific areas of focus and the impact thereof, as well as establishing if the market size would be big enough to sustain the technological development and competitivess of the region.

The South African aircraft industry indicated that, ideally, it should be doing more work in the second and third tier, with the second tier getting more emphasis. Based on the responses that contributions to the fourth and fifth tiers are not adding much value to the technological capability building process of the civil aircraft industry, the recommendation is to draw up policies that could encourage firms to contribute more on the second tier of the global aircraft industry structure. All three frameworks proposed by the researcher, aimed at improving the technological base or competence of the South African civil aircraft industry through technological capability building, could fit in well with the overall policy for encouraging firms to move up the value chain system of the aircraft industry structure. These proposed frameworks could help improve the coordination of major technological activities within the local aircraft industry, leading to national technological competitiveness. Based on current competencies, capabilities and the high level of competition within the global market (high entry barriers), further work could be done to look at the possibility of South Africa developing technological capabilities to manufacture and supply tier 1 civil aircraft but with a specific focus being on regional aircraft.

For South Africa to develop aircraft-related research institutes, it is recommended that government support the establishment of infrastructure and equipments for a specific period, for example 5 years, after which the institutions become self-sustainable, sourcing funding from the various other instruments available. Government can also provide directives that such institutions participate in collaboration activities such as R&D projects and skills transfer, as a requirement for accessing public funds.

An area of concern within the South African aircraft industry is that of scientists in the field of research reaching retirement age, without sufficient qualified replacements being available. There were common findings from both local and international experts that inadequate skilled resources were found to be a factor hampering technology capability building. The researcher proposed the establishment of a government-funded South African Aircraft Industry Corporation (SAAIC) whereby older or retired experts from the aircraft industry be tasked with various roles including technology or skills transfer to newly recruited graduates. South Africa needs to develop strategies to stimulate interest among younger scientists in joining research professions, in the aircraft industry, especially. The establishment of a major technology development and skills-transfer programme is recommended as a policy that could develop skills and technological capability building strategies. A possible area of further study is finding out what other strategies need to be developed within the aircraft industry to facilitate the involvement of younger scientists in professions within the sector.

REFERENCES AND BIBLIOGRAPHY

References

Africa Trade issue brief. 1995.

AISI Aerospace industry support initiative, Implementation strategy for the Department of Trade and Industry, SA. May **2005**.

AMTS Advanced manufacturing technology strategy for the Department of Science and Technology, SA. **2003**.

Answers Corporation. **2006**.

Antoniou, PH. & Ansoff, HI. 2004. Strategic management of technology. *Technology Analysis & Strategic Management.* June 2004, 16(2), 275-291.

ATAG Consultation report from the Air Transport Action Group to the Department of Transport. **2002**. The future development of air transport in the United Kingdom – 2002. Available from: http://www.atag.org [Accessed 20 November 2003].

Bell, M. & Pavitt, K. 1993. Technological accumulation and industrial growth: Contrasts between developed and developing countries'. *Industrial and Corporate Change,* Vol. 2 (no 2), 157-202.

Bennett, D. & Vaidya, K. 2001. Meeting technology needs of enterprises for national competitiveness. *Global Forum on Management of Technology: Focus on the Arab Region.* Organised by UNIDO, 29-30 May 2001, Vienna, Austria.

Blados, WR., Cotter, GA., and Ryan, RP. 2001. International aerospace information network: International cooperation and resource sharing. *Information Review*, 25(1), 54-61.

Bonaccorsi, A. & Giuri, P. 2001. *Learning, technological competition and network structure in the aero-engine industry*. LEM Papers series. Available from: http://netec.mcc.ac.uk/WoPEc/data/Papers//ssalemwps2000-01.html [Accessed 8 March 2003].

Brand, R. 2004. SAA cancels Airbus orders after loss of R8.7 bn. *Business Report*, 30 August 2004.

British Aerospace: Annual report and accounts. 1998.

Brusoni, S. & Prencipe, A. 2001. Unpacking the black box of modularity: Technology, products and organisation. *Industrial and Corporate Change*, 10(1), 179-205.

BuaNews. 2004. *New facility for aircraft engines*, South Africa, November 29, 2004.

Burgelman, RA., Maidique, MA. & Wheelwright, EC. 1996. *Strategic management of technology and innovation.* 2^{nd} ed. New York: McGraw-Hill/Irwin.

Buys, AJ. 2001. Technological decolonisation of South Africa by backwards integration of the national system of innovation. *First Conference on Managing Technological Innovation for Global Competitiveness.* 30 May–1 June 2001, Berg-en-Dal, Kruger National Park, SA. Available from South African Association for the Management of Technology and Innovation.

Buys, AJ. 2002. Industrial development in South Africa by backwards integration of the national system of innovation. *11th International Conference on Management of Technology (IAMOT 2002)*. 10–14 March 2002, Miami, Florida, USA.

Buys, AJ. 2004. Industrial innovation in a technology colony. *IEEE Africon 2004 Conference*, 15–17 September 2004, Gaborone, Botswana.

Buys, AJ. 2005. *Research guide for post-graduate students*. Issue 15, Department of Engineering and Technology Management: University of Pretoria.

Calliano, R. & Carpano, C. 2000. National systems of technological innovation, FDI, and economic growth: The case of Ireland. *Multinational Business Review,* Detroit, USA. Fall 2000.

Campbell, K. 2003. SA in big aerospace thrust. *Engineering News*. Available from: http://www.engineeringnews.co.za/eng/utilities/search/?show=42566 [Accessed 20 October 2003].

Campos, LMB. 2001. On the competition between Airbus and Boeing. *Air & Space Europe,* 3(1/2), 11-14.

Canta, A. 2003. Focus areas: Economic growth and international competitiveness. National Research Foundation. Available from: http://www.nrf.ac.za/focusareas/growth [Accessed 15 March 2003].

Chiang, J-T. 1999. Defense conversion and systems architecture: Challenges to Taiwan's aircraft industry. *Technology in Society,* Vol. 21, 263-274.

Cho, M. 2003. Restructuring of Korea's defense aerospace industry: Challenges and opportunities? *Bonn: BICC*, paper 28.

Cho, TH. 2000. Challenges in research and development for the Korean aircraft industry. Rand Publications.

Cohen, WM. & Levinthal, DA. 1990. Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, Vol. 35, 128-152.

Corporate performance and military production in South Africa, 2003.

Costa, I. & de Queiroz, SRR. 2001. FDI and technological capabilities in the Brazilian industry. *Nelson and Winter Conference*. June 2001 Druid.

Crawford, NW. 2000. U.S. Aerospace technology and implications for Korea. Rand Publications.

CSIR. 2003. A strategy for a sustainable, economical and growing aerospace industry (ASSEGAI): CSIR draft document for discussion with contributors, July 2003.

Dahlman, C. & Nelson, R. 1995. Social absorption capability, national innovation systems and economic development. In: Perkins, DH. & Koo, BH. eds. *Social capability and long-term growth*, Basingstoke: Macmillan Press.

DASEF Delaware AeroSpace Education Foundation, **2002**.

Da Silveira, GJC. 2002. Improvement trajectories in operations and technology management: Concept, process and content issues. *Technology Analysis & Strategic Management,* 14(2), 227-240.

Datamonitor. 2005*. Global aerospace & defense*. Industry profile, August 2005.

Davies, A. & Brady, T. 1998. Policies for a complex product system. *Futures,* 30(4), 293-304.

Davies, A. & Brady, T. 2000, Organisational capabilities and learning in complex product systems: Towards repeatable solutions. *Research Policy,* Vol.29, 931-953.

Davies, A., Tang, P., Brady, T., Hobday, M., Rush, H., & Gann, D. 2001. Integrated solutions:The new economy between manufacturing and services.

De Bruijn, EJ. & Steenhuis, H-J. 2004. Freedom of choice in technology strategy? An analysis of technology strategy in the large civil aircraft Industry. *Technology Analysis & Strategic Management,* 16(3), 381-393.

Denel SA. 2002. Input for Aviation Africa.

DTI (SA) Department of Trade and Industry. **2001**. Aerospace & defence industry profile. 2001.

DTI (SA) Department of Trade and Industry. **2003**. A strategy for an aerospace industry in South Africa: A discussion document for the Department of Trade and Industry, Department of Defence and the Department of Public Enterprises.

DTI (SA) Department of Trade and Industry. **2004a. the dti** Statistics in brief.

DTI (SA) Department of Trade and Industry. **2004b**. The technology development trends report.

DTI (SA) Department of Trade and Industry. **2005**. Positioning the South African aerospace industry as a priority sector. Presentation, July 2005.

DTI (SA) Department of Trade and Industry. **2007**. Draft technology policy framework for SA.

DTI (UK) Department of Trade and Industry. **2003**. An independent report by the Aerospace Innovation and Growth Team (AeIGT). *The Future of the UK Aerospace Industry - June 2003.*

Dosi, G., Pavitt, K., & Soete, L. 1990. *The economics of technical change and international trade*. New York: New York University Press.

Engineering News. **2003**. *Company highlights the importance of managing vibration in aircraft*. Available from: http://www.engineeringnews.co.za/eng/utilities/search/?show=41927 [Accessed 17 October 2003].

Engineering News. **2004**. *SA moves to create aerospace support programme*. Available from: http://www.engineeringnews.co.za/eng/utilities/search [Accessed 22 September 2004].

Eriksson, S. (1995). Global shift in the aircraft industry: A study of airframe manufacturing with special reference to the Asian NIEs.

Eriksson, S. (2000). Technology spill-over from the aircraft industry: the case of Volvo Aero. Technovation 20, pp. 653-664

Eriksson, S. (2003a). Indonesia's aircraft industry: technology and management impediments. The International Journal of Technology Transfer and Commercialisation (IJTTC), Inderscience Publishers, Vol. 2, No. 2

Eriksson, S. (2003b). Technology Policies in East and Southeast Asia: Creating a new global structure in the aircraft industry. ASIAN GEOGRAPHER, Volume 22, pp. 169-185

Eriksson, S. (2006). Cluster creation and innovation within an emerging Taiwanese "high tech" sector. The International Journal of Technology Transfer and Commercialisation (IJTTC), Inderscience Publishers, Vol. 5, No. 3, pp. 208-236

EUROPA. 2005. *Enterprise & industry, aerospace industry*

European Commission, 1996. EU White paper on innovation, 1996.

FAC Farnborough Aerospace Consortium. **2005**. Centre of excellence for aerospace and defence in the South East, UK. Presentation to DTI (SA) delegation. April 2005.

Flight International, 13th August **2002**.
Focus Group progress report. 2003. National innovation systems in catching-up economies.

Freeman, SP. 2002. Offsets and the development of the Brazilian arms industry. *International Conference on Offsets and International Development.* 25-27 September 2002, University of Cape Town, South Africa.

Gilbert, M. & Cordey-Hayes, M. 1996. Understanding the process of knowledge transfer to achieve successful technological innovation. *Technovation,* Vol. 16, 301-312.

Goel, RK. & Rich, D.P. 1997. On the adoption of new technologies. *Applied Economics*, Vol. 29, 513-518.

Goldstein, A. 2001. From national champion to global player: Explaining the success of EMBRAER. Working Paper Series CBS-17-2001, OECD Development Centre, Paris.

Gulati, R. 1998. Alliances and networks. *Strategic Management Journal*, Vol. 19, 293-317.

Hayward, K. 1994. *The world aerospace industry.* London.

Henderson, RM. & Clark, KB. 1990. Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. *Administrative Science Quarterly,* Vol. 35, 9-30.

Hobday, M. 1995. *Innovation in East Asia: The challenge to Japan.* England: Edward Edgar.

Hobday, M. 1998. Product complexity, innovation and industrial organisation. CoPS working paper.

Holmes, BJ. 1996. *Reinventing government–industry R&D collaboration.*

House of Commons Trade and Industry Committee. 2005. *The UK aerospace industry: Fifteenth report of session 2004-05*, March 22, 2005. London: The Stationery Office Limited.

Hwang, C. 2000. The Aircraft industry in a latecomer economy: The case of South Korea. *Science Policy Research Unit,* University of Sussex, Brighton, UK.

IADF International Aircraft Development Fund information. **2004**. Available from: http://www.iadf.or.jp/8361/h/IADF-HP/iadf-hp_katudou--E.htm [Accessed 11 March 2004].

Iles, P. & Yolles, M. 2002. Across the great divide: HRD, technology translation, and knowledge migration in bridging the knowledge gap between SMEs and universities. *Human Resource Development International*, 5(1), 23-53.

Info reporter. 2004a. *Regional maintenance hub South Africa*. Available from: http://www.nrf.ac.za/focusareas/growth [Accessed 16 April 2004].

Info reporter. **2004b**. *Two Malaysian contracts for Grintek, South Africa.* 16 April 2004.

Irwin, DA., & Pavcnik, N. 2001. Airbus versus Boeing revisited: International competition in the aircraft market. National Bureau of Economic Research, NBER Working Paper no 8648. Available from: http://netec.mcc.ac.uk/WoPEc/data/Papers//nbrnberwo8648.html [Accessed 8 March 2003].

Jackson, I. 2004. The future of the defence firm: The case of the UK aerospace industry. *Defence and Peace Economics*, Vol. 15(6), 519-534.

JADC. 2004. Outline of Japan Aircraft Development Corporation. Available from: http://www.jadc.or.jp/outline_jadc_e.htm [Accessed 3 March 2004].

Kandebo, SW. 2002. Technology development key to GE's future engine strategy. *Aviation Week & Space Technology,* 157(5), 29 July 2002.

Kim, L. 1997. *From imitation to innovation: The dynamics of Korea's technological learning.* Cambridge, MA: Harvard Business School Press.

Kim, L. & Seong, SM., 1997. Science and technology: Public policy and private strategy.

Kim, L. 1998a. Crisis construction and organizational learning: Capability building in catching-up at Hyundai Motor. *Organization Science*, Vol. 9, 506-521.

Kim, L. 1998b. Technology policies and strategies for developing countries: Lessons from the Korean experience. *Technology Analysis & Strategic Management,* 10(3).

Kim, L. 1980. Stages of development of industrial technology in a developing country: A model. *Research Policy*, Vol.9, 254-277.

Kleiner, MM., Leonard, JS., & Pilarski, AM., 1999. Do industrial relations affect plant performance?: The case of civil aircraft manufacturing. National Bureau of Economic Research, NBER Working Paper no 7414. Available from: http://netec.mcc.ac.uk/WoPEc/data/Papers//nbrnberwo7414.html [Accessed 8 March 2003].

Klesius, M. 2004. The airplane has come a long way in its first hundred years. *National Geographic Magazine*, pp1-2, 23 October 2004.

Lall, S. 1990. Building industrial competitiveness in developing countries. OECD.

Lall, S. 2000. The technological structure and performance of developing country manufactured exports, 1985–1998. QEH Working Paper Series, WP 44, Oxford.

Lall, S. 2001. Competitiveness indices and developing countries: An economic evaluation of the global competitiveness report. *World Development,* 29(9), 1501-1525.

Lall, S. 2003. Reinventing industrial strategy: The role of government policy in building industrial competitiveness. The Intergovernmental Group on Monetary Affairs and Development (G-24).

Leedy, PD. & Ormrod, JE. 2005. *Practical research: Planning and design.* 8th ed. New Jersey: Merrill Prentice Hall.

Leonard-Barton, D. 1995. *Wellsprings of knowledge: Building and sustaining the sources of innovation.* Boston, Massachusetts: Harvard Business School Press.

Lowe, P. 1995. *The Management of technology: Perception and opportunities.* London: Chapman & Hall.

Mathews, JA. 2001. National systems of economic learning: The case of technology diffusion management in East Asia. *International Journal of Technology Management,* 22(5/6), 455-479.

Mathews, JA. 2004. World industrial development in the 21st Century: Catch-up strategies and the latecomer effect. MGSM Working Papers in Management.

Mayindi, DH. & Kachienga, M.O. 2008. Analysis of national technological competitiveness: South Africa's civil aircraft industry. *PICMET 2008 Proceedings*. 27-31 July, Cape Town, South Africa © 2008 PICMET, 99-107.

McGuire, S. (1999). Sectoral innovation patterns and the rise of new competitors: The case of civil aerospace in Asia, *Industry and Innovation*, No 2, pp. 153-170

Mowery, DC. & Rosenberg, N. 1982. Technical change in the civil aircraft industry, 1925–1975, pp163–177. In: Rosenberg, N. 1982. *Inside the black box: Technology and economics,* Cambridge: Cambridge University Press.

Mowery, DC. & Rosenberg, N. 1984. Government policy, technical change, and industrial structure: The U.S. and Japanese civil aircraft industries, 1945–1983. *US/Japan High Technology Research Project Conference*. 21–23 March 1984, Stanford University, US.

Napier, DH. 2005. 2004 Year-end review and 2005 forecast: An analysis. Aerospace Industries Association (AIA).

National Science Board. 2003. *Science and engineering indicators – 2002*. National Science Foundation, Arlington, VA. Available from: http://www.nsf.gov/sbe/srs/seind02/start.htm [Accessed 13 March 2003].

Neven, D. & Seabright, P. 1995. European industrial policy: The Airbus case. *Economic Policy*, 0(21), 314-344.

Niosi, J. & Zhegu, M. (2005). Aerospace clusters: Local or global knowledge spillovers? Industry and Innovation, Vol. 12, Issue 1, p. 5-29

NIPP The National Industrial Participation Programme in review. **2002**. Leveraging growth in the South African economy. DTI Industrial Participation Secretariat.

NRC The National Research Council Report, **1994**. U.S. needs new approach towards aircraft cooperation with Japan. Available from:
http://www4.nationalacademies.org/news.nsf/isbn/0309050456?OpenDocument
[Accessed 11 March 2004].

OECD. 1996. Review of national science and technology policy: Republic of Korea, OECD, Paris.

Oerlemans, LAG., Pretorius, MW., Buys, A. & Rooks, G. 2004. *Industrial innovation in South Africa, 1998–2000.* University of Pretoria, Pretoria.

Oerlemans, LAG., Pretorius, MW., Buys, A. & Rooks, G. 2005. Industrial innovation in South Africa: A comparative study. *South African Journal of Science,* March/April 2005, Vol. 101, 149-150.

Okamoto, Y. & Sjöholm, F. 2001. Technology development in Indonesia: Chapter 14.

Orsenigo, L., Pammolli, F., & Riccaboni, M. 2001. Technological change and network dynamics: Lessons from the pharmaceutical industry. *Research Policy,* Vol. 30, 485-508.

Paras Report. 1998. *The role of government to promote technology in industry.* The Department of Trade and Industry, South Africa.

Parker, R. 2004. Foundations of technology development, innovation and competitiveness in the globalised knowledge economy. *Prometheus,* 22(3), September 2004.

Patel, P. & Pavitt, K. 1993. National systems of innovation: Why they are important, and how they might be defined, compared and assessed. Science Policy Research Unit, University of Sussex, Falmer, Brighton, UK.

Pavitt, K. 1999. *Technology, management and systems of innovation.* Massachusetts: Edward Elgar.

Pelc, KI. 2002. Knowledge mapping: The consolidation of the technology management discipline. *Knowledge, Technology, & Policy,* 15(3), 36-44, Fall 2002.

Porter, ME. 1990. *The competitive advantage of nations.* Macmillan Press Ltd.

Prencipe, A. 1997. Technological competencies and product's evolutionary dynamics: A case study from the aero-engine industry. *Research Policy*, Vol. 25, 1261-1276.
Prencipe, A. 2000. Breadth and depth of technological capabilities in CoPS: The case of aircraft engine control system. *Research Policy*, Vol. 29, 895-911.
Research, NBER Working Paper no 8648.

Prencipe, A. 2001. Exploiting and nurturing in-house technological capabilities: lessons from the aerospace industry. *International Journal of Innovation Management,* 5(3), 299-321.

Reuters News. 2004. *Boeing sees lucrative market in Africa*. 6 March **2004.**

SAA Technical: Presentation to SA aerospace industry players. 2003.

Sajid, M. 1995. Strategic management of technology. *Hydrocarbon Processing*, 74(6), 116-B, June 1995.

Saunders, M., Lewis, P., & Thornhill, A. 2003. *Research methods for business students.* 3rd ed. Boston: Prentice Hall Financial Times.

Science and Technology. 2003. High Flyers: Brazil: Sharing innovative experiences. Vol. 1, 8-11.

September 11 effects on aerospace industry: Terrorism attack on World Trade Center. Available from: http://www.eds.com/about_eds/homepage/home_page_911_heath_assess.shtml [Accessed 24 March 2003].

Smrcka, K. 2003. Aircraft maintenance: preparation in 3D. Engineering News. Available from: http://www.engineeringnews.co.za/eng/utilities/search/?show=41742 [Accessed 23 October 2003].

South African Embassy in Sweden: SA overview on agricultural economy – **2003**. Agricultural Economy. Available from: http://www.southafricanemb.se/agriae.htm [Accessed 23 March 2003]

Statistics South Africa, 2003: Statistical release p0441. Gross Domestic Product. Available from: http://www.statssa.gov.za/Products/Releases/GDP/GDPCurrent.htm [Accessed 24 March 2003]

Steenhuis, H-J. & de Bruijn, EJ. 2001. Developing countries and the aircraft industry: Match or mismatch? *Technology in Society,* Vol. 23, 551-562

Teece, D. & Pisano, G. 1994. The dynamic capabilities of firms: An introduction. *Industrial and Corporate Change*, 3(3), 537-555.

Teece, DJ. 1977. Technology transfer by multinational firms: The resource cost of transferring technological know-how. *The Economic Journal*, Vol. 87, 242-261.

The Israel aircraft industries: Past, present and future. Quality Translations Job 31401.

The US report on aerospace, 2003.

Thomas, R. 2002. The Aero club of South Africa. Available from: http://www.flying.org.za/news28.htm [Accessed 7 September 2004].

Tidd, J., Bessant, J., & Pavitt, K. 2001. *Managing innovation: Integrating technological, market and organizational change.* 2nd ed. Chichester: Wiley.

TISA Trade and Investment SA, **2004**. South African aerospace industry analysis – 2004.

TISA Trade and Investment SA, **2002**. Trade statistics. Available from: http://www.isa.org.za/transport/aircraft.asp [Accessed 14 August 2002].

Trade & Industry Monitor, 2004. *Newsletter of Trade and Industrial Policy Strategies* (TIPS), Vol 30, June 2004.

US Technology Position and Trend Report: Transportation category. **1995**. Washington DC: US Government Printing Office.

Van den Bosch, F., Volberda, H., & de Boer, M. 1999. Co-evolution of firm absorptive capacity and knowledge environment: Organizational forms and combinative capabilities. *Organization Science*, 10(5), 551-568.

Werksmans Attorneys. **2003**. Business guide to South Africa: The South African economy. Available from: http://www.mbendi.co.za/werksmns/sabus01.htm [Accessed 26 March 2003].

Wise, R. & Baumgartner, P. 1999. Go downstream: The new profit imperative in manufacturing. *Harvard Business Review,* pp133-141 September-October 1999.

Yin, RK. 1993. *Applications of case study research*. Applied Social Research Methods Series, Vol. 34. Thousand Oaks, CA. SAGE Publications.

Yin, RK. 1994. *Case study research design and methodology*. In Applied Social Research Methods Series, 2nd ed, Vol. 5. Thousand Oaks, CA. SAGE Publications.

Yin, RK. 2003. *Case study research: Design and methods*. 3rd ed. Applied Social Research Methods Series, Vol. 5. Thousand Oaks, CA. SAGE Publications.

Bibliography

Berenson, ML., Levine, DM., & Krehbiel, TC. 2002. *Basic business statistics: Concepts and applications. Student's solution manual*. 8th ed. Upper Saddle River, New Jersey: Prentice Hall.

Chen, J., Fujimoto, T., & Lee, C. 2000. The advance to car production and globalization of the Chinese munitions enterprises. Working paper for MIT IMVP Draft 30 June 2000.

Crawley, MJ. 2005. S*tatistics: An introduction using R.* Chichester, West Sussex, England: Wiley.

Dancey, CP. & Reidy, J. 2002. *Statistics without maths for psychology: Using SPSS for Windows*. 2nd ed. Harlow: Pearson Education.

Dosi, G. 1988. Sources, procedures, and microeconomic effects of innovation. *Journal of Economic Literature*, Vol. 26, 1120-1171.

Enis, BM., Cox, KK., & Mokwa, M.P. 1995. *Marketing classics: A selection of influential articles*. New Jersey: Prentice Hall.

Kim, J. 1999. Technology transfer, adoption and catching up: Innovation issues on South Korea. *Technology, Region and Policy*.

Mani, S. 2001. Role of government in promoting innovation: An international comparative study, Netherlands.

Mathers, N., Fox, N., & Hunn, A. 2002. *Trent focus for research and development in primary health care: Surveys and questionnaires*.

Mowery, DC. & Oxley, JE., 1995. Inward technology transfer and competitiveness: The role of national innovation systems. *Cambridge Journal of Economics*, Vol. 19, 67-93.

National science and technology policy for Guyana, 2005. Available from: www.iastguyana.org/st/stpolicy [Accessed 4 August 2005].

Penrose, E. 1995. *The theory of the growth of the firm*. Oxford, England: Oxford University Press.

Teece, DJ., Pisano, G., & Shuen, A. 1997. Dynamic capabilities and strategic management. *Strategic Management Journal*, Vol. 18, 509-533.

Textier, F. 1999. The take of the Korean aerospace industry, from license production to aircraft development. *3rd International Conference on Technology Policy and Innovation*.
Available from: http://www.utexas.edu/depts/ic2/austin99/abstracts/8_tex.htm [Accessed 19 May 2002]

Van der Westhuizen, LJ. & Le Roux, JH., 1997. *Armscor: The leading edge*. Institute for Contemporary History, UOFS, Bloemfontein.

Appendix I: Capabilities of South African aircraft firms

COMPANY		CAPABILITIES: Design & Produce Complete Systems	Design & Produce Major Sub-systems	Design & Produce Minor Sub-systems	Major Upgrades of Systems	Minor Upgrades of Systems	Systems Engineering and Integration	Provide Engineering Support Services	Provide Other Support Services	Manufacture of Major Sub-systems	Manufacture of Minor Sub-systems	Manufacture of Components	Manufacture of Parts	Repair and Overhaul Major Systems	Repair and Overhaul Minor Systems
DENEL	Denel Aviation	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Denel Kentron	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Turbomeca Africa					X	X			X	X	X	X	X	X
	Overberg Test Facility							X	X						X
	LIW			X			X				X	X	X		
	Eloptro			X		X	X	X			X	X	X	X	X
GRINTEK	Avitronics		X	X			X			X	X	X	X		
	Grintek Communications Systems		X	X			X			X	X	X	X		
	Ewation		X	X			X			X	X	X	X		
	Logtronics			X		X	X	X	X			X		X	X
REUNERT	Reunert Radar Systems		X	X			X			X	X	X	X		
	Reunert Defence Industries		X	X			X			X	X	X	X		
	Reunert Defence Logistics					X	X	X	X					X	X
CSIR	Defencetek			X			X	X	X				X		
	Manufacturing and Materials			X				X	X		X	X	X		X
ARMSCOR	Gennan							X	X						
	Gerotek							X	X						
African Defence Systems			X	X	X	X	X			X	X	X		X	X
Advanced Technologies and Engineering		X	X	X	X	X	X			X	X	X	X		
Alvis OMC		X	X	X	X	X	X				X			X	

	SAA Technical						X	X	X	X				X	X	X
	Aircraft Monitoting Systems			X								X	X	X		
	Telumat			X	X		X	X			X	X	X	X	X	X
	Aerosud				X	X	X	X	X		X	X	X	X		
	Ansys Integrated Systems				X		X	X				X	X	X		
	Epsilon Engineering				X		X	X	X			X	X	X		
	IST Dynamics			X	X			X			X	X	X	X		
	ISIS Information Systems			X	X	X	X	X								
	Aztec Components				X							X	X	X		X
	Contactserve											X	X			X
	Cybersim						X	X	X	X						
	Geopgraphic Information Sustems				X				X	X			X			
	Isiziba						X	X								
	Lachabile Quality Systems								X	X		X	X	X		
	M-Tek				X			X	X			X	X			
	Parachute Industries SA				X							X	X	X	X	X
	Paramount Group						X	X	X	X						
	Sattelite Application Centre									X						
	Volt Ampere				X			X				X	X	X		X
	Xcel Engineering			X	X	X	X	X								
	Sinjana Engineering													X		
	Ubombo Cliff's Way											X	X	X		
	Advanced Worx				X			X	X			X	X	X		X
	Aeromac				X		X	X	X	X		X	X	X		
	Isomac				X			X	X	X						
	Incomar				X		X	X	X	X						
	MMS				X		X	X	X			X	X	X		
	Parsec				X							X	X			
	Kreon				X			X				X				

Appendix II: Research questionnaire for South African experts

AREA OF STUDY

INDUSTRIAL CAPABILITY AND NATIONAL TECHNOLOGICAL COMPETITIVENESS: THE CASE OF SOUTH AFRICA'S CIVIL AIRCRAFT INDUSTRY

RESEARCH CONDUCTED BY:

Ms Daphney H Mhlanga

Director: Innovation & Technology

Department of Trade & Industry

Tel: +2712 - 394 1272

Fax: +2712 - 394 2272

Cell: +2782 806 7435

Email: Daphney@thedti.gov.za

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RESEARCH QUESTIONNAIRE

Confidentiality (The information provided by the interviewee remains confidential and shall not be disclosed in any way to any other persons/firms)

PERSONAL BACKGROUND

(*Optional, for follow up purposes on responses*)

NAME OF INTERVIEWEE:

ORGANIZATION:

JOB TITLE:

TELEPHONE NO:

FAX NO:

EMAIL:

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1. Please indicate your field of expertise below *(Mark on the relevant box)*

Engineering	1	
Management Sciences	2	
Natural Sciences	3	
Other (Please state …. ……………………………….)	4	

2. Please indicate your field of work within the organisation *(Mark on the relevant box)*

Technical Production	1	
Manufacturing	2	
Sales & Marketing	3	
Other (Please state ……………………………………)	4	

3. Please indicate your work experience within the aircraft industry or within aircraft-related policy development *(Mark on the relevant box)*

Less than 6 months	1	
Between 6 and 12 months	2	
Between 1 and 2 years	3	
Between 2 and 3 years	4	
Between 3 and 5 years	5	
More than 5 years	6	

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RESEARCH QUESTIONS (PART I)

Please choose your answer by ticking on the relevant box.

1. Does your institution/organization/firm have or previously had any joint ventures with other international aircraft institutions? *(Please tick where appropriate)*

   Yes ☐ No ☐

2. Has your institution/organization/firm been involved in aircraft projects for an international contractor? *(Please tick where appropriate)*

   Yes ☐ No ☐

   If yes, please state the percentage contribution of such contract to the turnover of your institution/organization/firm.

   ____

3. Has your institution/organization/firm been involved in any form of collaboration with other local institutions? *(Please tick where appropriate)*

   Yes ☐ No ☐

4. Has your institution/organization/firm been involved in any form of technological innovation or improvement within the aircraft industry? *(Please tick where appropriate)*

   Yes ☐ No ☐

5. Did your institution/organization/firm acquire some business contracts through Government assistance in the past, where without their involvement it might have been difficult if not impossible to attain such business? *(Please tick where appropriate)*

Yes ☐ No ☐

6. Has your institution/organization/firm been involved in any form of aircraft-related Technology Transfer with global institutions? *(Please tick where appropriate)*

Yes ☐ No ☐

If yes, please state the country where technology is transferred from and the area of application of such technology.

____

7. In what area of the Aircraft industry structure is your institution/organization/firm making a major contribution? (*More than one answer could be chosen)*

1st tier (System integration)	1	
2nd tier (Major sub-system supply)	2	
3rd tier (Minor sub-system supply)	3	
4th tier (Component supply)	4	
5th tier (Parts supply)	5	

Other (please state) ……………………………………

8. Where do you think South African firms should be playing more important role within the Aircraft industry structure? (*More than one answer could be chosen for this question).*

1st tier (System integration)	1	
2nd tier (Major sub-system supply)	2	
3rd tier (Minor sub-system supply)	3	
4th tier (Component supply)	4	
5th tier (Parts supply)	5	

Other (please state) …………………………

RESEARCH QUESTIONS (PART II)

9. The following are assumed to be the current major gaps that affect the technology capability-building process of the South African civil aircraft industry.
(Please rate on a scale of 1-5, where 1=Strongly disagree and 5=Strongly agree)

Insufficient in-house technological capability	
Under-developed National Systems of Innovation	
Lack of firm collaboration	
Poorly developed aircraft Infrastructure	
Insufficient skilled resources	
Under-developed technological capabilities	
Lack of appropriate technologies	
Insufficient R&D investment	

9.cont. The following are assumed to be the current major gaps that affect the technology capability-building process of the South African civil aircraft industry.

(Please rate on a scale of 1-5, where 1=Strongly disagree and 5=Strongly agree)

Insufficient knowledge	
Insufficient skills development programme	
Insufficient strategic alliances with global firms	
Lack of skills transfer/knowledge transfer programme	
Poor levels of innovation	
Poor external environment	
Poor governing structures to oversee the industry	

10. Where do you think South African private sector firms within the aircraft industry should be playing a bigger role in building national technological competitiveness within the civil industry?
(Please rank them on a scale of 1-5, with 1=highest priority and 5=least priority)

Research and technology development	
Business development	
Skills development	
Infrastructure development	
Support higher education & research institutions	
Other (please state)	

11. What form of interventions is your firm doing in relation to Human Resource development to enhance in-house technological capabilities? *(More than one answer could be chosen for this question. Also indicate if you have been involved or not in such interventions)*

		Already involved	Envisage involvement
In-house skills development programme			
Inter-firm skills exchange program (national)			
Inter-firm skills exchange program (international)			
Knowledge transfer during technology transfer			
Inter-firm research collaboration (national)			
Inter-firm research collaboration (international)			
Other ……………………………………………… ……………………………………………… ………………………………………………			

12. Which countries do you think South African aircraft firms should place their emphasis in terms of developing their market relations as part of enhancing national technological competitiveness and technology capability-building? *(Please rank them on a scale of 1-5, with 1=highest priority, 5=least priority).*

Africa	
Europe (excluding United Kingdom)	
United Kingdom	
United States	
Asia	
Latin America	
Other (please state)	

13. To what extent do you agree or disagree with the following statements?

Statements	**Strongly disagree** *1*	**Disagree** *2*	**Neither agree nor disagree** *3*	**Agree** *4*	**Strongly agree** *5*
Inter-firm collaboration can enhance technology & business capability development within SA aircraft firms through skills transfer, joined investment and learning from each other.					
Government interventions are necessary for business acquisition and improved market access by SA aircraft firms.					
R&D programme, in line with applied technology development could improve the technology base of the SA aircraft industry.					
Technology transfer would be key towards development of technology capabilities, improved innovation and competitiveness of SA aircraft industry.					
SA firms should form joint ventures with global firms to have improved technology and business development capabilities, as well as better market accessibility.					
Collaborative efforts from academia, research institutions, firms and government are essential for enhancing innovation and technology development within the aircraft industry.					
SA government should collaborate with governments from other countries on major projects so as to facilitate development and market access for SA aircraft firms.					

14. For technology development to improve within the civil aircraft industry, the following should be established:

(Please rank them on a scale of 1-5, with 1=highest priority, 5=least priority).

Research and technology development programme	1	
Firm collaboration (national)	2	
Firm collaboration (international)	3	
Aircraft-related research institutes	4	
Government support/involvement	5	
Market acquisition assistance	6	
Research collaboration (government, research institutes, academia, firms)	7	
Technology transfer	8	
Skills development	9	

15. The following are assumed to be the factors hampering business acquisition and technology capability-building for South African civil aircraft firms:
(Please rate on a scale of 1-5, where 1=Strongly disagree and 5=Strongly agree)

Highly regulated environment (global & local)	
Insufficient financial resources	
Inadequate skilled resources	
Lack of appropriate technologies	
Projects too costly	
Poor strategic alliances or networks	
Not meeting customers' demands	
Insufficient government support	
Insufficient experience in global supply	
Negative perception by global customers on quality of products	

16. What are the existing competencies, capabilities, skills and technologies available within the South African aircraft industry?
(More than one answer could be chosen for this question.)

Aircraft maintenance skills	1	
Aircraft conversions and modification skills	2	
Manufacture of components and sub-system levels	3	
Manufacture of composites, rotor wing propeller blades, gear-boxes	4	
Specialists in avionics	5	
Capabilities for interior designs	6	
Design and manufacturing skills for helicopters	7	
Manufacture of military aircraft	8	
Other (please state) ……………………………………………… ……………………………………………… ……………………………………………… ………………………………………………	9	

17. What would be the ideal key competencies, capabilities, skills and technologies needed for technology development within the South African civil aircraft industry?

(Please rank them on a scale of 1-5, with 1=highest priority, 5=least priority).

Aircraft maintenance skills	1	
Aircraft conversions and modification skills	2	
Manufacture of components and sub-system levels	3	
Manufacture of composites, rotor wing propeller blades, gear-boxes	4	
Design and manufacturing of complete engines	5	
Specialists in avionics	6	
Capabilities for interior designs	7	
Design and manufacturing skills for helicopters	8	
Design and manufacturing skills for passenger aircraft	9	
Full assembling skills for passenger aircraft	10	
Civil-military technology linkages	11	
Other (please state) …………………………………………… ……………………………………………	12	

18. How would you rate the current level of innovation in South Africa as compared to that of other successful organizations/institutions/firms in developing countries (South Korea, Japan, Brazil, etc) within the civil aircraft industry?

Extremely poor	1	
Poor	2	
Moderate	3	
Strong	4	
Very strong	5	

Please state the percentage level of investment on innovation (R&D) by your institution towards technological development within the civil aircraft industry _______%

Appendix III: Research questionnaire for international experts

AREA OF STUDY

INDUSTRIAL CAPABILITY AND NATIONAL TECHNOLOGICAL COMPETITIVENESS: THE CASE OF SOUTH AFRICA'S CIVIL AIRCRAFT INDUSTRY

CONTACT PERSON:

Ms Daphney H Mhlanga

Director: Innovation & Technology

Dept of Trade & Industry (South Africa)

Tel: +2712 - 394 1272

Fax: +2712 - 394 2272

Cell: +2782 806 7435

Email: Daphney@thedti.gov.za

RESEARCH QUESTIONNAIRE

Confidentiality (The information provided by the interviewee remains confidential and shall not be disclosed in any way to any other persons/firms)

PERSONAL BACKGROUND
(***Optional***, *for follow up purposes on responses*)

NAME OF INTERVIEWEE:

ORGANIZATION:

JOB TITLE:

TELEPHONE NO:

FAX NO:

EMAIL:

1. Please indicate your field of expertise below *(Mark on the relevant box)*

Engineering	1	
Management Sciences	2	
Natural Sciences	3	
Other (Please state …. ……………………………….)	4	

2. Please indicate your field of work within the organisation *(Mark on the relevant box)*

Technical Production	1	
Manufacturing	2	
Sales & Marketing	3	
Other (Please state …………………………………….)	4	

3. Please indicate your work experience within the aircraft industry or within aircraft-related policy development *(Mark on the relevant box)*

Less than 6 months	1	
Between 6 and 12 months	2	
Between 1 and 2 years	3	
Between 2 and 3 years	4	
Between 3 and 5 years	5	
More than 5 years	6	

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RESEARCH QUESTIONS (PART I)

(To be completed by firms only)

Please choose your answer by ticking on the relevant box.

1. Does your firm have or had any joint ventures with other aircraft firms/institutions/organisations outside your country? *(Please tick where appropriate)*

Yes ☐ No ☐

2. Has your firm been involved in any form of collaboration with other local firms/institutions/organisations? *(Please tick where appropriate)*

Yes ☐ No ☐

3. Is your firm subcontracting some of its work to firms/institutions/organisations outside your country? *(Please tick where appropriate)*

Yes ☐ No ☐

If yes, please state the percentage contribution of such subcontract(s) to the turnover of your firm/institution/organisation.

____

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4. Has your firm/institution/organisation been involved in aircraft projects for an international contractor? *(Please tick where appropriate)*

Yes ☐ No ☐

If yes, please state the percentage contribution of such contract to the turnover of your firm/institution/organisation.

____

5. Has your firm/institution/organisation been involved in any form of technological innovation or improvement within the aircraft industry? *(Please tick where appropriate)*

Yes ☐ No ☐

6. Did your firm/institution/organisation acquire some business contracts through Government assistance in the past, where without their involvement it might have been difficult if not impossible to attain such business? *(Please tick where appropriate)*

Yes ☐ No ☐

7. Has your firm/institution/organisation been involved in any form of aircraft-related Technology Transfer with global firms/institutions? *(Please tick where appropriate)*

Yes ☐ No ☐

If yes, please state the country where technology is transferred from and the area of application of such technology.

____

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8. In what area of the Aircraft industry structure is your firm/institution making a major contribution? (*More than one answer could be chosen for this question).*

1st tier (System integration)	1	
2nd tier (Major sub-system supply)	2	
3rd tier (Minor sub-system supply)	3	
4th tier (Component supply)	4	
5th tier (Parts supply)	5	

Other (please state) …………………

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RESEARCH QUESTIONS (PART II)

9. It is the role of government to promote national technological competence through interventions such as these: *(Mark on the relevant box to show the extent that you agree or disagree with such possible government interventions)*

Government interventions	**Strongly agree** *5*	**Agree** *4*	**Neither agree nor disagree** *3*	**Disagree** *2*	**Strongly disagree** *1*
Support R&D programmes					
Support infrastructure development					
Stimulate local & international partnerships					
Provide safety and Regulatory environment guidelines					
Oversee establishment of enabling or governing structures					
Support skills development					

10. The following are essential interventions for successful technology capability-building or technological competitiveness within the aircraft industry: *(Mark on the relevant box to show the extent that you agree or disagree with the statements)*

Statements	**Strongly agree** *5*	**Agree** *4*	**Neither agree nor disagree** *3*	**Disagree** *2*	**Strongly disagree** *1*
Inter-firm collaboration can enhance Technology capability development within aircraft firms through skills transfer, joined investment and learning from each other.					
Government interventions are essential for fostering proper structures necessary for building technology competence.					
Large investment on R&D could improve technology competence within firms thereby enhancing technological competitiveness of the national aircraft industry.					
Technology transfer would be key towards development of technology capabilities, improved innovation and competitiveness of aircraft industry.					
Firms should form joint ventures or strategic alliances with global firms to have improved technology development capabilities, as well as better market accessibility.					
Government should collaborate with governments from other countries on major projects so as improve technology competence and global market access for aircraft firms.					

10Cont. The following are essential interventions for successful technology capability-building or technological competitiveness within the aircraft industry: *(Mark on the relevant box to show the extent that you agree or disagree with the statements)*

Statements	**Strongly agree** *5*	**Agree** *4*	**Neither agree nor disagree** *3*	**Disagree** *2*	**Strongly disagree** *1*
Collaborative efforts from academia, research institutions, firms and government are essential for enhancing innovation and technology development within the aircraft industry.					
User-producer kind of linkages should be maintained to foster inter-firm learning and proper understanding of technology development requirements.					
Government should invest in developing future engineers at all levels of training, so as to build a strong technology development skilled nation.					

11. To grow the aircraft industry towards national technological competitiveness, the following should be established:

(More than one answer could be chosen for this question. Also rate them on a scale of 1-5, with 1=highest priority and 5=least priority)

Research and technology development programme	1	
Firm collaboration (national)	2	
Firm collaboration (international)	3	
Aircraft-related research institutes	4	
Government support for technological innovation	5	
Market acquisition assistance	6	
Research collaboration (government, research institutes, academia, firms)	7	
Technology transfer	8	
Skills development programme	9	
Good governance structures	10	
Well-supported higher education & research institutions	11	
Appropriate infrastructure	12	
Other ……………………………………………..	13	

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12. The following are the most well known aspects that impact on the technological competitiveness of firms within the civil aircraft industry. *(Mark on the relevant box to show the extent that you agree or disagree with the following)*

Aspects of impact	**Strongly agree** *5*	**Agree** *4*	**Neither agree nor disagree** *3*	**Disagree** *2*	**Strongly disagree** *1*
Insufficient in-house technological capability					
Under-developed National Systems of Innovation					
Lack of firm collaboration					
Poorly developed aircraft Infrastructure					
Insufficient skilled resources					
Under-developed technological capabilities					
Insufficient R&D investment					
Insufficient skills development programme					
Insufficient strategic alliances with global firms					
Lack of skills transfer/knowledge transfer programme					
Poor levels of innovation					
Poor external environment (e.g govt policy, demand, firm rivalry)					
Poor governing structures to oversee the industry					

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13. What form of interventions should firms do in relation to human resource development to enhance in-house technological capabilities? *(More than one answer could be chosen for this question. Please rate them on a scale of 1-5, with 1=highest priority, 5=least priority. Also indicate if you have been involved or not in such interventions)*

		Have been involved	**Never involved**
In-house skills development programme			
Inter-firm skills exchange program (national)			
Inter-firm skills exchange program (international)			
Knowledge transfer during technology transfer			
Inter-firm research collaboration (national)			
Inter-firm research collaboration (international)			
Other …………………………………………… …………………………………………… ……………………………………………			

14. The following are assumed to be the factors hampering global business acquisition and technology capability-building needed for enhancing technology development within the civil aircraft firms:

(Please rate on a scale of 1-5, where 1=Strongly disagree and 5=Strongly agree)

Highly regulated environment (global & local)	
Insufficient financial resources	
Inadequate skilled resources	
Lack of appropriate technologies	
Projects too costly	
Poor strategic alliances or networks	
Not meeting customers' demands	
Insufficient government support	
Insufficient experience in global supply	
Negative perception by global customers on quality of products	

15. What would be the ideal key competencies, capabilities, skills and technologies needed for civil aircraft technology development by developing economies? *(More than one answer could be chosen for this question. Also rate them on a scale of 1-5, with 1=highest priority and 5=least priority)*

Aircraft maintenance skills	1	
Aircraft conversions and modification skills	2	
Manufacture of components and sub-system levels	3	
Manufacture of composites, rotor wing propeller blades, gear-boxes	4	
Design and manufacturing of complete engines	5	
Specialists in avionics	6	
Capabilities for interior designs	7	
Design and manufacturing skills for helicopters	8	
Design and manufacturing skills for passenger aircraft	9	
Full assembling skills for passenger aircraft	10	
Civil-military technology linkages	11	
Other (please state) …………………………………………… ……………………………………………	12	

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16. How would you rate the current level of innovation in your firm/country as compared to that of successful firms/countries specifically within the civil aircraft industry? *(Please mark on the relevant box)*

Extremely poor	1	
Poor	2	
Moderate	3	
Strong	4	
Very strong	5	

Please state the percentage level of investment on innovation (R&D) by your firm or country towards technological development within the civil aircraft industry _______%

Appendix IV: Discussion on data collected from South African experts

On the **Research questionnaire for South African experts** the responses were categorised as follows:

A. Responses by aircraft *Firms*
B. Responses by *Research institutions*
C. Responses by *Academia* (Higher education institutions), and
D. Responses by *Government* officials.

On **personal background**, three (3) questions were asked as follows:

1. Please indicate your field of expertise.

Engineering

Management Sciences

Natural Sciences

Other (Combination of natural and management sciences)

The dominant field of expertise from respondents was '*engineering'*, where these experts were mostly from *Firms* and *Academia*, with 100% score on that particular category. The analysis would mean that '*engineering'* is a critical field needed for Aerospace technology development and competence. Table (iv)1 and Figure (iv)1 below indicate the distribution of the findings.

Table (iv)1 Field of expertise by respondents (Percentages)

	Firms	**Govt**	**Research**	**Academia**	**Total %**
Engineering	100	0	60	100	**73.33**
Management Sciences	0	50	0	0	**6.67**
Natural Sciences	0	0	40	0	**13.33**
Management/Natural Sciences	0	50	0	0	**6.67**

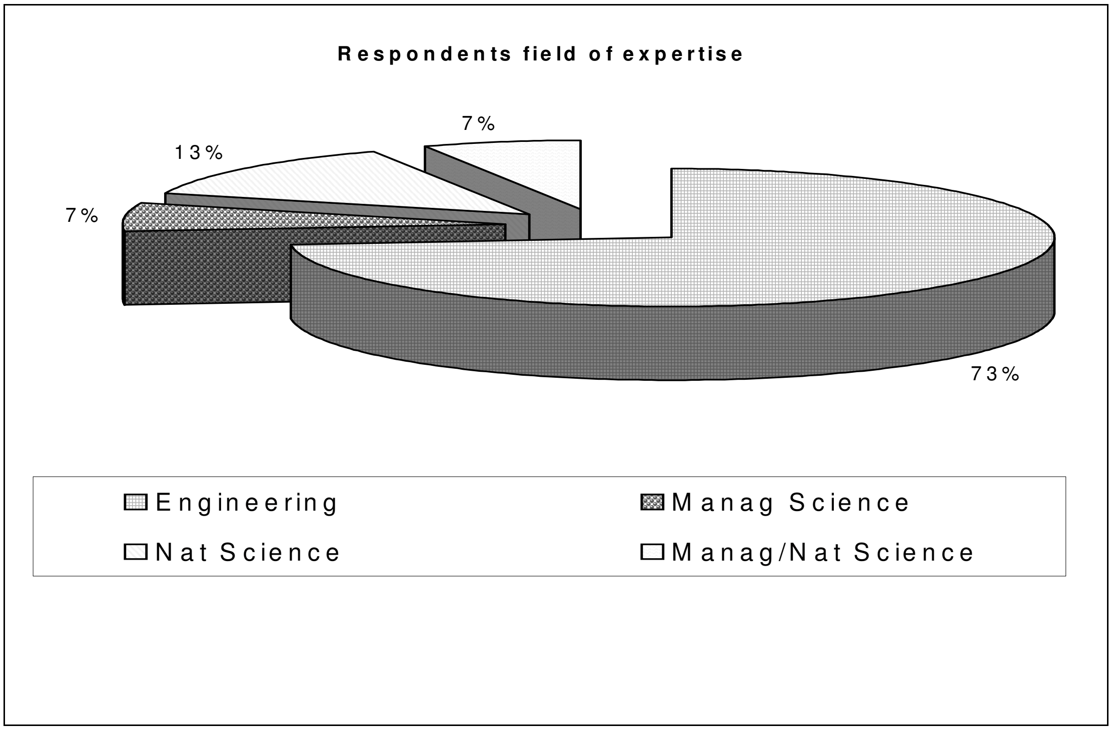

Figure (iv)1 Distribution of respondents' field of expertise

2. Please indicate your field of work within the organisation.

The majority of respondents fell outside the listed fields, where the score was 61% (‘*others*’). The next higher score was on the field of ‘*manufacturing’* (15%). The distribution is graphically illustrated on Figure (iv)2. The analysis would mean that most of the top personnel within the aircraft industry were not directly involved on the listed fields, possibly because they were in top management positions, they would fall under the field named ‘*others’*, which could mean ‘*management*’ field.

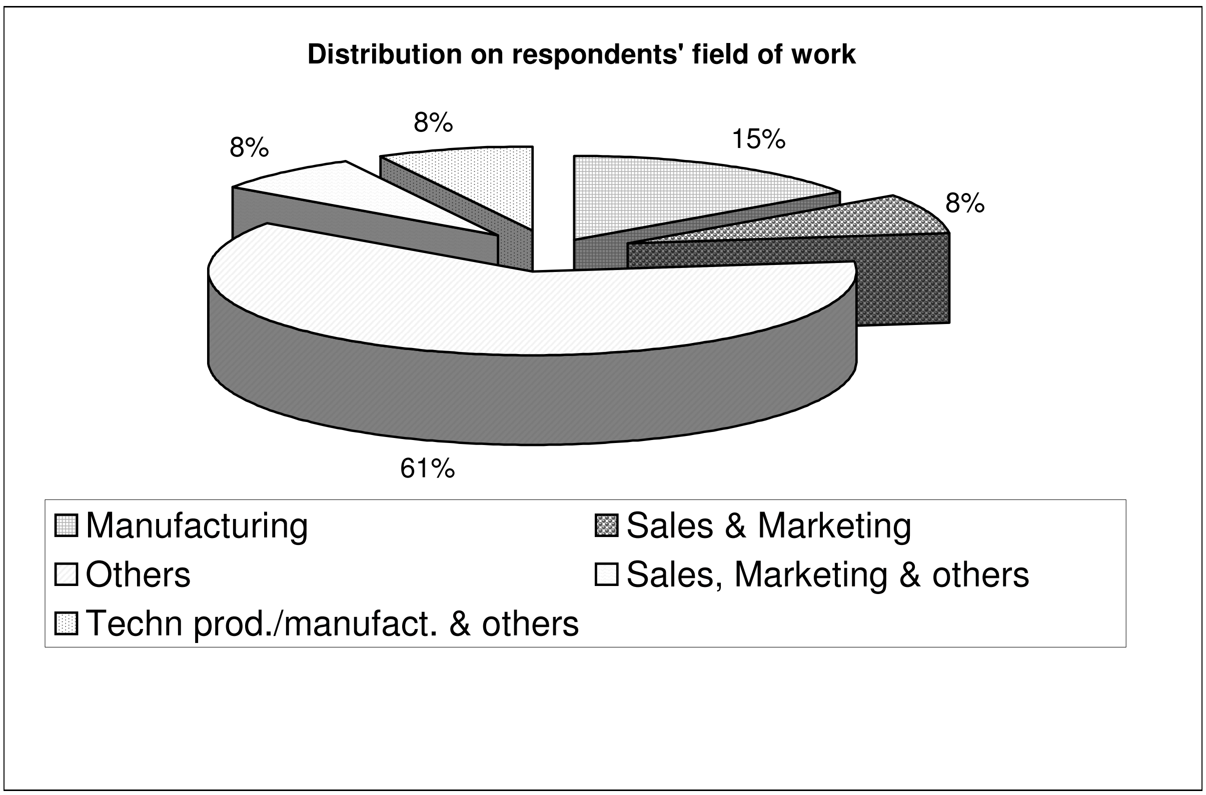

Figure (iv)2 Distribution of respondents’ field of work

3. Please indicate your work experience within the aircraft industry.

About 67% of the respondents have been in the industry for over 5 years. When specifically looking at *Firms* there was 100% indication that they have been working on this industry for over 5 years, which could mean that it is quite critical to have experienced people because of the complexity of such an industry. This is graphically illustrated on Figure (iv)3.

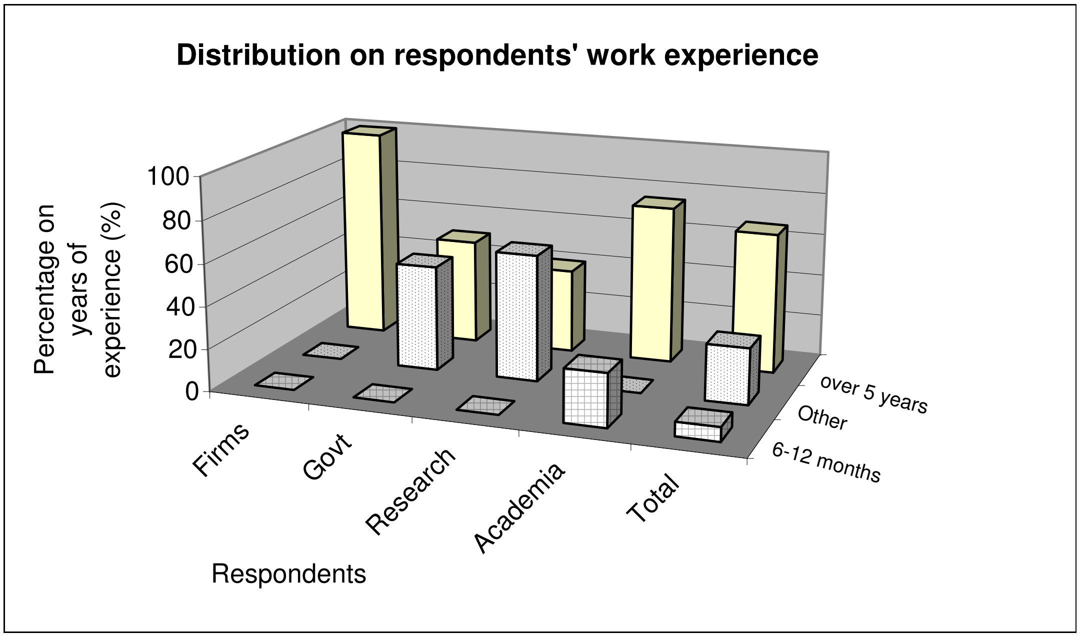

Figure (iv)3 Distribution of respondents' work experience

On the **main research questions** there were two sections, Part I and II.

Part I looked at the technological innovation related background in the form of activities (both current and previous) that firms have embarked on, so as to be able to make a comparison to the successful countries' pattern of technology development. This was in line with the theory on technological competence and capability building paths followed by most of the successful countries studied (Chapter 2). It also looked at the current and future positioning of firms in relation to the aircraft industry structure.

Responses to **Part I** questions were received as follows:

1. Does your institution/organisation/firm have or previously had any joint ventures with other international aircraft institutions?

About 60% of the total respondents said 'NO', meaning that they do not have joint ventures with international aircraft institutions. Responses by *Firms* indicated that only 50% have had joint ventures with international institutions, whereas *Research institutions* had 80% of such joint ventures. This is graphically illustrated on Figure (iv)4.

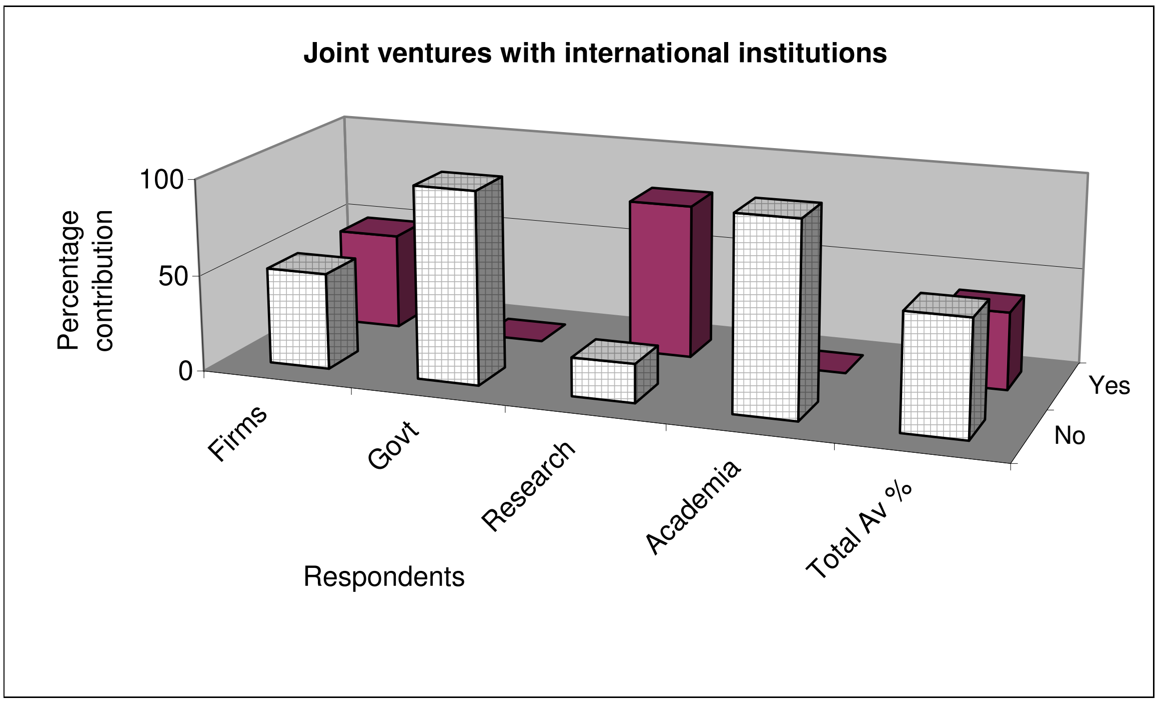

Figure (iv)4 Existing joint ventures with international institutions

2. Has your institution/organisation/firm been involved in aircraft projects for an international contractor?

About 47% of the total respondents agreed to have been involved in aircraft projects for an international contractor. Of such responses, *Firms* showed a 100% involvement in that they all agreed to have been involved. *Firms* further indicated that such involvement on projects for international contractors contribute about 95% to their total turnover. This could mean that the firms are getting opportunities to learn and could also be an indication of the existing capability by local firms when they are in a position to do work for international market. It also indicates that the international market is very crucial to the success of the local firms if such kind of work contributes about 95% to the total of their turnover. The distribution is graphically illustrated on Figure (iv)5.

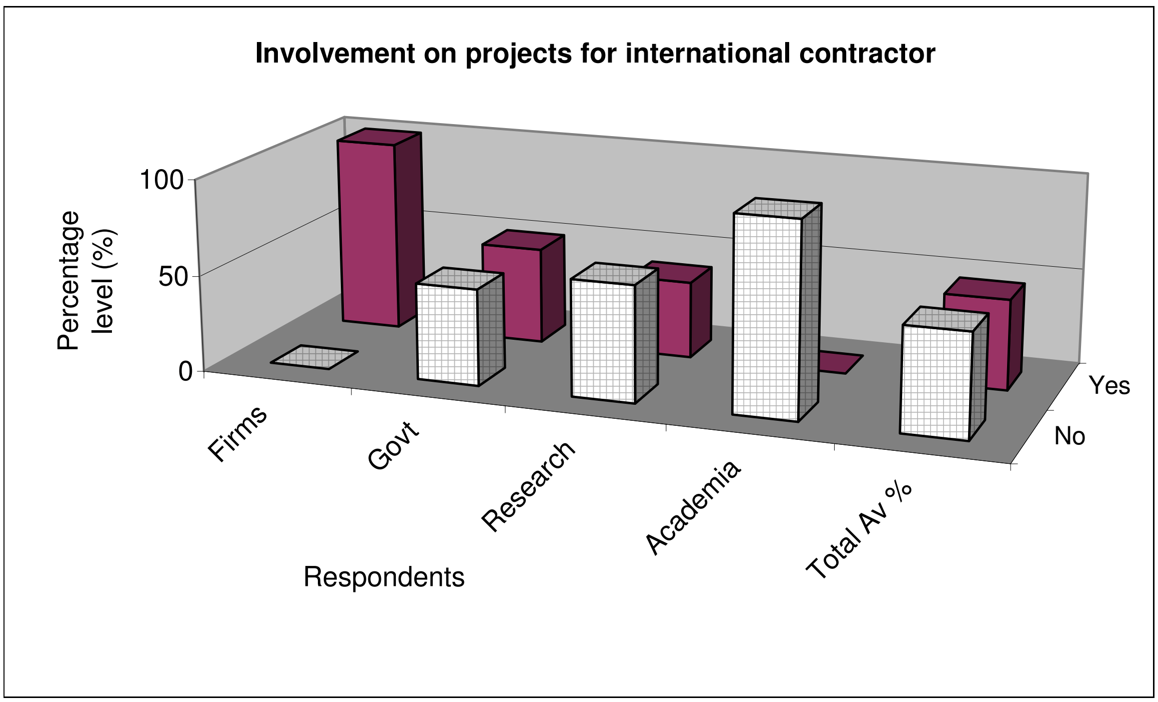

Figure (iv)5 Respondents' involvement on projects for international contractor

3. Has your institution/organisation/firm been involved in any form of collaboration with other local institutions?

A 100% response was received from all respondents, meaning that they all agree that they have been involved in some form of collaboration activities with local institutions.

4. Has your institution/organisation/firm been involved in any form of technological innovation or improvement within the aircraft industry?

Majority of respondents agreed to have been involved in technological innovation within the aircraft industry, where 93% of the total said 'YES'. A 100% response was received from *Firms, Government* and *Research institutions*, whereas 75% indication of such involvement was by *Academia*. This is graphically illustrated on Figure (iv)6.

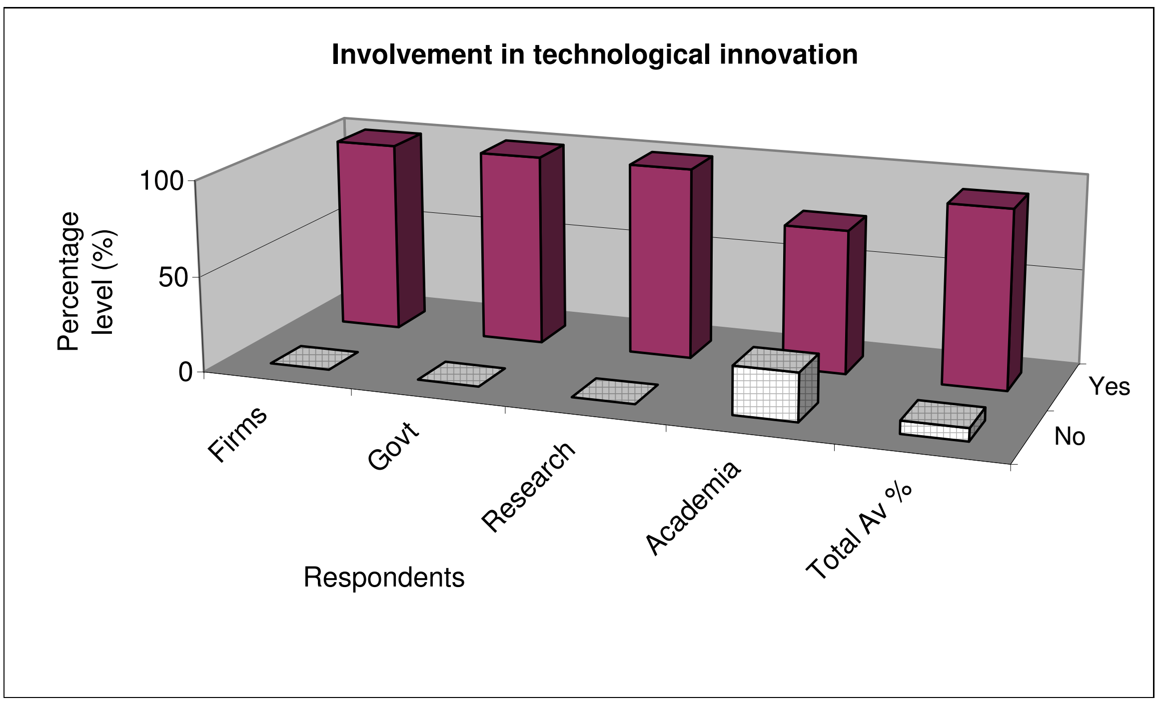

Figure (iv)6 Involvement in technological innovation by respondents

5. Did your institution/organisation/firm acquire some business contracts through government assistance in the past, where without their involvement it might have been difficult if not impossible to attain such business?

About 73% of the total respondents agree that government assistance has contributed towards their acquisition of some business contracts. Out of that, *Firms* had a 100% response, also agreeing that government has somehow assisted them to acquire some business contracts. This is graphically illustrated on Figure (iv)7.

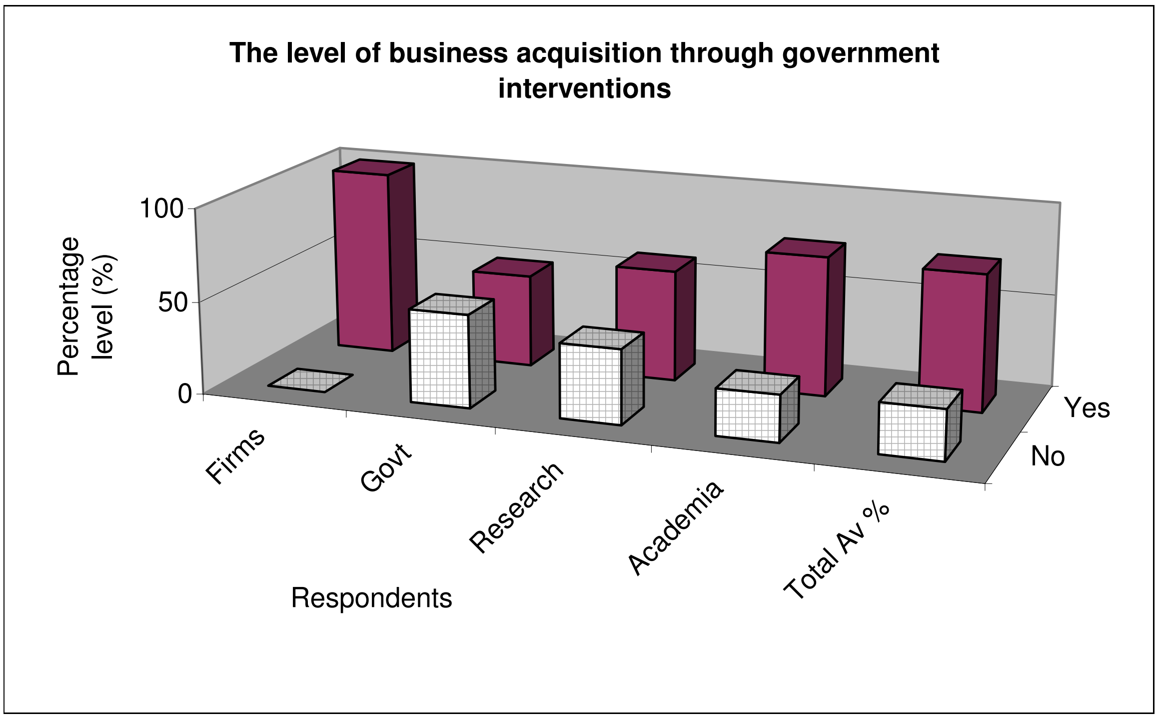

Figure (iv)7 The level of business acquisition through government interventions

6. Has your institution/organisation/firm been involved in any form of aircraft-related technology transfer with global institutions?

The responses received were not very different, where about 53% of the total respondents answered 'YES' to the question, and 47% answered NO. However, for *Firms*, it appeared that technology transfer is very critical for their success in that they had a 100% response, where they agreed that they have been transferring technology. This is graphically illustrated on Figure (iv)8.

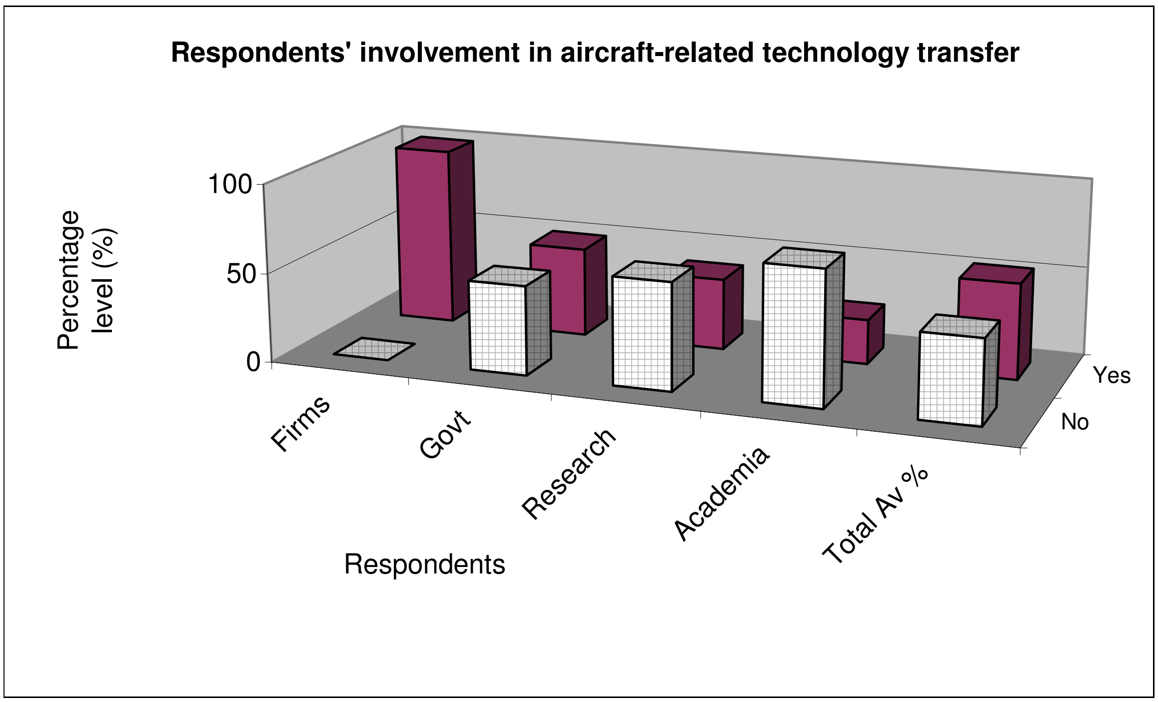

Figure (iv)8 Respondents' involvement in aircraft-related technology transfer

7. In what area of the aircraft industry structure is your institution/organisation/firm making a major contribution?

On average respondents indicated that their major contribution is on **fourth tier** (component supply) with a 47% overall response, and also **third tier** (minor subsystem supply) with a 40% overall response. *Firms* specifically had a 100% response rate, showing that they make a contribution in both third and fourth tiers equally. However, they had a 75% response with regard to contribution they make on **first tier** (full assembly/system integrators) and **second tier** (major subsystem supply). For **fifth tier** (parts supply), the total respondents showed that it is only 20% contribution that they make. These results show that firms and research institutions are already moving up the value chain supply system (pyramid) of the aircraft industry structure as indicated on Figure 1.1 (from Chapter I). This does not necessarily mean that they cannot have technologies that could contribute towards the development of the first tier, but the market could be the determining factor as well.

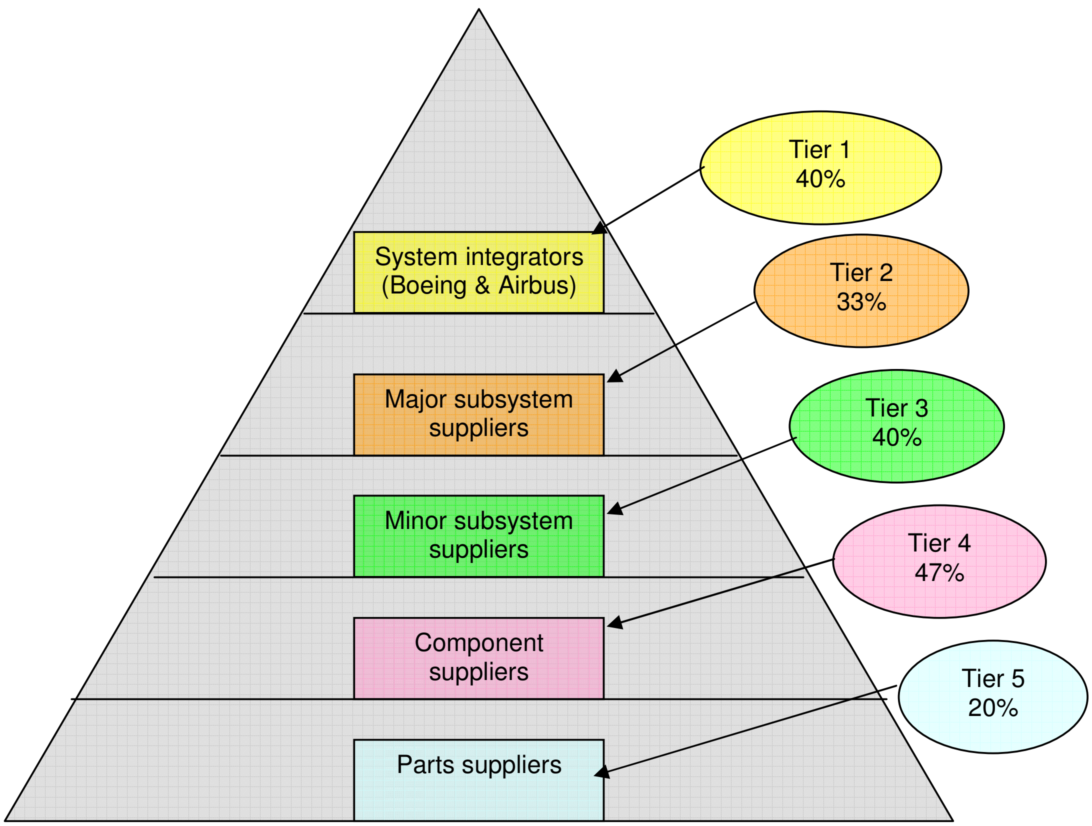

Figure 1.1 The aircraft industry structure

Source: Adapted from British Aerospace Annual Report and Accounts (1998), include respondents contribution percentages on tier levels.

Figure (iv)9 shows findings on South Africa's major contribution percentages by tier levels.

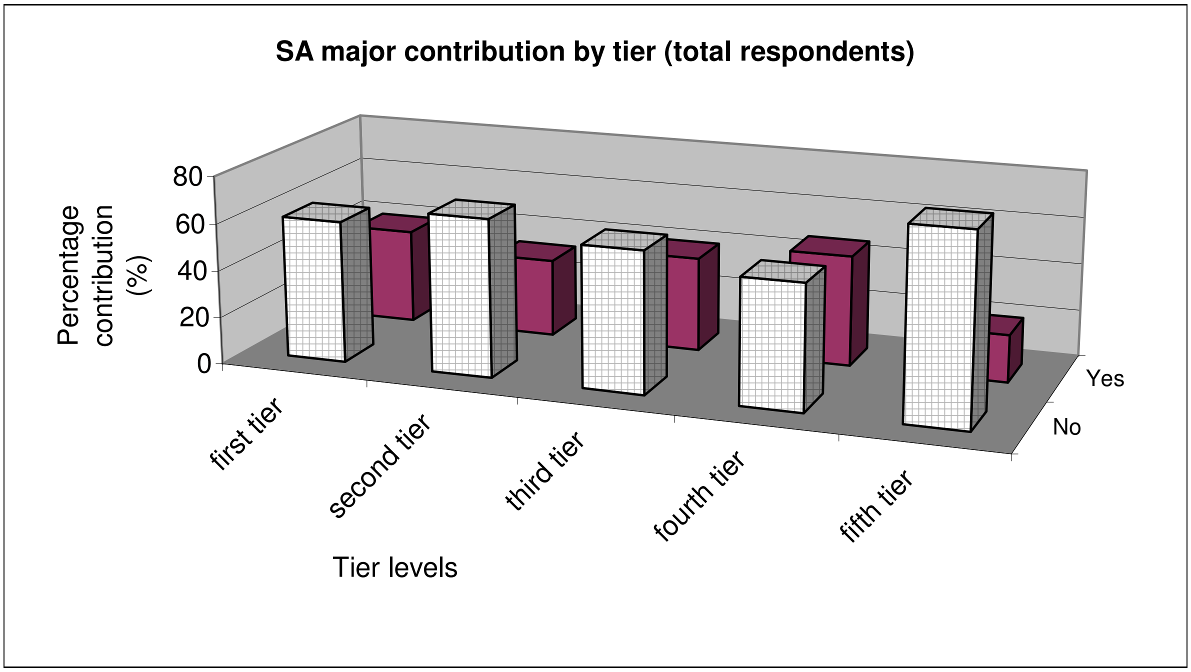

Figure (iv)9 South Africa's major contribution percentages by tier levels

The graphical representation of the contribution by respondents on the tier with the highest contribution (fourth tier) is illustrated on Figure (iv)10.

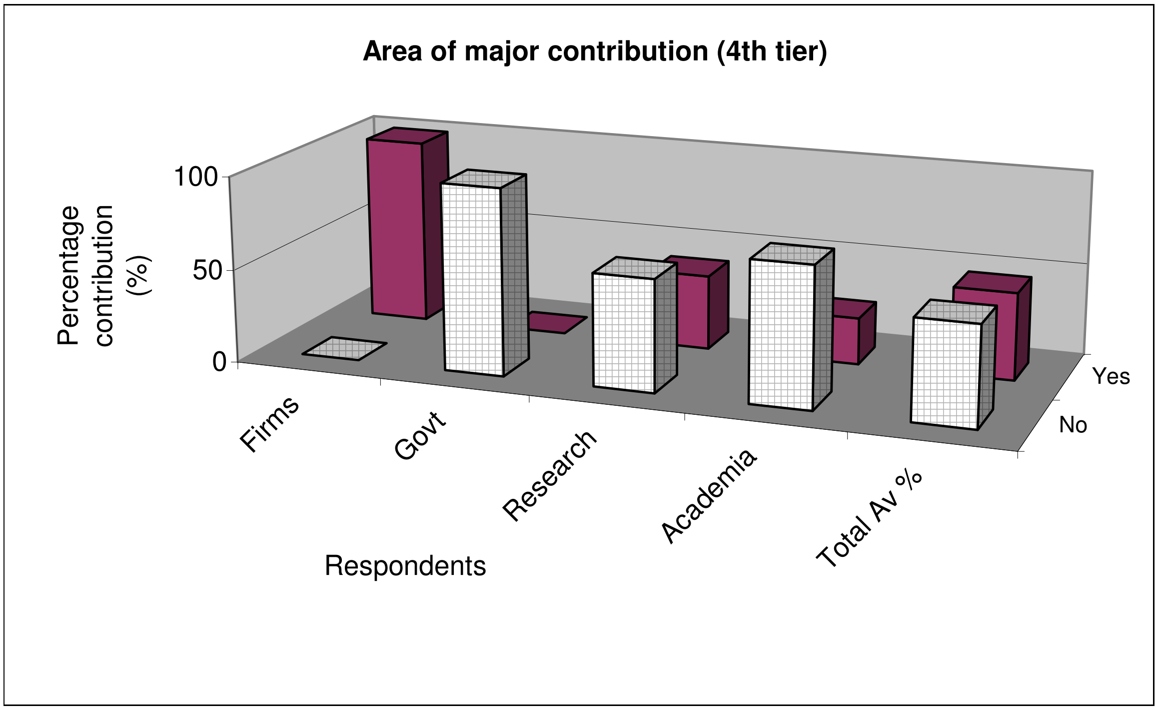

Figure (iv)10 Respondents' contribution on the fourth tier

8. Where do you think South African firms should be playing more important role within the aircraft industry structure?

Respondents believe that South African firms should be contributing more towards developing the second and third tier levels. The total response was about 87% for second tier and 80% for third tier. *Firms* responded with 100% in both categories, indicating that the bigger contribution should equally be on second and third tier levels. The interpretation of the result is that firms can therefore develop technological capabilities more within the second and third tiers of the aircraft industry structure. A graphical representation of the results is illustrated on Figure (iv)11.

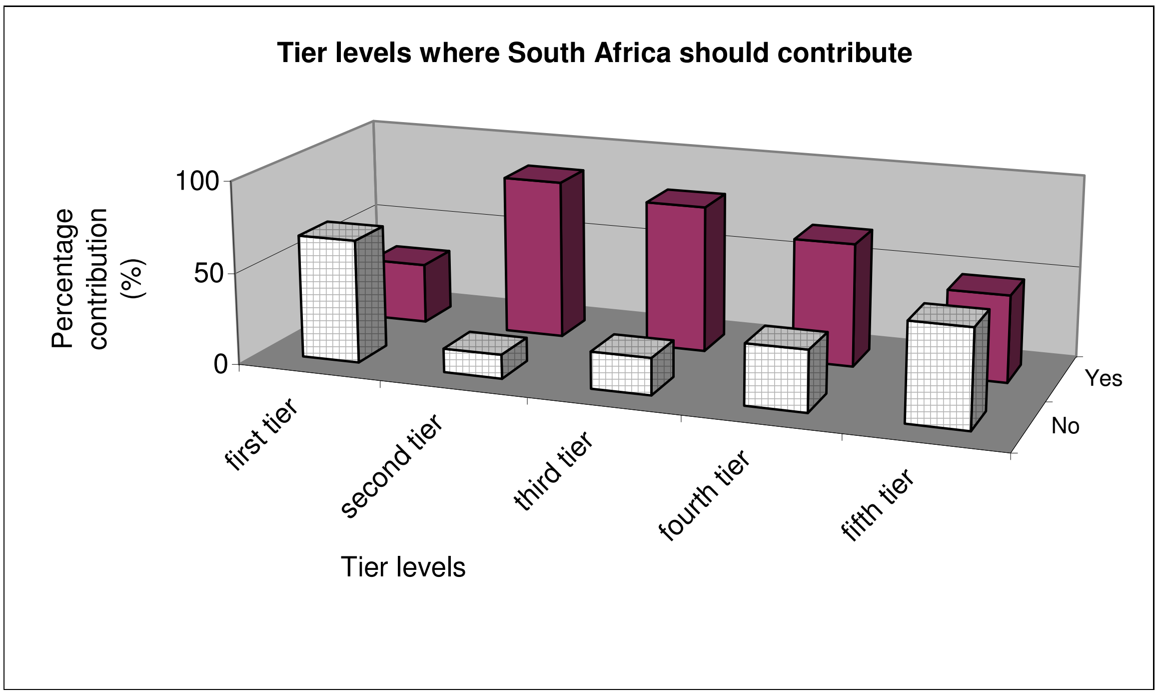

Figure (iv)11 Percentage levels by tier level where South Africa should contribute

Both *Firms* and *Government* responses converged when they responded by answering 'YES' (100%), indicating that South African firms should contribute more on the second tier. Responses by *Research institutions* and *Academia* had 80% and 75% respectively, also agreeing to South African firms' need to contribute more towards developing the second tier. This is illustrated on Figure (iv)12.

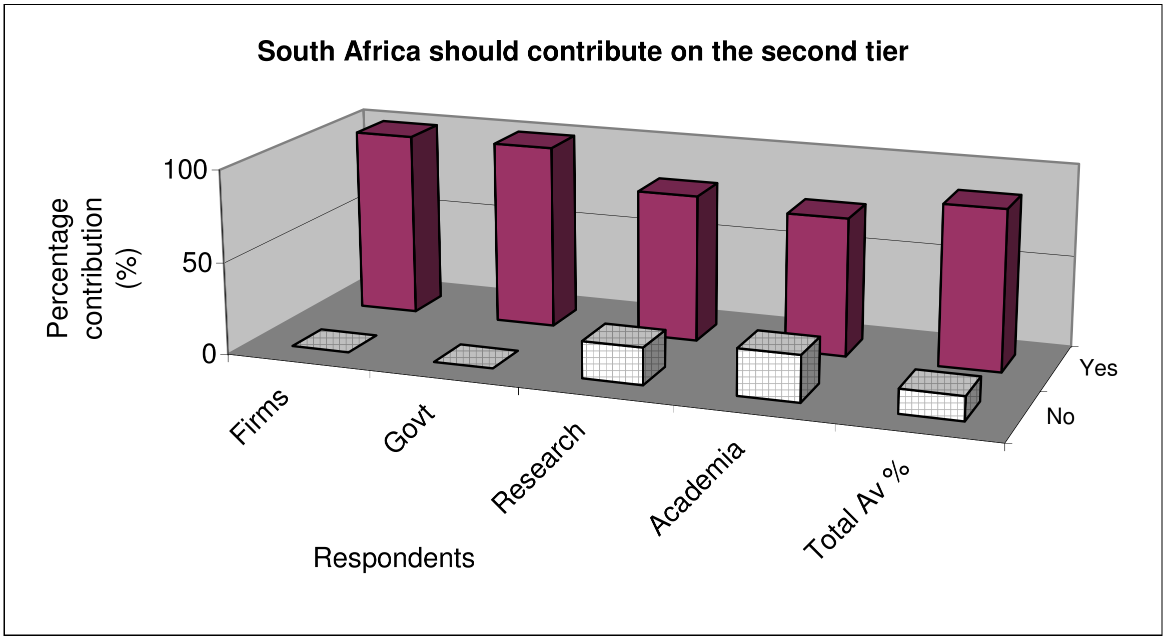

Figure (iv)12 Respondents' percentage contribution for the second tier

Part II, looked at the technological competencies, factors that impact on technological capability-building process for South African civil aircraft industry, market feasibility for South African firms, and testing the conceptual framework as proposed by the researcher. This is based on the theory on technological competence and capability building paths followed by most of the successful countries. In short, the section is aimed at identifying the technological challenges believed to be faced by the local civil aircraft industry, and if the framework proposed by the researcher on building technological competencies could be useful in resolving such challenges.

For **Part II,** responses were received as follows:

9. The following are assumed to be the current major gaps that affect the technology capability-building process of the South African civil aircraft industry:

a) Insufficient in-house technological capability

When focusing on the total responses combined, those that *Strongly agree* had the highest score **(33%)**, followed by those that *Agree* (20%). *Firms* had the highest score of 75% (*Strongly agree* + *Agree*), agreeing that the above is a major gap affecting technology capability-building process of the South African civil aircraft industry. The findings are graphically represented on Figure (iv)13.

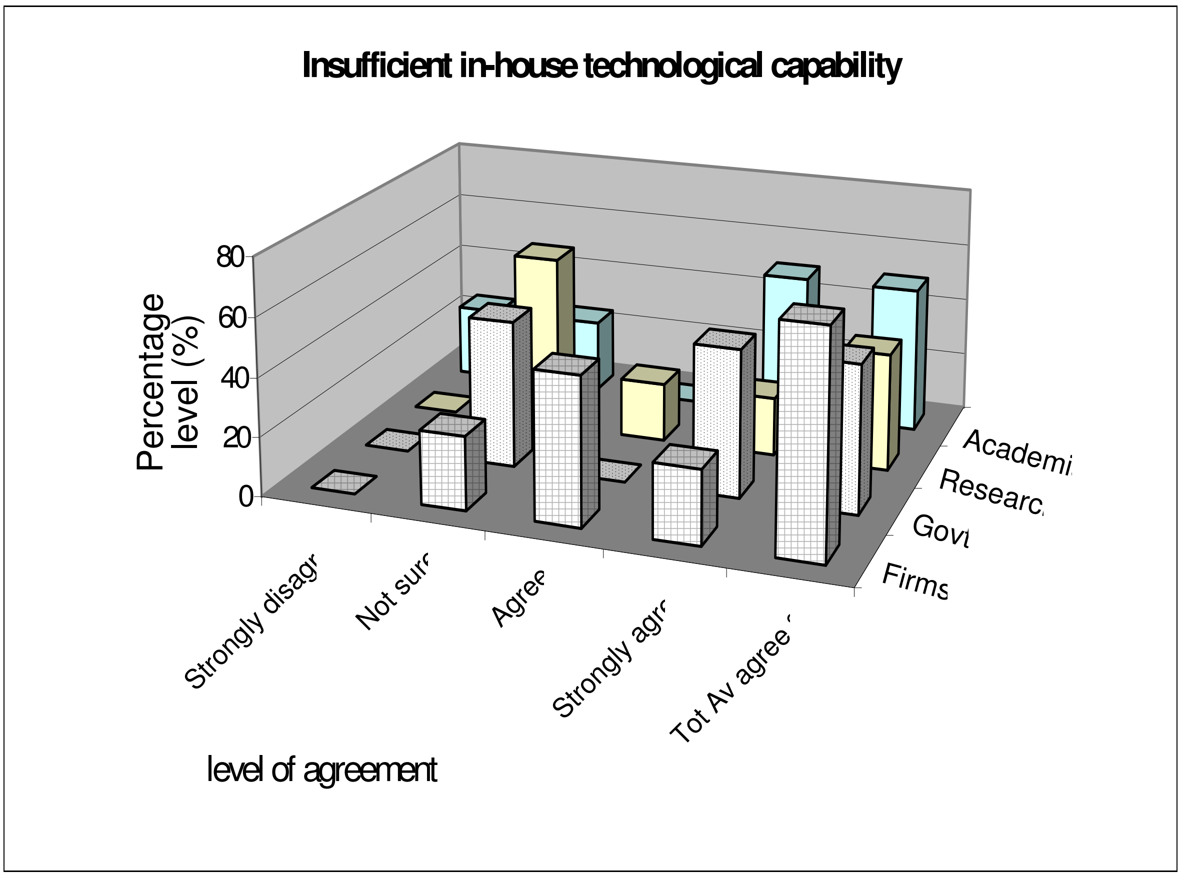

Figure (iv)13 "Insufficient in-house technological capability" as a gap that impacts on the technology capability-building process

b) Underdeveloped National System of Innovation

For this aspect, the highest score for total respondents was on *Strongly agree* **(53%)**. *Disagree* and *Agree* had a score of 13% each. *Firms* had a 100% score on *Strongly agree*. The findings are illustrated on Figure (iv)14.

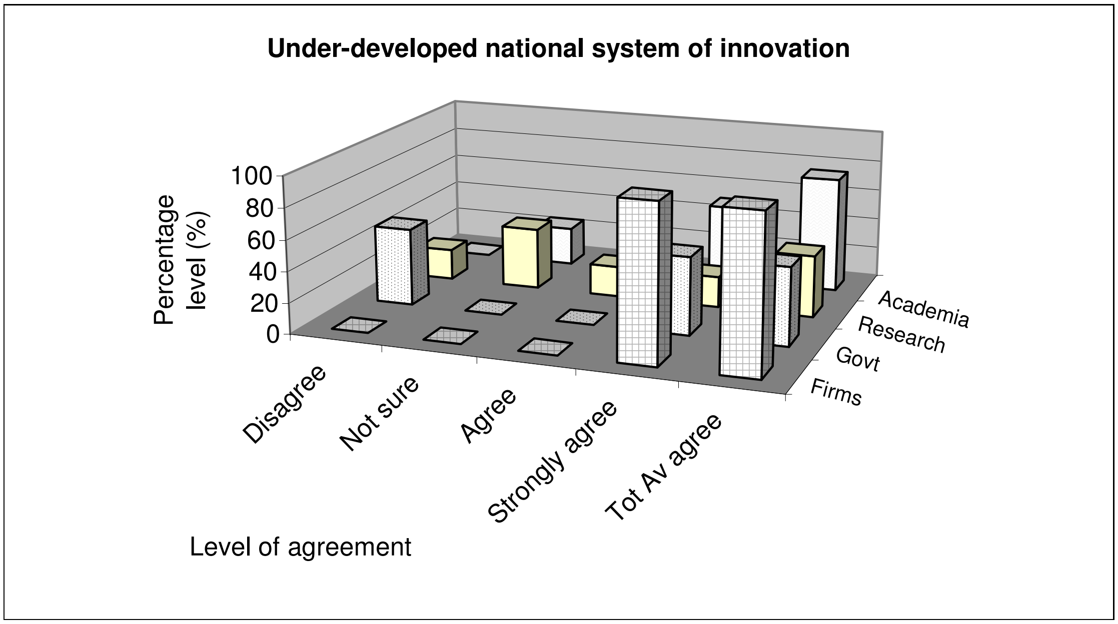

Figure (iv)14 "Under-developed national system of innovation" as a gap that impacts on the technology capability-building process

c) Lack of firm collaboration

Total respondents scored **33%** on both *Strongly agree* and *Agree*. *Government* had a 50% score on *Strongly agree*, with *Research institutions* scoring 40%. The findings are illustrated on Figure (iv)15.

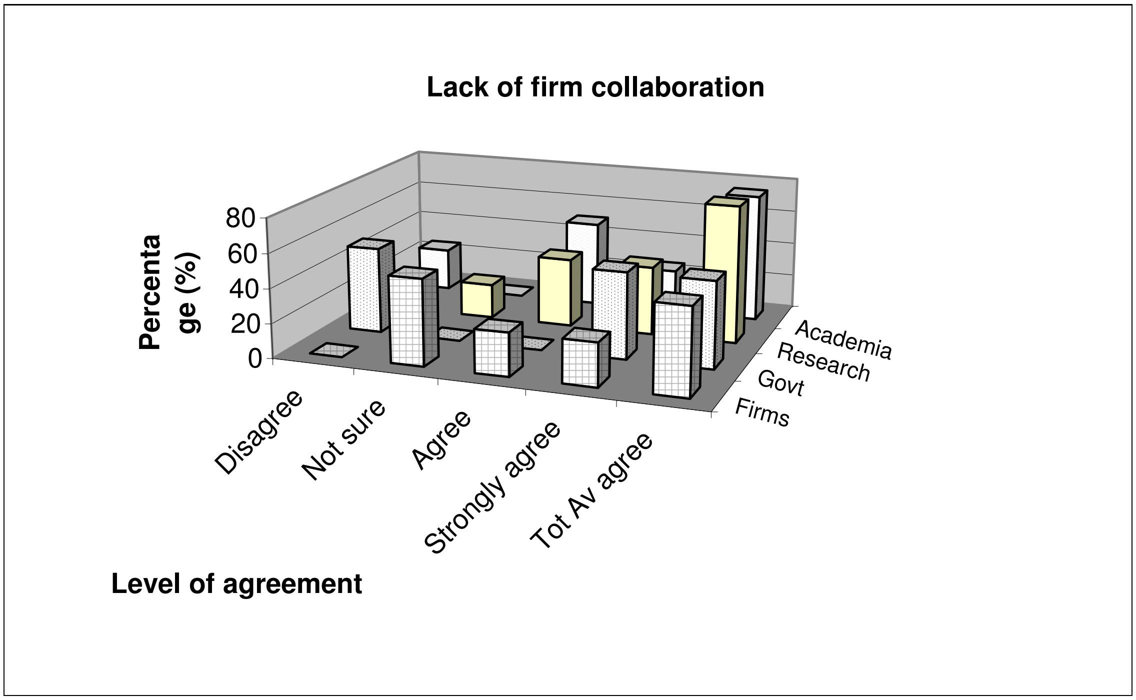

Figure (iv)15 "Lack of firm collaboration" as a gap that impacts on the technology capability-building process

d) Poorly developed aircraft infrastructure

Total respondents scored **27%** on both *Agree* and *Disagree*. *Strongly agree* scored 13%. A graphical representation on the findings is shown on Figure (iv)16.

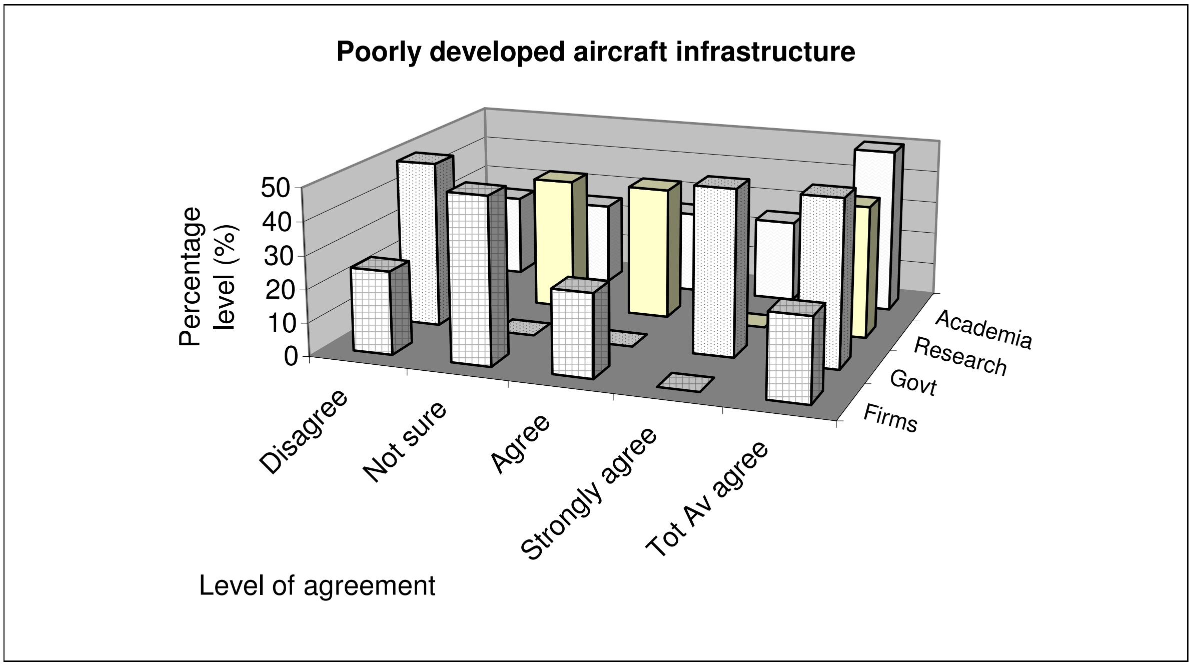

Figure (iv)16 "Poorly developed aircraft infrastructure" as a gap that impacts on the technology capability-building process

e) Insufficient skilled resources

The highest score for total respondents was on *Strongly agree*, with **40%**, followed by 27% on *Agree*. Both *Firms* and *Government* had a 50% score on *Strongly agree*. A graphical representation of the findings is shown on Figure (iv)17.

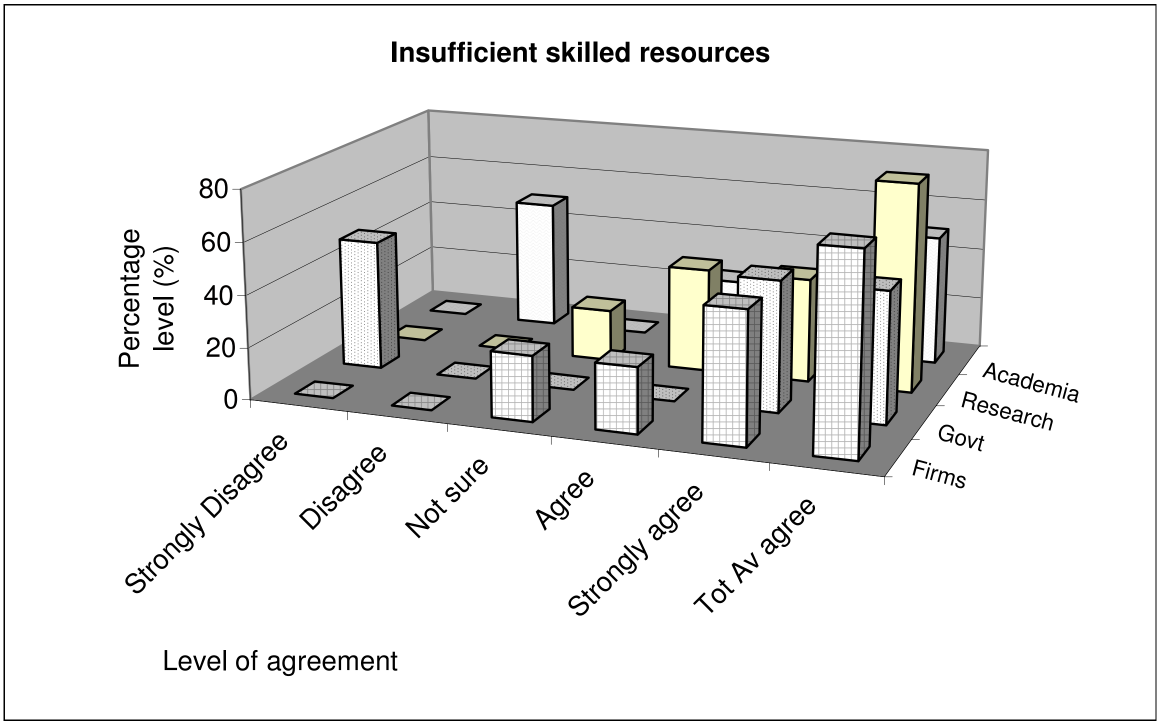

Figure (iv)17 "Insufficient skilled resources" as a gap that impacts on the technology capability-building process

f) Underdeveloped technological capabilities

Total respondents had a highest score of about **27%** on both *Strongly agree* and *Agree*. Responses under *Not sure* had a total score of 40%. *Academia* specifically had a score of 50% on both *Strongly agree* and *Agree*, when *Firms* had 25% in both *Strongly agree* and *Agree*. A graphical representation of the findings is shown on Figure (iv)18.

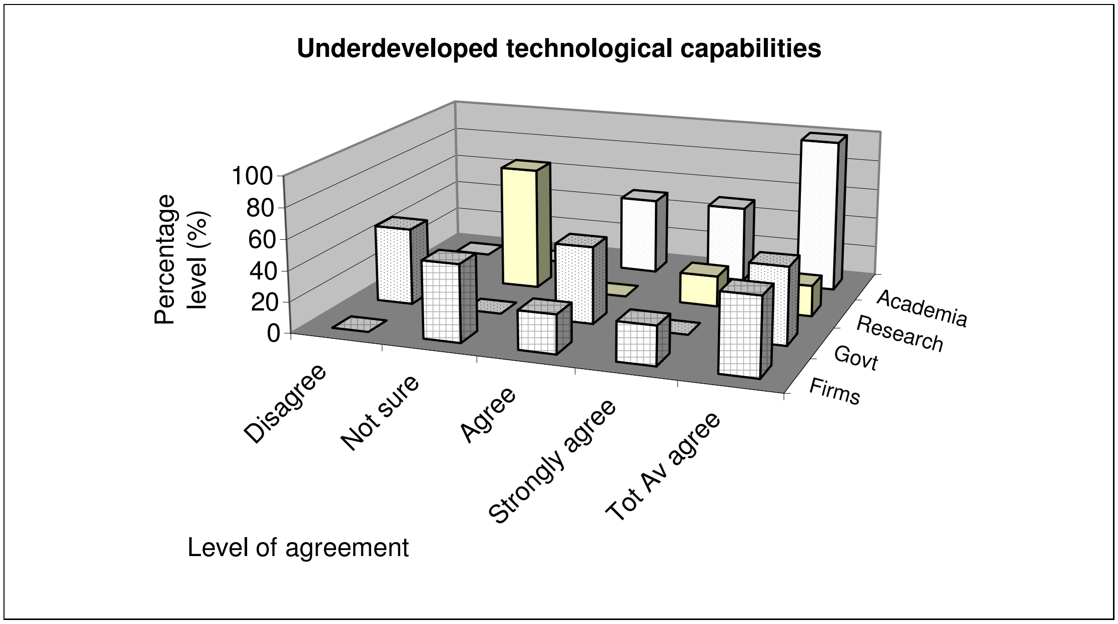

Figure (iv)18 "Underdeveloped technological capabilities" as a gap that impacts on the technology capability-building process

g) Lack of appropriate technologies

Total respondents had the highest score of about **33%** on *Agree*, and also 33% on *Disagree*. However, on *Strongly agree* the score was 20%, which when combined with the score on *Agree* (33%) leads to total agreement. *Firms* had a highest score of 50% on *Strongly agree*, with another 25% on *Agree*. *Research institutions* had 60% on *Agree*. A graphical representation of the findings is illustrated on Figure (iv)19.

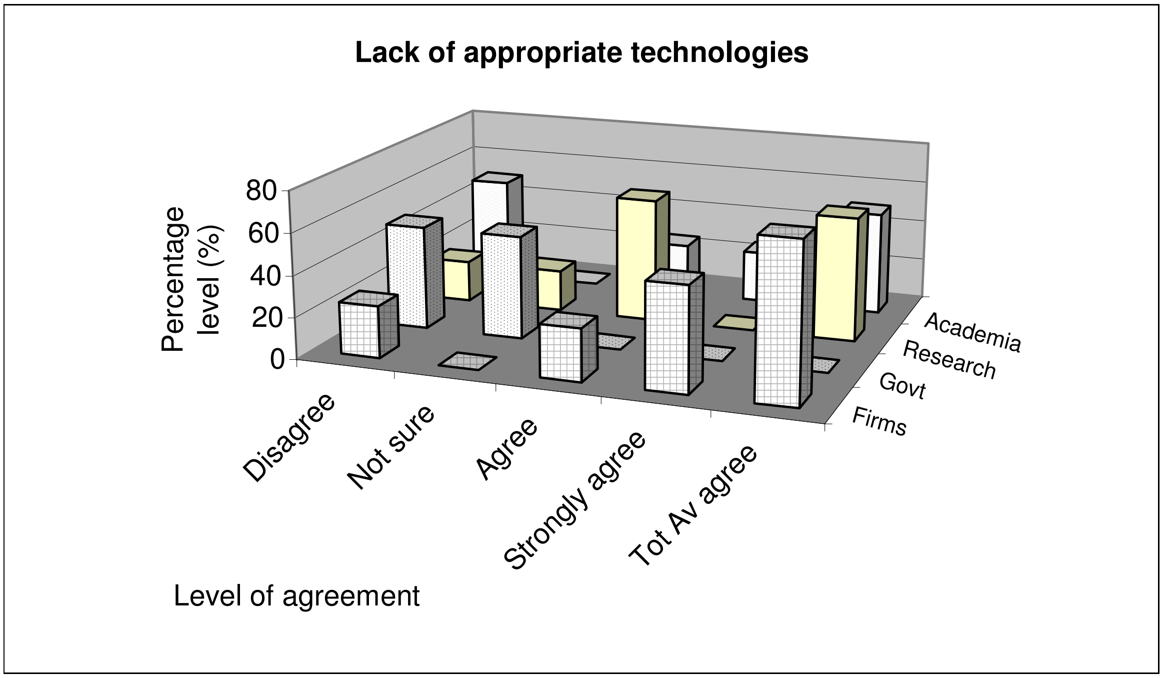

Figure (iv)19 "Lack of appropriate technologies" as a gap that impacts on the technology capability-building process

h) Insufficient R&D investment

Responses in total had a highest score of **60%** on *Strongly agree*, followed by 27% on *Agree*. *Not sure* had a score of 13%. Both *Firms* and *Academia* had a 75% score on *Strongly agree*, with *Research institutions* scoring 60% on the same aspect. Figure (iv)20 illustrates the graphical representation of the findings.

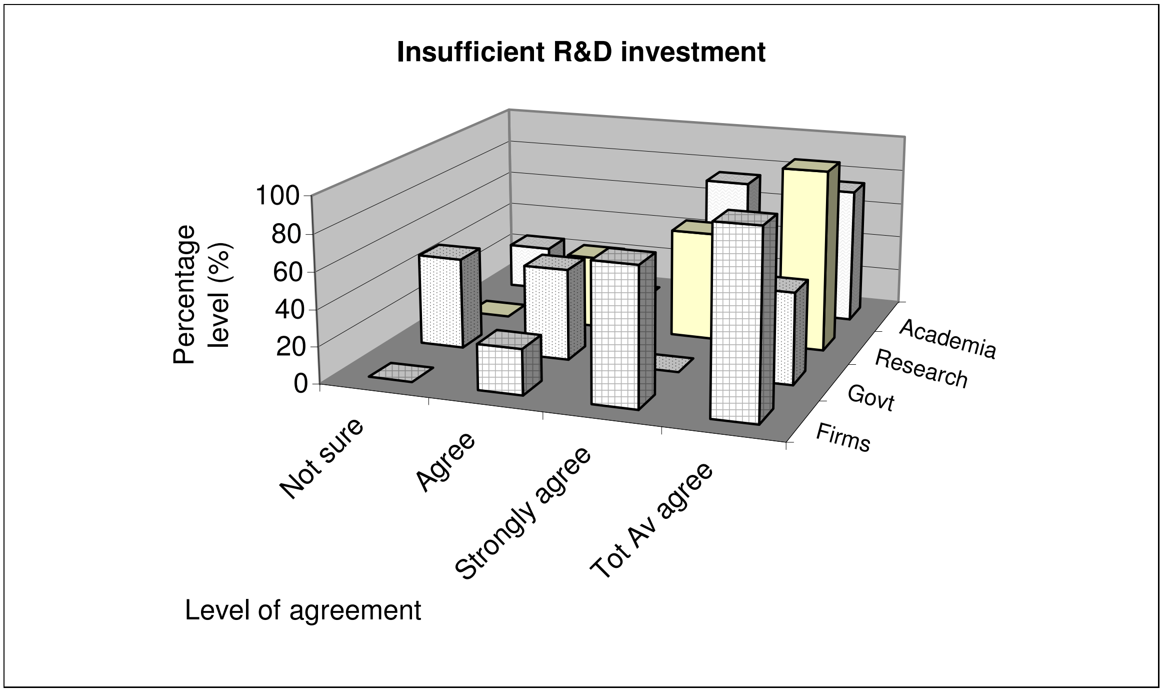

Figure (iv)20 "Insufficient R&D investment" as a gap that impacts on the technology capability-building process

i) Insufficient knowledge

The highest score on total respondents was **40%** at both *Agree* and *Not sure*. Both *Strongly agree* and *Disagree* had a similar score of about 7%. *Firms* only had a score of 50% on *Agree*, whereas *Research institutions* had 60% score on same aspect of *Agree*. A graphical representation on the findings is shown on Figure (iv)21.

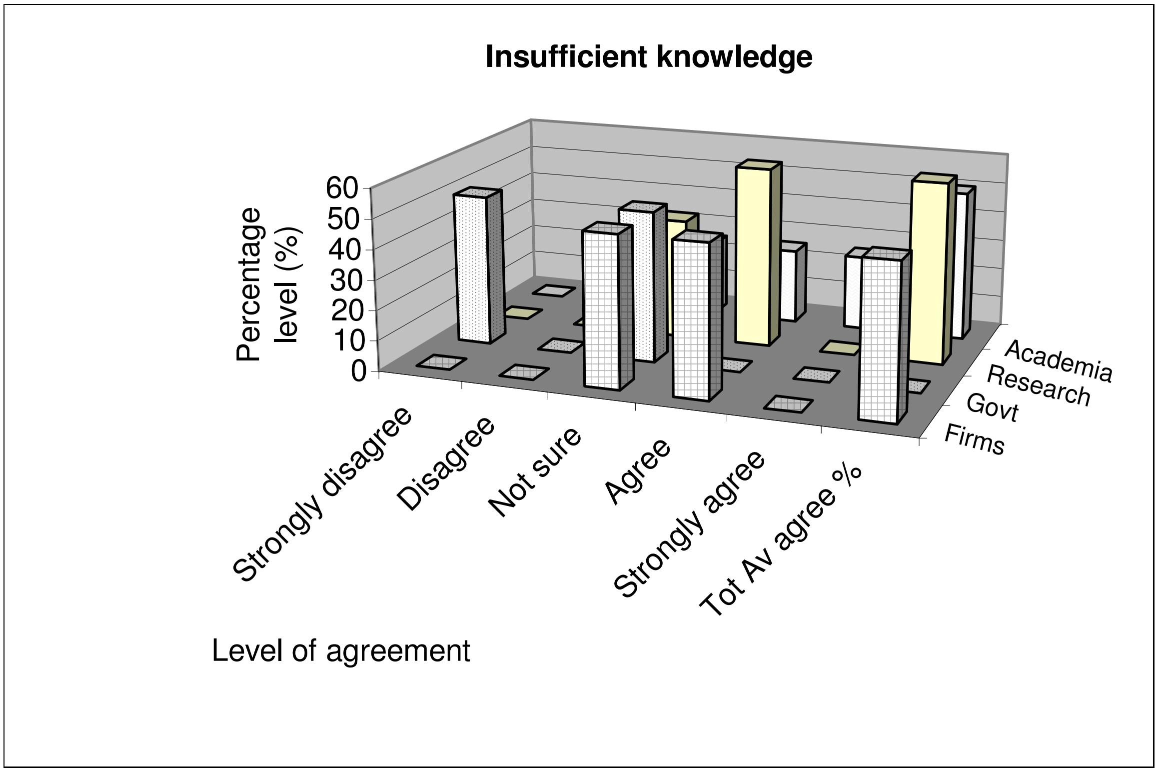

Figure (iv)21 "Insufficient knowledge" as a gap that impacts on the technology capability-building process

j) Insufficient skills development programmes

On this aspect, the highest score on total respondents was **33%** for both *Strongly agree* and *Agree*. A graphical representation on the findings is shown on Figure (iv)22.

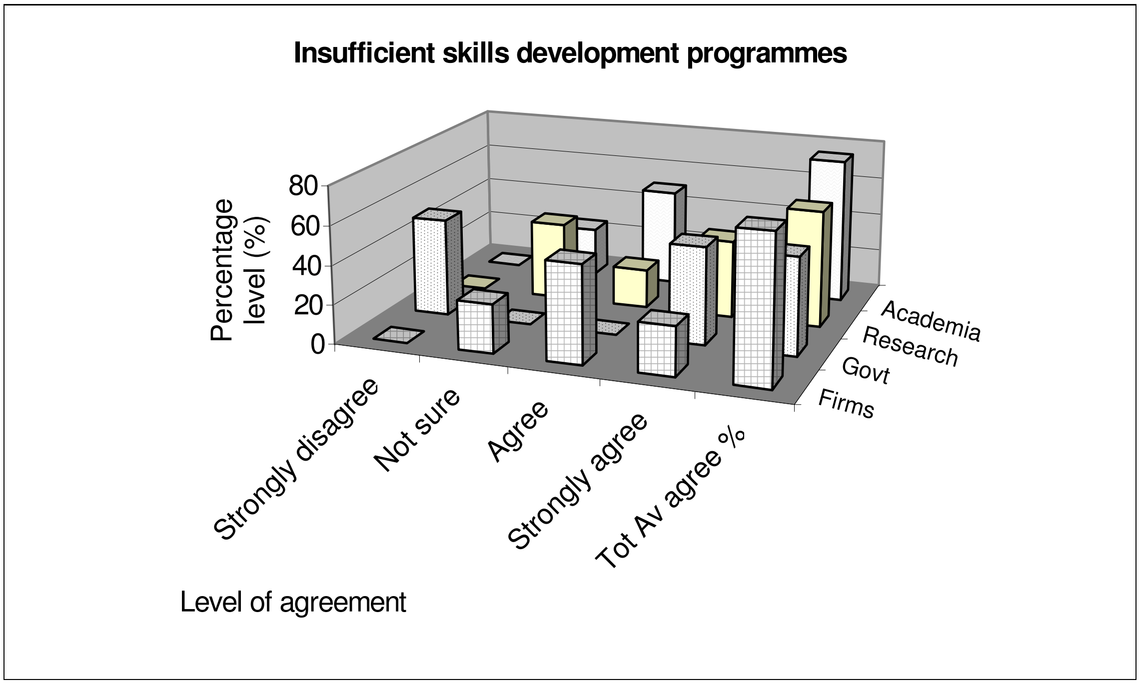

Figure (iv)22 “Insufficient skills development programmes” as a gap that impacts on the technology capability-building process

k) Insufficient strategic alliances with global firms

The total respondents' score was **33%** for both *Strongly agree* and *Agree*. A graphical representation on the findings is shown on Figure (iv)23.

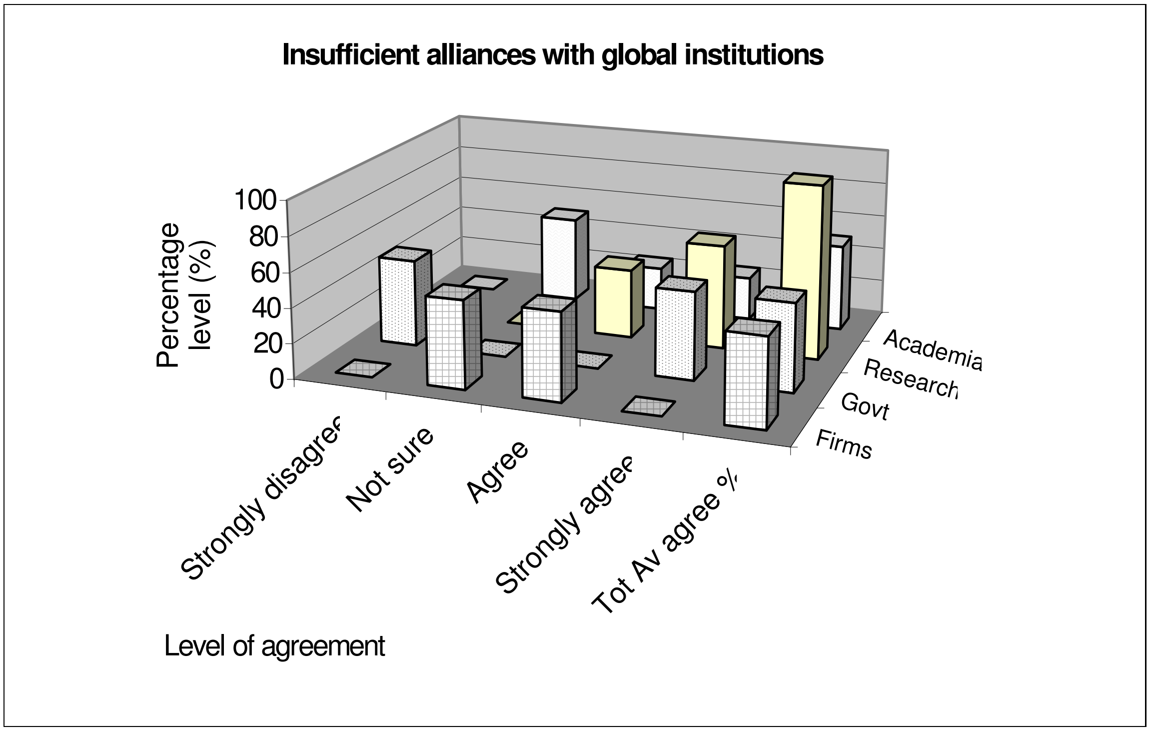

Figure (iv)23 "Insufficient alliances with global institutions" as a gap that impacts on the technology capability-building process

l) Lack of skills/knowledge transfer programmes

A highest score of **53%** was obtained for *Agree* on total respondents, followed by 20% on *Strongly agree*. Both *Strongly disagree* and *Disagree* had a score of about 7% each. *Not sure* had a score of 13%. *Firms* scored 75% on *Agree*, followed by *Research institutions* (60%) and *Government* (50%). *Research institutions* had a further 40% on *Strongly agree*. A graphical representation on the findings is shown on Figure (iv)24.

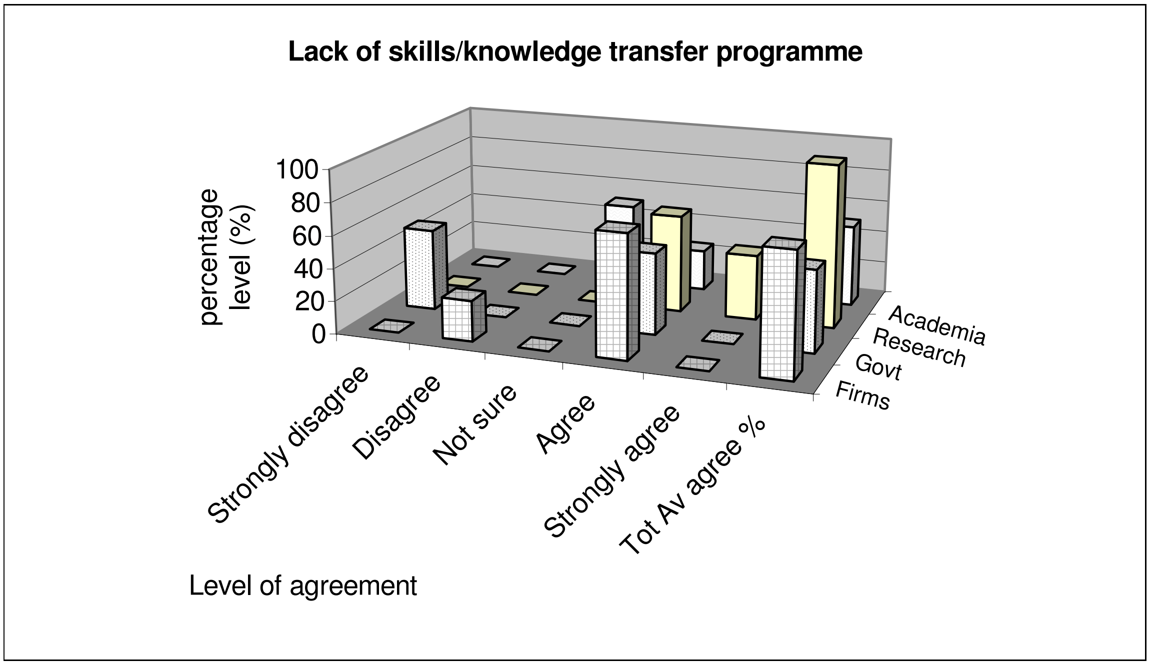

Figure (iv)24 "Lack of skills/knowledge transfer programmes" as a gap that impacts on the technology capability-building process

m)Poor levels of innovation

The total respondents' score was **33%** for both *Strongly agree* and *Agree*. This was followed by *Disagree* (20%), then *Strongly disagree* (7%). *Not sure* scored 7%. *Firms* specifically scored high on *Agree* (75%). *Government* and *Research institutions* had higher scores on *Strongly agree*, with 50% and 40% respectively. A graphical representation on the findings is shown on Figure (iv)25.

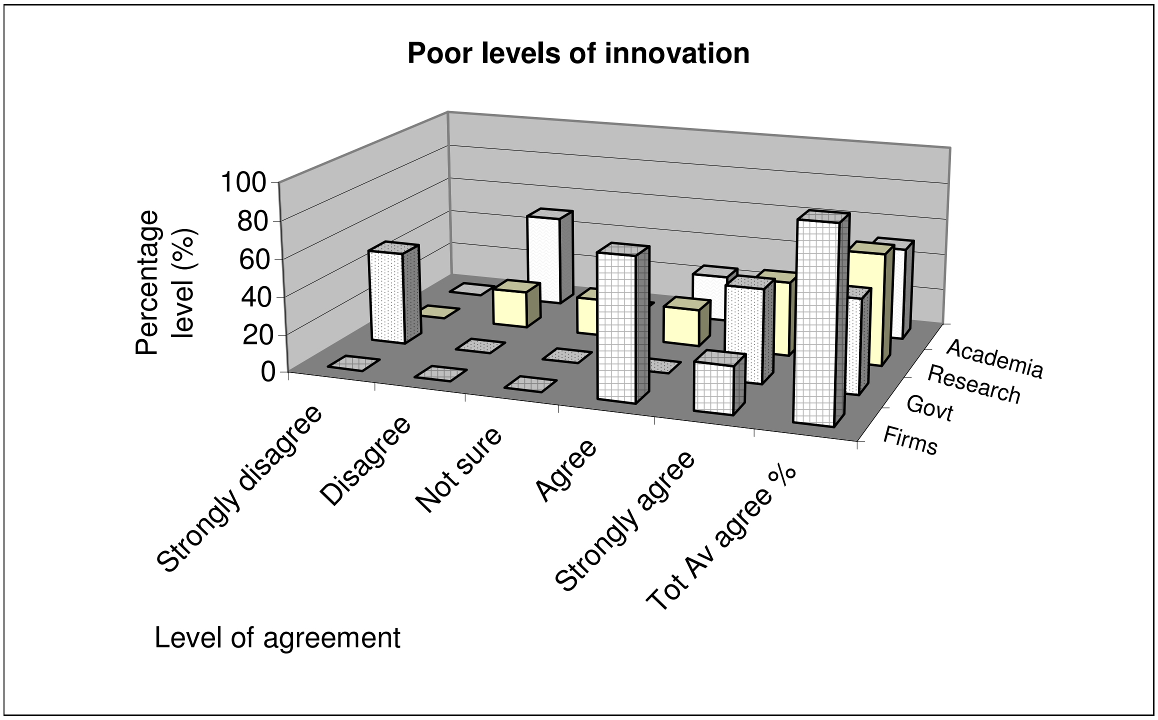

Figure (iv)25 "Poor levels of innovation" as a gap that impacts on the technology capability-building process

n) Poor external environment

A highest score of **40%** was obtained for *Agree* on total respondents, with a further 13% on *Strongly agree*. *Strongly disagree* also scored about 13%. *Not sure* had 33%. *Firms* specifically scored 50% on *Agree*, with a further 25% on *Strongly agree*. *Research institutions* scored 60% on *Agree*. A graphical representation on the findings is shown on Figure (iv)26.

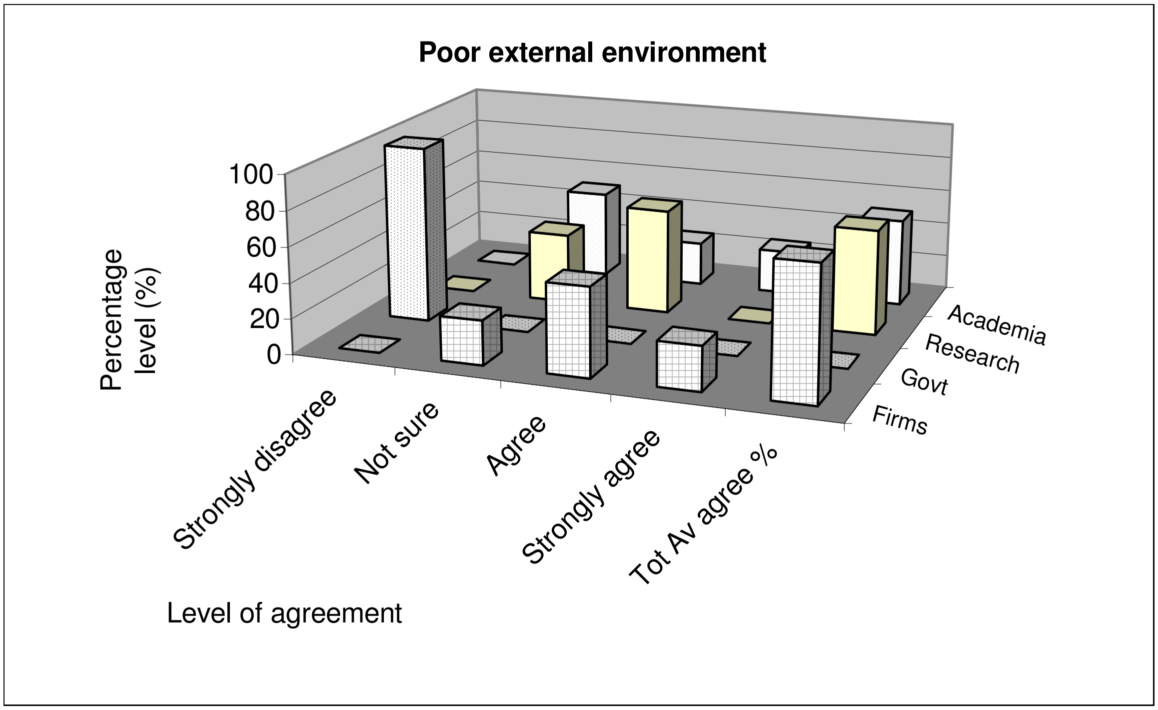

Figure (iv)26 "Poor external environment" as a gap that impacts on the technology capability-building process

o) Poor governing structures

A highest score of **47%** was obtained for *Agree* on total respondents, followed by 20% on *Strongly agree*. For *Disagree* the total respondents' score was 13%. *Not sure* had 13% score. *Firms* specifically scored 100% on *Agree*. A graphical representation on the findings is shown on Figure (iv)27

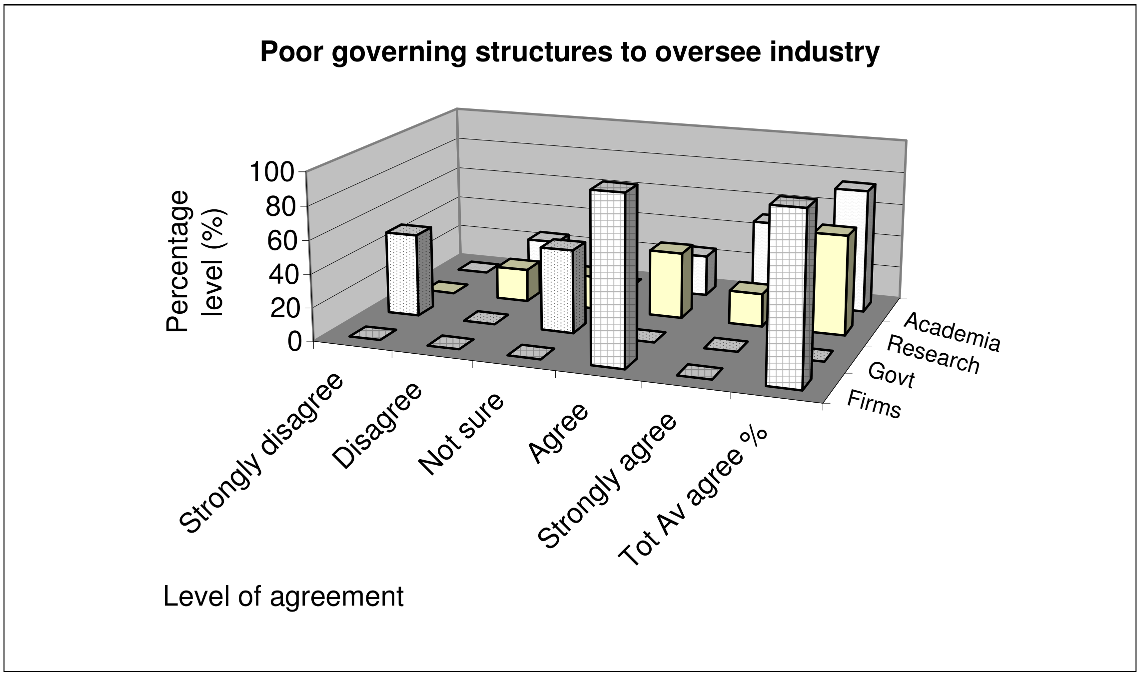

Figure (iv)27 "Poor governing structures" to oversee industry as a gap that impacts on the technology capability-building process

10. Where do you think South African private sector firms within the aircraft industry should be playing a bigger role in building national technological competitiveness within the civil industry?

a) Research and technology development

In total the highest score of **40%** for *Highest priority* was obtained, followed by 33% on *Medium*. *Government* scored 100% on *Highest priority*, whereas *Firms* found the aspect to be of *Medium* (100%) *priority*. A graphical representation of the scores is illustrated on Figure (iv)28.

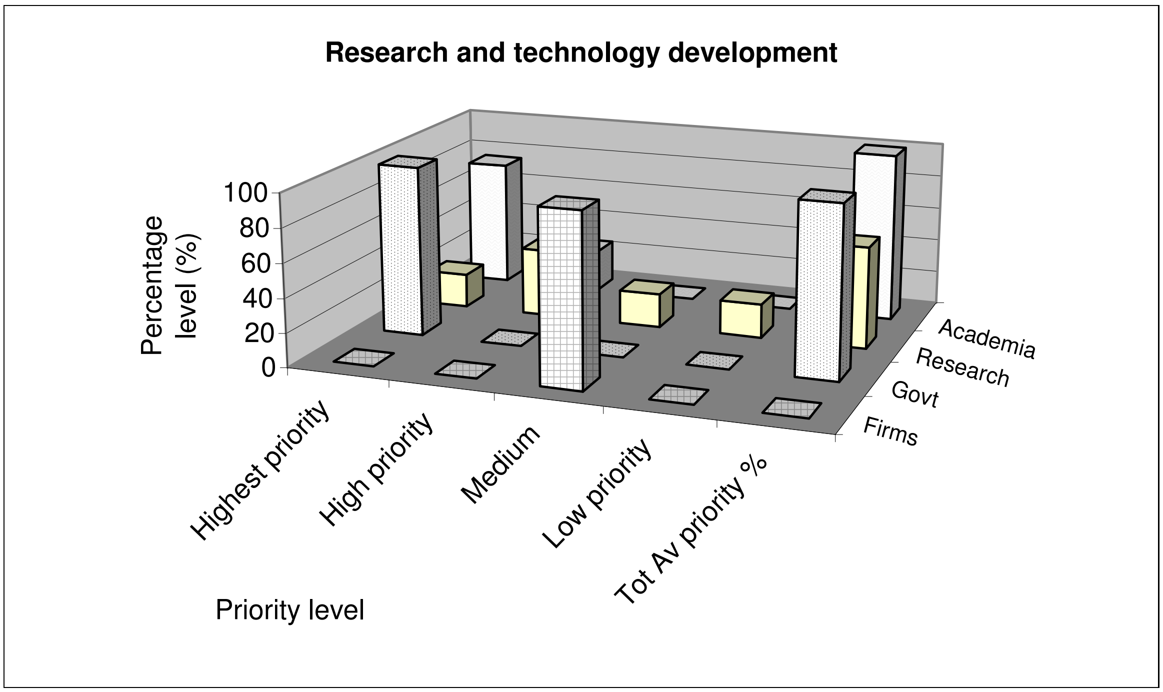

Figure (iv)28 Percentages for prioritising focus on research and technology development

b) *Business Development*

Total respondents scored **40%** on *Highest priority*, with a further 20% on *High priority*. A score of 20% was also obtained on *Least priority*. *Government* found this aspect to be of *Highest priority* (100% score), whereas *Firms* had a score of 50% on *Highest priority*. *Academia* scored 75% (*Highest priority*). A graphical representation of the scores is illustrated on Figure (iv)29.

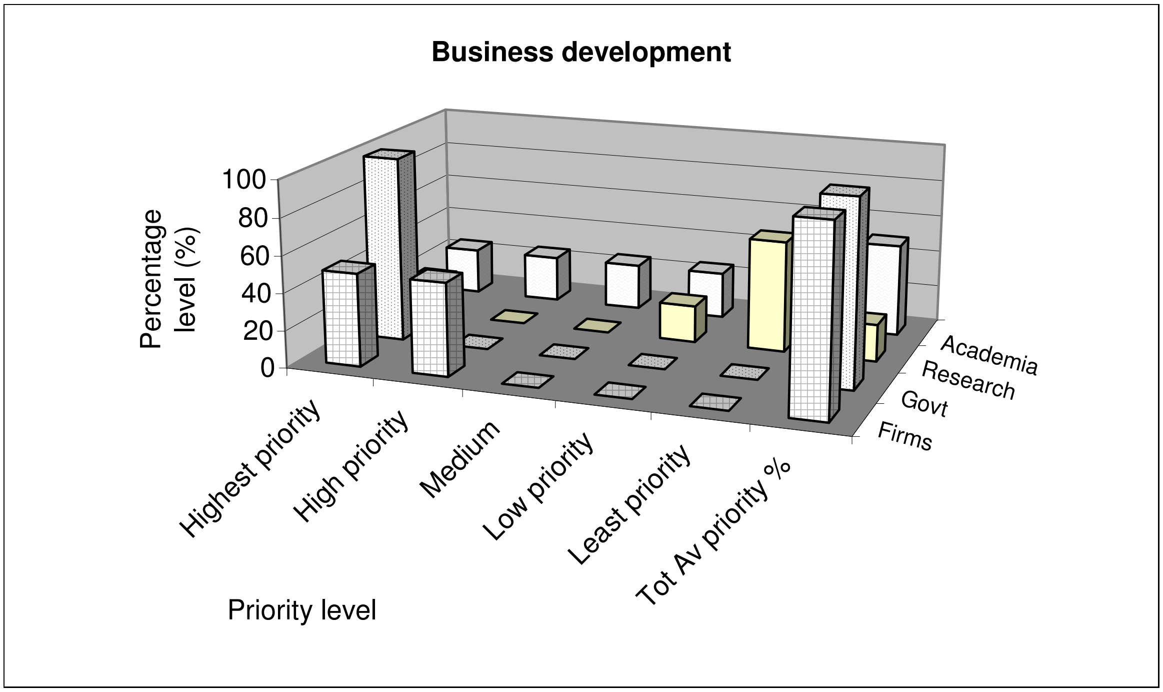

Figure (iv)29 Percentages for prioritising focus on business development

c) Skills Development

The highest score by total respondents was **53%** on *Highest priority*, followed by 27% on *High priority*. *Government* found this aspect to be of *Highest priority* (100% score), whereas *Firms* had a score of 50% on *Highest priority*. A graphical representation of the scores is illustrated on Figure (iv)30.

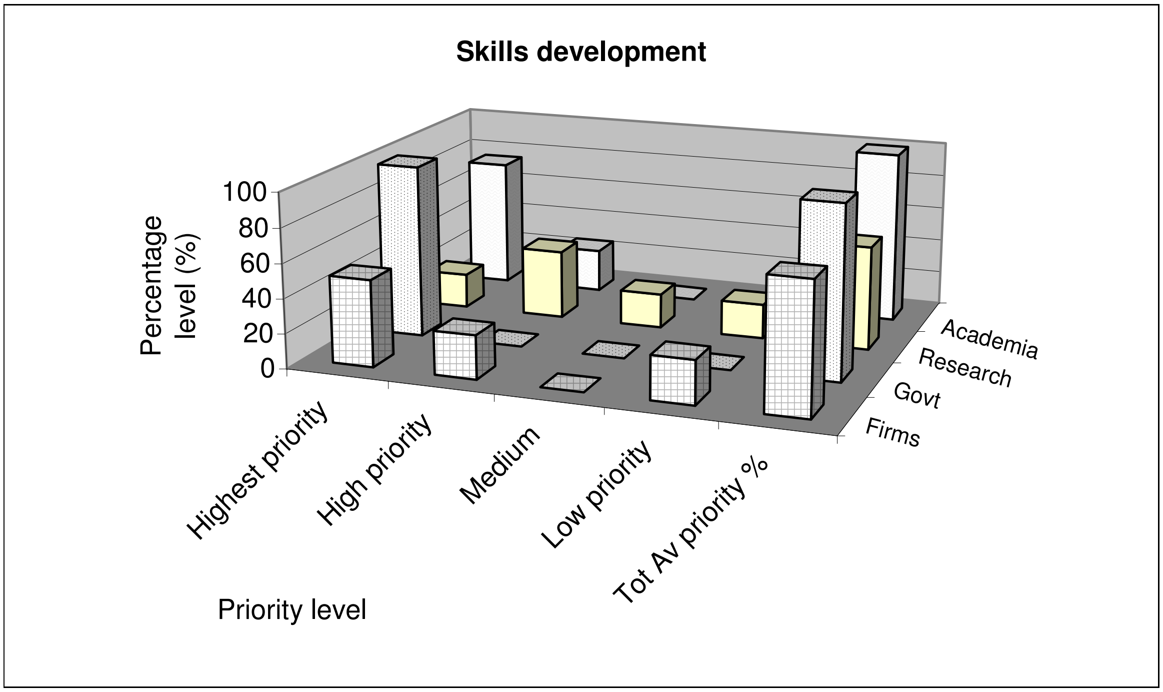

Figure (iv)30 Percentages for prioritising focus on skills development

d) Infrastructure development

The highest score by total respondents was **40%** on *High priority*, followed by 33% on *Highest priority*. *Government* found this aspect to be of *Highest priority* (100% score), whereas *Firms* found it to be of *High priority* (100%). A graphical representation of the scores is illustrated on Figure (iv)31.

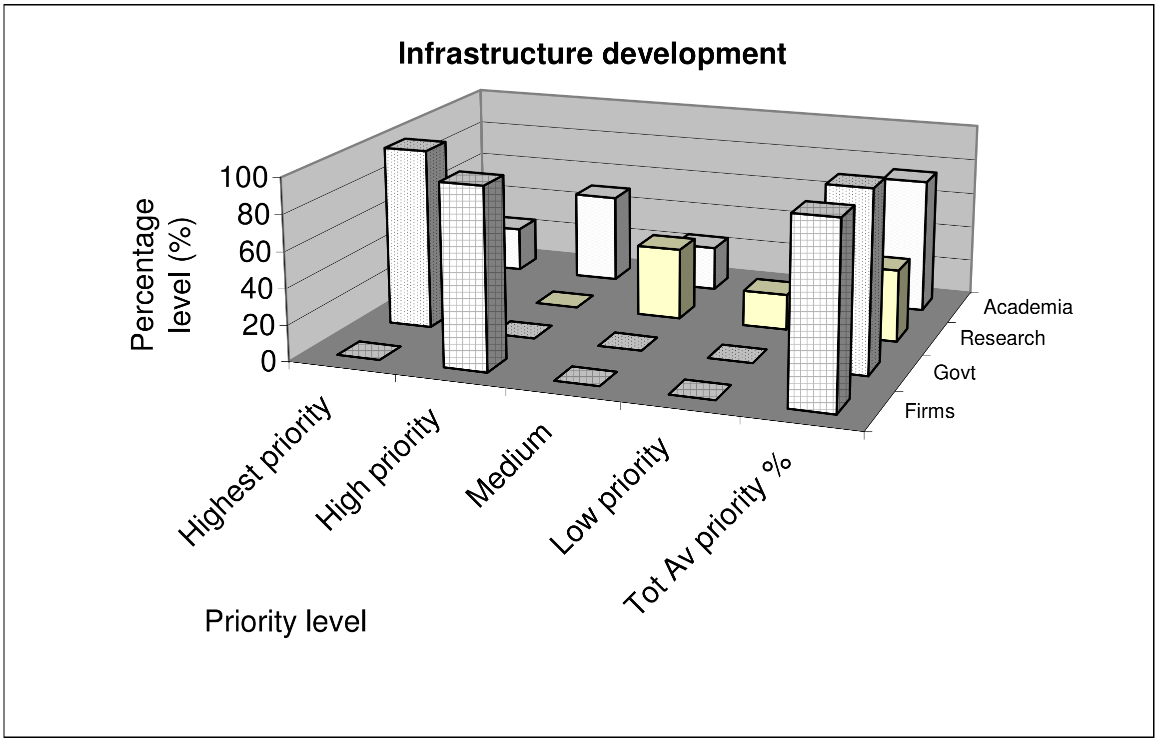

Figure (iv)31 Percentages for prioritising focus on infrastructure development

e) Support higher education

The highest score by total respondents was **40%** on *Highest priority*, with a further 13% on *High priority*. 27% was scored on *Low priority*. Both *Government* and *Academia* found this aspect to be of *Highest priority (*100% score), whereas *Firms* found it to be of *Low priority* (50%). A graphical representation of the scores is illustrated on Figure (iv)32.

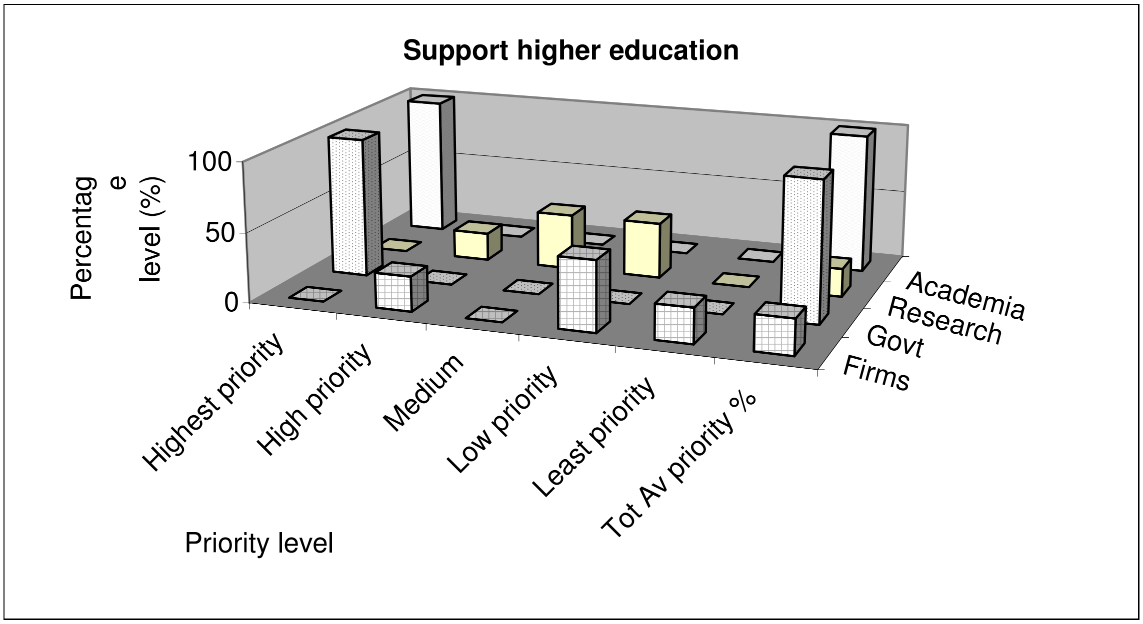

Figure (iv)32 Percentages for prioritising focus on support for higher education

11. What form of interventions is your firm doing in relation to human resource development to enhance in-house technological capabilities? Indicate if you have been involved or not in relation to such interventions.

Responses were obtained on the following list of interventions:

A. In-house skills development programme

B. Inter-firm skills exchange programme (national)

C. Inter-firm skills exchange programme (international)

D. Knowledge transfer during technology transfer

E. Inter-firm research collaboration (national)

F. Inter-firm research collaboration (international)

For intervention **A** *(In-house skills development programme)*, the highest score of **92%** on total responses was obtained, indicating that majority of respondents were *Already involved* in that intervention. *Firms*, *Government* and *Research institutions*, all had individual scores of 100%, indicating that they were fully involved in such intervention. A graphical representation of the scores for intervention **A** is illustrated on Figure (iv)33.

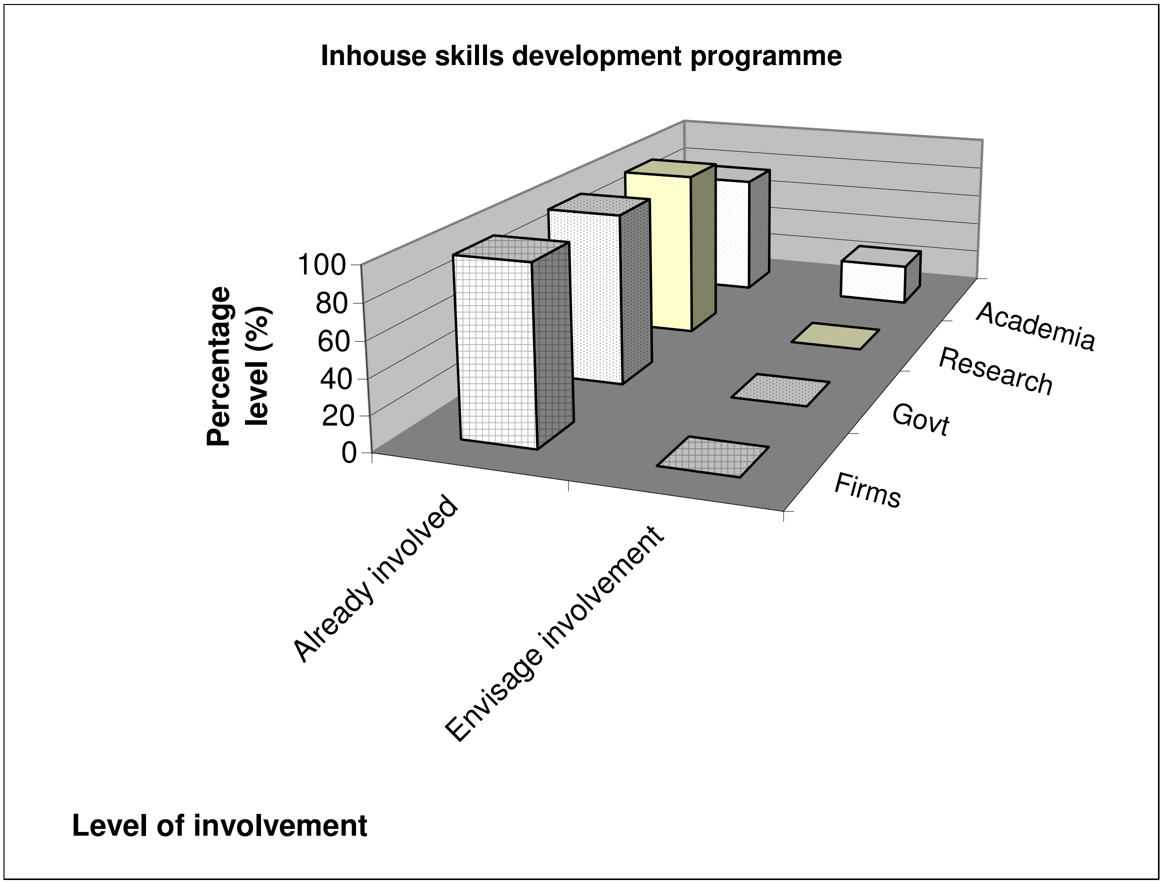

Figure (iv)33 Level of involvement in "In-house skills development programme" as an intervention for human resource development

Intervention **C** (*Inter-firm skills exchange programme - international)* had the second highest score of **70%** by total respondents, also showing that they were *Already involved* in that intervention. Third highest score **(64%)** was obtained on intervention **D** (*Knowledge transfer during technology transfer)*, also indicating that firms were *Already involved* in that intervention. A graphical representation of the scores showing the level of involvement on all interventions is illustrated on Figure (iv)34.

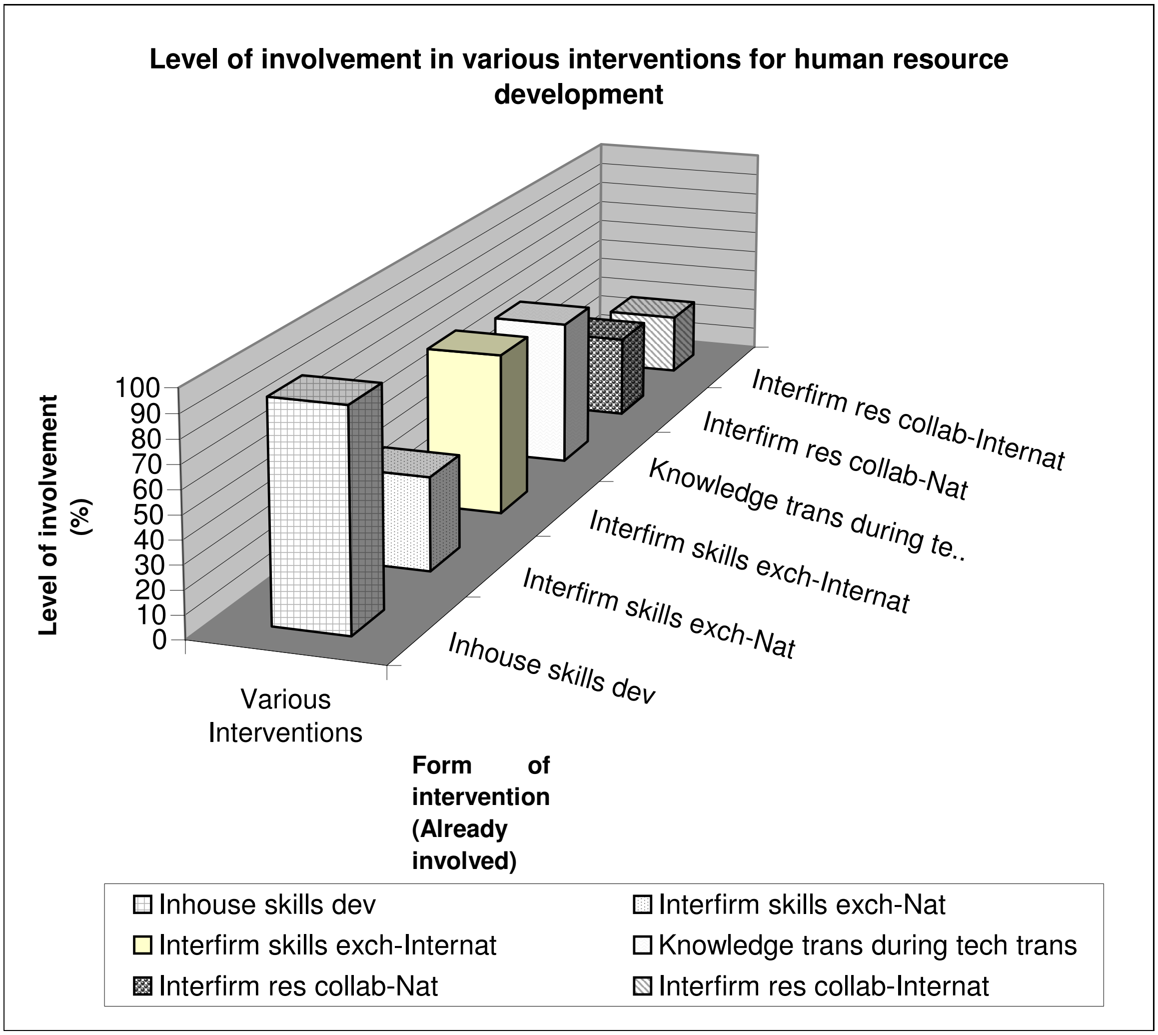

Figure (iv)34 Level of involvement in various interventions for human resource development

12. Which countries/continents do you think South African aircraft firms should place their emphasis in terms of developing their market relations as part of enhancing national technological competitiveness and technology capability-building?

Responses were obtained on the following list of countries/continents:

A. Africa

B. Europe

C. United Kingdom (UK)

D. United States (US)

E. Asia

F. Latin America

The highest score of **71%** (*Highest priority*) on total responses was obtained for Europe, thereby indicating that majority of respondents think Europe should be the business focus area for South African aircraft firms. Both *Firms* and *Government* had individual scores of 100% (*Highest priority*), with *Research institutions* at 60% (*Highest priority*) and *Academia* at 33%. A graphical representation of the scores is illustrated on Figure (iv)35.

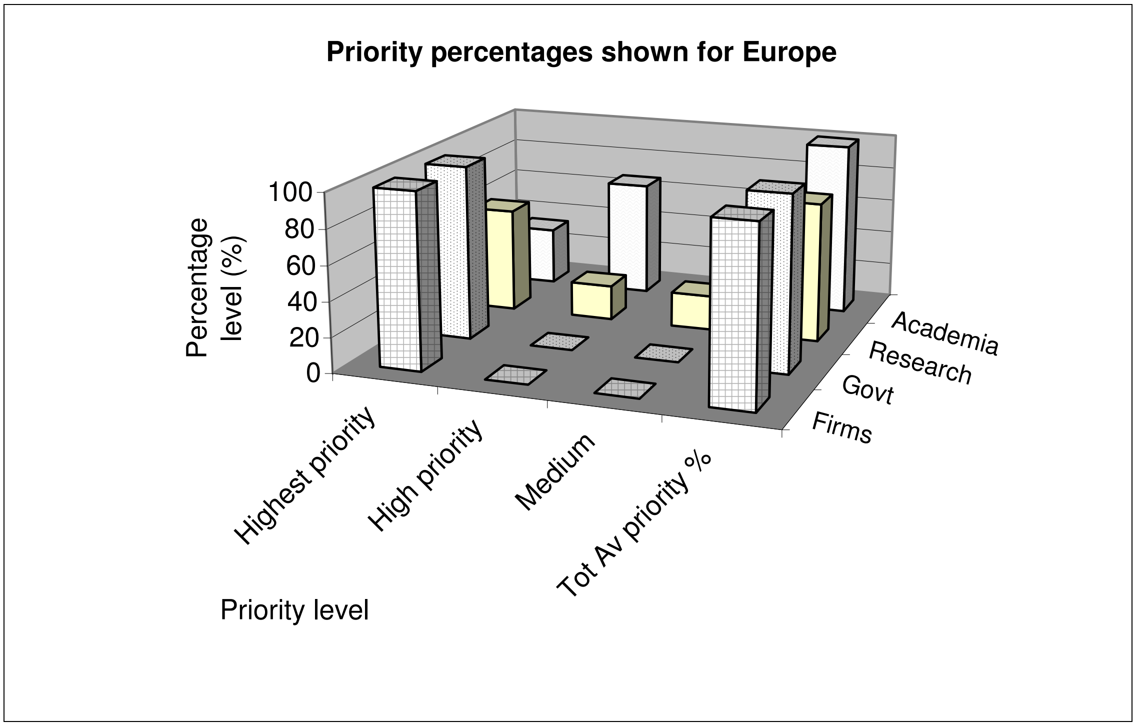

Figure (iv)35 Percentages for Europe as priority for business market by South African aircraft industry

The second highest score of **69%** (*Highest priority*) on total responses was obtained for UK, with a difference of 2% when compared with the highest score (Europe). An obvious conclusion would be that the majority of respondents think that UK should also be the business focus area for South African aircraft firms. In this instance, *Firms*, *Government* and *Academia* had individual scores of 100% (*Highest priority*). A graphical representation of the scores is illustrated on Figure (iv)36.

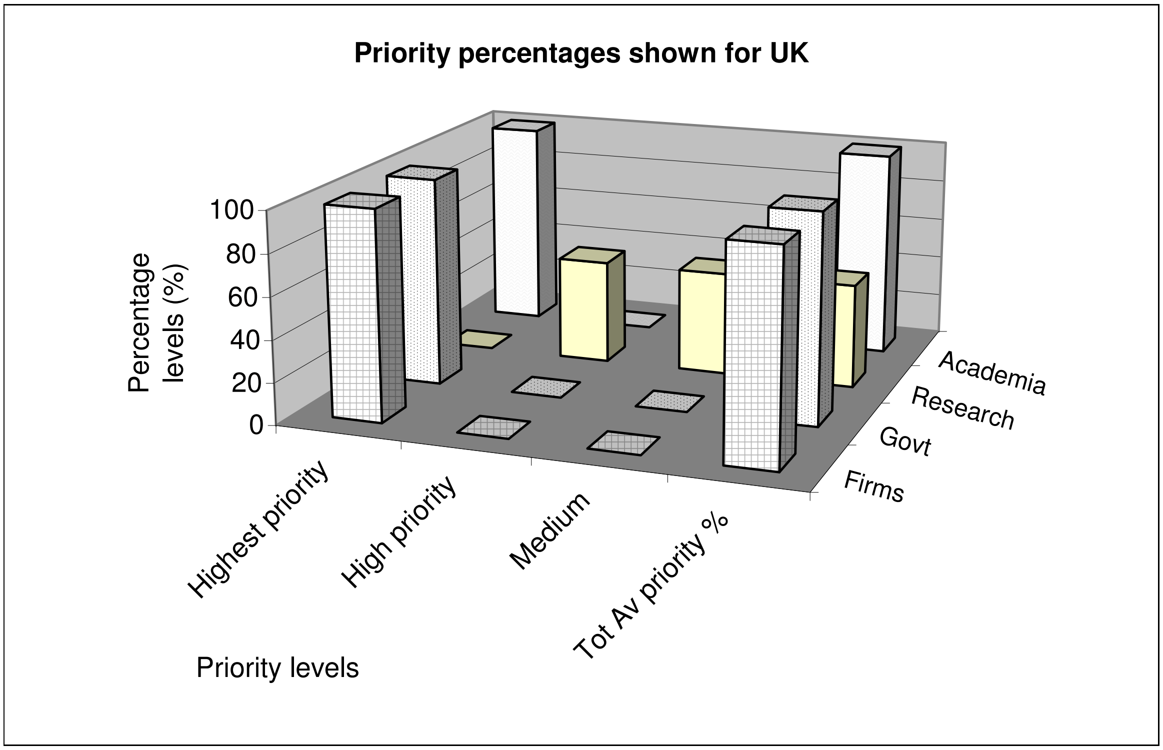

Figure (iv)36 Percentages for UK as priority for business market by South African aircraft industry

In summary, total responses shown the highest score of **71%** (*Highest priority*) for Europe, followed by a score of 69% (*Highest priority*) for UK, then Africa at 54% (*Highest priority*), USA at 42% (*Highest priority*), Latin America at 10% (*Highest priority*) and Asia at 8% (*Highest priority*). A graphical representation of the scores is illustrated on Figure (iv)37.

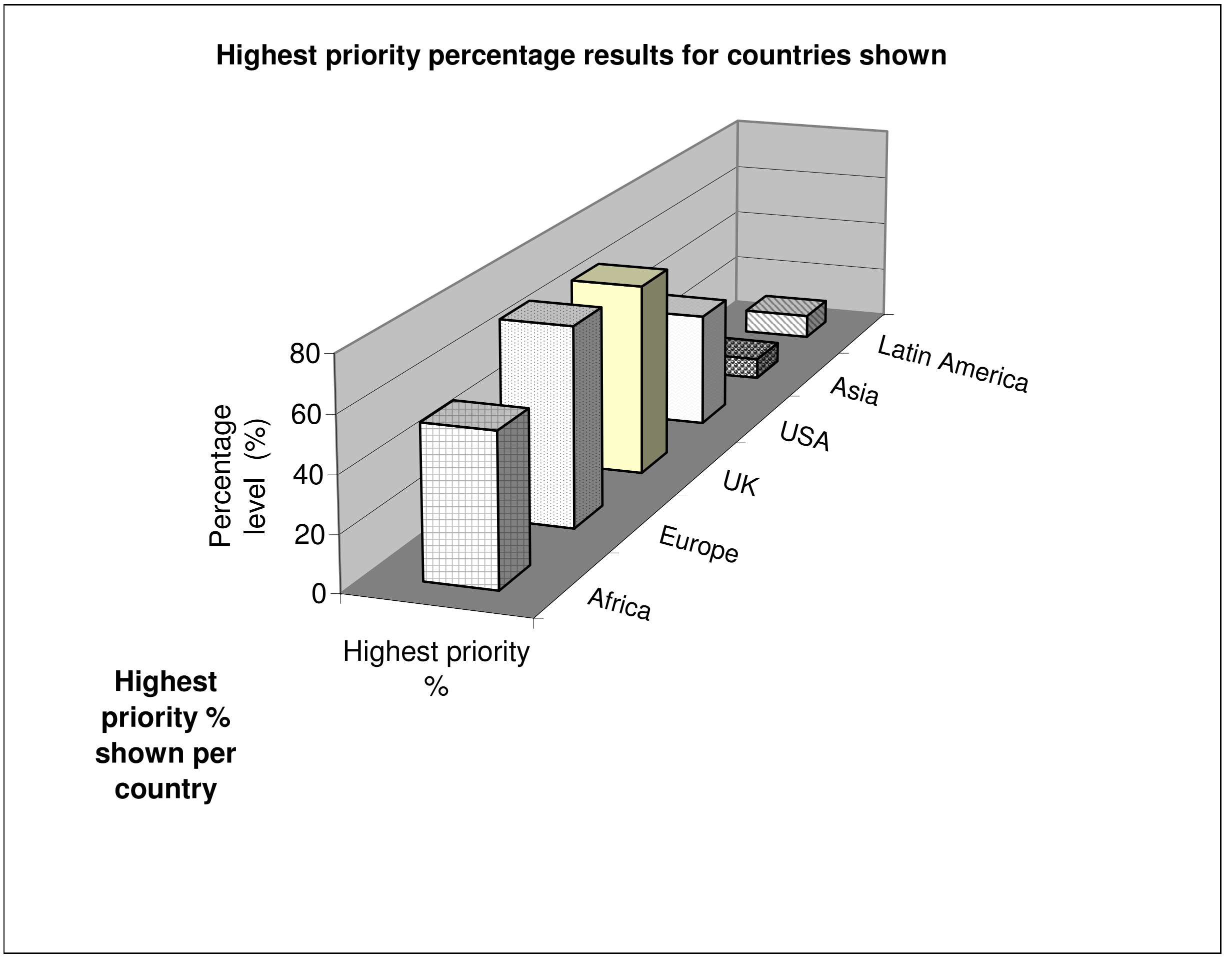

Figure (iv)37 Highest priority percentages for countries/continents of focus by South African aircraft industry to develop market

13. To what extent do you agree or disagree with the following statements?

A. Inter-firm collaboration can enhance technology & business capability development within South African aircraft firms through skills transfer, joined investment and learning from each other.

On this statement the highest score for total respondents was on *Agree* (**53%**), followed by *Strongly agree* (40%). *Government* scored 100% on *Strongly agree*. *Firms* and *Academia* both agree, with individual scores of 75% each on *Agree*. A graphical representation of the scores is illustrated on Figure (iv)38.

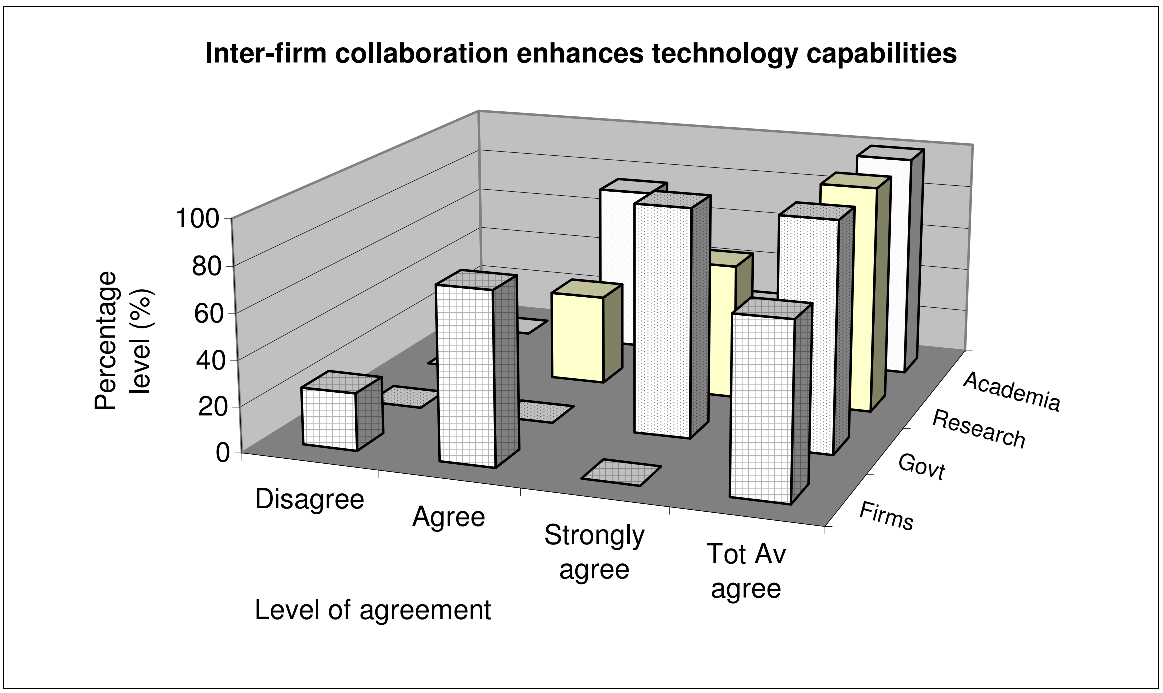

Figure (iv)38 Level of agreement on Statement A: "Inter-firm collaboration enhances technology capabilities ….".

B. Government interventions are necessary for business acquisition and improved market access by South African aircraft firms.

On this statement the highest score for total respondents was equal for both *Strongly agree* (**50%**) and *Agree* (**50%**). *Government* scored 100% on *Strongly agree*, with *Firms* scoring 75% on the same (*Strongly agree*). *Academia* scored 80% on *Agree*. A graphical representation of the scores is illustrated on Figure (iv)39.

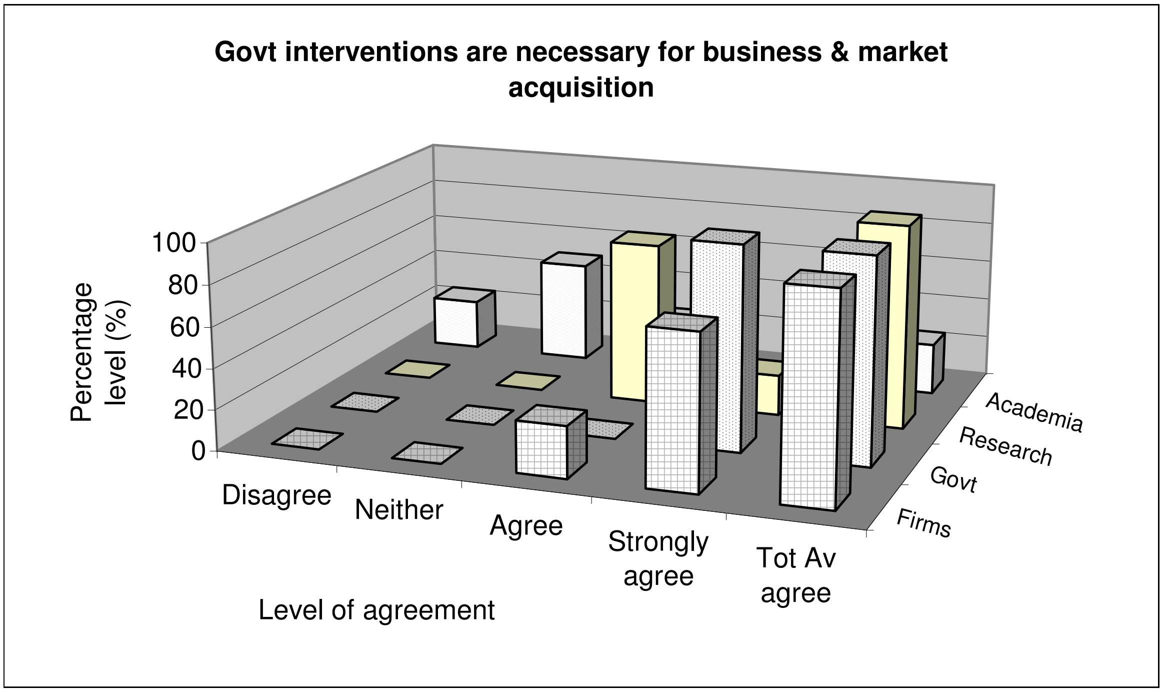

Figure (iv)39 Level of agreement on Statement B: "Government interventions are necessary for business acquisition …".

C. R&D programme, in line with applied technology development could improve the technology base of the South African aircraft industry.

For this statement the highest score on total respondents was **80%** on *Strongly agree*. Both *Government* and *Research institutions* had individual scores of 100% each on *Strongly agree*, with *Firms* scoring 75% on the same (*Strongly agree*). The graphical representation of the scores is illustrated on Figure (iv)40.

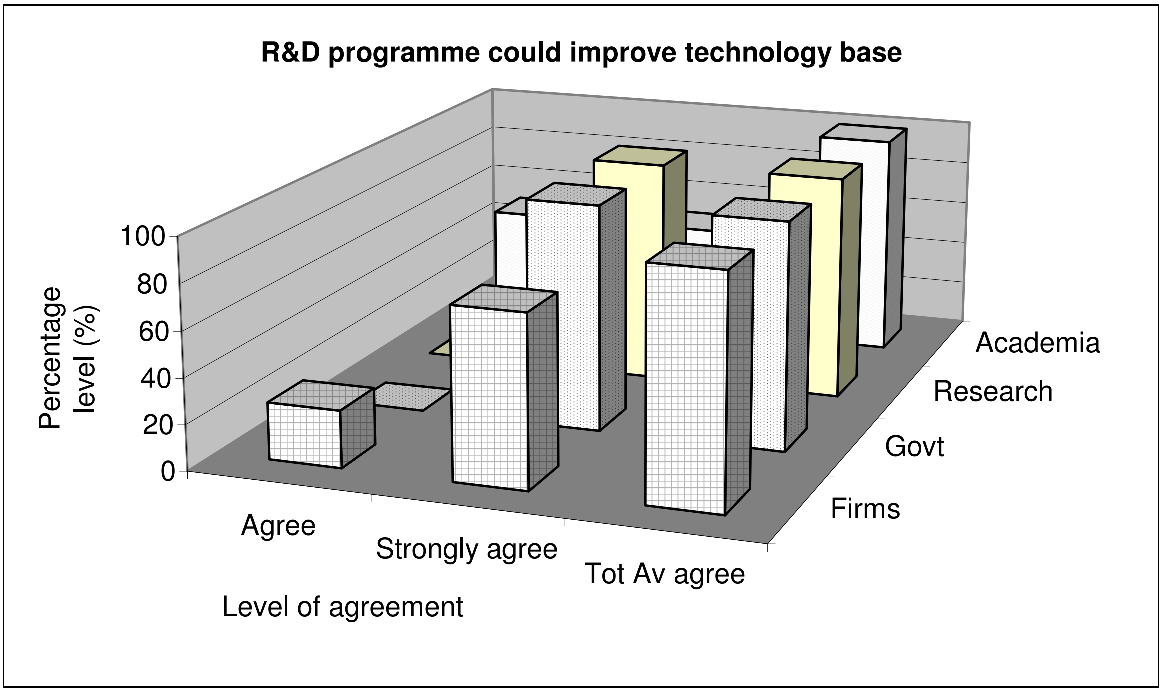

Figure (iv)40 Level of agreement on Statement C: "R&D programme could improve technology base …."

D. Technology transfer would be key towards development of technology capabilities, improved innovation and competitiveness of South African aircraft industry.

The highest score for total respondents was equal on both *Strongly agree* (**47%**) and *Agree* (**47%**). *Government* scored 100% on *Strongly agree*, with *Firms* scoring 50% on both categories of *Strongly agree* and *Agree*. *Academia* scored 75% on *Agree*. A graphical representation of the scores is illustrated on Figure (iv)41.

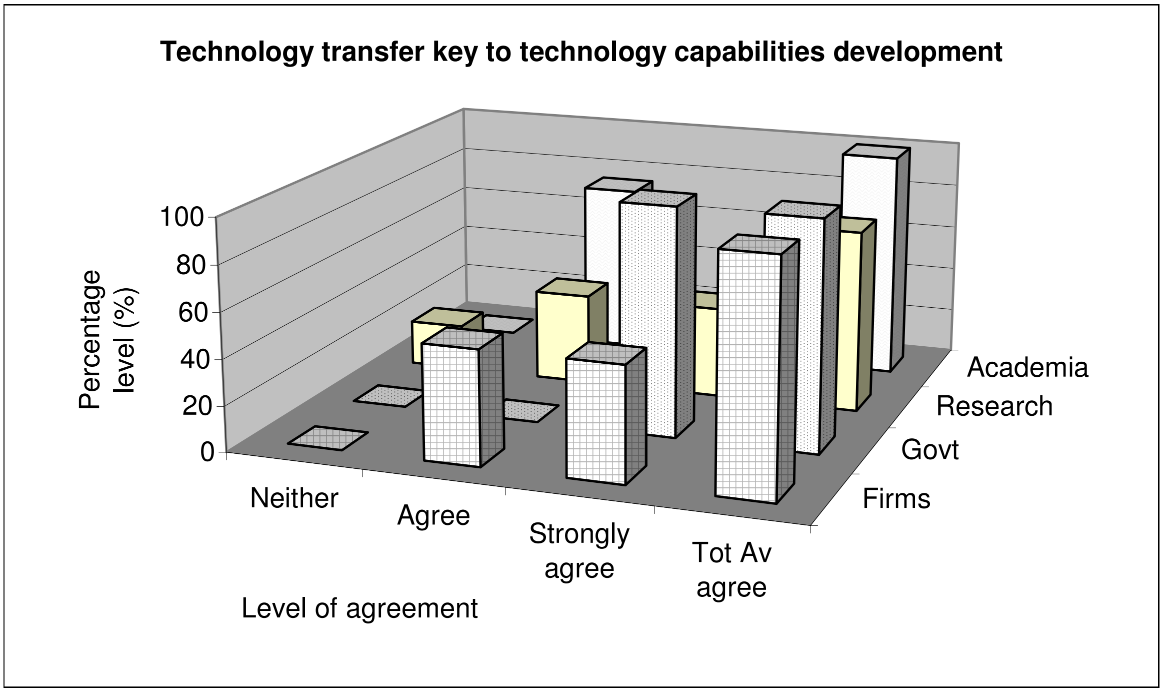

Figure (iv)41 Level of agreement on Statement D: "Technology transfer would be key to development of technology capabilities …"

E. South African firms should form joint ventures with global firms to have improved technology and business development capabilities, as well as better market accessibility.

Total respondents had a score of **60%** on *Strongly agree*, and 40% on *Agree*. *Government* still had a 100% score on *Strongly agree*, followed by *Research institutions* with 60% (*Strongly agree*). When *Strongly agree* and *Agree* are combined, all individual respondents had 100% as average for agreeing. The graphical representation of the results is illustrated on Figure (iv)42.

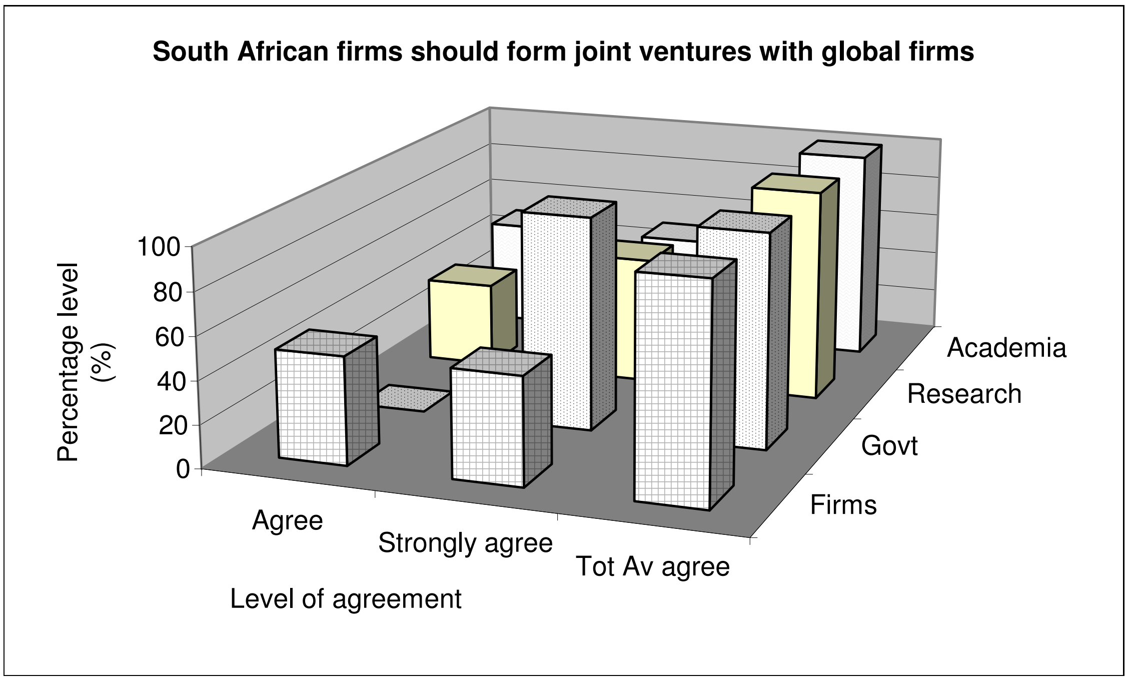

Figure (iv)42 Level of agreement on Statement E: "South African firms should form joint ventures with global firms .....".

F. Collaborative efforts from academia, research institutions, firms and government are essential for enhancing innovation and technology development within the aircraft industry.

For this statement the highest score on total respondents was **80%** on *Strongly agree*. Both *Government* and *Research institutions* had individual scores of 100% each on *Strongly agree*, with *Firms* scoring 50% on the same (*Strongly agree*). *Academia* scored 75% on the same (*Strongly agree*). The graphical representation of the scores is illustrated on Figure (iv)43.

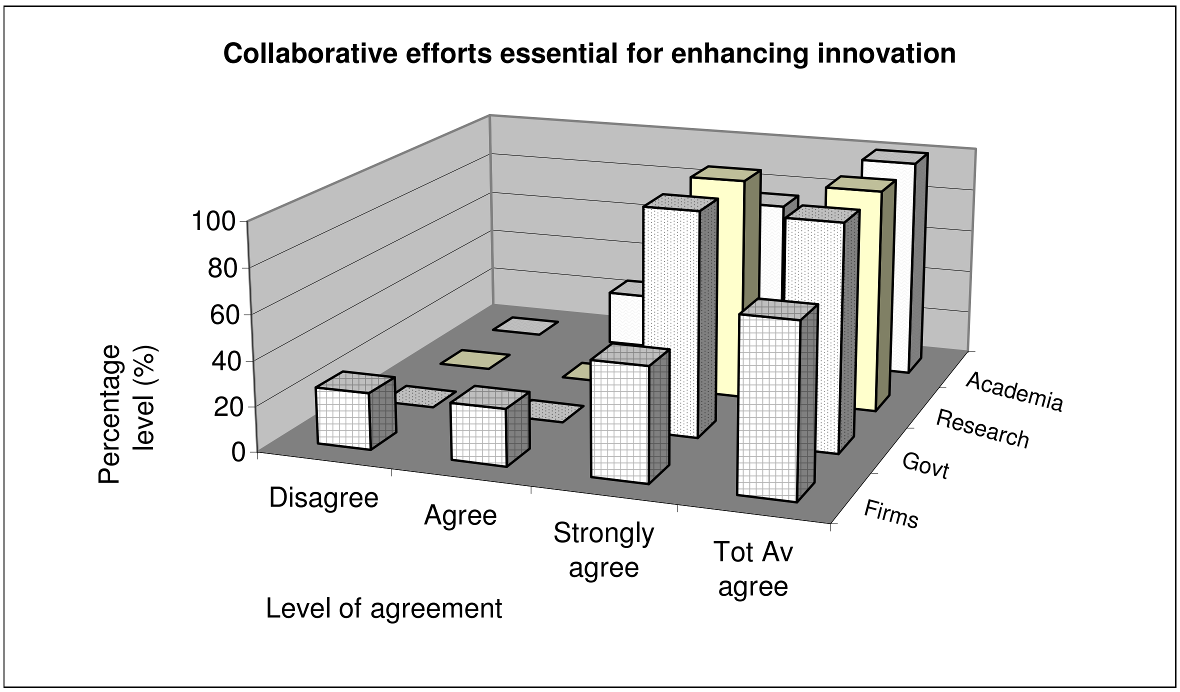

Figure (iv)43 Level of agreement on Statement F: "Collaborative efforts from academia, research institutions, firms and government key to enhancing innovation ……".

G. South African government should collaborate with governments from other countries on major projects so as to facilitate development and market access for South African aircraft firms.

Total respondents had a score of **60%** on *Strongly agree*, and 33% on *Agree*. Both *Firms* and *Government* had a 100% score on *Strongly agree*. Figure (iv)44 illustrates the findings.

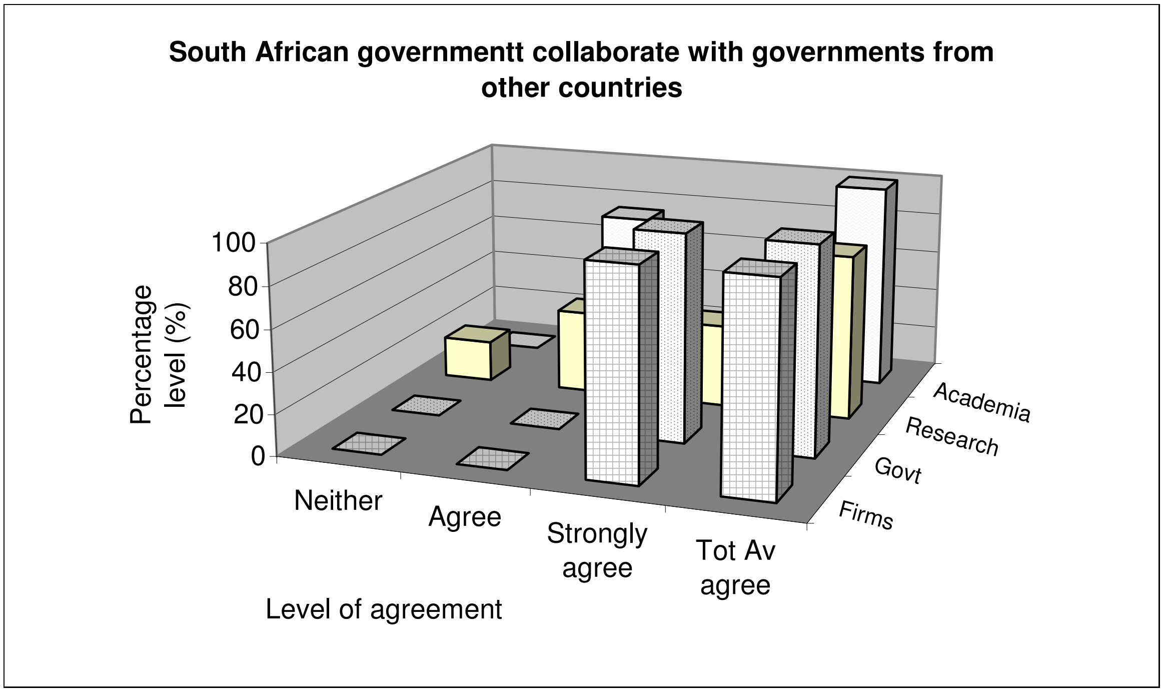

Figure (iv)44 Level of agreement on Statement G: "South African government should collaborate with government from other countries …".

In all statements grouped together, on total respondents, Statement **C** *(R&D programme, in line with applied technology development could improve the technology base of the South African aircraft industry Research and development)* had the highest score of **80%** on *Strongly agree*, and 20% on *Agree*. Statement **F** *(Collaborative efforts from Academia, Research institutions, Firms and Government are essential for enhancing innovation and technology development within the aircraft industry)* also had the highest score of **80%** on *Strongly agree*, but only 13% on *Agree*. Statement **E** *(South African firms should form joint ventures with global firms to have improved technology* *and business development capabilities, as well as better market accessibility)* had the second highest score of **60%** on *Strongly agree*, and 40% on *Agree*. Statement **G** *(South African government should collaborate with government from other countries on major projects so as to facilitate development and market access for South African aircraft firms)* also had the second highest score of **60%** on *Strongly agree*, but only 33% on *Agree*.

14. For technology development to improve within the civil aircraft industry, the following should be established:

a) Research and technology development programme

For this aspect total respondents had a score of **60%** on *Highest priority*, with *Government* and *Academia* scoring 100% each on the same (*Highest priority*). *Firms* scored 50% on *High priority*.

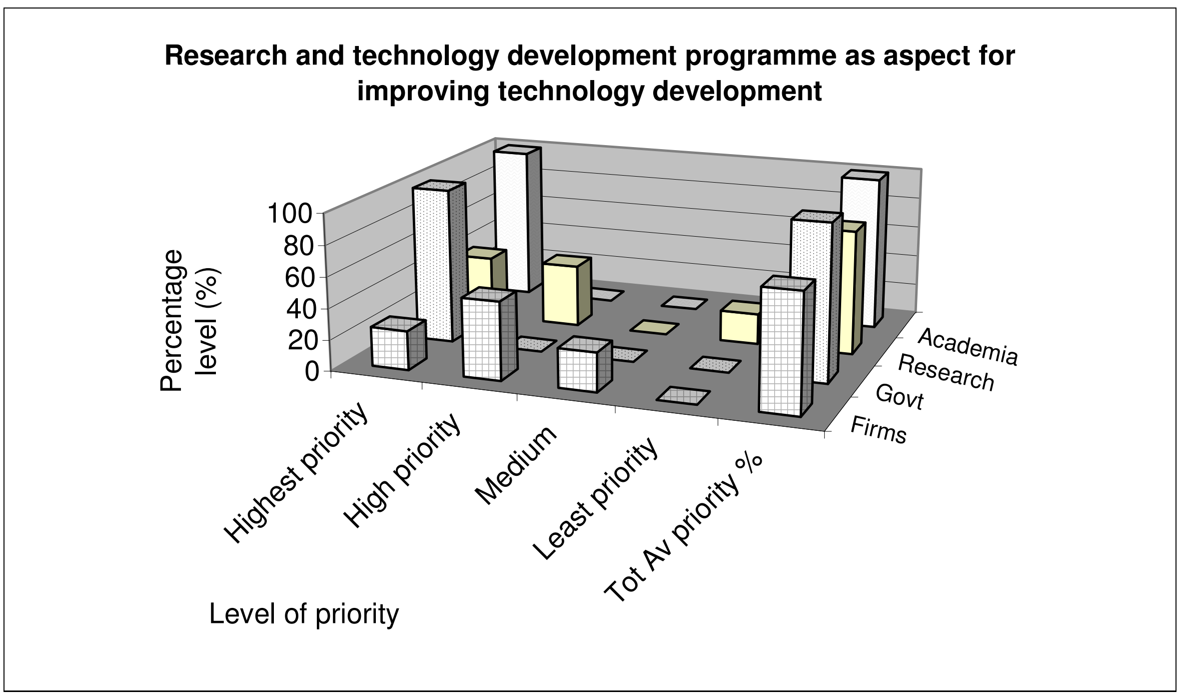

Figure (iv)45 Level of priority of "Research and technology development programme" as aspect for improving technology development

b) Firm Collaboration (national)

The total respondents' score on *Highest priority* was low (**31%**), although *Government* had a score of 100% (*Highest priority*).

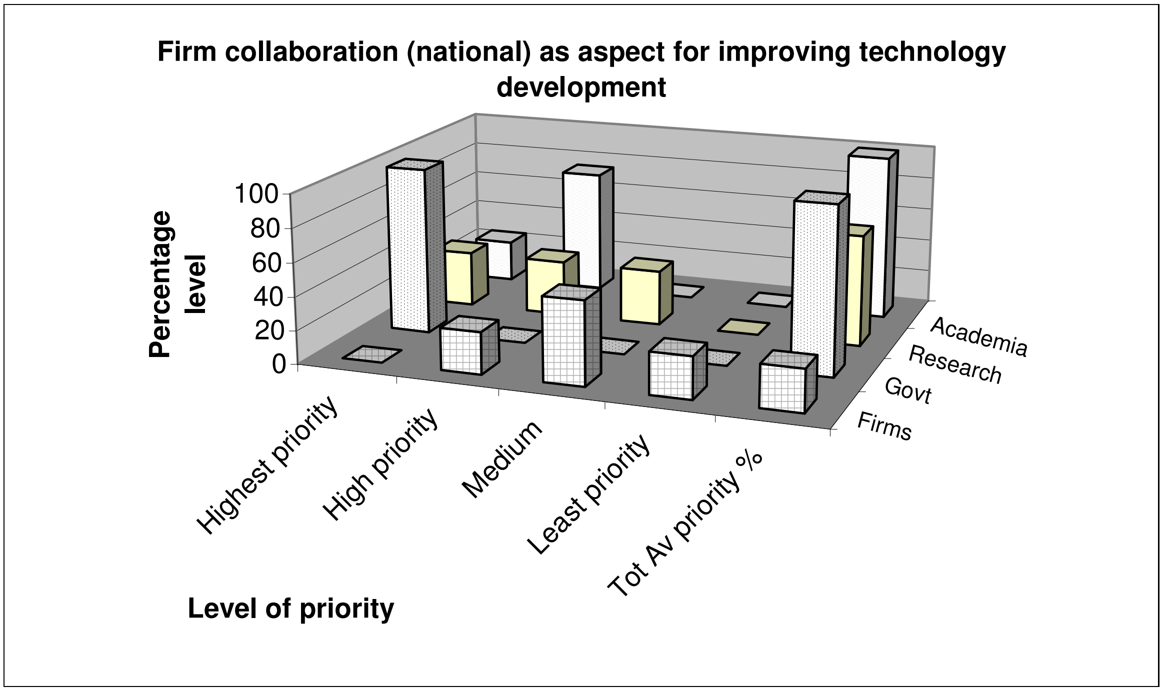

Figure (iv)46 Level of priority of "Firm collaboration (national)" as aspect for improving technology development

c) Firm collaboration (international)

A score of **46%** on *Highest priority* by total respondents was obtained. *Government* had 100% score on *Highest priority*, with *Firms* scoring 75% on same (*Highest priority*).

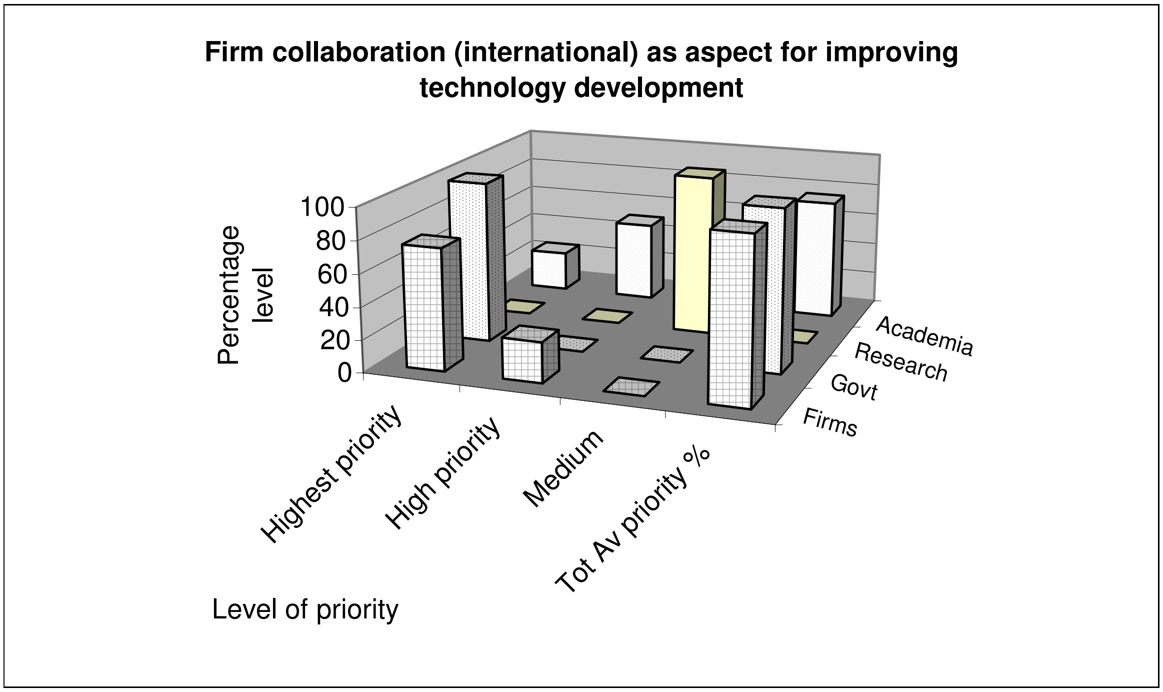

Figure (iv)47 Level of priority of "Firm collaboration (international)" as aspect for improving technology development

d) Aircraft-related research institutes

A score of **54%** on *Highest priority* by total respondents was obtained. Both *Government* and *Academia* had individual scores of 100% each on *Highest priority*. *Firms* found this aspect to be of *Medium priority* (50%).

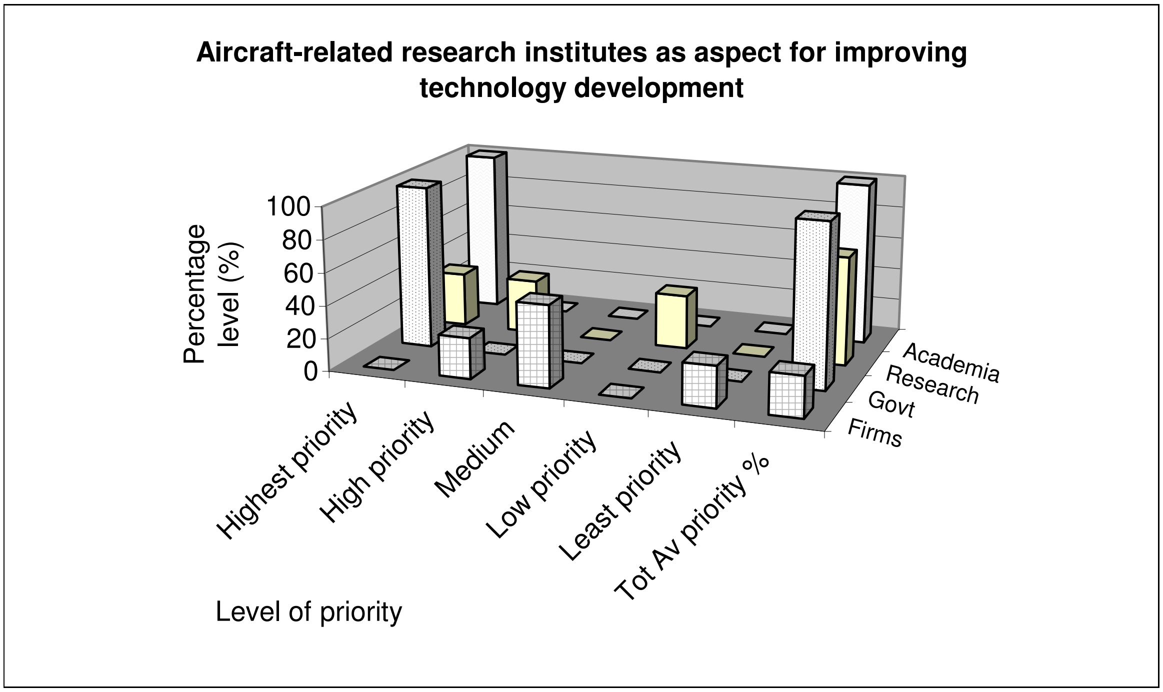

Figure (iv)48 Level of priority of "Aircraft-related research institutes" as aspect for improving technology development

e) Government support/involvement

For this aspect the highest score of **67%** by total respondents was obtained on *Highest priority*. Both *Firms* and *Government* had individual scores of 100% each on the same (*Highest priority*), with *Academia* scoring 75% (*Highest priority*).

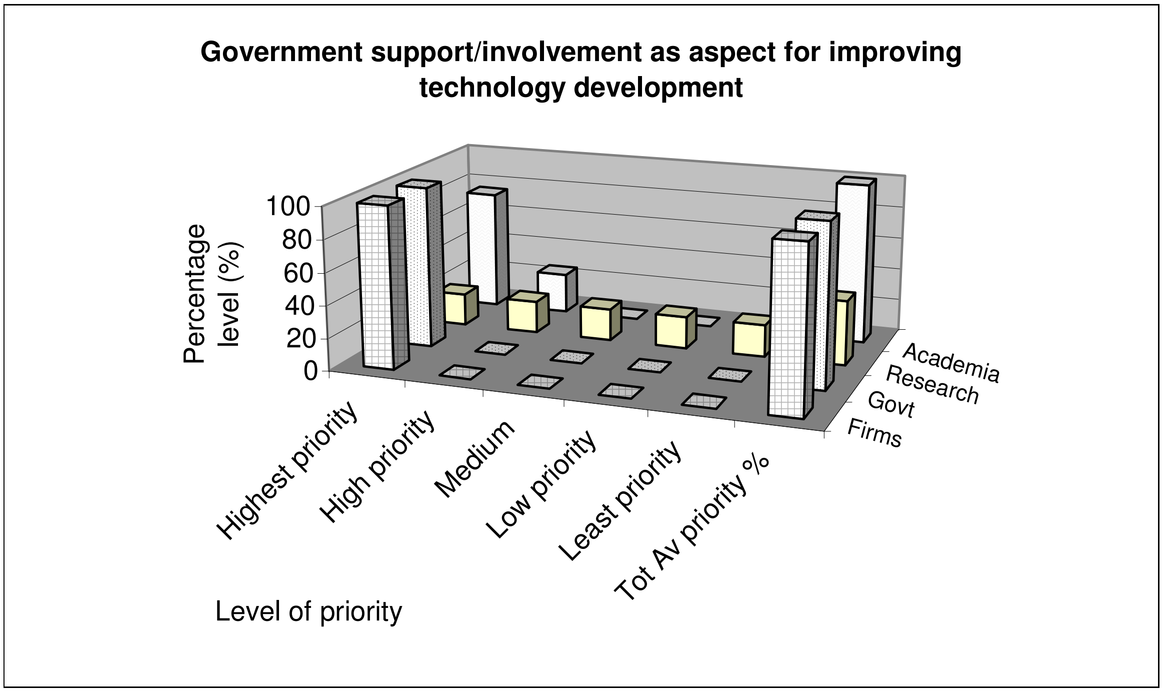

Figure (iv)49 Level of priority of "Government support/involvement" as aspect for improving technology development

f) Market acquisition assistance

The lowest score of **15%** by total respondents was obtained under *Highest priority*, indicating that this aspect is not of priority. *Firms*, *Government* and *Academia* scored 50% on *High priority*.

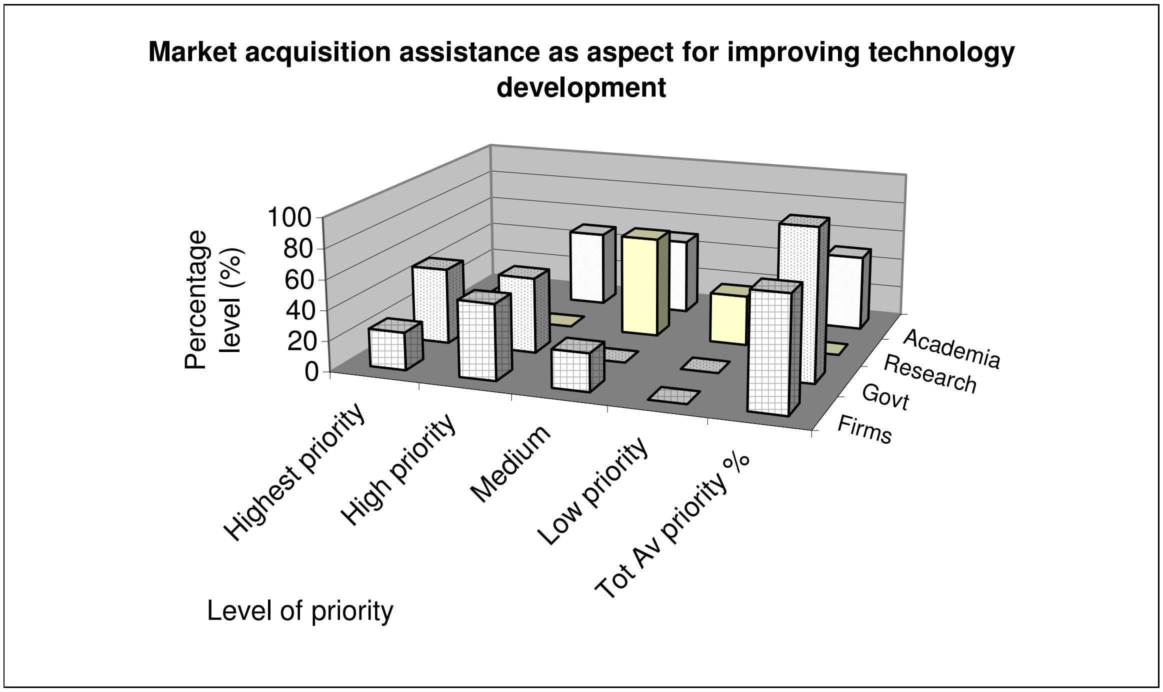

Figure (iv)50 Level of priority of "Market acquisition assistance" as aspect for improving technology development

g) Research collaboration (government, research institutes, academia, firms)

A score of **54%** on *Highest priority* by total respondents was obtained. *Government* had a 100% score (on *Highest priority*), with *Academia* scoring 75% (*Highest priority*). *Firms* found this aspect to be of *High priority* (50%).

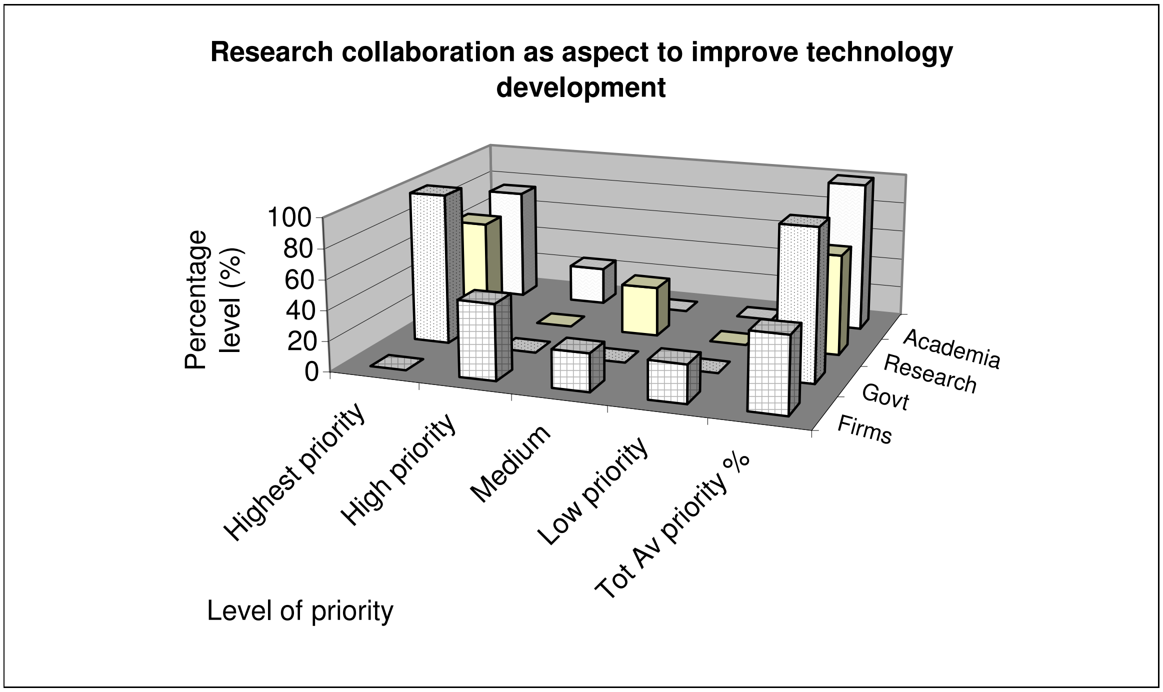

Figure (iv)51 Level of priority of "Research collaboration" as aspect for improving technology development

h) Technology transfer

A score of **50%** by total respondents was obtained under *Highest priority*, with *Government* scoring 100% on same (*Highest priority*). *Firms* found this aspect to be of *High priority* (67%).

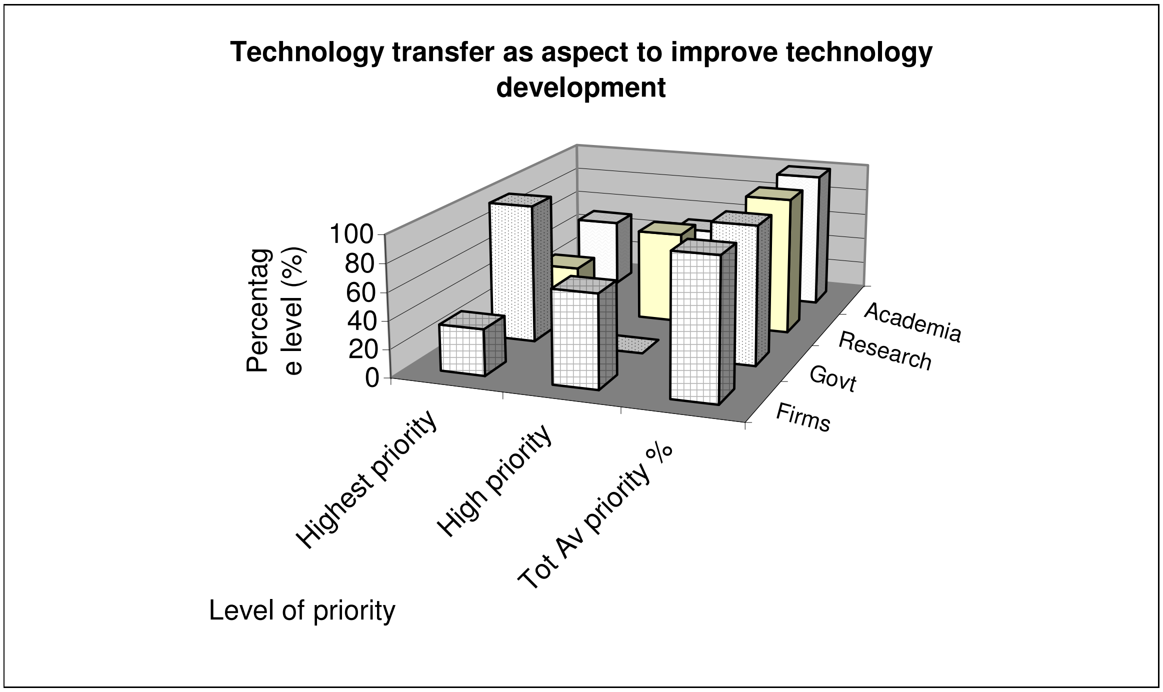

Figure (iv)52 Level of priority of "Technology transfer" as aspect for improving technology development

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i) Skills development

A score of **60%** by total respondents was obtained under *Highest priority*, with *Government* scoring 100% (*Highest priority*) and *Academia* 75% (*Highest priority*). *Firms* found the aspect to be of *High priority* (75%).

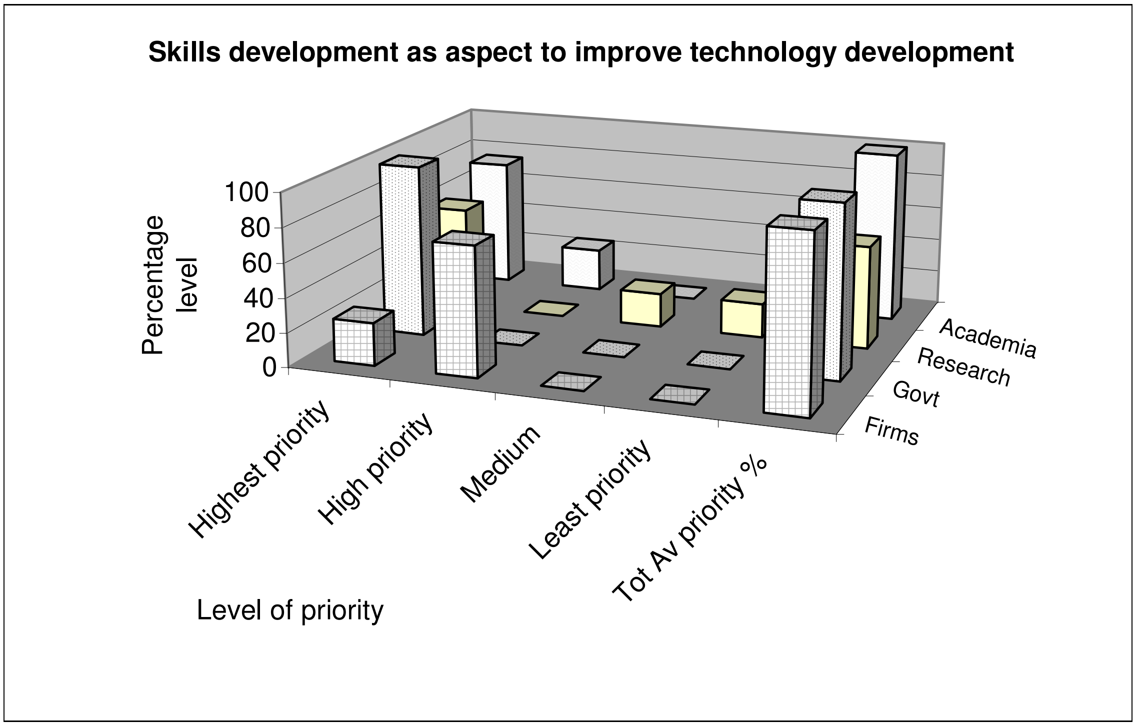

Figure (iv)53 Level of priority of "Skills development" as aspect for improving technology development

When all the factors are grouped together, on total respondents, the factor on *Government support/involvement* had the highest ranking (**67%** *Highest priority*), with *Firms* affirming the ranking with a score of 100% (*Highest priority*). Both factors on *Research and technology development programme* and *Skills development* had the second highest ranking (**60%** *Highest priority*). The difference is that *Firms* scored 50% (*High priority*) and 75% (*High priority*) respectively. The factors of *Research collaboration (government, research institutes, academia, firms)* and *Aircraft-related research institutes* both had the third highest ranking (**54%** *Highest priority*). The difference is also that *Firms* scored 50% (*High priority*) and 25% (*High priority*) respectively. The fourth ranked factor is *Technology transfer*, with **50%** (*Highest priority*), followed by

Firm collaboration (international) that scored **46%** (*Highest priority*), then *Firm collaboration (national)* at **31%** (*Highest priority*), last factor being *Market acquisition assistance* (**15%** *Highest priority*).

15. The following are assumed to be the factors hampering business acquisition and technology capability-building for South African civil aircraft firms:

Responses were obtained on the following list of factors:

A. Highly regulated environment (global & local)
B. Insufficient financial resources
C. Inadequate skilled resources
D. Lack of appropriate technologies
E. Projects too costly
F. Poor strategic alliances or networks
G. Not meeting customers' demands
H. Insufficient government support
I. Insufficient experience in global supply
J. Negative perception by global customers on quality of products

The factor that obtained the highest score on total responses was **C** *(Inadequate skilled resources),* with **40%** (*Strongly agree*). *Firms* also had the highest individual score (75%) on *Strongly agree*. A graphical representation of the scores is illustrated on Figure (iv)54.

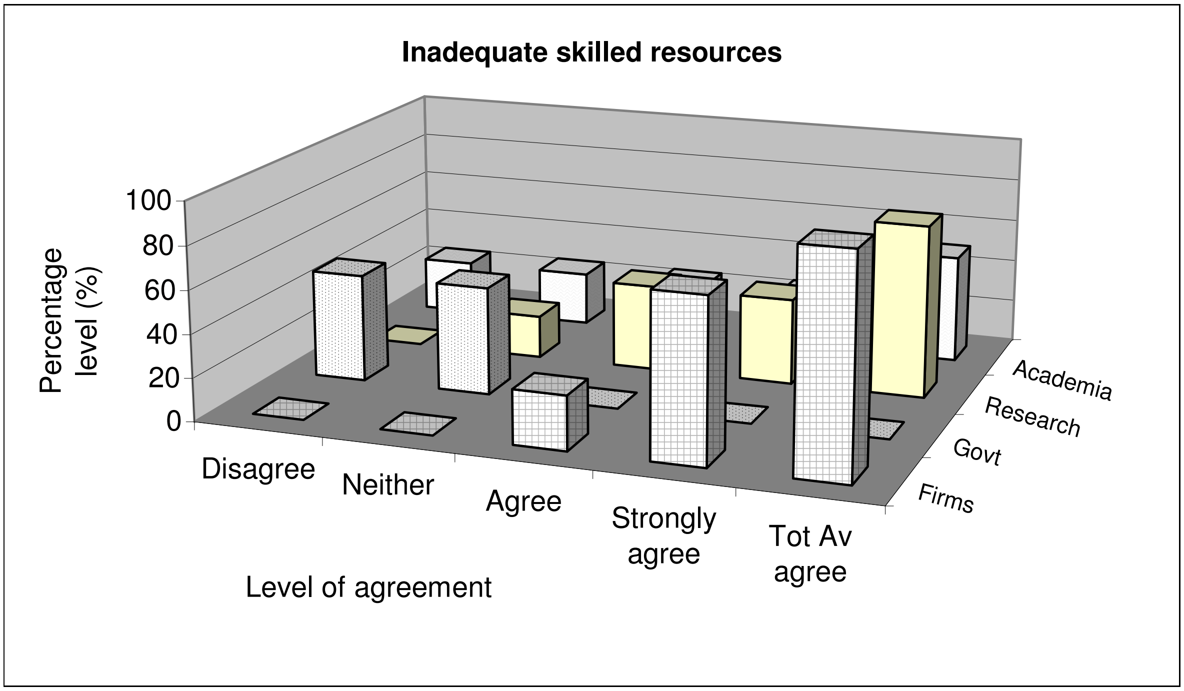

Figure (iv)54 Level of agreement on "Inadequate skilled resources" as a factor hampering business acquisition and technology development

Factors **I** *(Insufficient experience in global supply)* and **A** *(Highly regulated environment – global and local)* obtained the second highest score of **33%** (*Strongly agree*) on total responses. What separates them is that factor I had a further 40% (*Agree*) whereas factor A had 27% (*Agree*). *Firms* also scored 100% (*Agree*) on factor I, with factor A scoring 50% (*Agree*) by *Firms*. Graphical representations of the scores for factors I and A are illustrated on Figures (iv)55 and (iv)56 respectively.

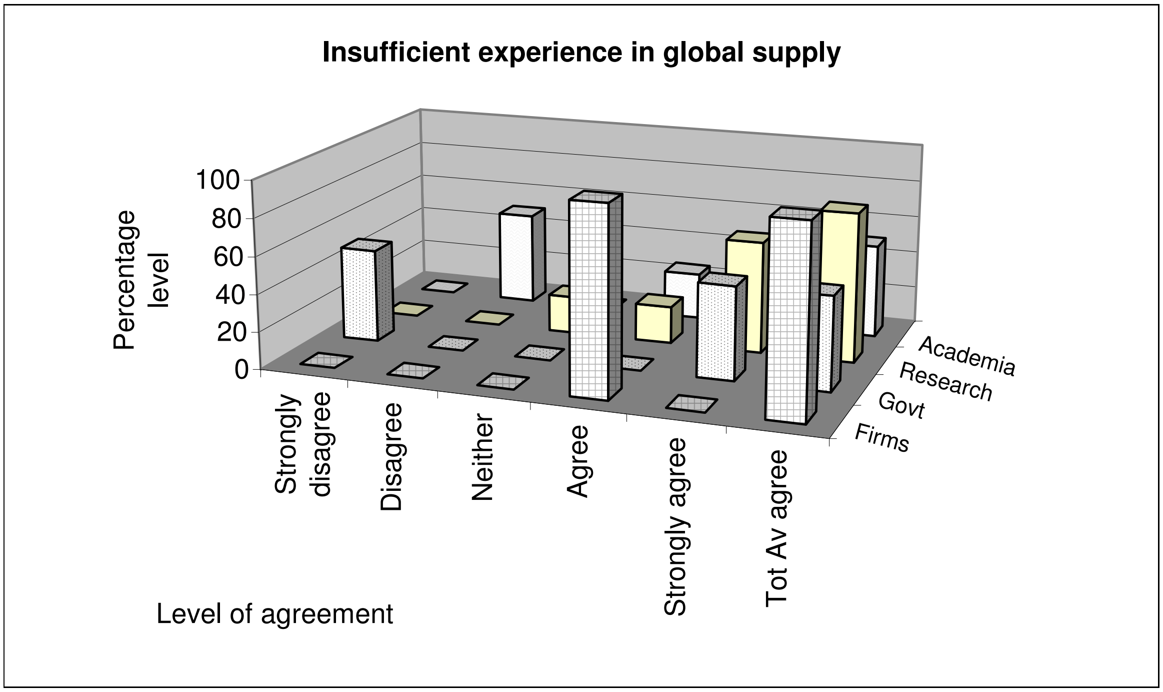

Figure (iv)55 Level of agreement on "Insufficient experience in global supply" as a factor hampering business acquisition and technology development

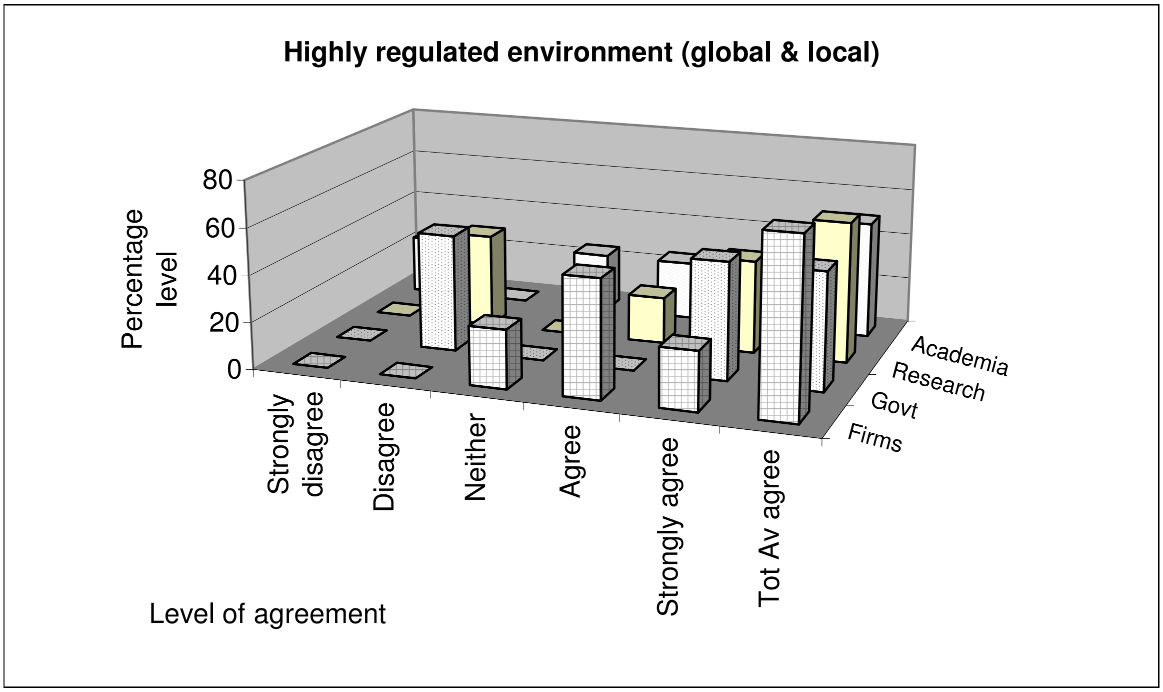

Figure (iv)56 Level of agreement on "Highly regulated environment" as a factor hampering business acquisition and technology development

Third highest score of **27%** (*Strongly agree*) was obtained for both factors **B** (*Insufficient financial resources)* and **F** *(Poor strategic alliances or networks)* on total responses. Factor B had a further 47% (*Agree*) with factor F scoring 33% (*Agree*). For factor B, *Firms* scored 25% (*Strongly agree*) with a further 50% (*Agree*). For factor F, *Firms* scored only 50% (*Agree*), nothing on *Strongly agree*.

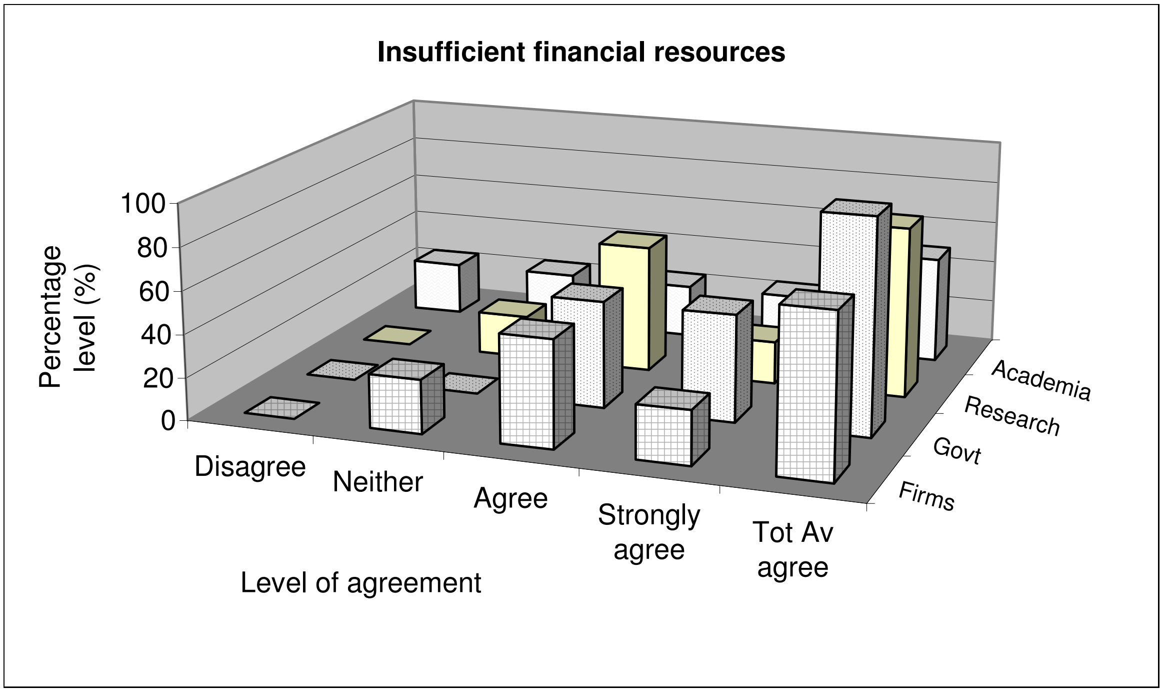

Figure (iv)57 Level of agreement on "Insufficient financial resources" as a factor hampering business acquisition and technology development

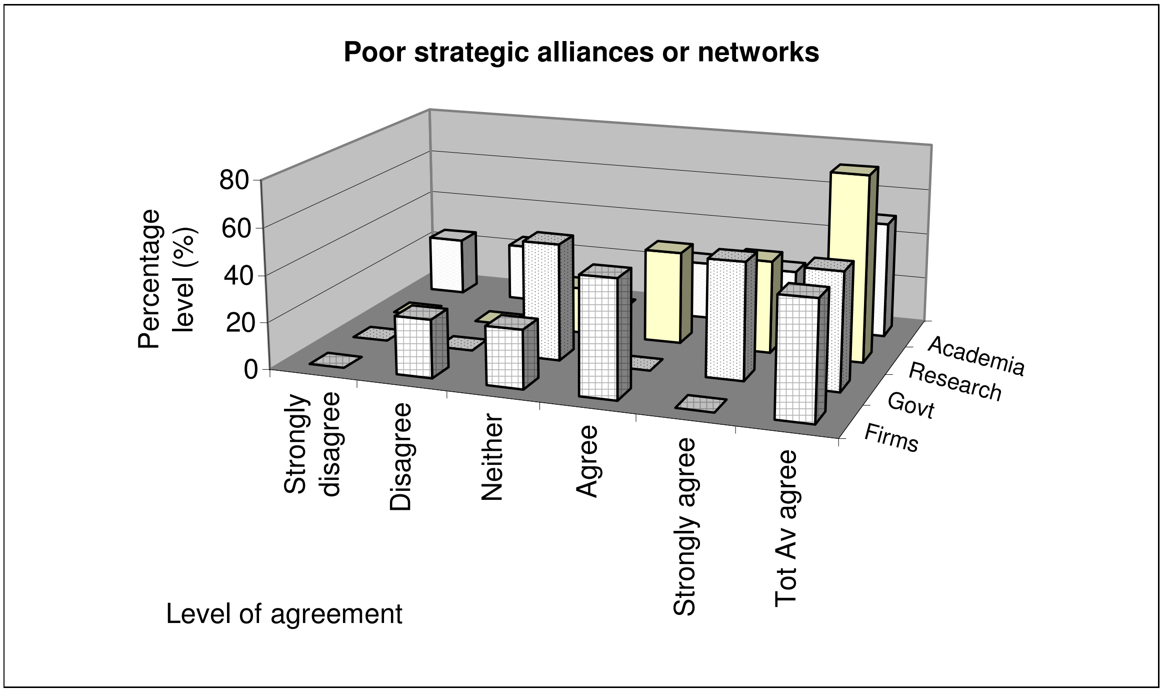

Figure (iv)58 Level of agreement on "Poor strategic alliances or networks" as a factor hampering business acquisition and technology development

Fourth highest score of **13%** (*Strongly agree*) was obtained for factors **E** (*Projects too costly),* **G** (*Not meeting customers' demands*) and **J** (*Negative perception by global customers on quality of products*) on total responses. Both factors E and J had a further 40% (*Agree*) with factor G scoring 27% (*Agree*). For factors E and J, *Firms* scored 75% (*Agree*), whereas for factor F, *Firms* scored only 25% (*Agree*).

Factor **D** (*Lack of appropriate technologies*) followed on total responses with a score of **7%** (*Strongly agree*) and a further 40% (*Agree*). *Firms* had 50% on *Agree*.

Factor **H** (*Insufficient government support*) was last, with nothing on Strongly agree but 40% (*Agree*) for the total responses. *Firms* only had 25% on *Agree*.

16. What are the existing competencies, capabilities, skills and technologies available within the South African aircraft industry?

Responses were obtained on the following list of specialty areas:

A. Aircraft maintenance skills (93% YES)

B. Aircraft conversions and modification skills (80% YES)

C. Manufacture of components and sub-system levels (93% YES)

D. Manufacture of composites, rotor wing propeller blades, gear-boxes (80% YES)

E. Specialists in avionics (80% YES)

F. Capabilities for interior designs (80% YES)

G. Design and manufacturing skills for helicopters (73% YES)

H. Manufacture of military aircraft (47% YES)

The results showed that all the specialty areas as listed above exist within the South African aircraft industry. Specialty Areas **A** *(Aircraft maintenance skills)* and **C** *(Manufacture of components and sub-system levels)* had the highest score of **93%** (YES) by total respondents. In both instances, *Firms*, *Government* and *Research institutions* had individual scores of 100% (YES).

Specialty Areas **B** (*Aircraft conversions and modification skills*), **D** (*Manufacture of composites, rotor wing propeller blades, gear-boxes*), **E** (*Specialists in avionics*) and **F** (*Capabilities for interior designs*) had the second highest score of **80%** (YES). For B, D and F, both *Firms* and *Government* had individual scores of 100% (YES). However, E scored 75% (YES) on responses by *Firms*.

Specialty Area **G** (*Design and manufacturing skills for helicopters*) followed with a **73%** (YES) score by total respondents. *Firms* had an individual score of 75% (YES).

Specialty Area **H** (*Manufacture of military aircraft*) scored **47%** (YES) by total respondents, thereby indicating that such a skill or competency is at very minimal levels if it does exist within the country. *Government* scored 100% (YES), with *Academia* scoring 75% (YES).

17. What would be the ideal key competencies, capabilities, skills and technologies needed for technology development within the South African civil aircraft industry?

Responses were obtained on the following list of elements:

A. Aircraft maintenance skills

B. Aircraft conversions and modification skills

C. Manufacture of components and sub-system levels

D. Manufacture of composites, rotor wing propeller blades, gear-boxes

E. Design and manufacturing of complete engines

F. Specialists in avionics

G. Capabilities for interior designs

H. Design and manufacturing skills for helicopters

I. Design and manufacturing skills for passenger aircraft

J. Full assembling skills for passenger aircraft

K. Civil-military technology linkages

Element **I** *(Design and manufacturing skills for passenger aircraft)* had the highest score by total respondents, where *Highest priority* obtained **82%.** Both *Government* and *Academia* had individual scores of 100% on *Highest priority*, with *Firms* scoring 75% on the same (*Highest priority*). The graphical representation of the results is shown on Figure (iv)59.

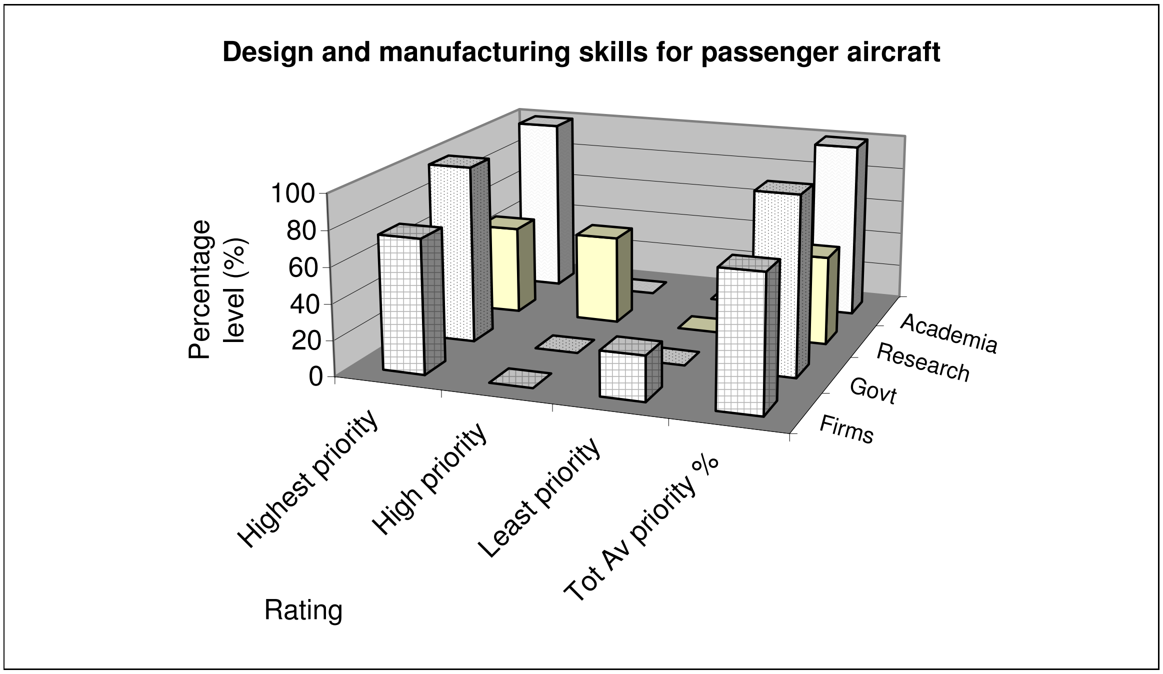

Figure (iv)59 Rating on "Design and manufacturing skills for passenger aircraft" as competency needed for technology development

Element **A** *(Aircraft maintenance skills)* had the second highest score by total respondents, where *Highest priority* obtained **67%**. Both *Firms* and *Government* had individual scores of 100% on *Highest priority*. The graphical representation of the results is shown on Figure (iv)60.

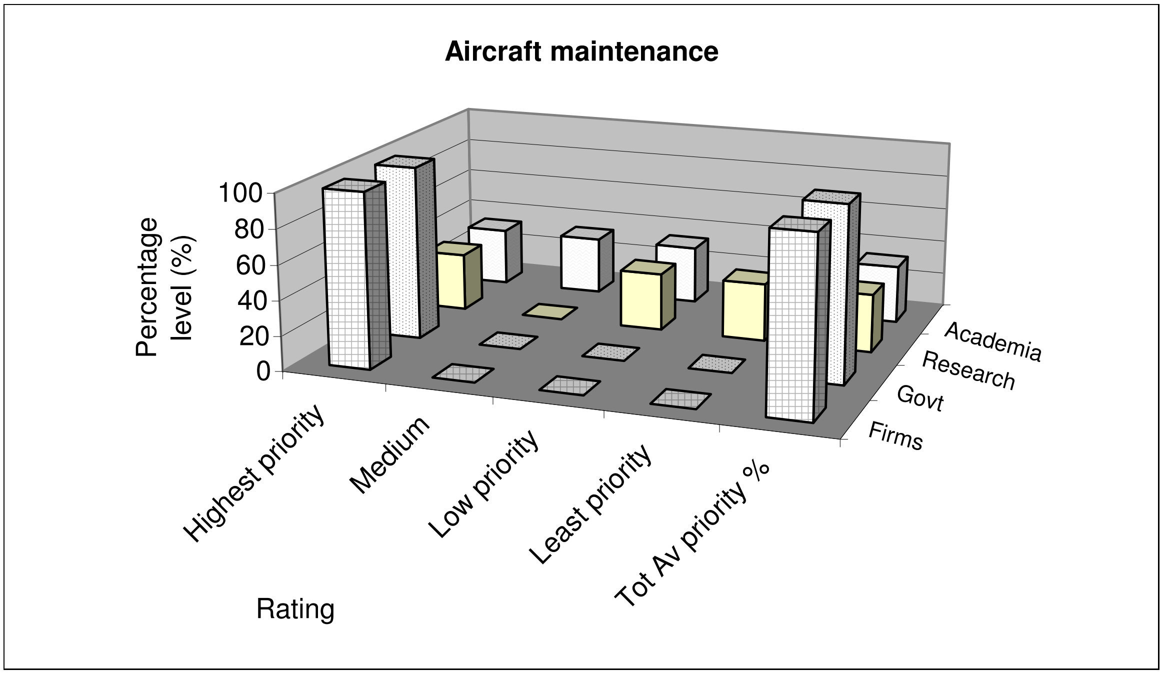

Figure (iv)60 Rating on "Aircraft maintenance" as competency needed for technology development

Element **C** (*Manufacture of components and sub-system levels)* followed with a score of **64%** on *Highest priority* by total respondents. Again, *Government* had a 100% score on *Highest priority*, with *Research institutions* scoring 80% (*Highest priority*) and *Firms* 50% (*Highest priority*). The graphical representation of the results is shown on Figure (iv)61.

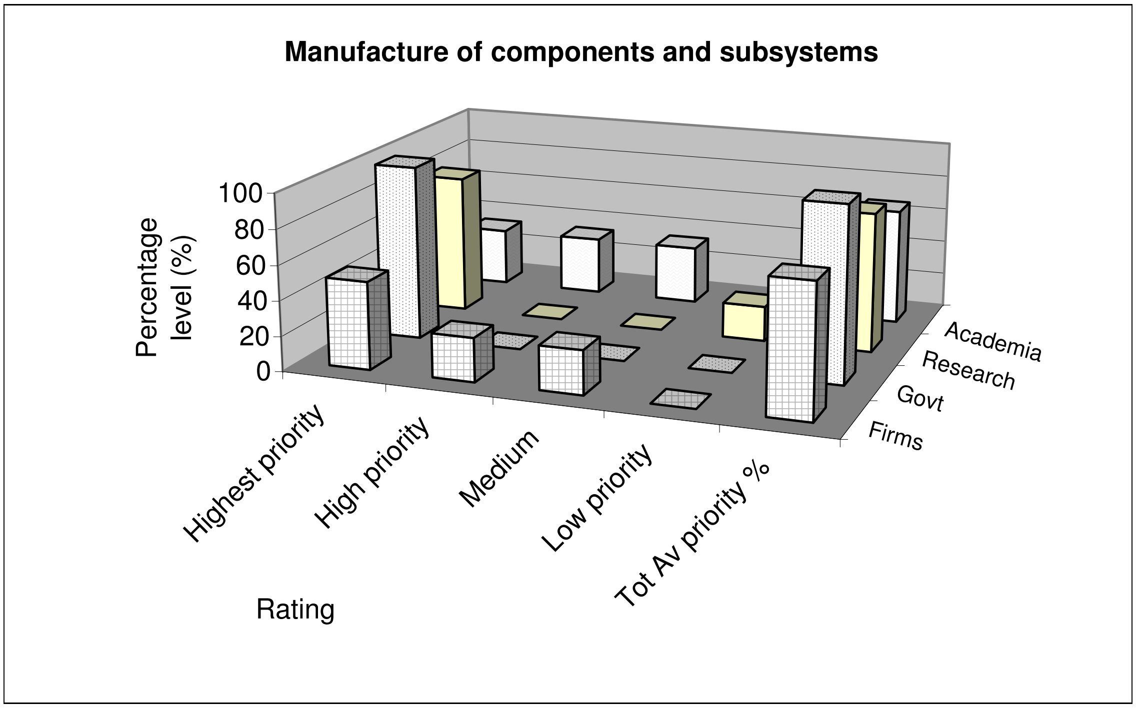

Figure (iv)61 Rating on "Manufacture of components and subsystems" as competency needed for technology development

Both Elements **K** (*Civil-military technology linkages)* and **J** (*Full assembling skills for passenger aircraft)* had the same score of **60%** *Highest priority* by total respondents. However, Element K had a further 40% score on *High priority* whereas Element J had 20% on same (*High priority*). For both Elements K and J, *Government* and *Research* had individual scores of 100% on *Highest priority*. The graphical representation of the results for both elements is shown on Figures (iv)62 and (iv)63.

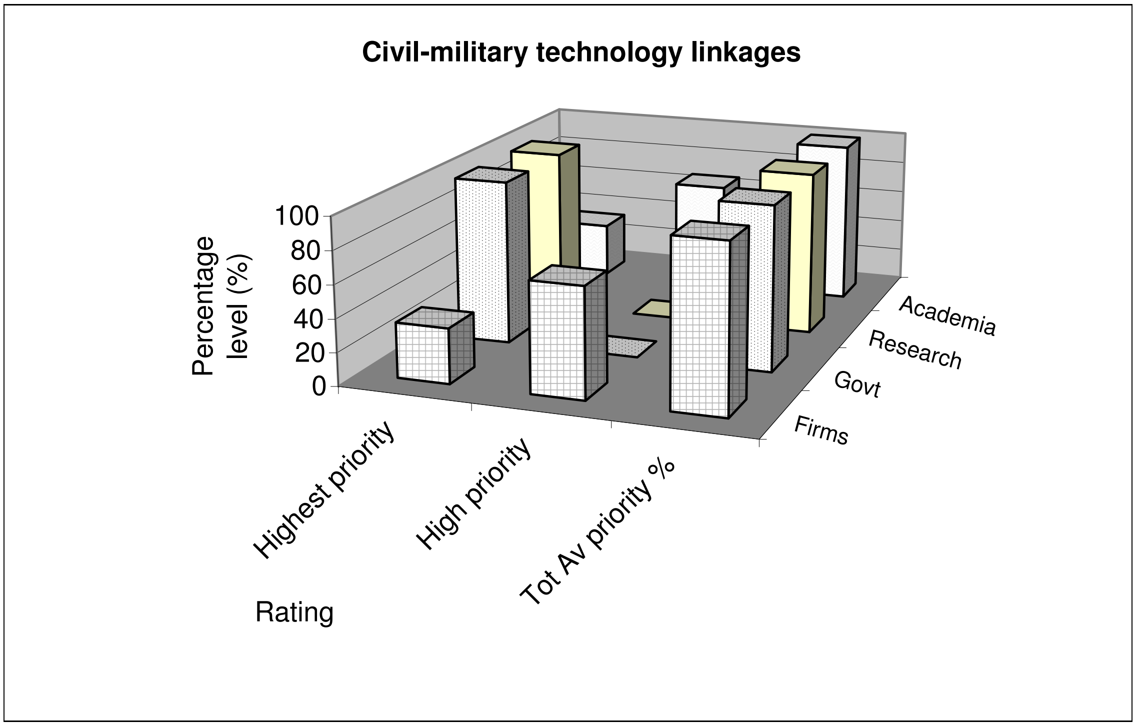

Figure (iv)62 Rating on "Civil-military technology linkages" as skill needed for technology development

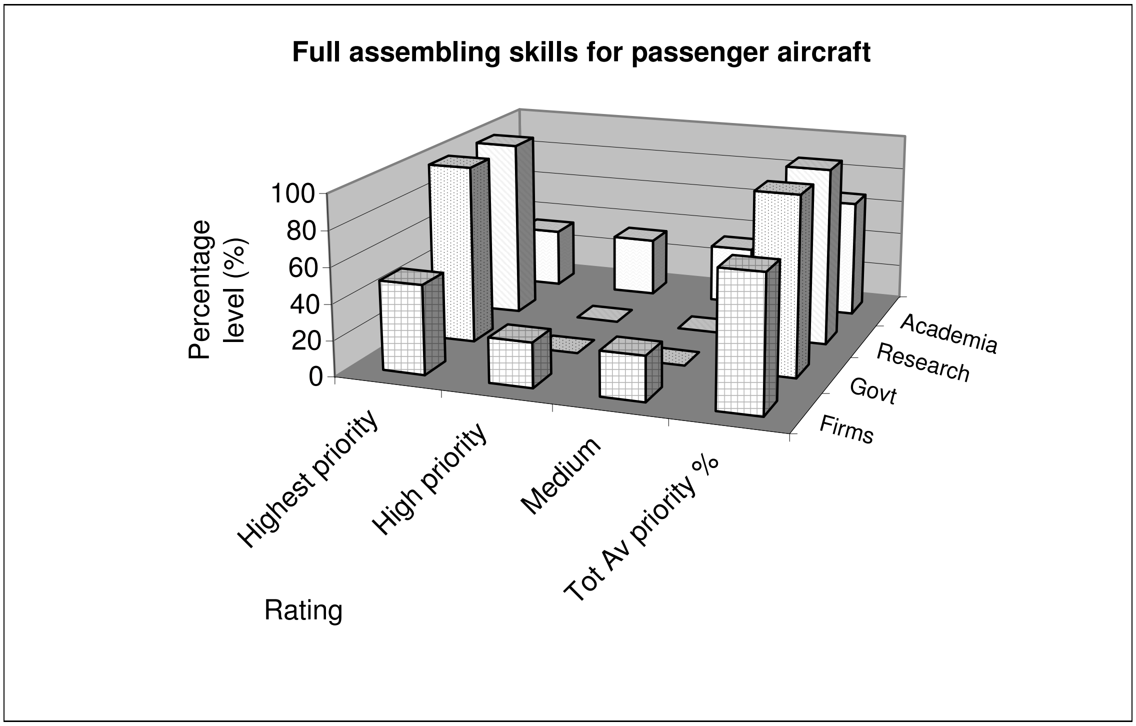

Figure (iv)63 Rating on "Full assembling skills for passenger aircraft" as skill needed for technology development

Element **F** (*Specialists in avionics*) had a score of **46%** on *Highest priority* by total respondents. Both Elements **B** (*Aircraft conversions and modification skills*) and **H** (*Design and manufacturing skills for helicopters*) scored **42%** on *Highest priority* by total respondents. They also had a further score of 17% each on *High priority*. Element **E** (*Design and manufacturing of complete engines*) had a score of **40%**, followed by Element **D** (*Manufacture of composites, rotor wing propeller blades, gear-boxes*) with **37%** (*Highest priority*). The last Element was **G** (*Capabilities for interior designs*) with **33%** on *Highest priority*.

18. How would you rate the current level of innovation in South Africa as compared to that of other successful organisations/institutions/firms in developing countries (South Korea, Japan, Brazil, etc) within the civil aircraft industry?

Score by total respondents on ***Poor*** is **57%**, indicating that the level of innovation in South Africa is poor when compared to other developing countries. 35% was scored on *Moderate*, and only 7% on *Strong*. *Firms* had a score of 75% on *Poor*.

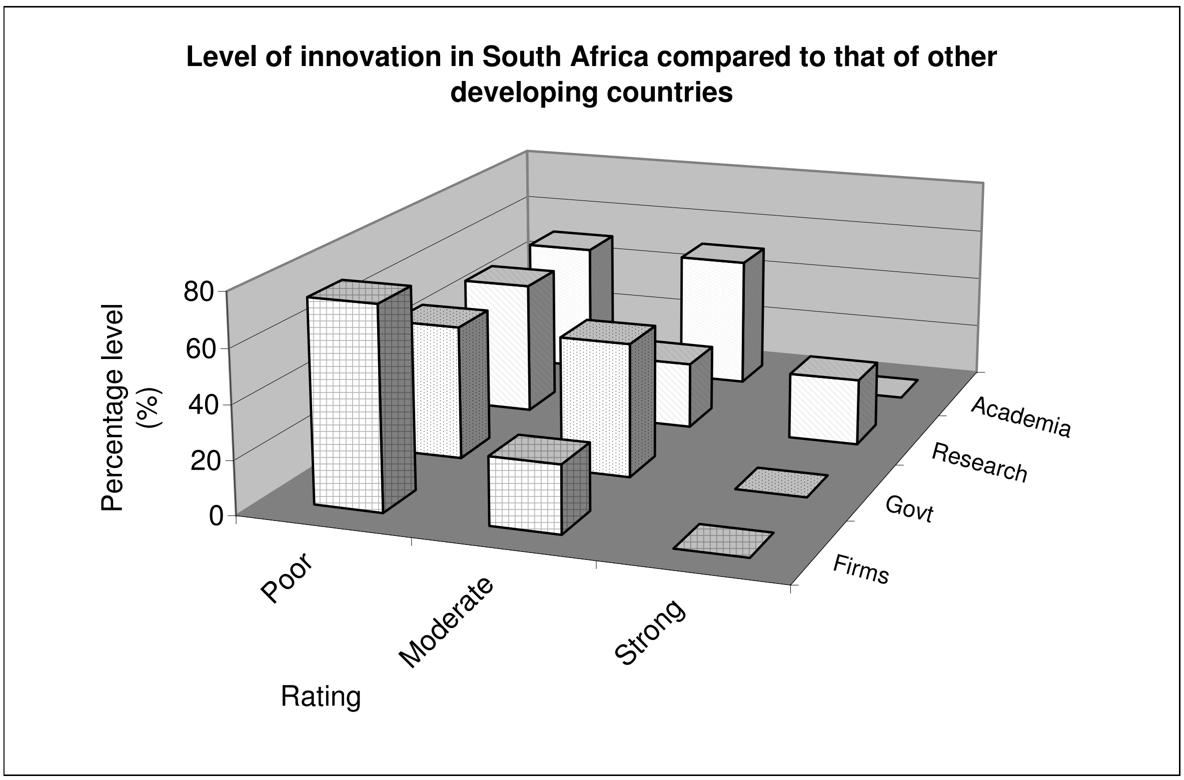

Figure (iv)64 Rating on level of innovation in South Africa compared to that of other developing countries

Respondents were further asked to state the percentage level of investment in innovation (R&D) by their institutions towards technological development within the civil aircraft industry.

Only 22% of the total responses indicated a 70% investment in innovation. *Research institutions* had the highest score of 50% showing the 70% investment, with 25% indicating a 50% investment. 25% of *Firms* indicated a 10% investment in innovation. Academia indicated 0% investment in innovation. Figure (iv)65 illustrates the results.

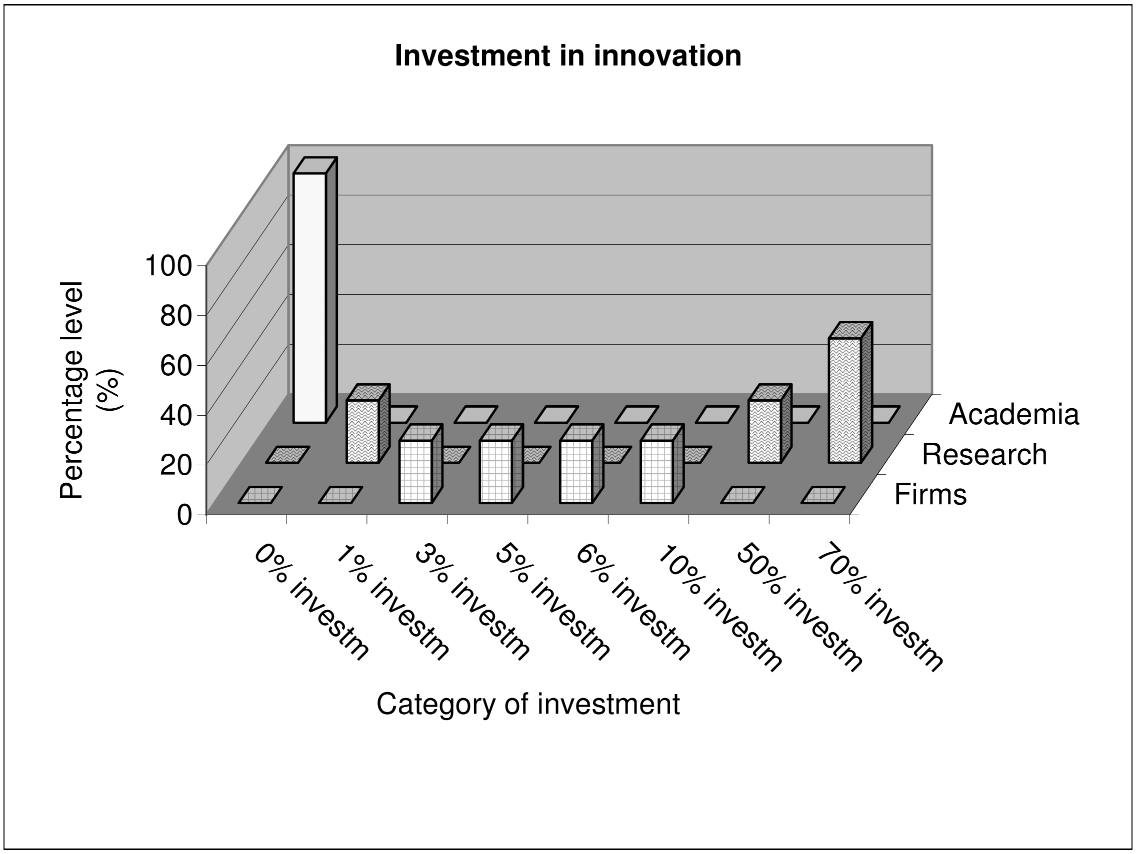

Figure (iv)65 Rating on level of investment in innovation in various categories

Appendix V: Discussion on data collected from international experts

On the **Research questionnaire for international experts**, responses were gathered from respondents as illustrated on figures (v)1 and (v)2:

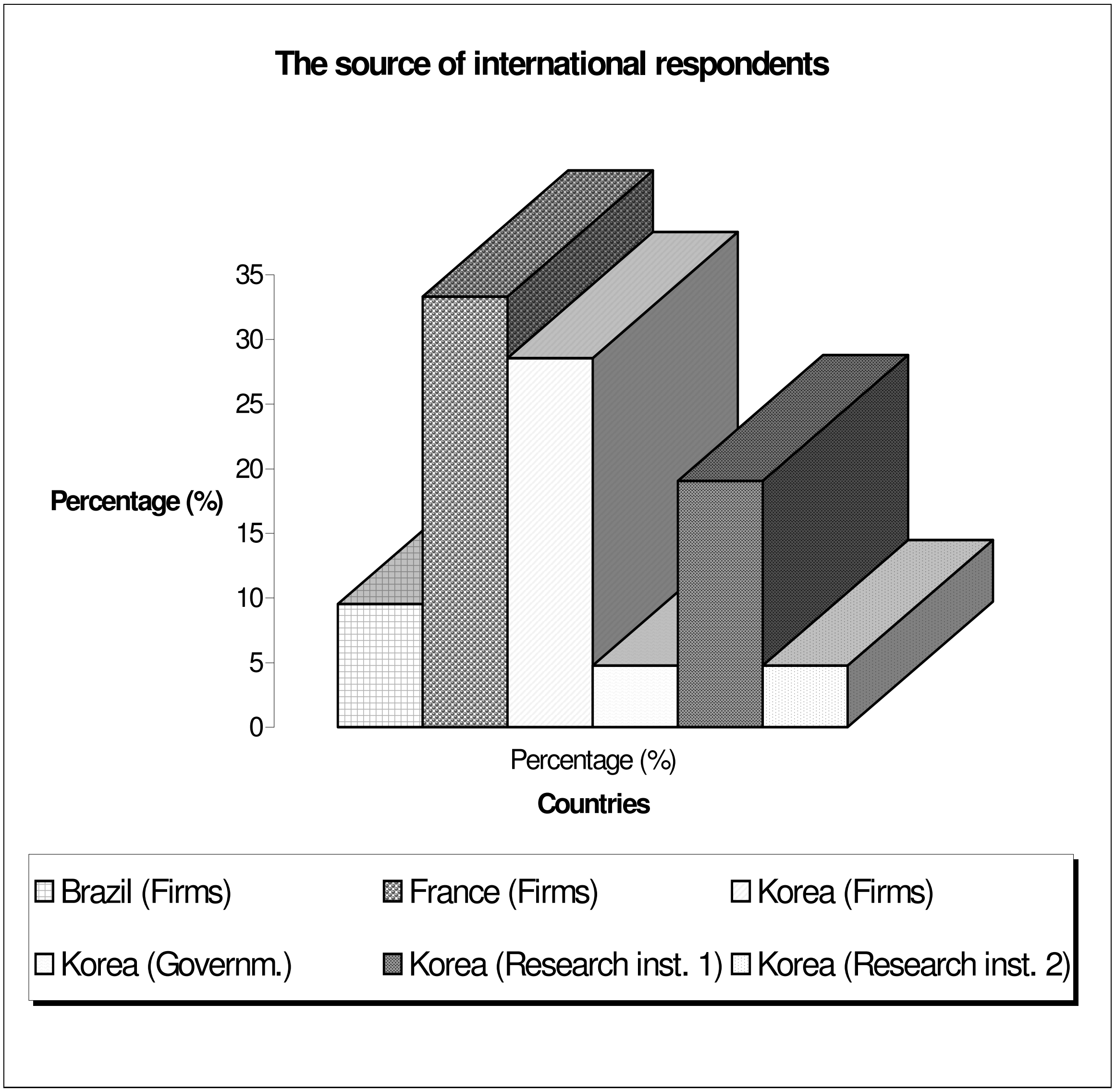

Figure (v)1 The source of international respondents (a)

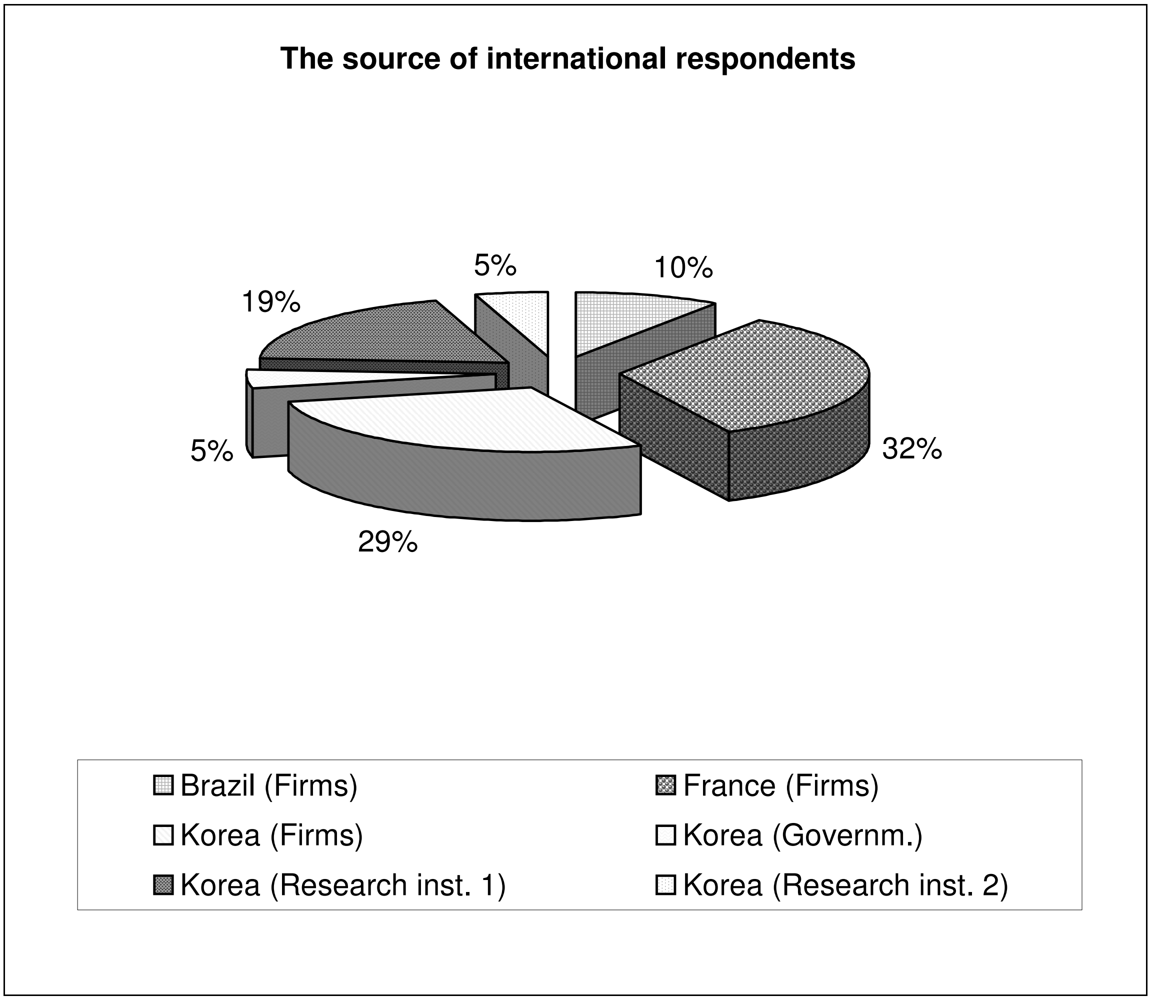

Figure (v)2 The source of international respondents (b)

Three (3) questions were asked under **Personal background** as follows:

1. Please indicate your field of expertise below

The results showed that the majority of respondents were experts within the *'engineering'* field (70%). The analysis would mean that the aircraft industry is dominated by engineers because of the technicality and complexity of it. The graphical representation of such results is illustrated on figures (v)3 and (v)4.

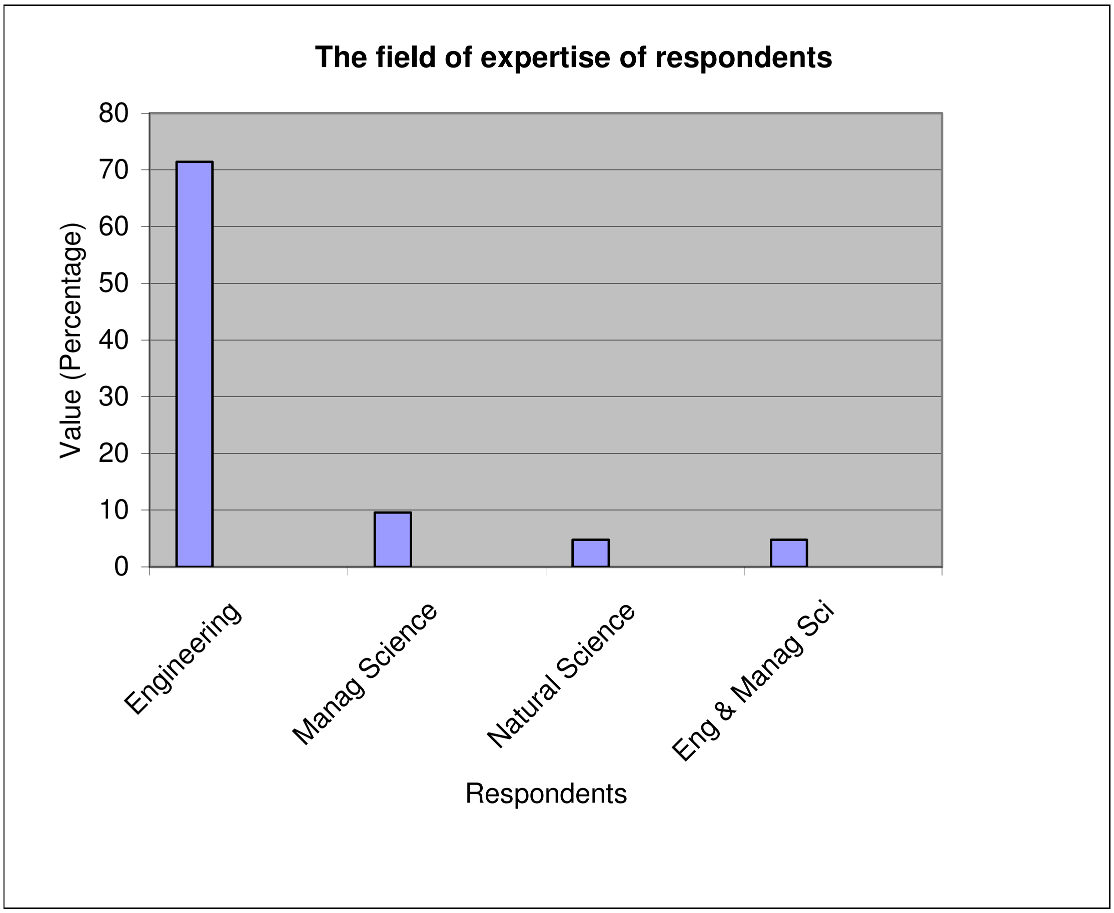

Figure (v)3 The field of expertise of respondents (a)

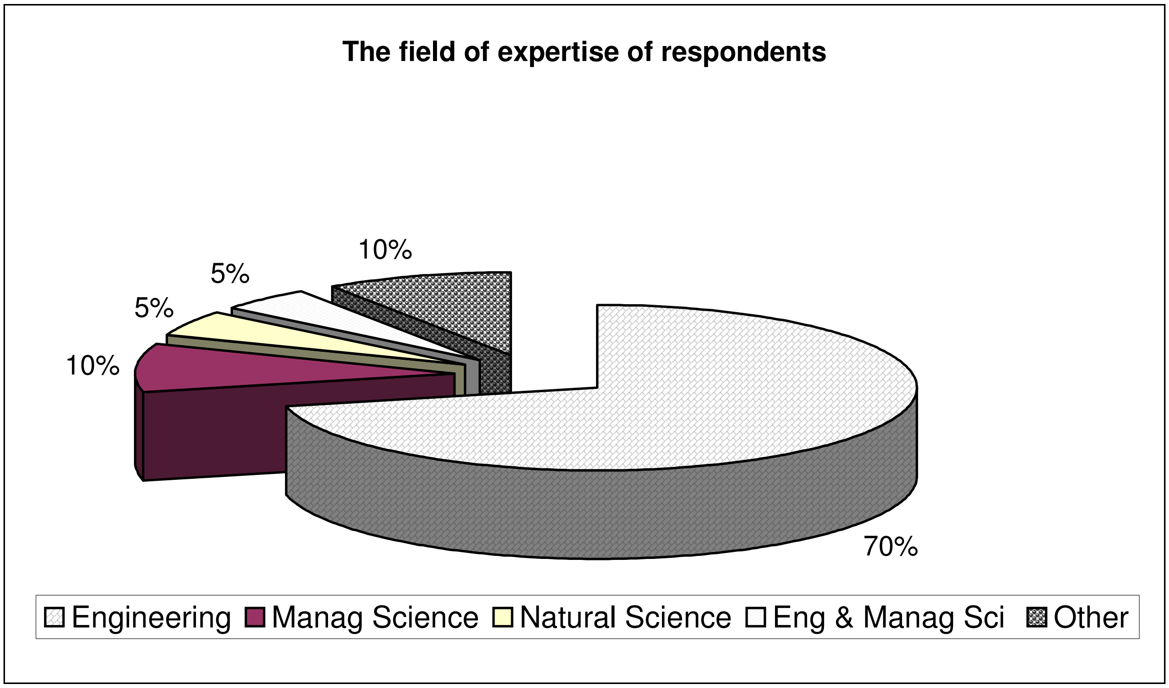

Figure (v)4 The field of expertise of respondents (b)

2. Please indicate your field of work within the organisation

The distribution showed a score of 38% on '*Other*', which is either the combination of fields within '*manufacturing*, '*technical production'*, '*sales'* and '*marketing*', or other fields that were not listed. '*Manufacturing'* had a score of 29%, '*sales*' and '*marketing*' (19%), followed by '*technical production'* with 14%. The analysis would mean that most of the top personnel within the aircraft industry were not directly involved in the listed fields, possibly because they were in top management positions. They would therefore fall under the field named '*Other*', which could also include '*management'* field. Figure (v)5 illustrates the distribution.

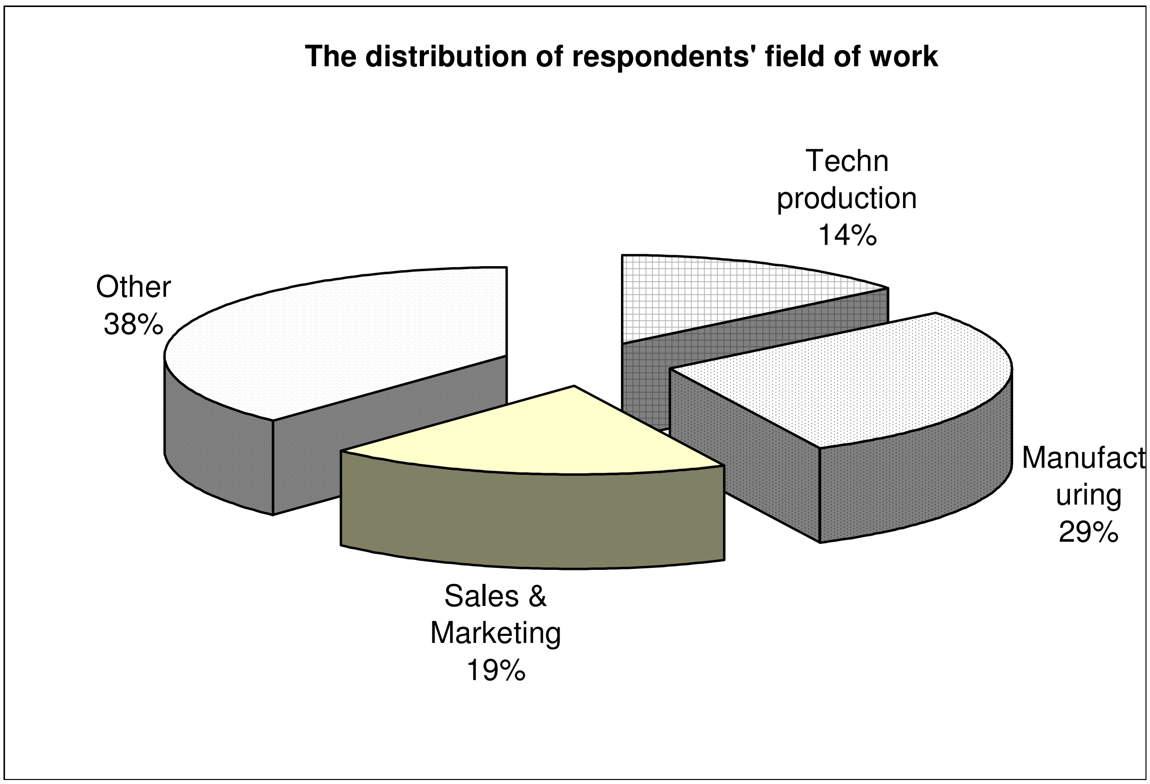

Figure (v)5 The distribution of respondents' field of work

3. Please indicate your work experience within the aircraft industry or within aircraft-related policy development

The results showed that the majority of respondents (85%) had work experience of over 5 years. Only 5% of the respondents had work experience of between 6 and 12 months. 10% ('*Other*') did not respond to this question. Figure (v)6 illustrates the distribution.

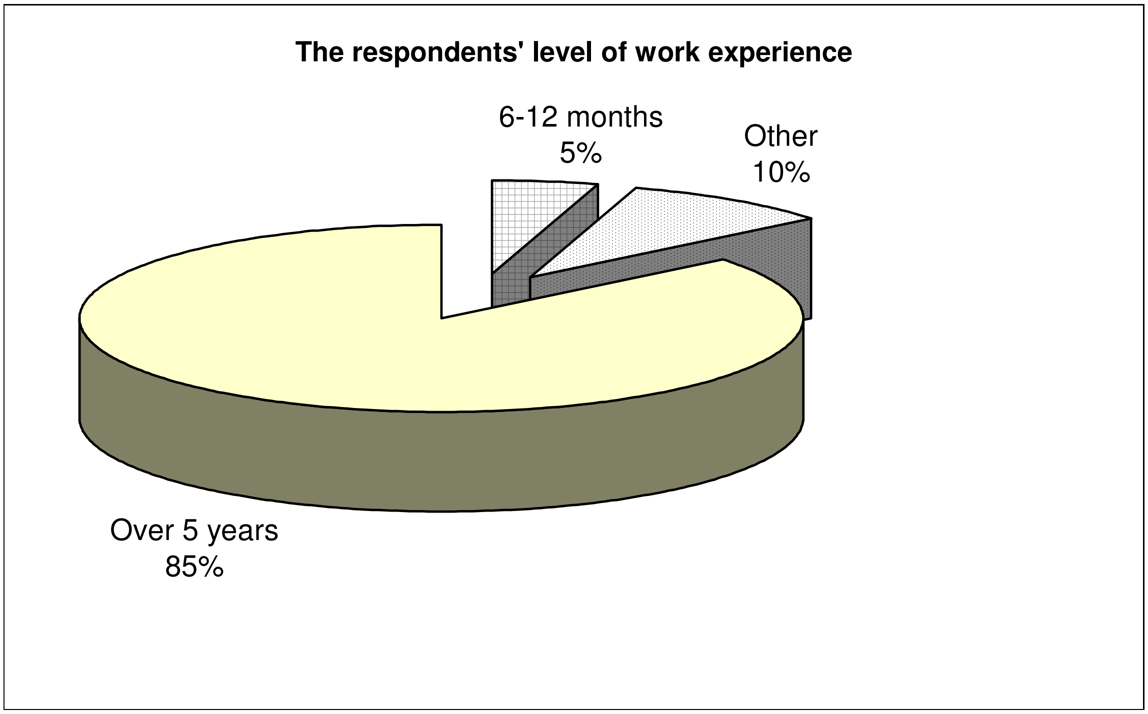

Figure (v)6 The respondents' level of work experience

On the **main research questions** there were two sections, Part I and II.

Part I looked at the technological innovation related background in the form of activities (both current and previous) that firms have embarked on, so as to compare the successful countries' pattern of technology development to the current gaps by South African firms. This was in line with the theory on technological competence and capability building paths followed by most of the successful countries studied (Chapter 2). It also looked at the current and future positioning of firms in relation to the aircraft industry structure.

Responses to **Part I** questions were received as follows:

1. Does your firm have or had any joint ventures with other aircraft firms/institutions/organisations outside your country?

48% of the respondents agreed (YES) to have had joint ventures with institutions outside their country, whereas 47% responded with a NO. 5% ('*Other*') did not respond.

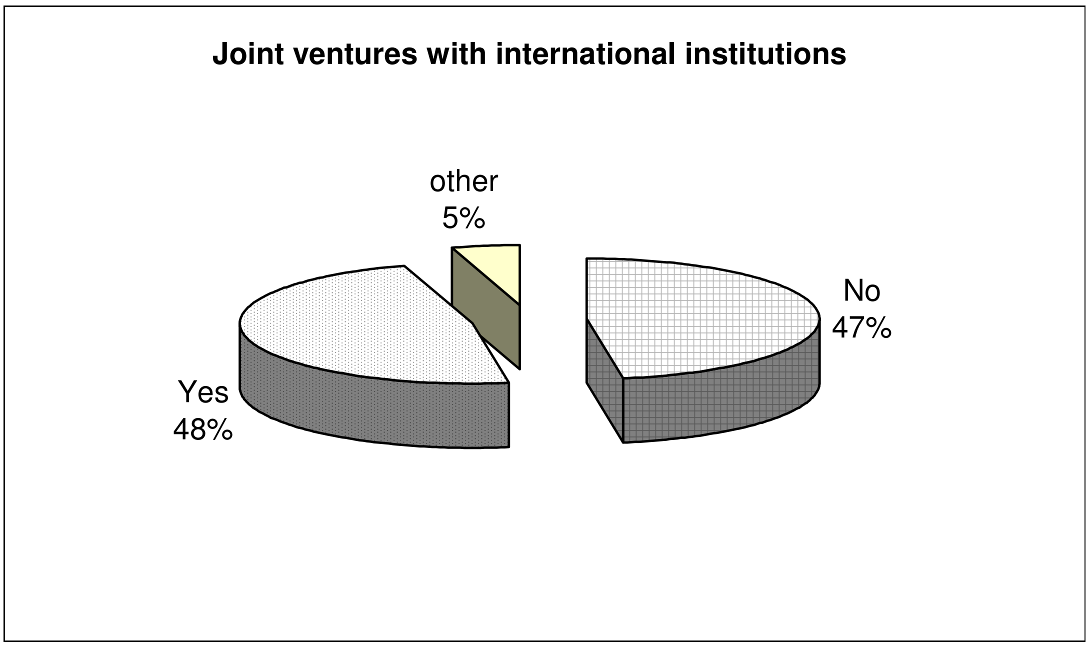

Figure (v)7 If respondents have had joint ventures with international institutions

2. Has your firm been involved in any form of collaboration with other local firms/institutions/organisations?

Majority of respondents agreed (YES 90%) to have been involved in collaboration activities with local institutions. 5% ('*Other*') did not respond, whereas 5% (NO) denied having had any collaborative activities.

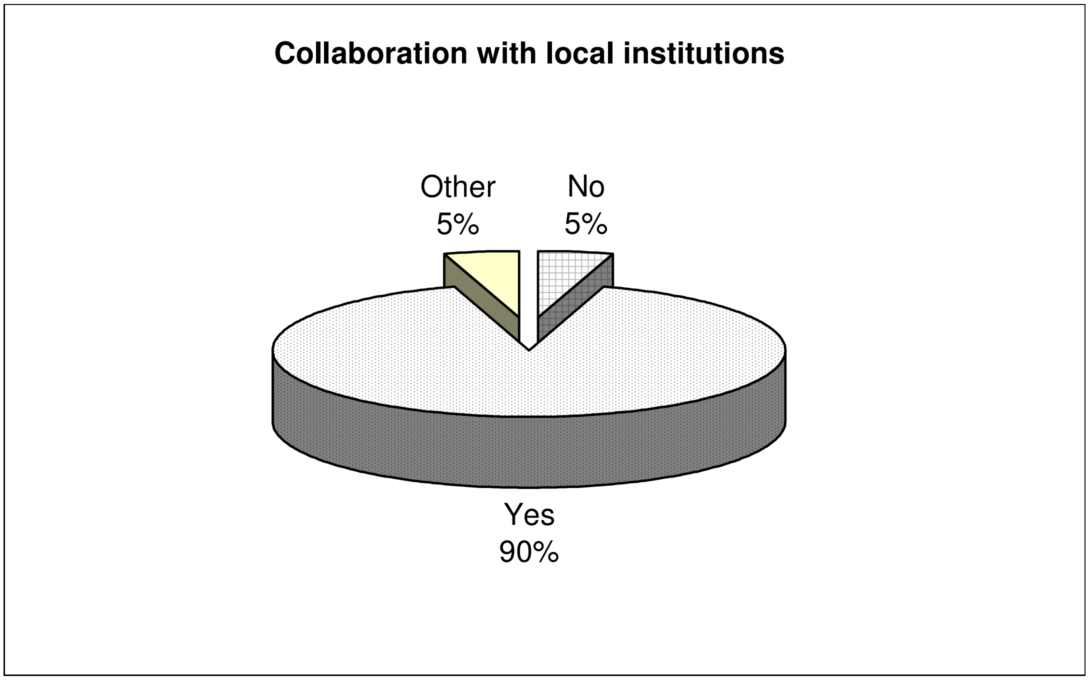

Figure (v)8 If respondents collaborate with local institutions

3. Is your firm subcontracting some of its work to firms/institutions/organisations outside your country?

About 66% (YES) of the respondents indicated that they subcontract some of their work to institutions outside their country. 29% (NO) responded that they do not subcontract to institutions outside their country, with only 5% (‘*Other*’) not responding.

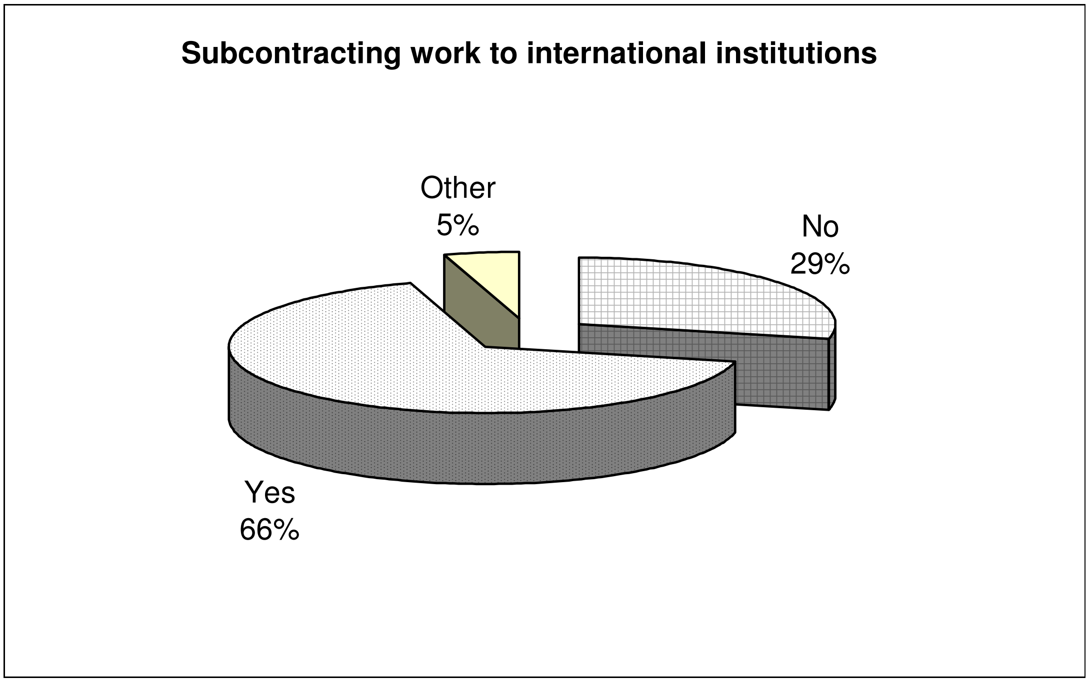

Figure (v)9 If respondents subcontract work to institutions outside their country

The respondents that agreed to be subcontracting work to institutions outside their country have further responded as follows with regard to percentage contribution by such work to the sales of their institution:

23% stated that the contribution of such work to their sales is 40%.

5% stated that the contribution of such work to their sales is 50%.

Another 5% stated that the contribution of such work to their sales is 0%.

About 66% of the respondents did not state the percentage contribution of such work to their sales.

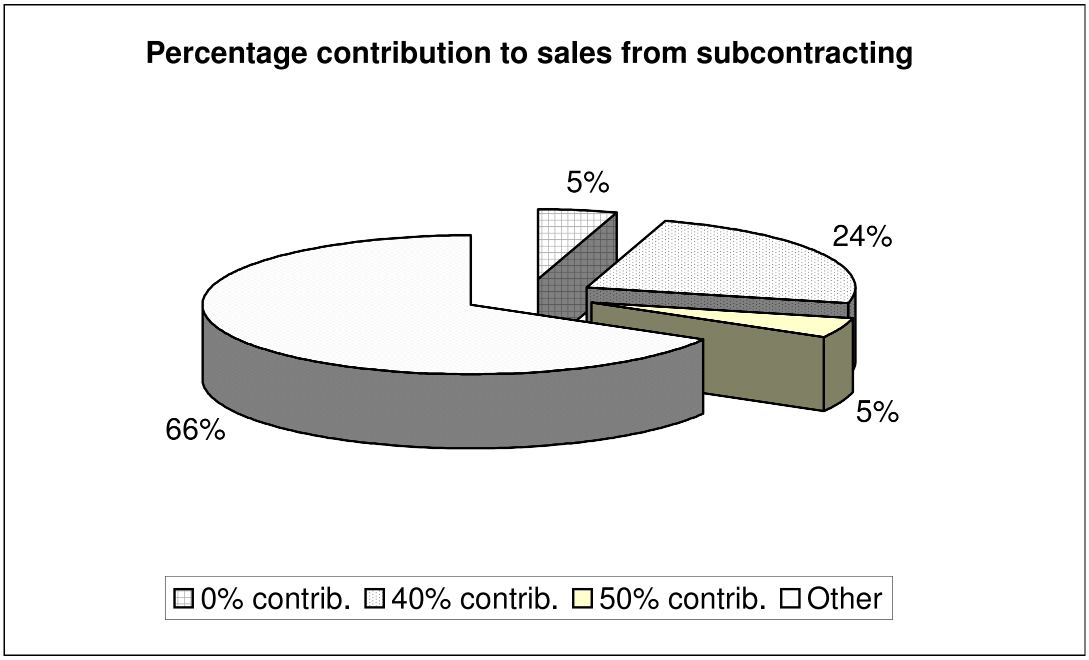

Figure (v)10 The percentage contribution to sales from subcontracting

4. Has your firm/institution/organisation been involved in aircraft projects for an international contractor?

66% (YES) of the respondents indicated that they have been involved in aircraft projects for an international contractor. 29% indicated that they have not been involved (NO), with only 5% ('*Other*') not responding to the question.

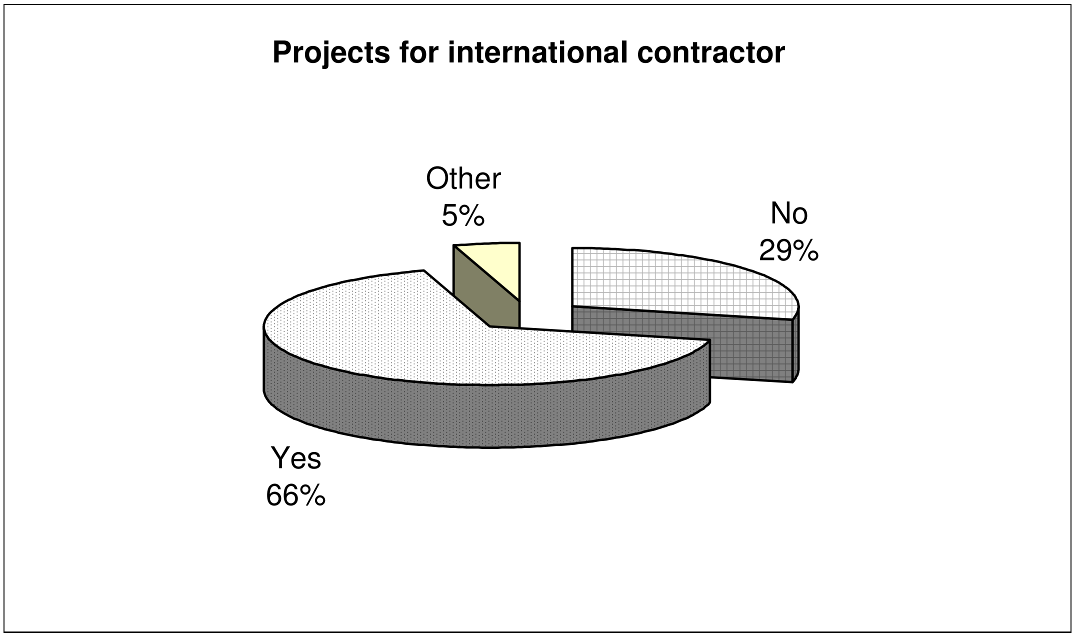

Figure (v)11 If respondents have been involved in projects for an international contractor

Those that agreed to have been involved have further responded as follows with regard to the percentage contribution of such work to the sales of their institutions:

29% stated that the contribution of such work to their sales is 20%.

14% stated that the contribution of such work to their sales is 1%.

5% stated that the contribution of such work to their sales is 0%.

About 52% of the respondents did not state the percentage contribution of such work to their sales.

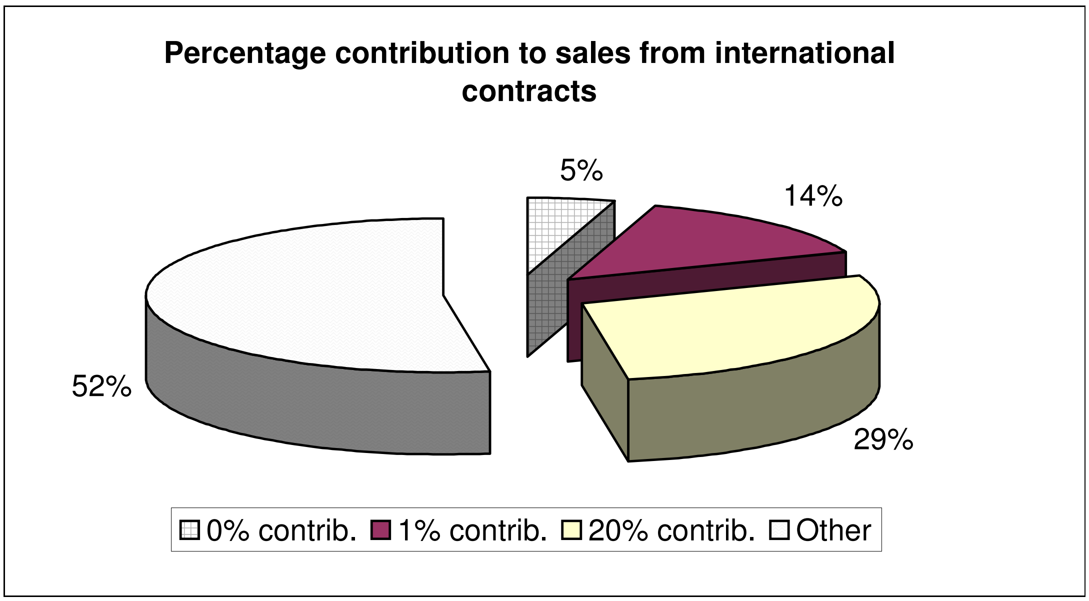

Figure (v)12 The percentage contribution to sales from international contracts

5. Has your firm/institution/organisation been involved in any form of technological innovation or improvement within the aircraft industry?

95% of the respondents agreed that they have been involved in some form of technological innovation or improvement within the aircraft industry. 5% did not respond to the question.

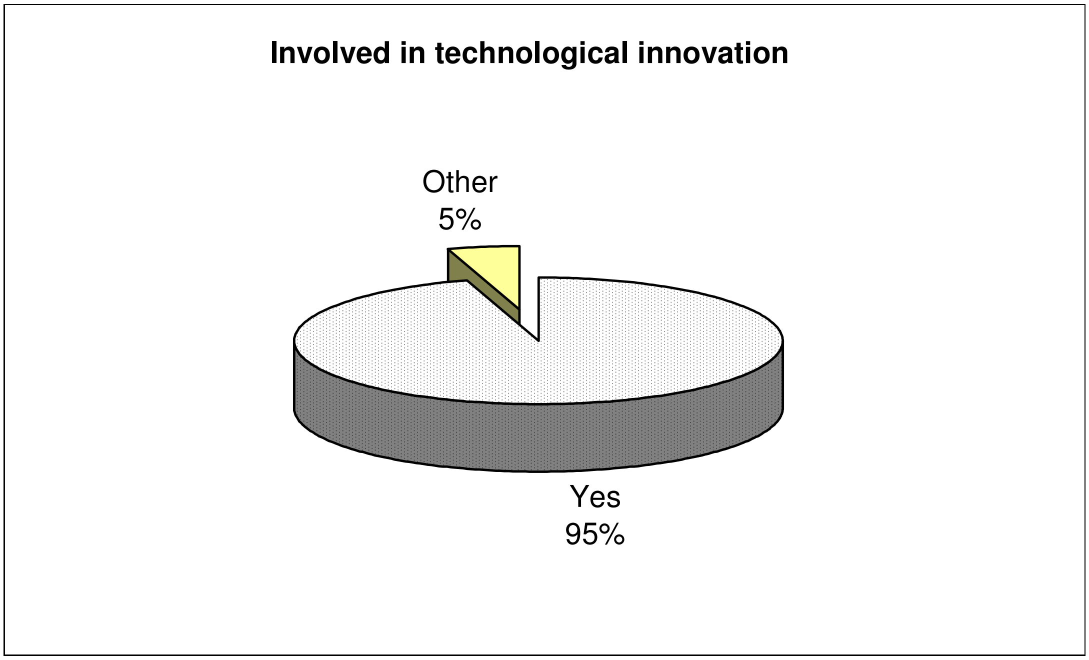

Figure (v)13 The level of involvement by respondents in technological innovation

6. Did your firm/institution/organisation acquire some business contracts through government assistance in the past, where without their involvement it might have been difficult if not impossible to attain such business?

52% of the respondents indicated that they have acquired some business contracts through the assistance of government. 43% indicated that they never acquired business contracts through the intervention of government. 5% did not respond to the question.

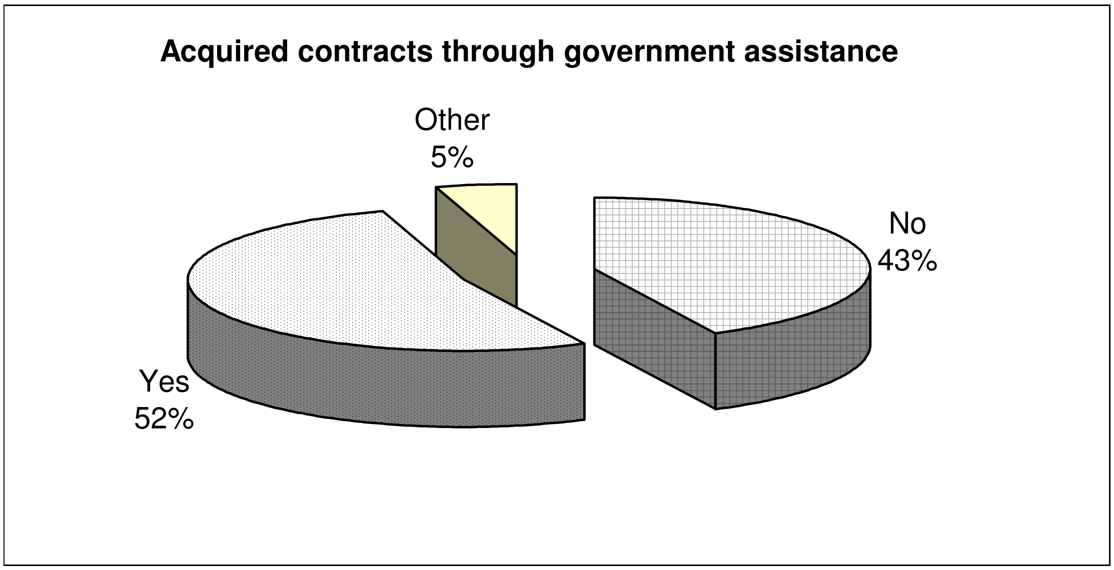

Figure (v)14 If respondents acquired contracts through government assistance

7. Has your firm/institution/organisation been involved in any form of aircraft-related technology transfer with global firms/institutions?

48% (YES) indicated that they have been involved in aircraft-related technology transfer with global institutions, whereas 47% (NO) said they have not been involved. 5% ('*Other*') did not respond to the question.

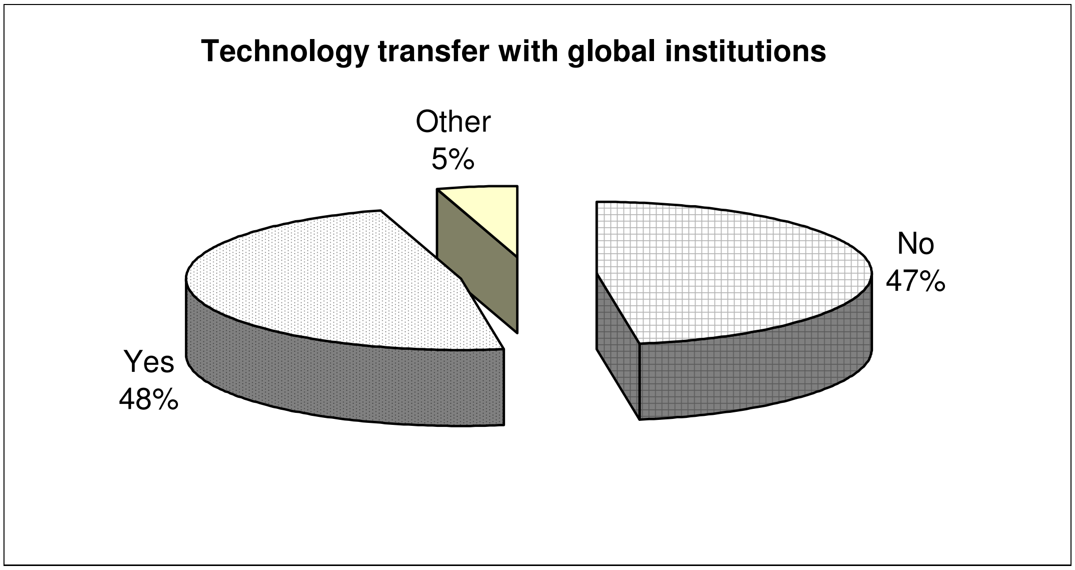

Figure (v)15 Respondents' involvement in technology transfer with global institutions

If yes, please state the country where technology is transferred from and the area of application of such technology.

Brazil did not indicate their source countries for technology transfer. However, it is more likely that it was from US, looking at the volumes of technology business interaction between the two countries.

Korea indicated US and Europe (area of application being on aircraft design & system integration).

France indicated China and Europe (area of application not indicated).

8. In what area of the aircraft industry structure is your firm/institution making a major contribution?

On average respondents indicated that they make a major contribution on **second tier** level (Major sub-system supply) of the aircraft industry structure, where the score was **67%.** The second highest score (**62%**) was for both **first tier** and **fourth tier**, where respondents also indicated that they make a major contribution in those aspects. **Third tier** followed with a **48%** score, the last being **fifth tier** with an indication of **5%** major contribution. The findings are illustrated on figure (v)16.

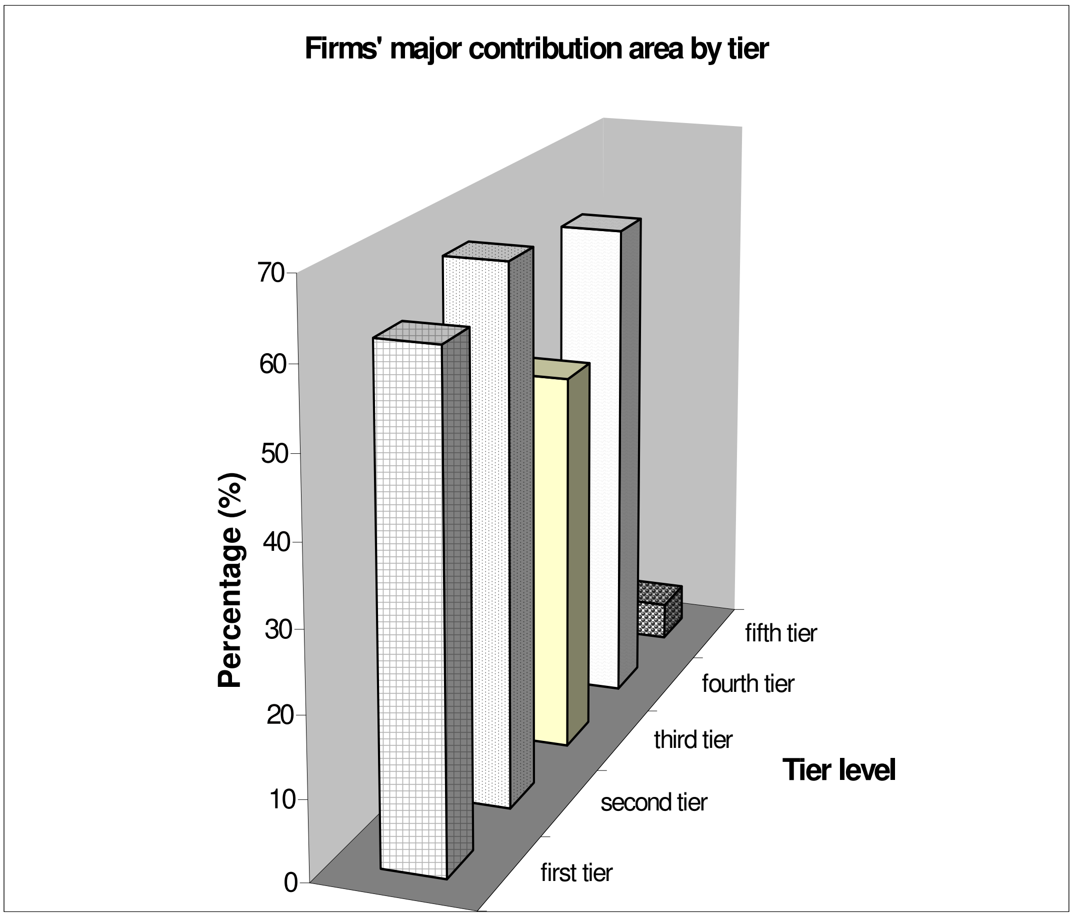

Figure (v)16 Firms' major contribution on various tiers of the aircraft industry structure

Part II looked at the trends on the factors and interventions believed to be key in building technological competencies within the aircraft industry. Data would be compared to that gathered from local respondents so as to establish the existence of a pattern on the technological capability building paths followed by various countries.

For **Part II**, responses were received on the questions as follows:

9. It is the role of government to promote national technological competence through interventions such as these.

Responses were received on the following list of interventions:

A. Support R&D programmes
B. Support infrastructure development
C. Stimulate local and international partnerships
D. Provide safety and regulatory environment guidelines
E. Oversee establishment of enabling or governing structures
F. Support skills development

Intervention **A** (*Support R&D programmes*) had the highest score of **86%** on *Strongly agree*, indicating that government should use such intervention as a tool to promote national technological competence within the aircraft industry. The graphical representation of the results is shown on figure (v)17.

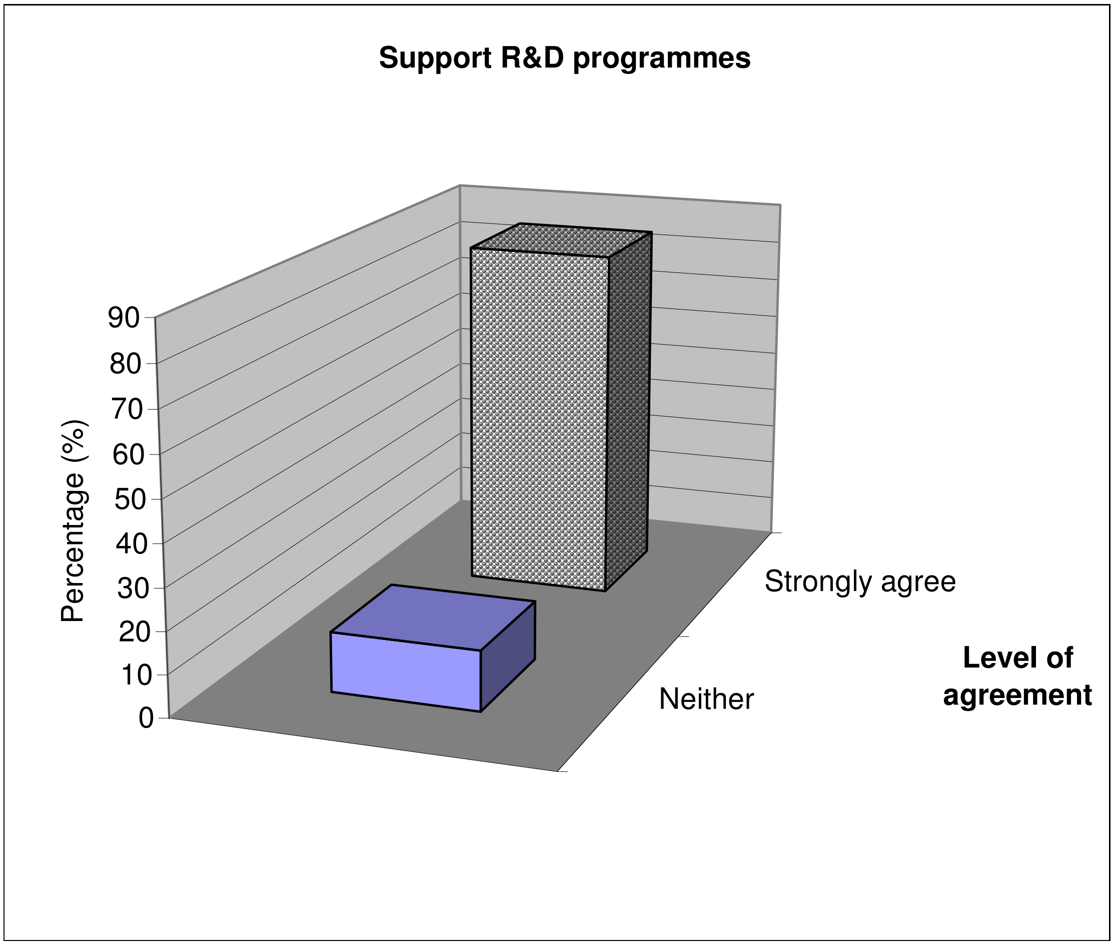

Figure (v)17 The level of agreement by respondents on the intervention to "Support R&D programmes"

Intervention **B** (*Support infrastructure development*) had the second highest score of **67%** on *Strongly agree*. The graphical representation of the results is shown on figure (v)18.

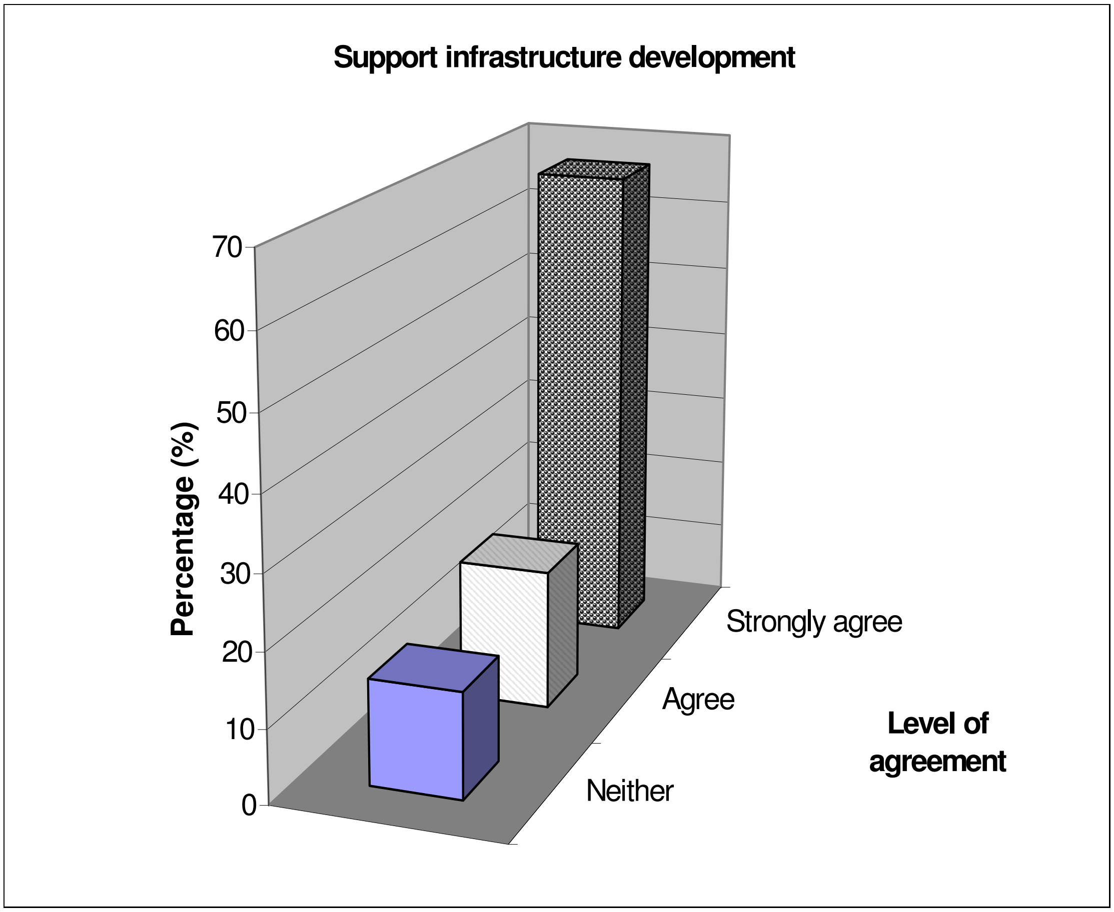

Figure (v)18 The level of agreement by respondents on the intervention to "Support infrastructure development"

Intervention **F** (*Support skills development*) obtained the third highest score of **38%** on *Strongly agree*. A graphical representation of the results is illustrated on figure (v)19.

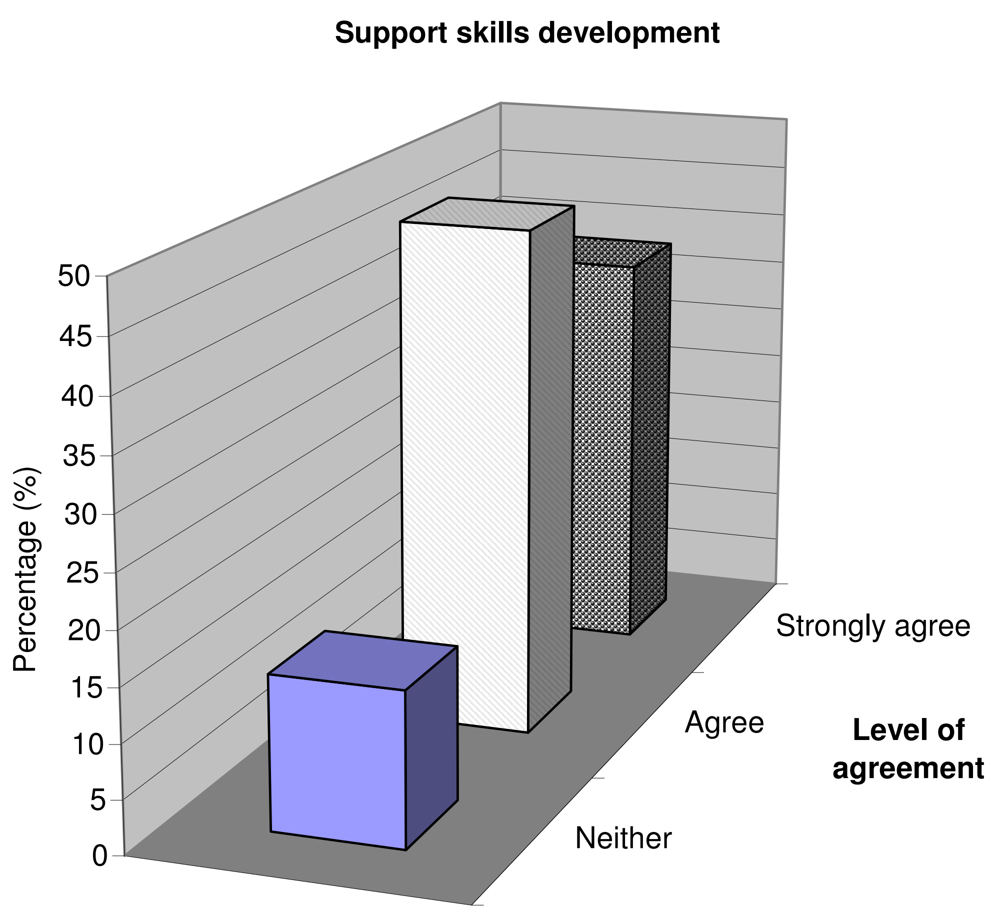

Figure (v)19 The level of agreement by respondents on the intervention to "Support skills development"

Intervention **D** (*Provide safety and regulatory environment guidelines*) followed with **33%** score on *Strongly agree*. A graphical representation of the results is illustrated on figure (v)20.

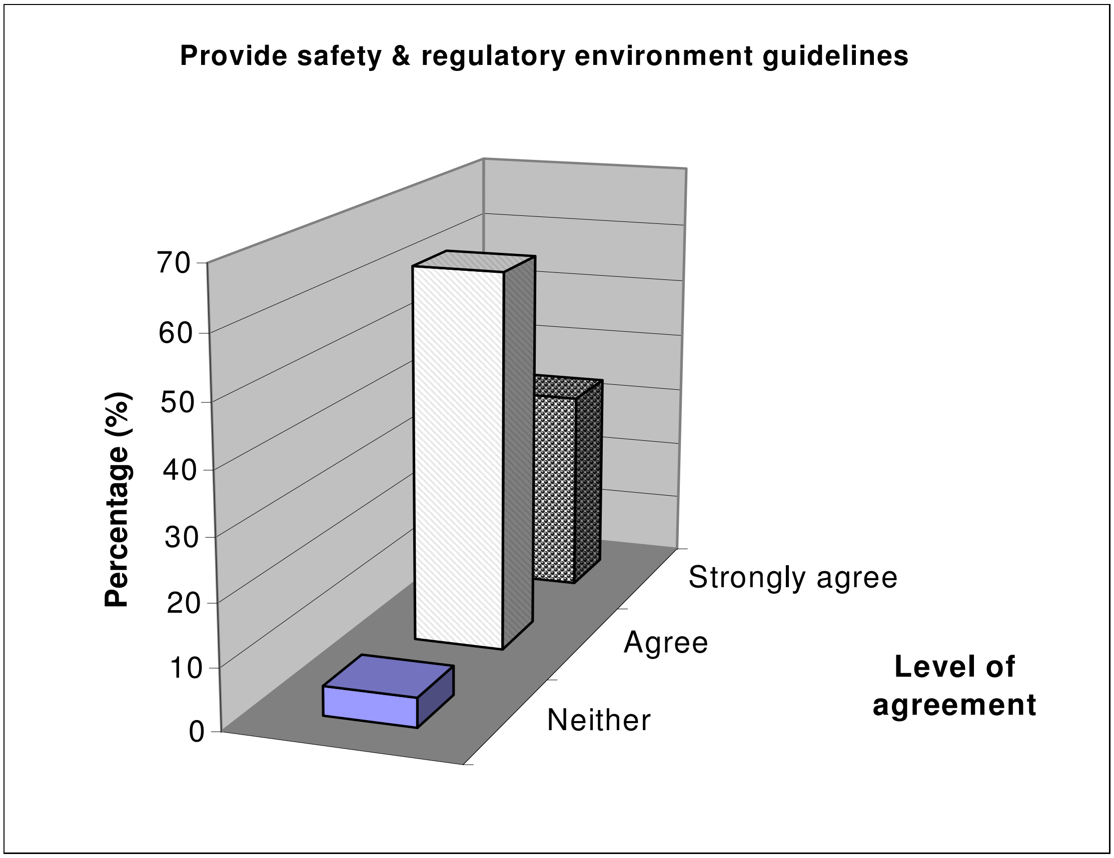

Figure (v)20 The level of agreement by respondents on the intervention to "Provide safety & regulatory environment guidelines"

Both interventions **C** (*Stimulate local and international partnerships*) and **E** (*Oversee establishment of enabling or governing structures*) followed last with a score of **14%** on *Strongly agree*, but with 81% and 62% respectively on *Agree*.

10. The following are essential interventions for successful technology capability-building or technological competitiveness within the aircraft industry. (Show the extent that you agree or disagree with the statements).

A. *Inter-firm collaboration can enhance technology capability development within aircraft firms through skills transfer, joined investment and learning from each other.*

B. *Government interventions are essential for fostering proper structures necessary for building technology competence.*

C. *Large investment on R&D could improve technology competence within firms thereby enhancing technological competitiveness of the national aircraft industry.*

D. *Technology transfer would be key towards development of technology capabilities, improved innovation and competitiveness of aircraft industry.*

E. *Firms should form joint ventures or strategic alliances with global firms to have improved technology development capabilities, as well as better market accessibility.*

F. *Government should collaborate with governments from other countries on major projects so as improve technology competence and global market access for aircraft firms.*

G. *Collaborative efforts from academia, research institutions, firms and government are essential for enhancing innovation and technology development within the aircraft industry.*

H. *User-producer kind of linkages should be maintained to foster inter-firm learning and proper understanding of technology development requirements.*

I. *Government should invest in developing future engineers at all levels of training, so as to build a strong technology development skilled nation.*

Statement **G** (*Collaborative efforts from academia, research institutions, firms and government are essential for enhancing innovation and technology development within the aircraft industry*) had the highest score of **81%** on *Strongly agree*, with a further 19% on *Agree*. The graphical representation of the results is illustrated on figure (v)21.

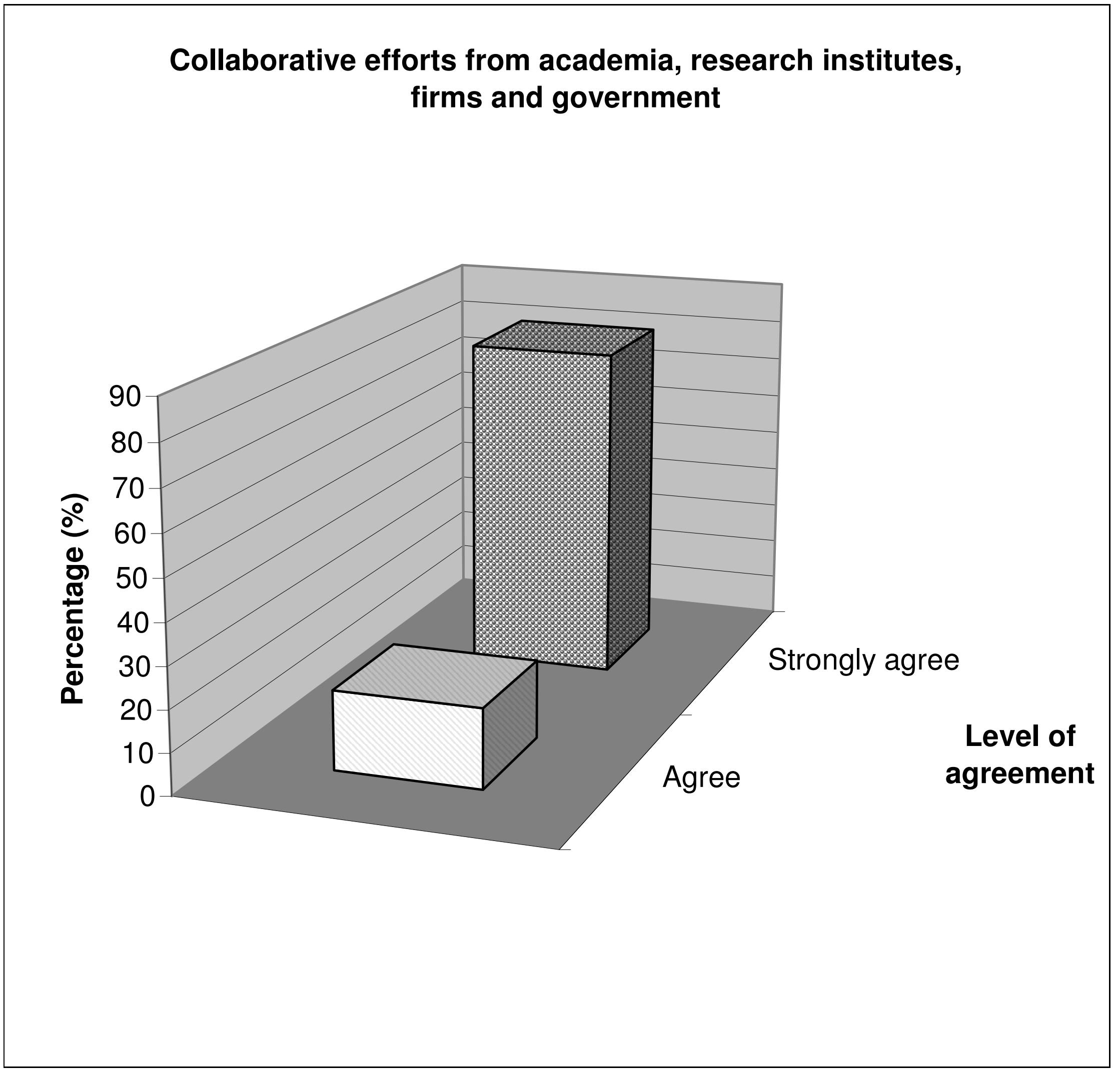

Figure (v)21 The level of agreement on Statement G

Statement **I** (*Government should invest in developing future engineers at all levels of training, so as to build a strong technology development skilled nation)* had the second highest score of **76%** on *Strongly agree*, with a further 24% on *Agree*. The graphical representation of the results is illustrated on figure (v)22.

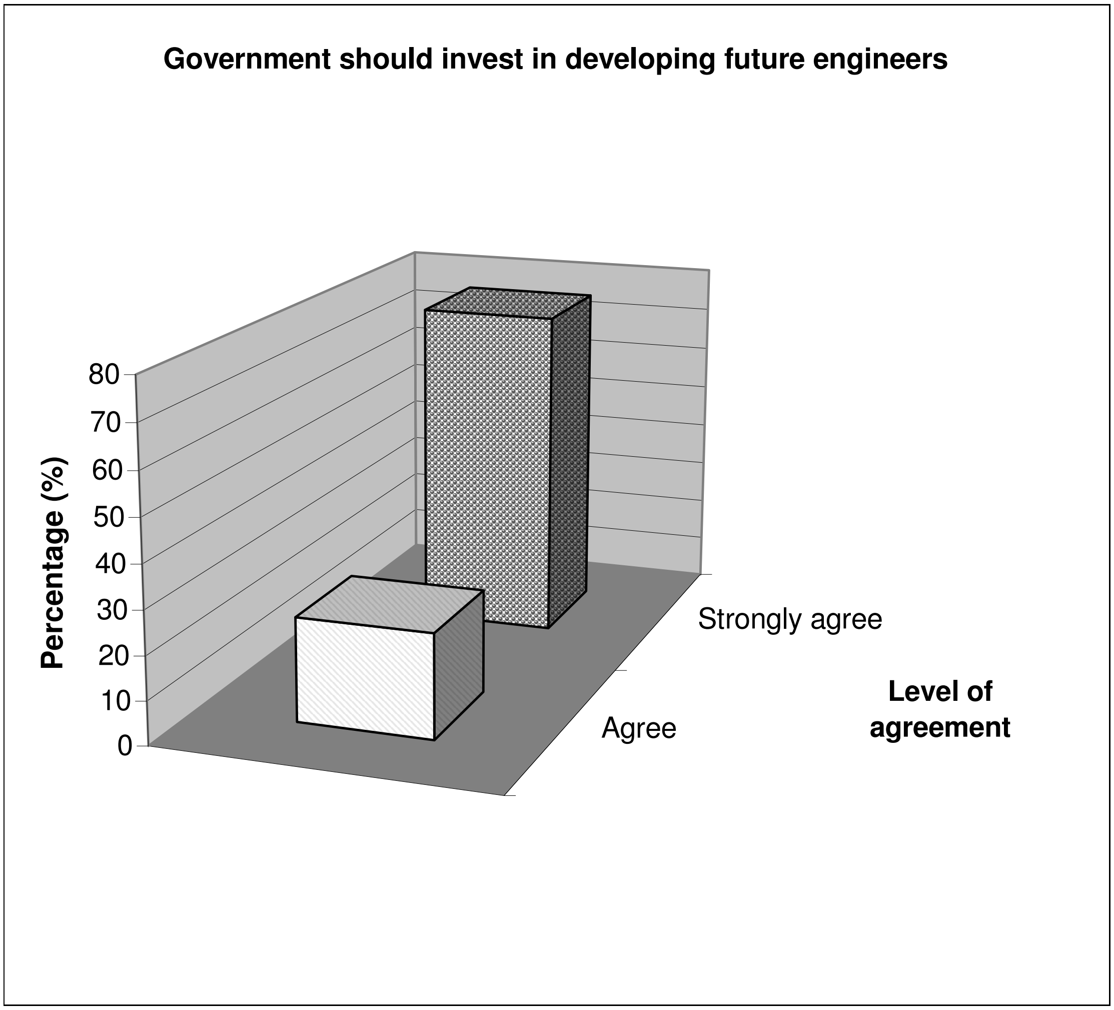

Figure (v) The level of agreement on Statement I

Statement **A** (*Inter-firm collaboration can enhance technology capability development within aircraft firms through skills transfer, joined investment and learning from each other)* had the third highest score of **67%** on *Strongly agree*, with a further 29% on *Agree*. The graphical representation of the results is illustrated on figure (v)23.

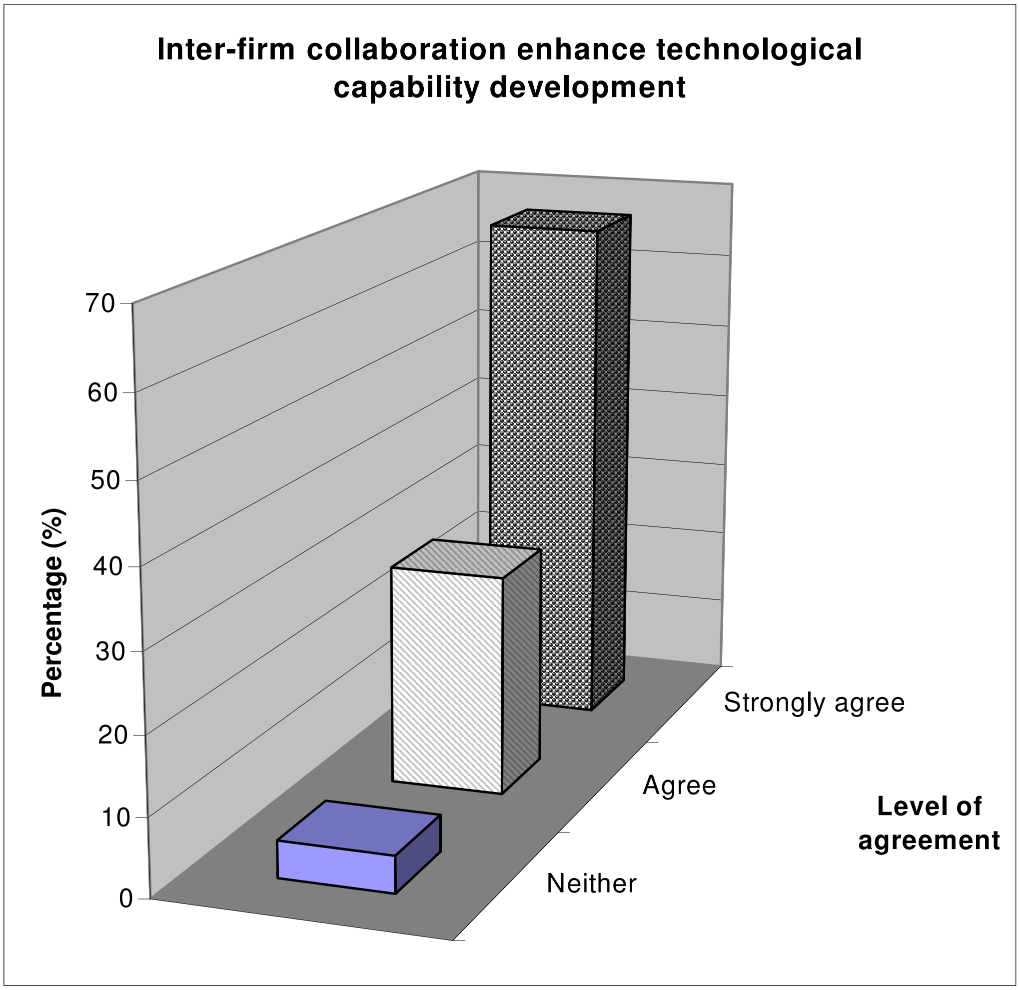

Figure (v)23 The level of agreement on Statement A

Statement **C** (*Large investment on R&D could improve technology competence within firms thereby enhancing technological competitiveness of the national aircraft industry*) followed with a score of **62%** on *Strongly agree*, with a further 38% on *Agree*. The graphical representation of the results is illustrated on figure (v)24.

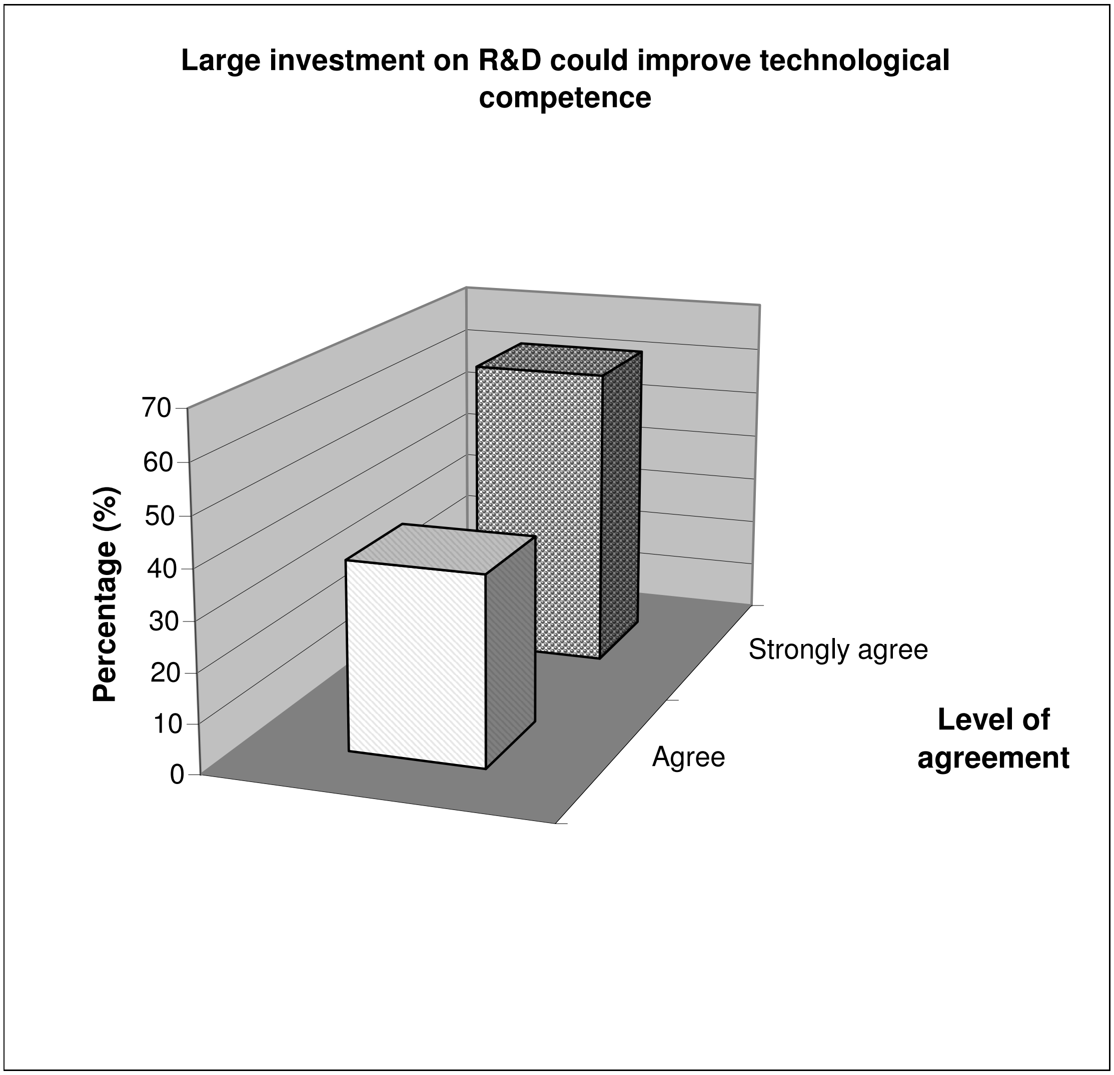

Figure (v)24 The level of agreement on Statement C

Statements **B** (*Government interventions are essential for fostering proper structures necessary for building technology competence)* and **E** (*Firms should form joint ventures or strategic alliances with global firms to have improved technology development capabilities, as well as better market accessibility)* both scored **29%** on *Strongly agree*, with a further 62% and 57% respectively on *Agree*. The graphical representations of both B and E are illustrated on figures (v)25 and (v)26 respectively.

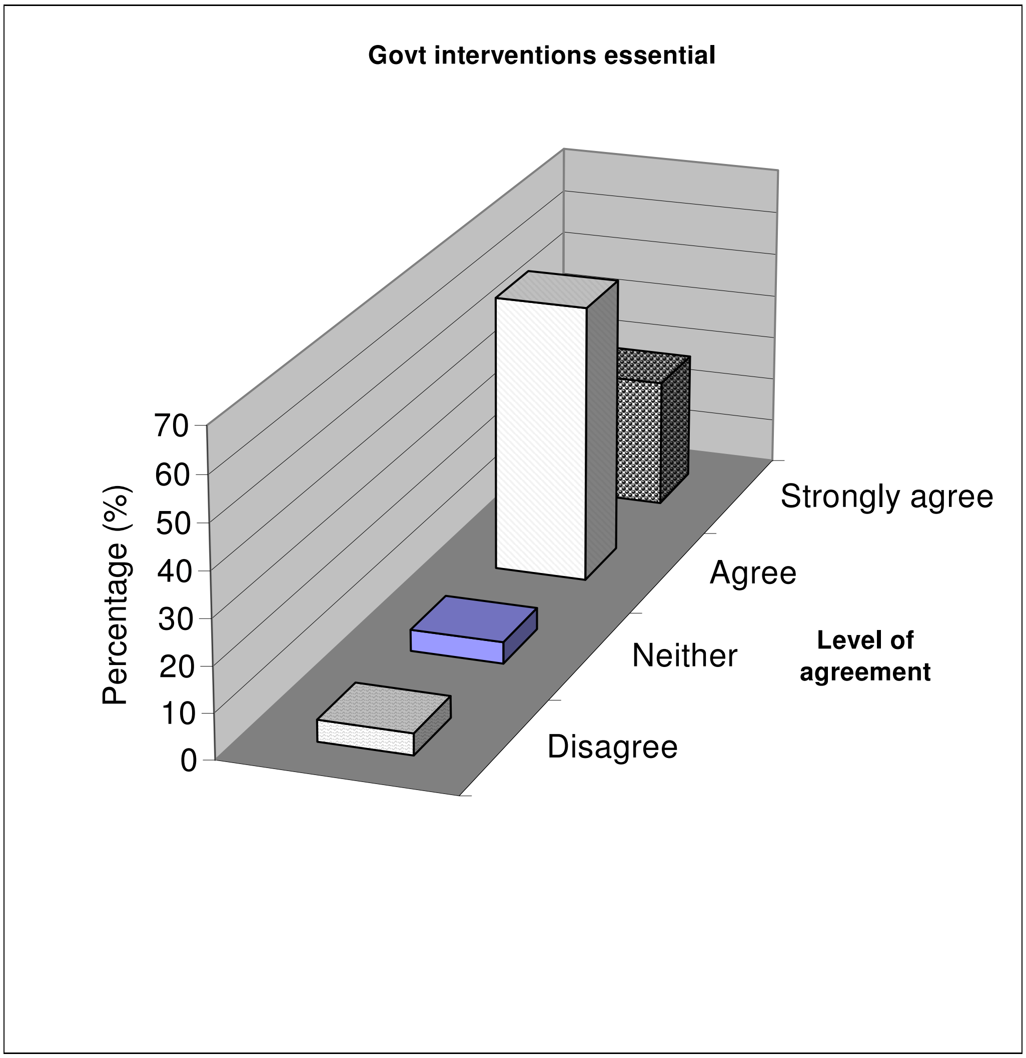

Figure (v)25 The level of agreement on Statement B

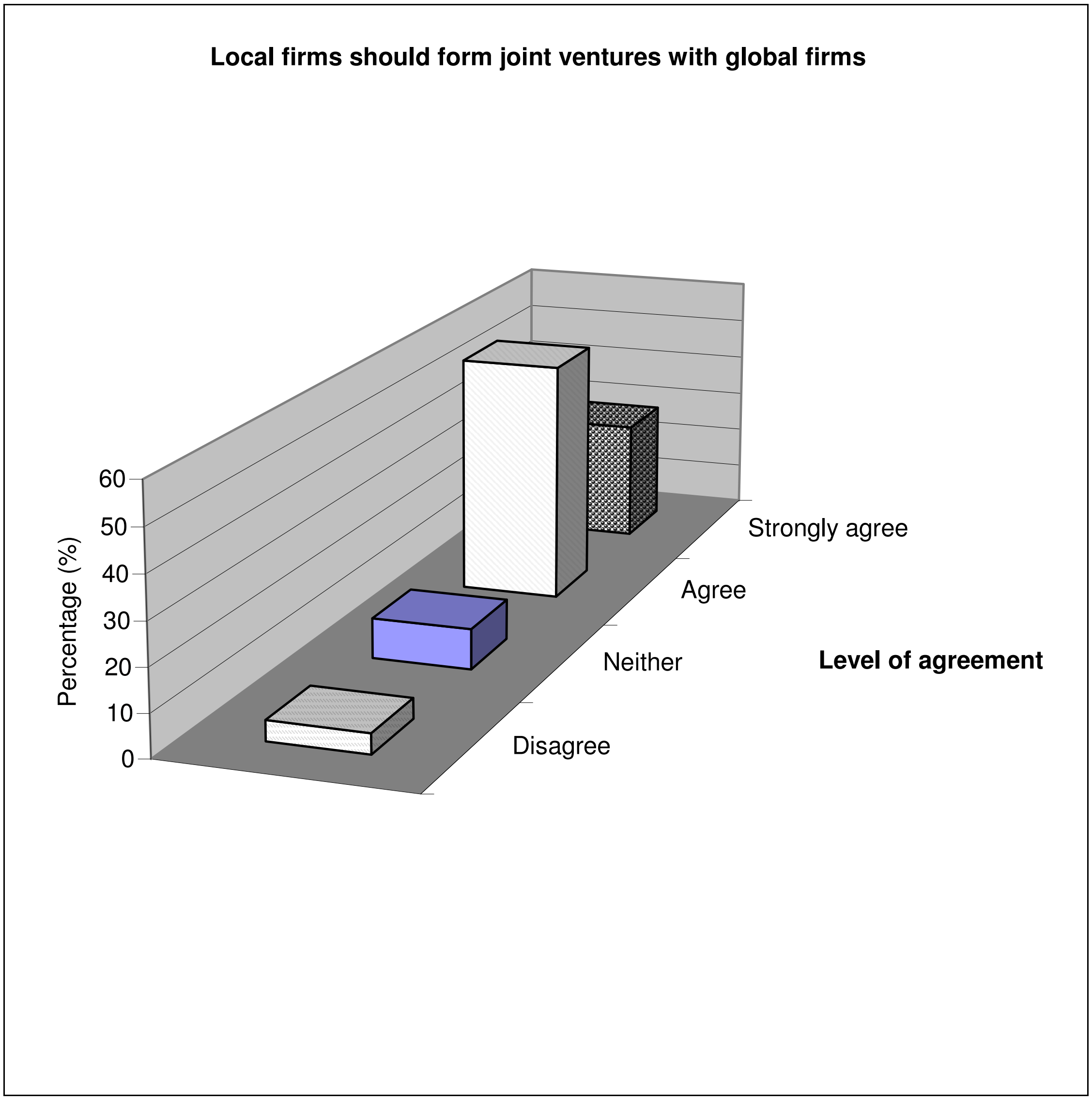

Figure (v)26 The level of agreement on Statement E

Statements H *(User-producer kind of linkages should be maintained to foster inter-firm learning and proper understanding of technology development requirements)*, F (*Government should collaborate with governments from other countries on major projects so as improve technology competence and global market access for aircraft firms)* and D (*Technology transfer would be key towards development of technology capabilities, improved innovation and competitiveness of aircraft industry)* had lower scores. Both **H** and **F** scored **24%** on *Strongly agree*, but with a further 72% and 43% respectively on *Agree*. **D** scored **14%** on *Strongly agree* and 52% on *Agree*.

11. To develop the aircraft industry towards national technological competitiveness, the following should be established:

Responses were obtained on the following list of elements:

A. Research and technology development programme
B. Firm collaboration (national)
C. Firm collaboration (international)
D. Aircraft-related research institutes
E. Government support for technological innovation
F. Market acquisition assistance
G. Research collaboration (government, research institutes, academia, firms)
H. Technology transfer
I. Skills development programme
J. Good governance structures
K. Well-supported higher education & research institutions
L. Appropriate infrastructure

Element **A** (*Research and technology development programme*) had the highest score of **95%** on *Highest priority*, indicating that this element is quite critical when developing or improving national technological competencies within the aircraft industry. The graphical representation of the results is illustrated on figure (v)27.

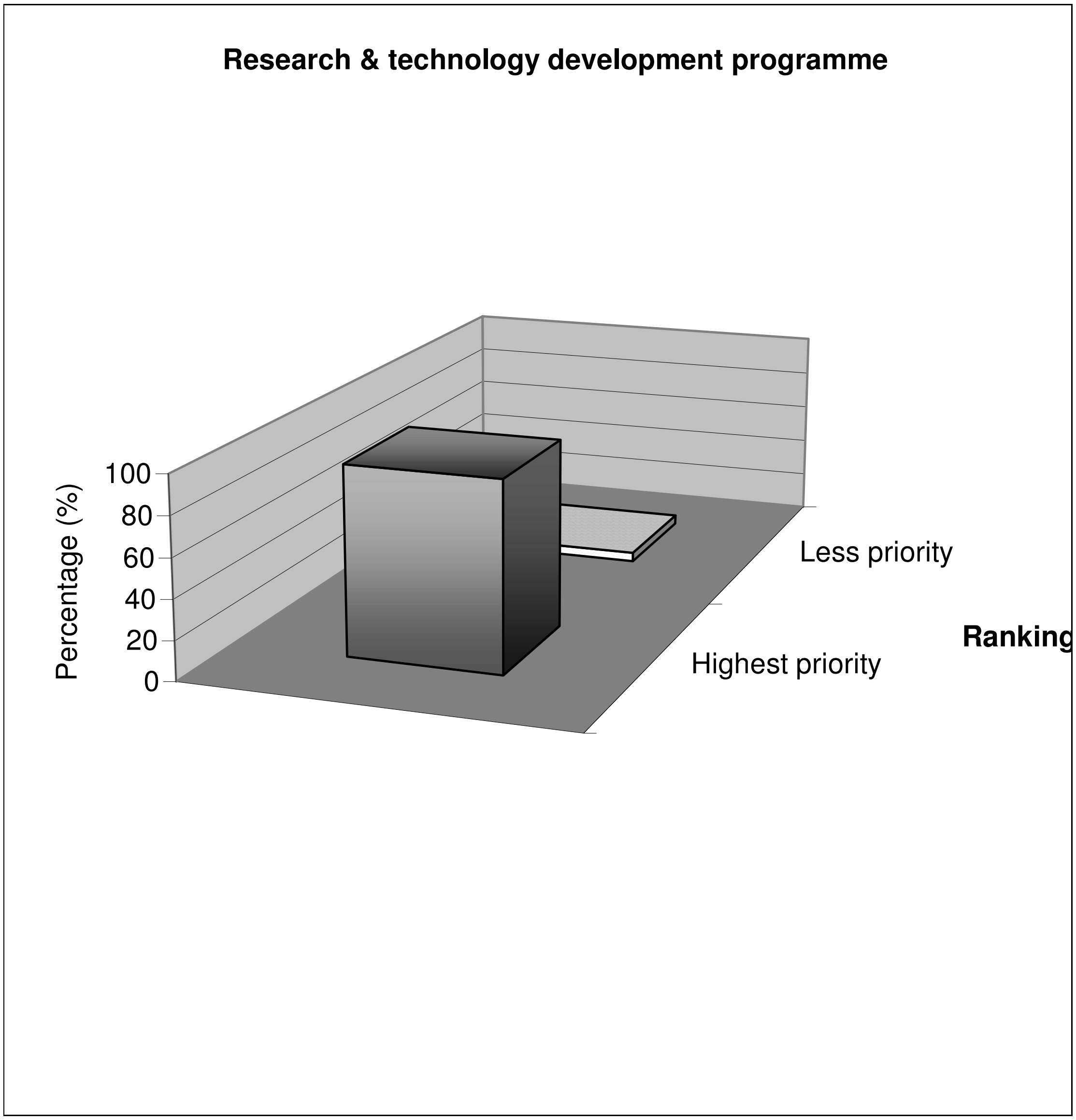

Figure (v)27 Ranking on "Research & technology development programme" as an element for developing/improving technological competence

Element **D** (*Aircraft-related research institutes*) had the second highest score of **43%** on *Highest priority*.

Aircraft-related research institute

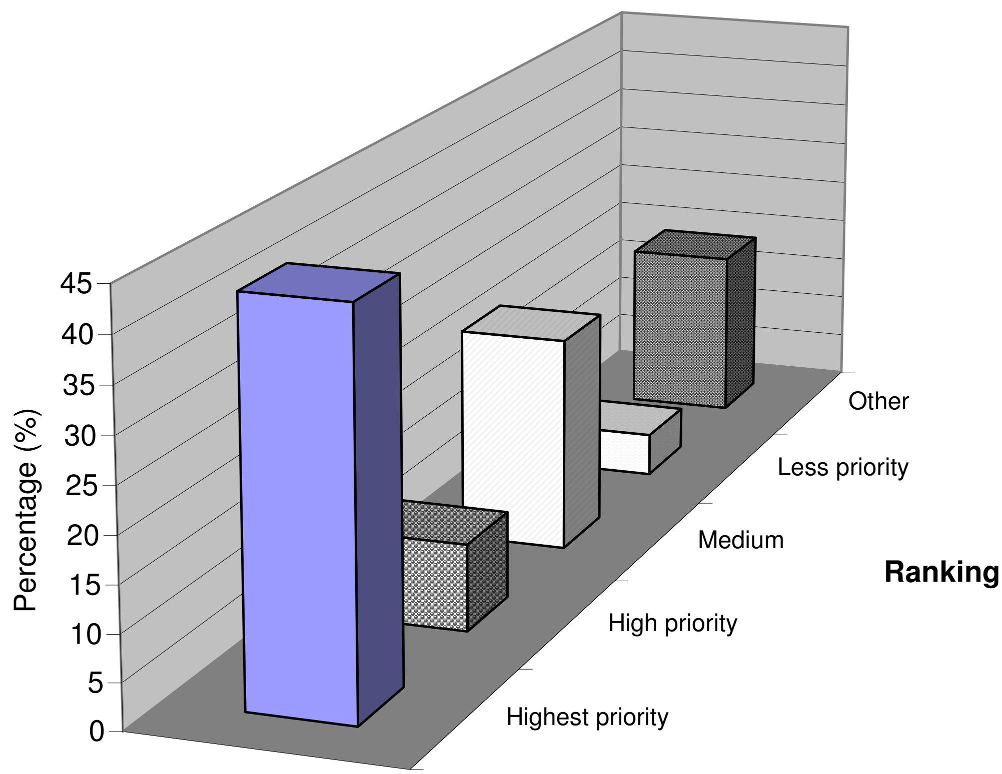

Figure (v)28 Ranking on "Aircraft-related research institute" as an element for developing/improving technological competence

Both Elements **E** (*Government support for technological innovation*) and **G** (*Research collaboration - government, research institutes, academia, firms*) had the third highest score of **38%** on *Highest priority*, with a further 29% on *High priority* in both instances. The graphical representations on the results for both (E and G) are illustrated on figures (v)29 and (v)30 respectively.

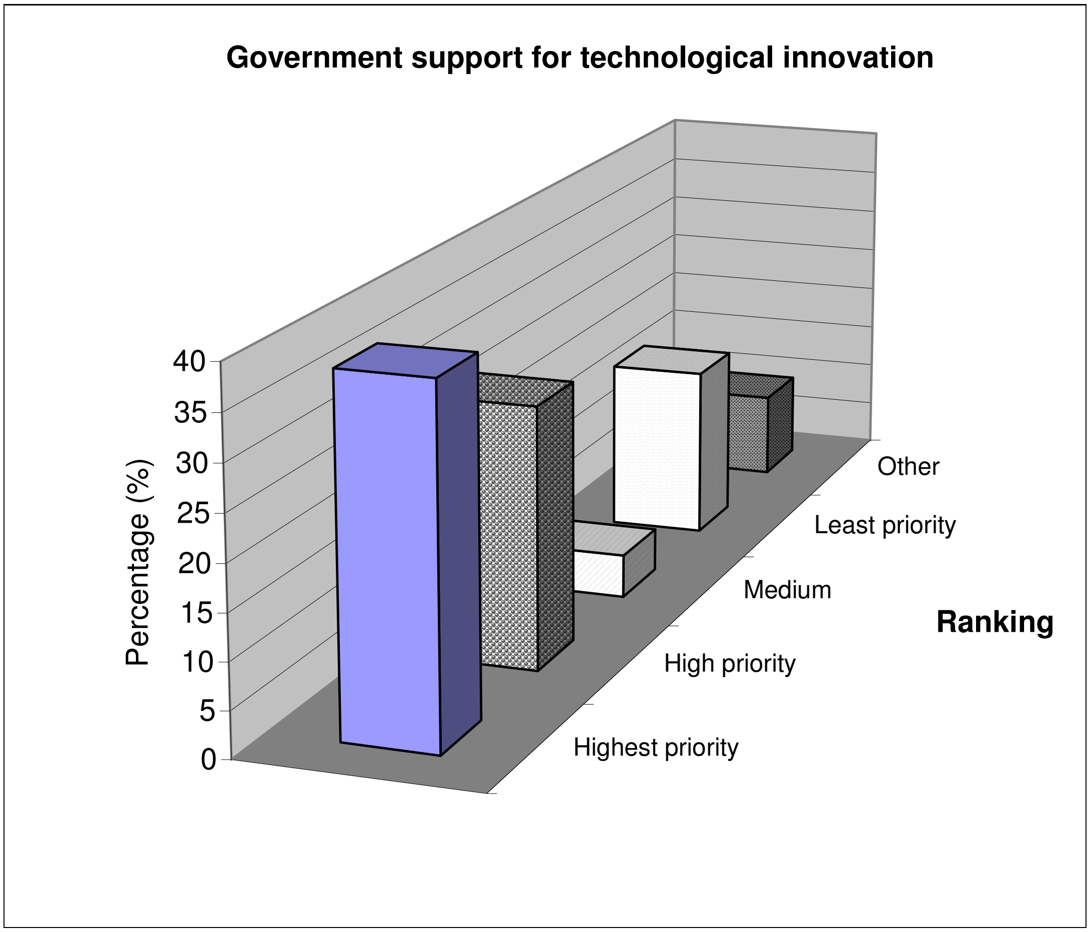

Figure (v)29 Ranking on "Government support for technological innovation" as an element for developing/improving technological competence

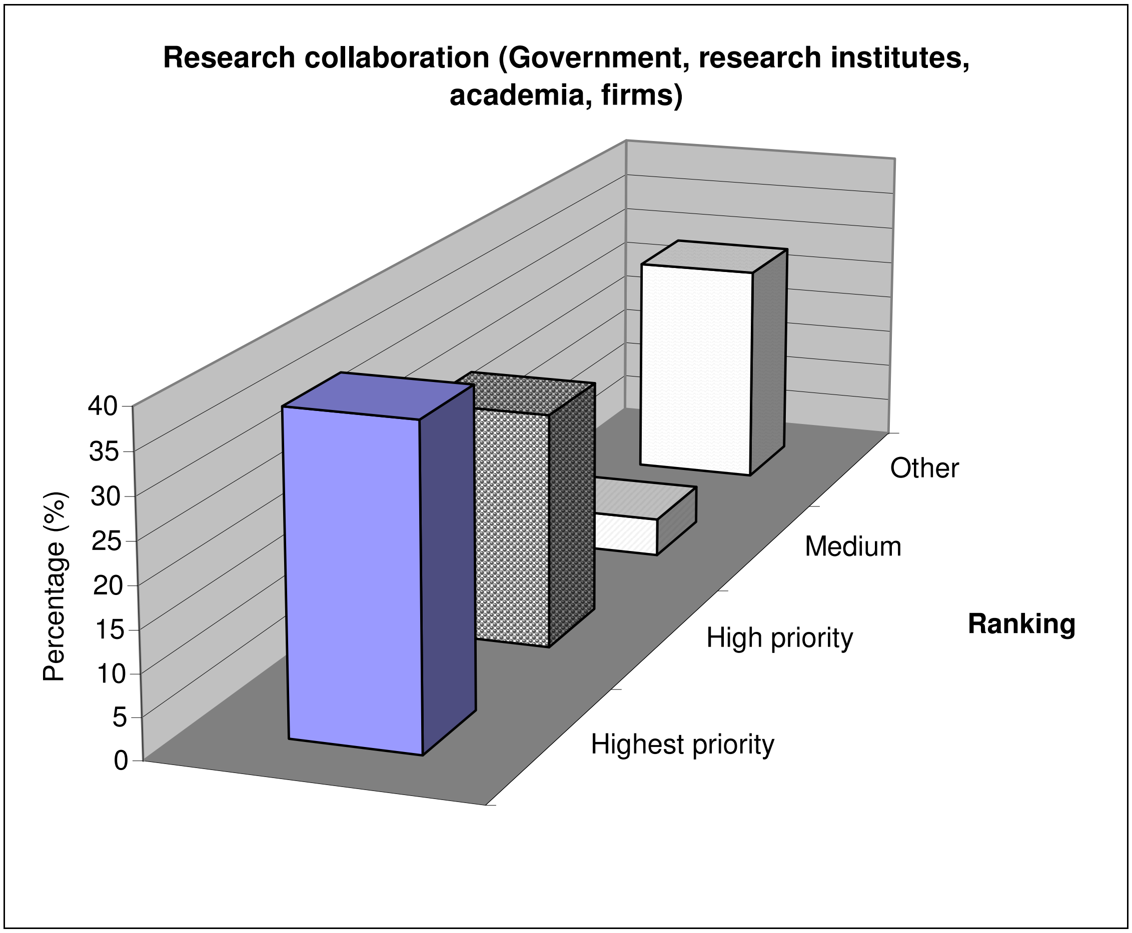

Figure (v)30 Ranking on "Research collaboration" as an element for developing/improving technological competence

Elements **L** (*Appropriate infrastructure*) and **K** (*Well-supported higher education and research institutions*) followed with a score of **33%** on *Highest priority*. Element L had a further 14% on *High priority*, with K scoring 5% on *High priority*. Graphical representations of both results are shown of figures (v)31 and (v)32 respectively.

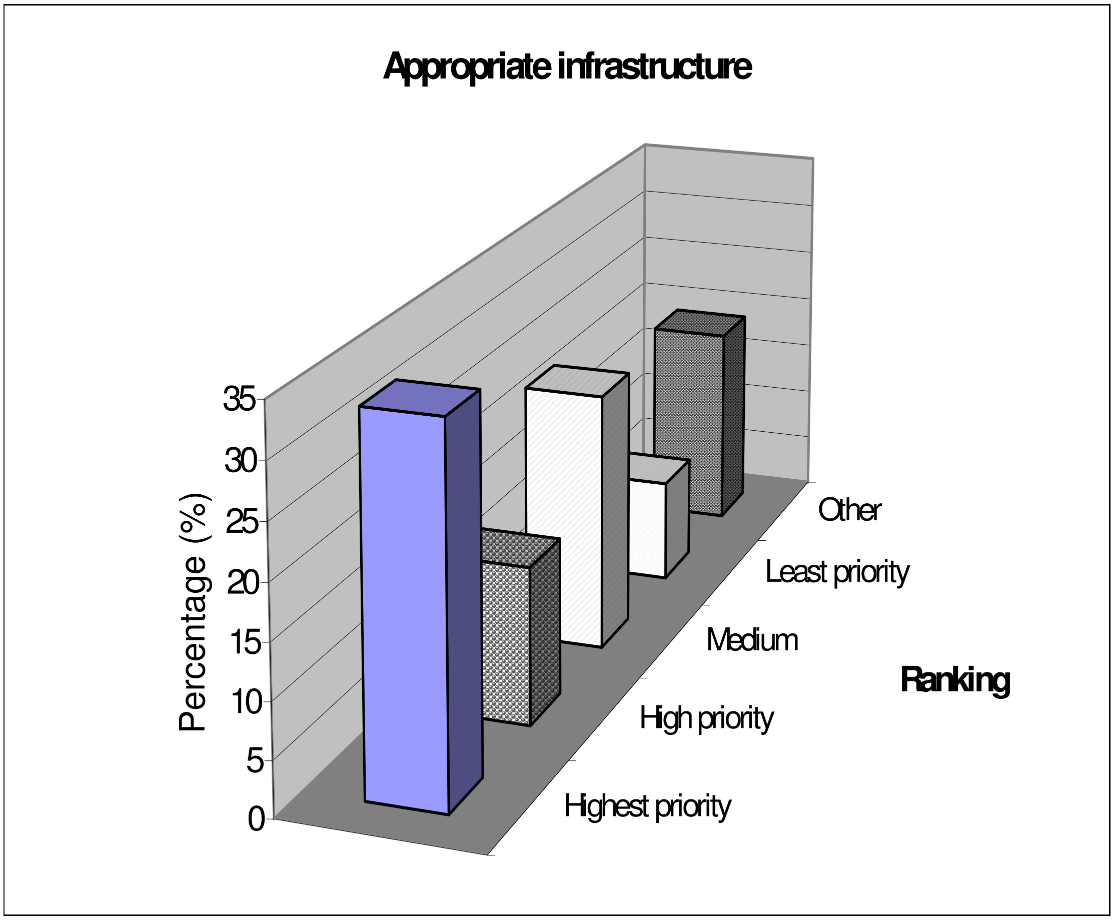

Figure (v)31 Ranking on "Appropriate infrastructure" as an element for developing/improving technological competence

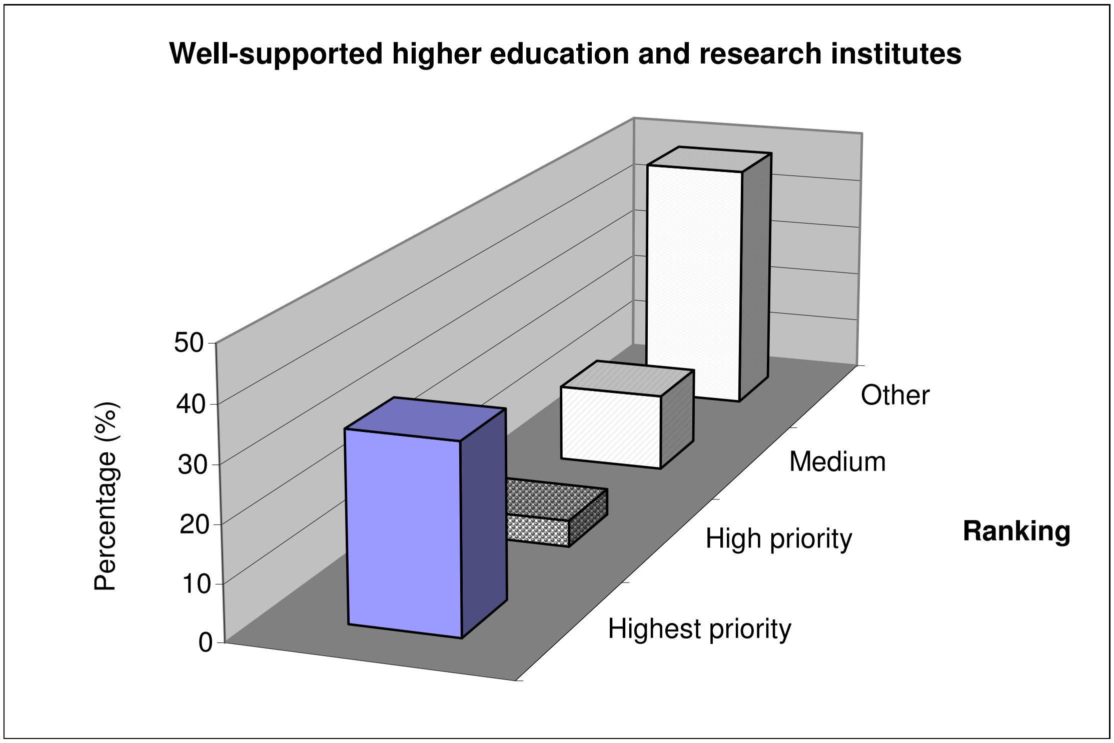

Figure (v)32 Ranking on "Well-supported higher education and research institutes" as an element for developing/improving technological competence

The other Elements that followed with a score of **10%** on *Highest priority* were **I** (*Skills development programme*), **B** (*Firm Collaboration - national*), **J** (*Good governance structures*), and **F** (*Market acquisition assistance*). Element I had a further 67% on *High priority*, B with 48% (*High priority*), J with 29% (*High priority*) and F scoring 10% (*High priority*).

Element H (*Technology transfer*) followed with only 62% on *High priority*, the last being C (*Firm collaboration - international*) with 52% (*High priority*).

12. The following are the most well known aspects that impact on the technological competitiveness of firms within the civil aircraft industry.

Responses were obtained on the following list of elements:

A. Insufficient in-house technological capability

B. Under-developed national systems of innovation

C. Lack of firm collaboration

D. Poorly developed aircraft Infrastructure

E. Insufficient skilled resources

F. Under-developed technological capabilities

G. Insufficient R&D investment

H. Insufficient skills development programme

I. Insufficient strategic alliances with global firms

J. Lack of skills transfer/knowledge transfer programme

K. Poor levels of innovation

L. Poor external environment (e.g government policy, demand, firm rivalry)

M. Poor governing structures to oversee the industry

Element **E** (*Insufficient skilled resources*) had **86%** score on *Strongly agree*, leading to the indication that the aspect has an impact on technological competitiveness of firms. The graphical representation on the results is illustrated on figure (v)33.

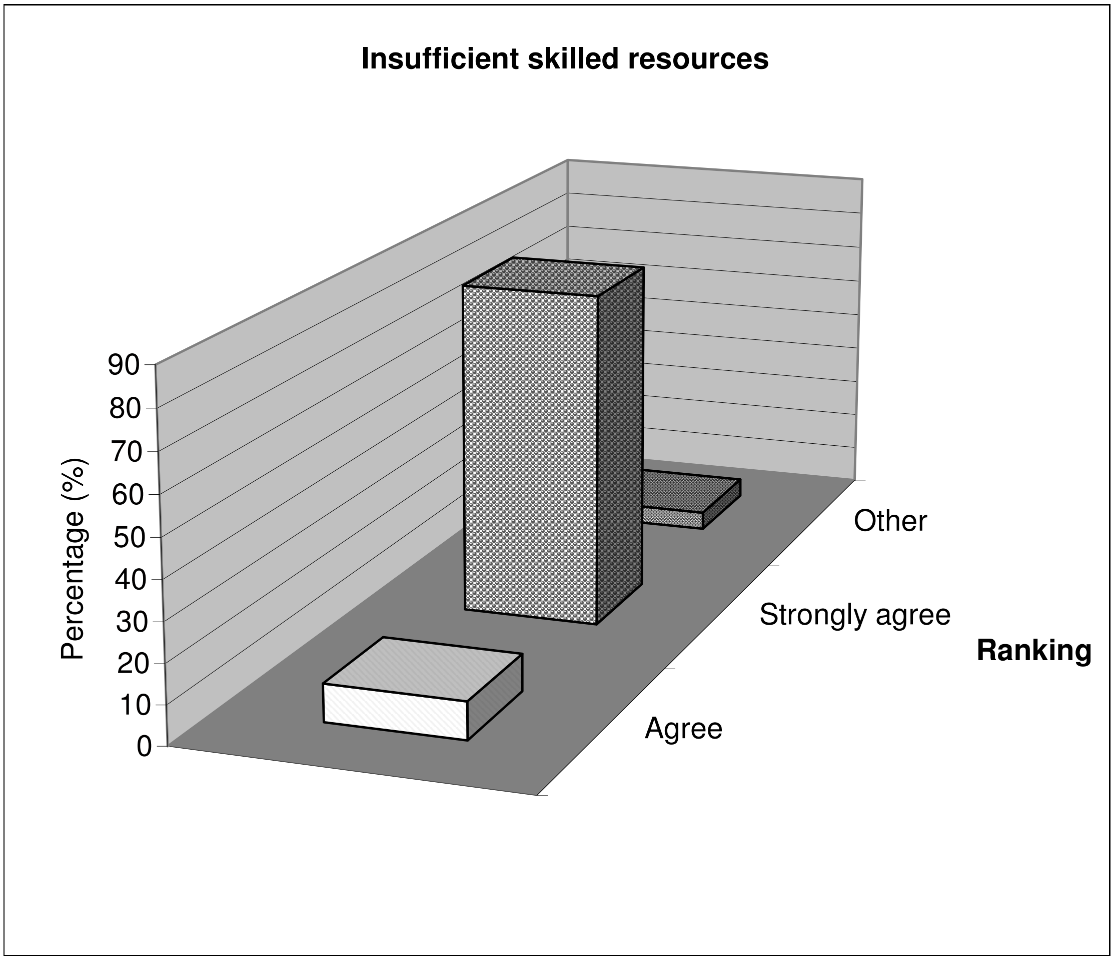

Figure (v)33 Level of agreement on "Insufficient skilled resources" as an element impacting on technological competence

Element **A** (*Insufficient in-house technology capability*) had the second highest score of **62%** on *Strongly agree*, with a further 33% on *Agree*. The graphical representation is illustrated on figure (v)34.

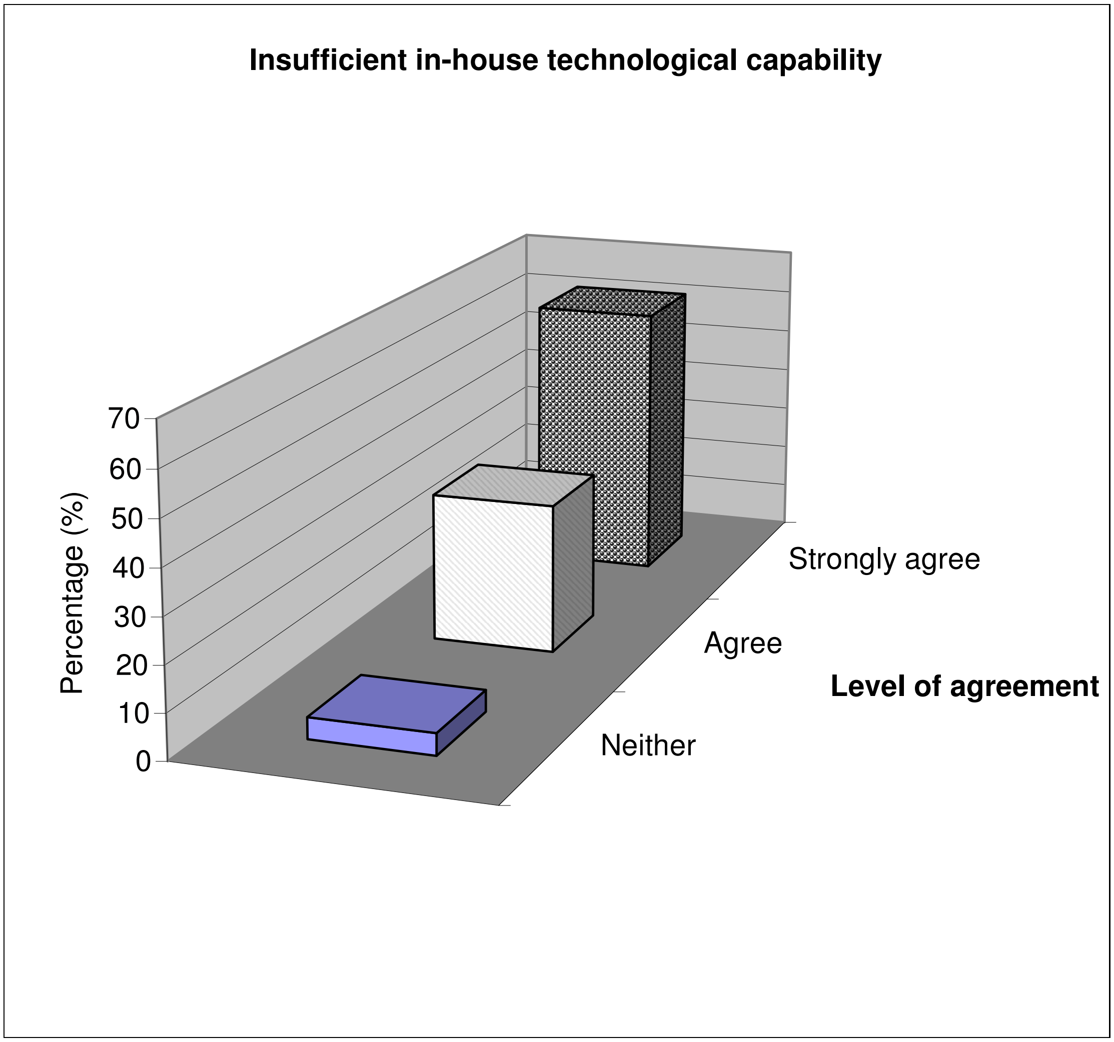

Figure (v)34 Level of agreement on "Insufficient in-house technological capability" as an element impacting on technological competence

Both Elements **F** (*Under-developed technological capabilities*) and **G** (*Insufficient R&D investment*) had the third highest score of **57%** on *Strongly agree*. They further had 38% score under *Agree* on both sides. The graphical representation of results for both elements is illustrated on figures (v)35 and (v)36 respectively.

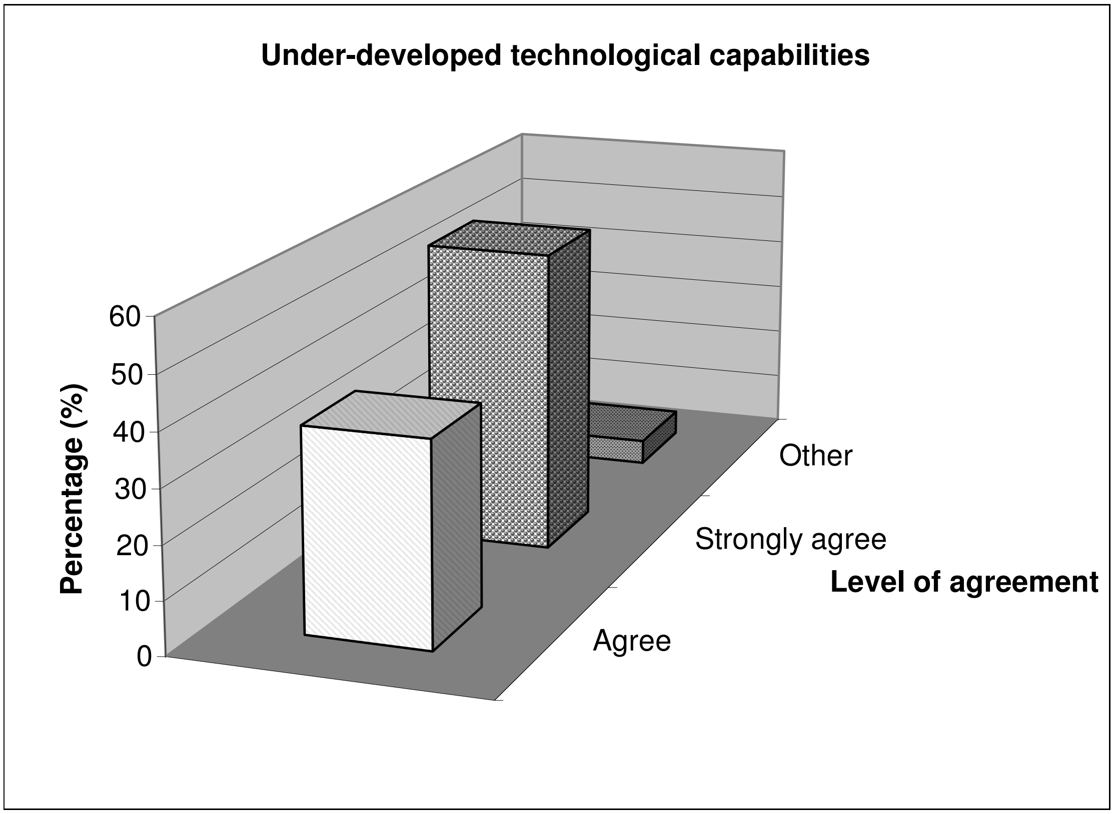

Figure (v)35 Level of agreement on "Under-developed technological capabilities" as an element impacting on technological competence

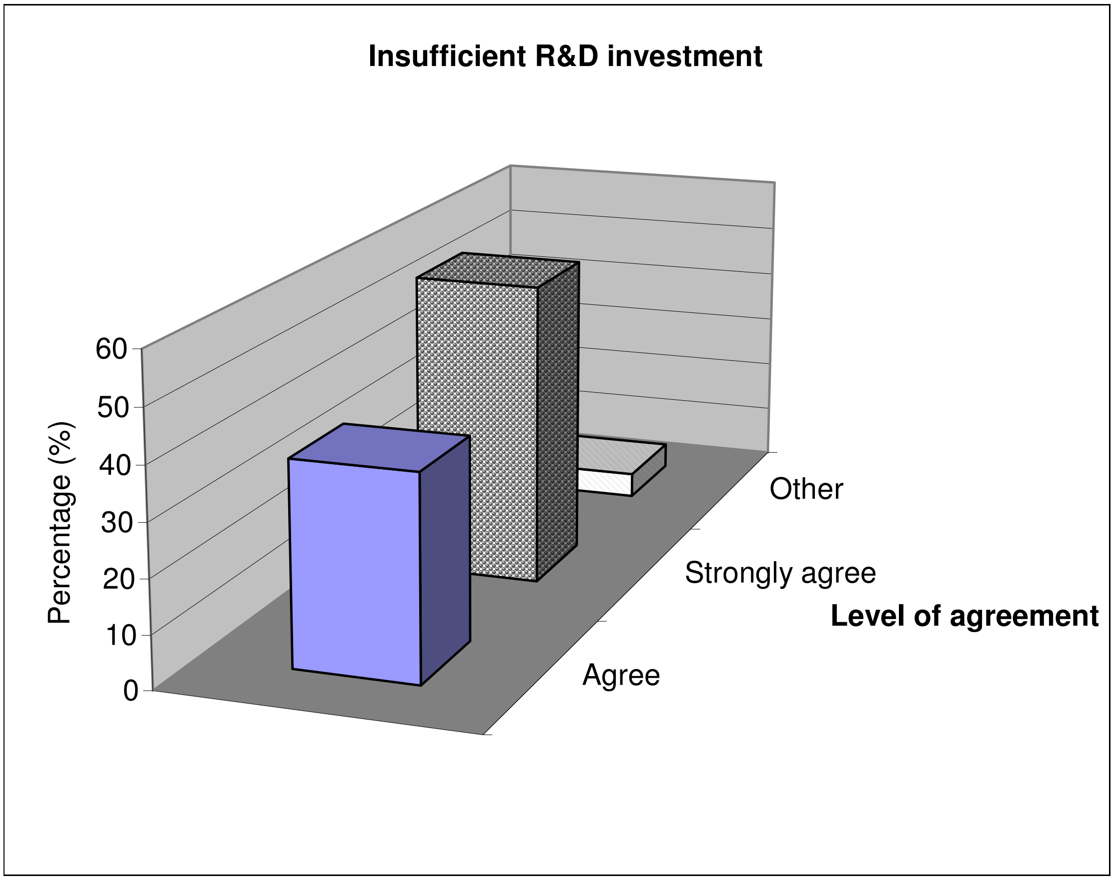

Figure (v)36 Level of agreement on "Insufficient R&D investment" as an element impacting on technological competence

Element **L** (*Poor external environment*) followed with a score of **48%** on *Strongly agree* with a further 43% on *Agree*. Figure (v)37 illustrates the results.

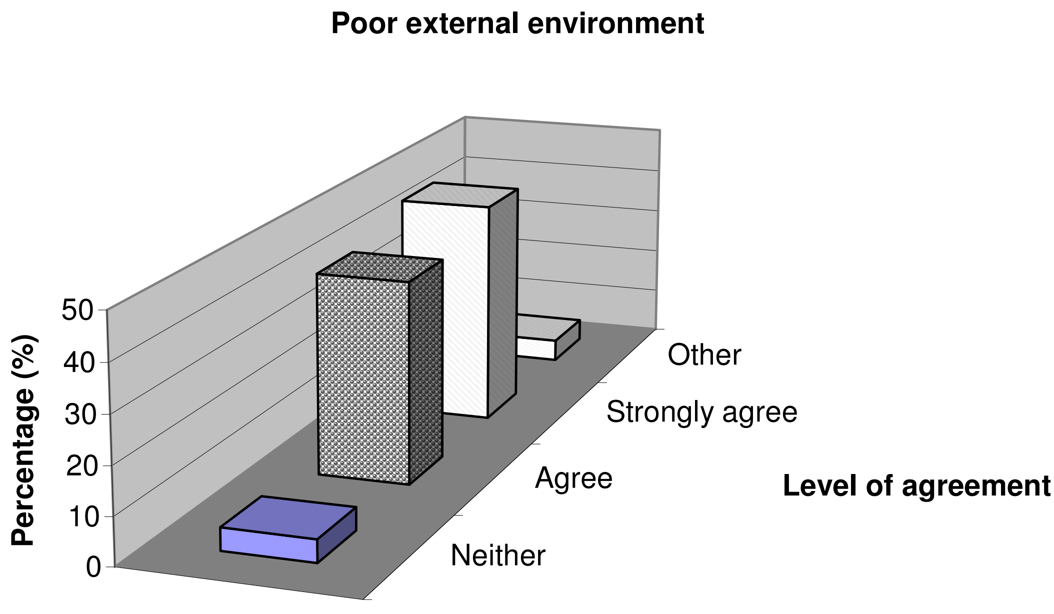

Figure (v)37 Level of agreement on "Poor external environment" as an element impacting on technological competence

Elements **H** (*Insufficient skills development programme*), **K** (*Poor levels of innovation*) and **I** (*Insufficient strategic alliances with global firms*) followed with a common score of **38%** on *Strongly agree*. However, H had a further 62% on *Agree*, whereas K had 52% (*Agree*) and I with 57% (*Agree*).

Element **B** (*Under-developed national systems of innovation*) scored **33%** on *Strongly agree*, with a further 57% on *Agree*. Both Elements **M** (*Poor governing structures to oversee the industry*) and **D** (*Poorly developed aircraft Infrastructure*) scored **29%** on *Strongly agree*, with a further 67% (*Agree*) and 43% (*Agree*) respectively. Element **J** (*Lack of skills transfer/knowledge transfer programme*) followed with **24%** on *Strongly agree* and 67% *Agree*. Element **C** (*Lack of firm collaboration*) had the least score of **10%** on *Strongly agree*, and

71% on *Agree*.

13. What form of interventions should firms do in relation to human resource development to enhance in-house technological capabilities?

Responses were received on the following list of interventions:

A. In-house skills development programme

B. Inter-firm skills exchange program (national)

C. Inter-firm skills exchange program (international)

D. Knowledge transfer during technology transfer

E. Inter-firm research collaboration (national)

F. Inter-firm research collaboration (international)

Intervention **A** (In-house skills development programme) had the highest score of **33%** on *Highest priority*. Intervention **F** (Inter-firm research collaboration – international) had the second highest score (**29%**) on *Highest priority*. Intervention **E** (Inter-firm Research collaboration – national) followed with a score of **19%** on *Highest priority*. Intervention **D** (Knowledge transfer during technology transfer) had a score of **5%** on *Highest priority*. Both interventions B (Inter-firm skills exchange program – national) and C (Inter-firm skills exchange program – international) were not scored for *Highest priority*, but had 33% and 19% respectively on *High priority*. The graphical representation of the findings is illustrated on figure (v)38.

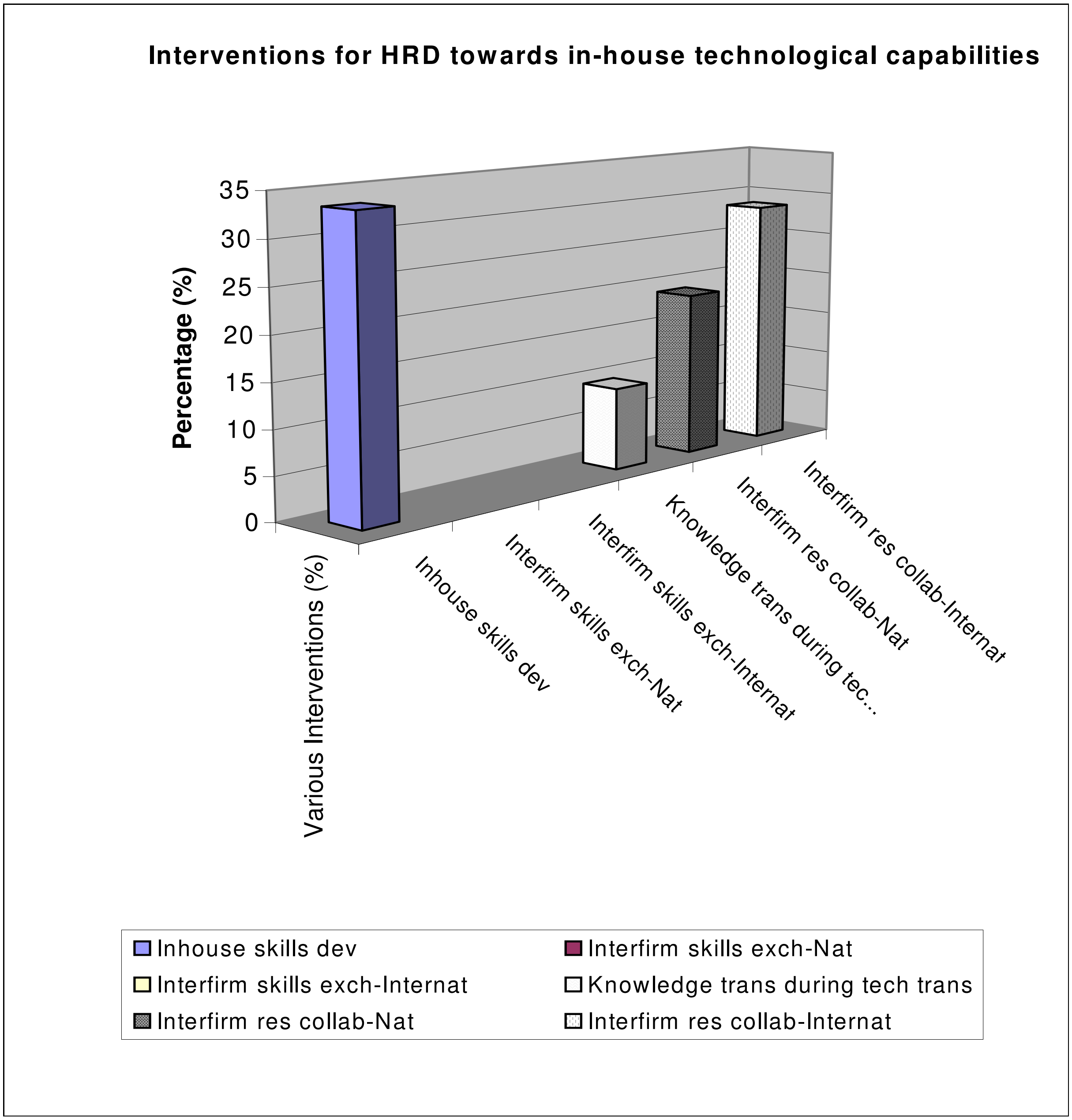

Figure (v)38 Ranking of various interventions for HRD to enhance in-house technological capabilities

14. The following are assumed to be the factors hampering global business acquisition and the technology capability-building needed for enhancing technology development within the civil aircraft firms:

Responses were received on the following list of factors:

A. Highly regulated environment (global and local)

B. Insufficient financial resources

C. Inadequate skilled resources

D. Lack of appropriate technologies

E. Projects too costly

F. Poor strategic alliances or networks

G. Not meeting customers' demands

H. Insufficient government support

I. Insufficient experience in global supply

J. Negative perception by global customers on quality of products

Factor **B** (*Insufficient financial resources*) had the highest score of **57%** on *Strongly agree*, indicating that respondents strongly feel that this is one of the key factors hampering global business acquisition and technology capability-building. The graphical representation of the results is illustrated on figure (v)39.

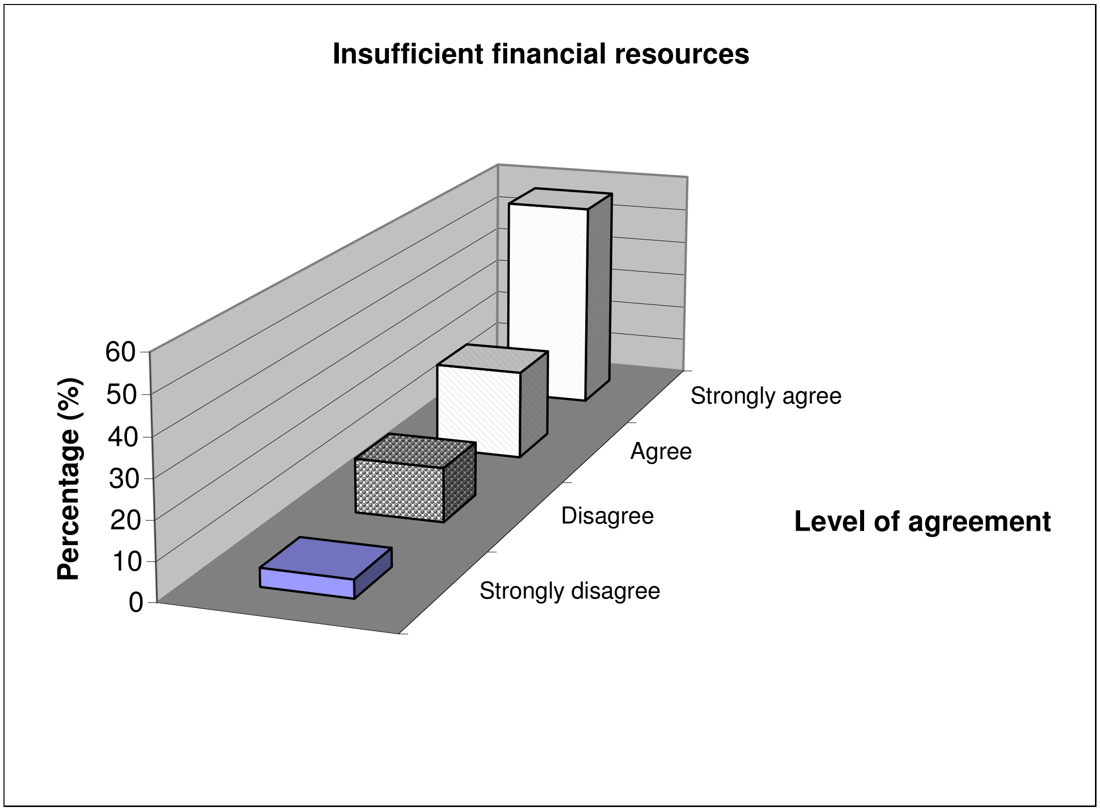

Figure (v)39 Level of agreement on "Insufficient financial resources" as a factor hampering global business acquisition and the technology capability-building process

Factor **E** (*Projects too costly*) had the second highest score of **52%** on *Strongly agree.*

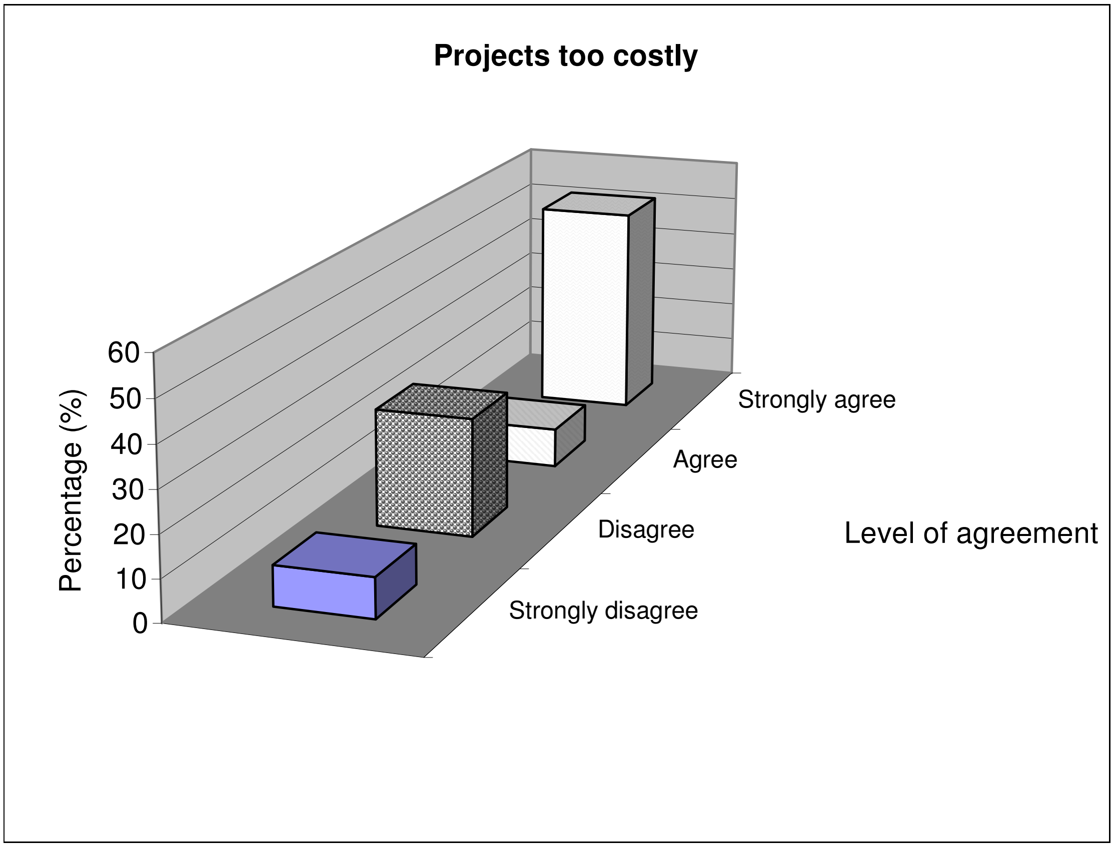

Figure (v)40 Level of agreement on "Projects too costly" as a factor hampering global business acquisition and the technology capability-building process

Factor **G** (Not meeting customers' demand) obtained the third highest score of **43%** on *Strongly agree*, with a further 33% on *Agree*.

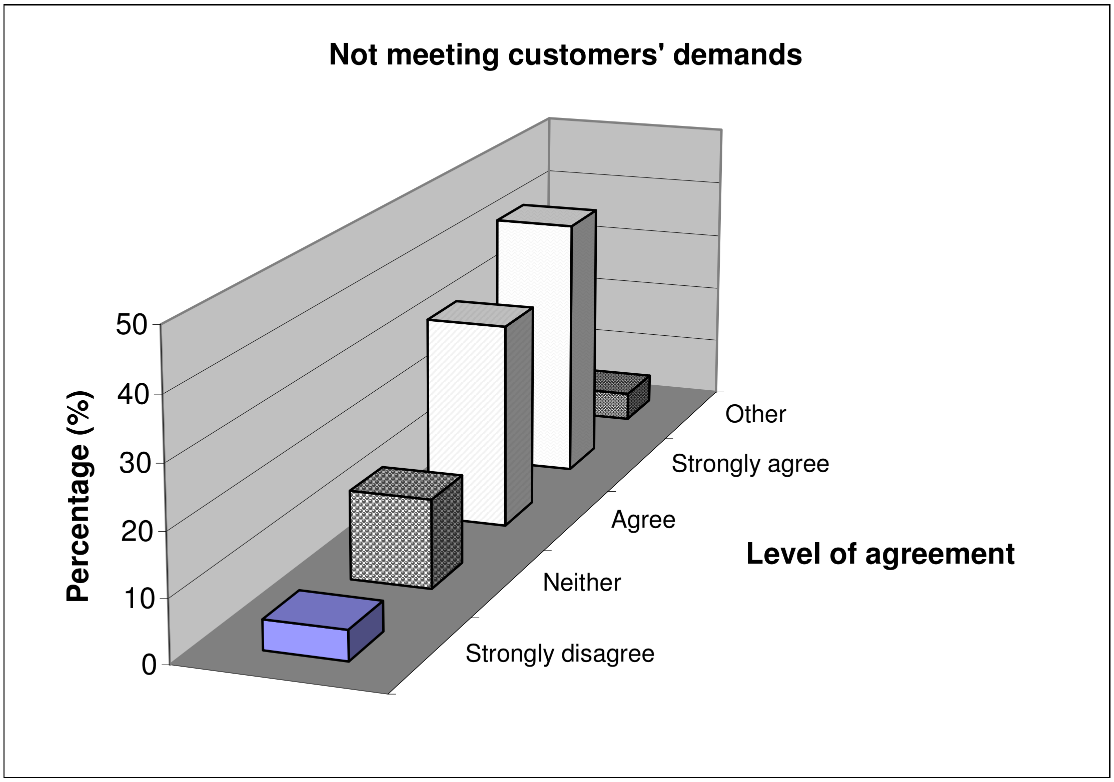

Figure (v)41 Level of agreement on "Not meeting customers' demands" as a factor hampering global business acquisition and the technology capability-building process

Factors **D** (*Lack of appropriate technologies)* and **F** (*Poor strategic alliances or networks)* followed with a common score of **24%** on *Strongly agree*. D had a further 62% on *Agree*, with F scoring 38% (*Agree*). The graphical representations of both are illustrated on figures (v)42 and (v)43 respectively.

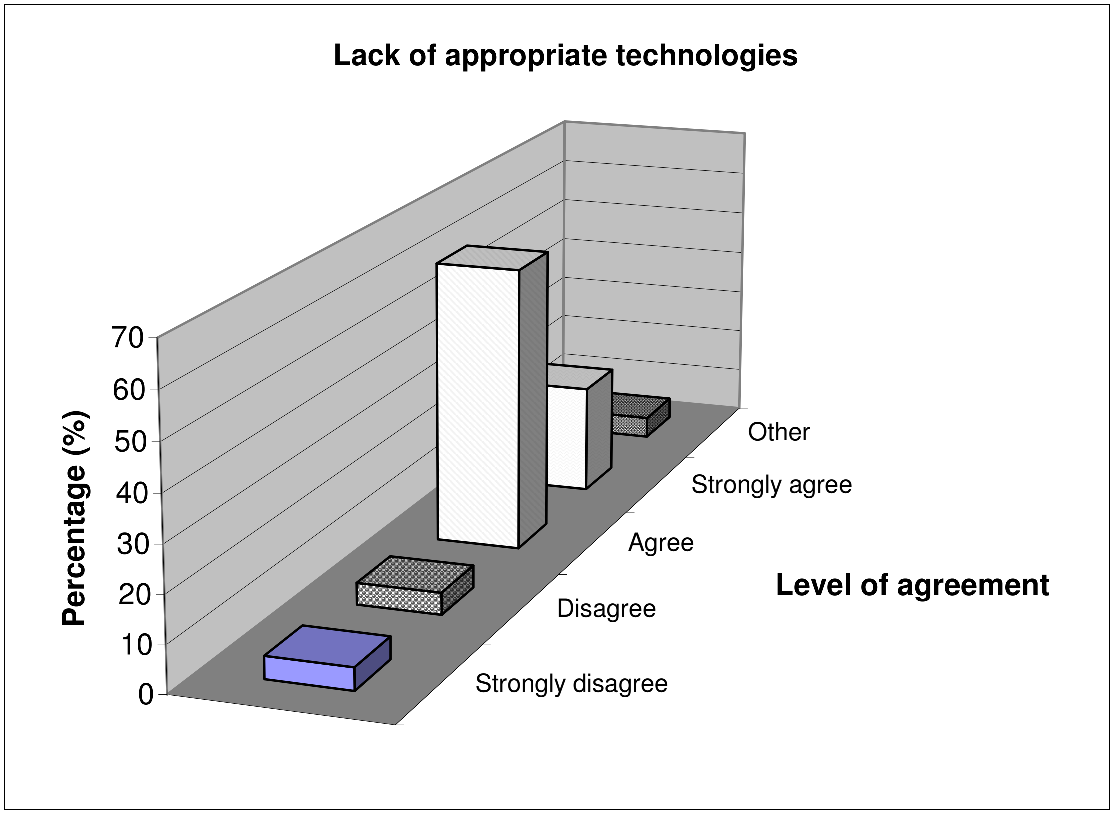

Figure (v)42 Level of agreement on "Lack of appropriate technologies" as a factor hampering global business acquisition and the technology capability-building process

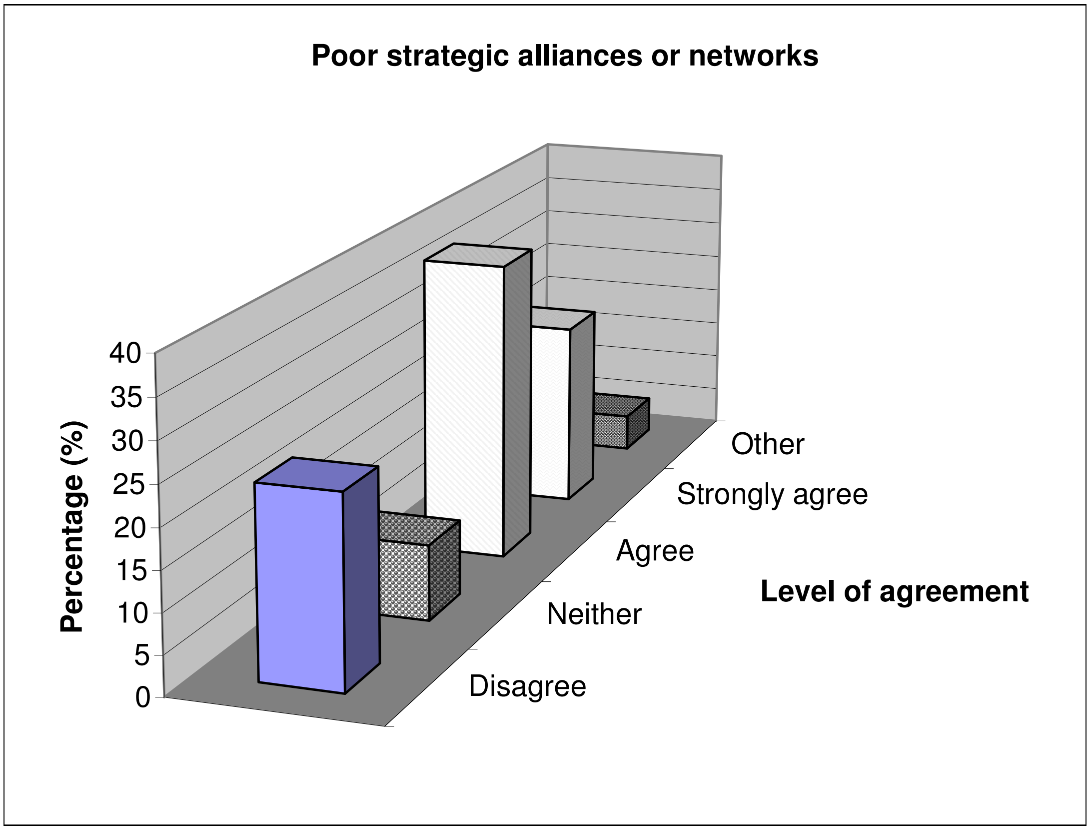

Figure (v)43 Level of agreement on "Poor strategic alliances or networks" as a factor hampering global business acquisition and the technology capability-building process

Factors **H** (*Insufficient government support)* and **I** (*Insufficient experience in global supply)* followed with a common score of **19%** on *Strongly agree*. H had a further 43% on *Agree* with I scoring 23% (*Agree*).

Factor **C** *(Inadequate skilled resources)* then followed with a score of **14%** on *Strongly agree*, and a further 71% on *Agree*.

Factor **J** (*Negative perception by global customers on quality of products)* had **10%** on *Strongly agree*, with 48% on *Agree*.

Factor **A** (*Highly regulated environment - global and local)* had **5%** on *Strongly agree*, and 33% *Agree*.

15. What would be the ideal key competencies, capabilities, skills and technologies needed for the civil aircraft technology development by developing economies?

Responses were obtained on the following list of elements:

A. Aircraft maintenance skills

B. Aircraft conversions and modification skills

C. Manufacture of components and sub-system levels

D. Manufacture of composites, rotor wing propeller blades, gear-boxes

E. Design and manufacturing of complete engines

F. Specialists in avionics

G. Capabilities for interior designs

H. Design and manufacturing skills for helicopters

I. Design and manufacturing skills for passenger aircraft

J. Full assembling skills for passenger aircraft

K. Civil-military technology linkages

Element **K** (*Civil-military technology linkages*) had the highest score of **67%** on *Highest priority*, indicating that this would be the crucial capability required by developing economies for the civil aircraft technology development. A graphical representation on findings is illustrated on figure (v)44.

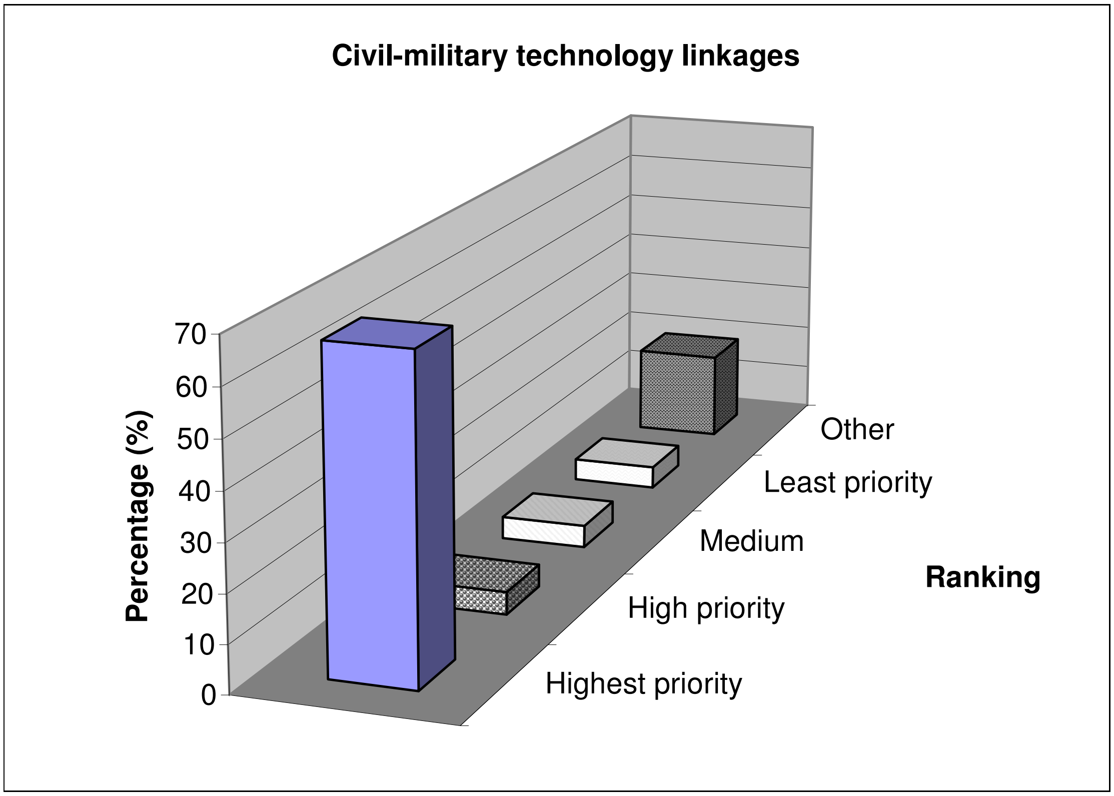

Figure (v)44 Ranking on "Civil-military technology linkages" as a competency/capability/skill needed by developing economies for the civil aircraft technology capability-building process

Element **A** (*Aircraft maintenance skills*) had the second highest score of **52%** on *Highest priority*, with a further 33% on *High priority*. A graphical representation on findings is illustrated on figure (v)45.

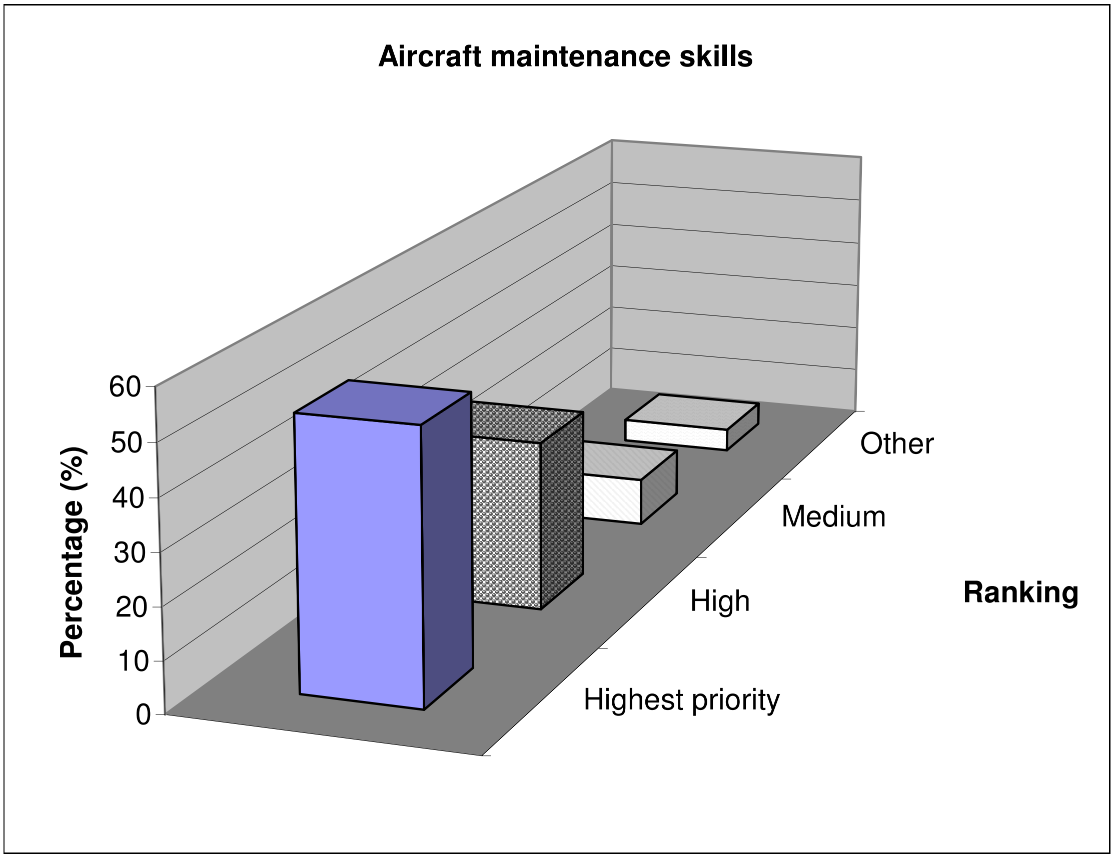

Figure (v)45 Ranking on "Aircraft maintenance skills" as a competency/capability/skill needed by developing economies for the civil aircraft technology capability-building process

Elements **B** (*Aircraft conversions and modification skills*) and **D** (*Manufacture of composites, rotor wing propeller blades, gear-boxes*) both had the third highest score of **38%** on *Highest priority*. B had a further 52% on *High priority*, with D scoring 10% (*High priority*). Graphical representations of both results are illustrated on figures (v)46 and (v)47.

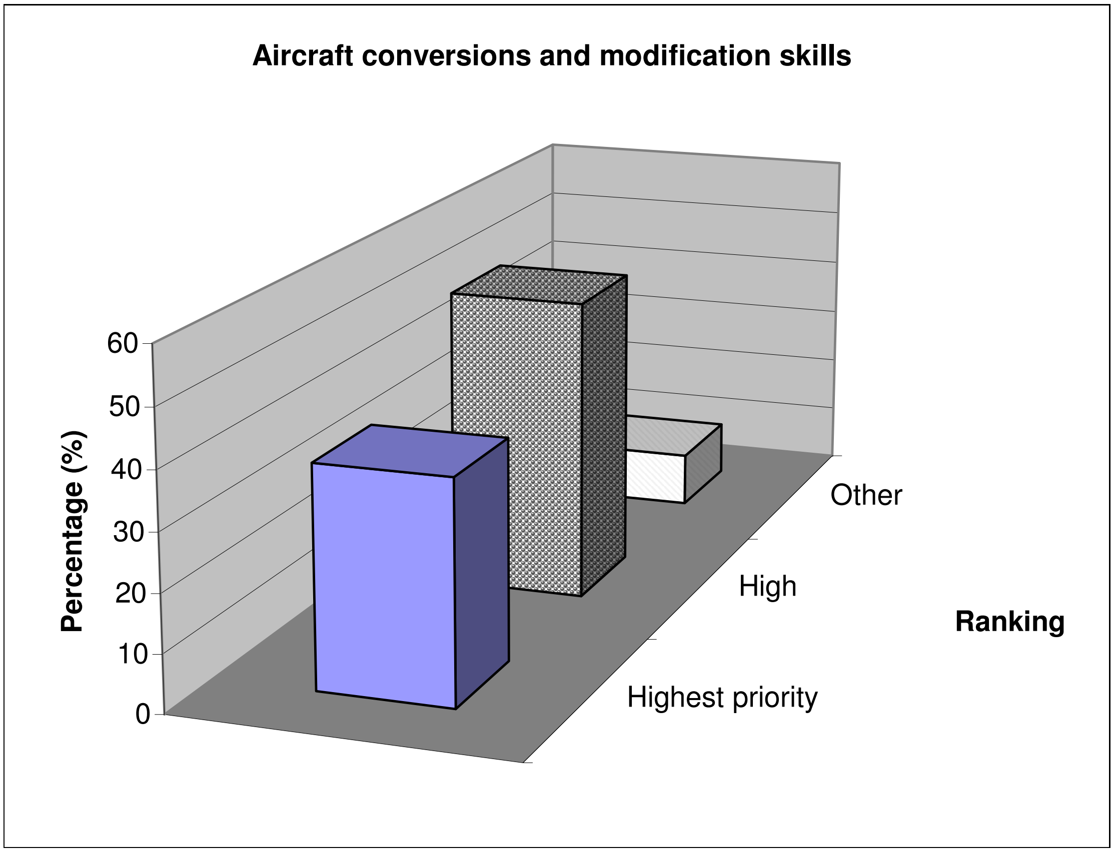

Figure (v)46 Ranking on "Aircraft conversions and modification skills" as a competency/capability/skill needed by developing economies for the civil aircraft technology capability-building process

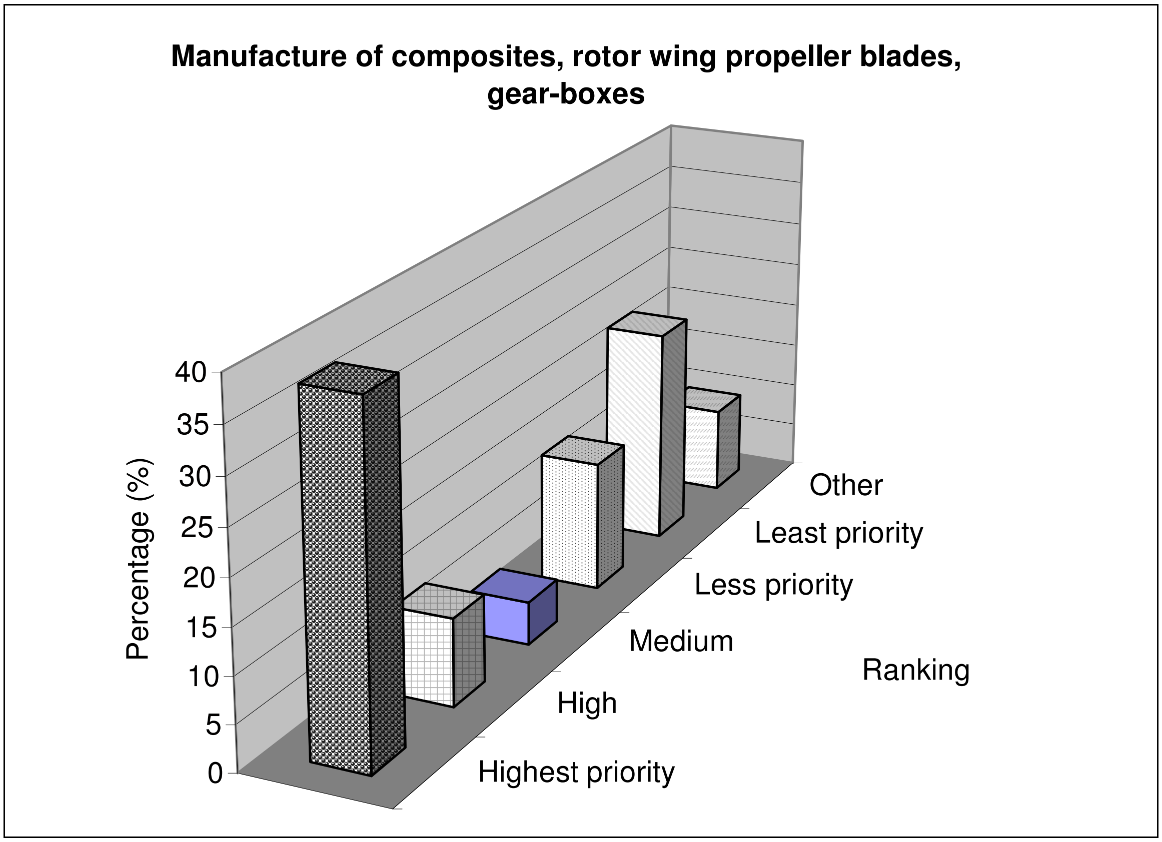

Figure (v)47 Ranking on "Manufacture of composites, rotor wing propeller blades, gear-boxes" as a competency/capability/skill needed by developing economies for the civil aircraft technology capability-building process

Elements **C** (*Manufacture of components and sub-system levels*) and **E** (*Design and manufacturing of complete engines*) followed with a score of **24%** on *Highest priority*. C had a further 33% on *High priority*. Figures (v)48 and (v)49 illustrate the findings.

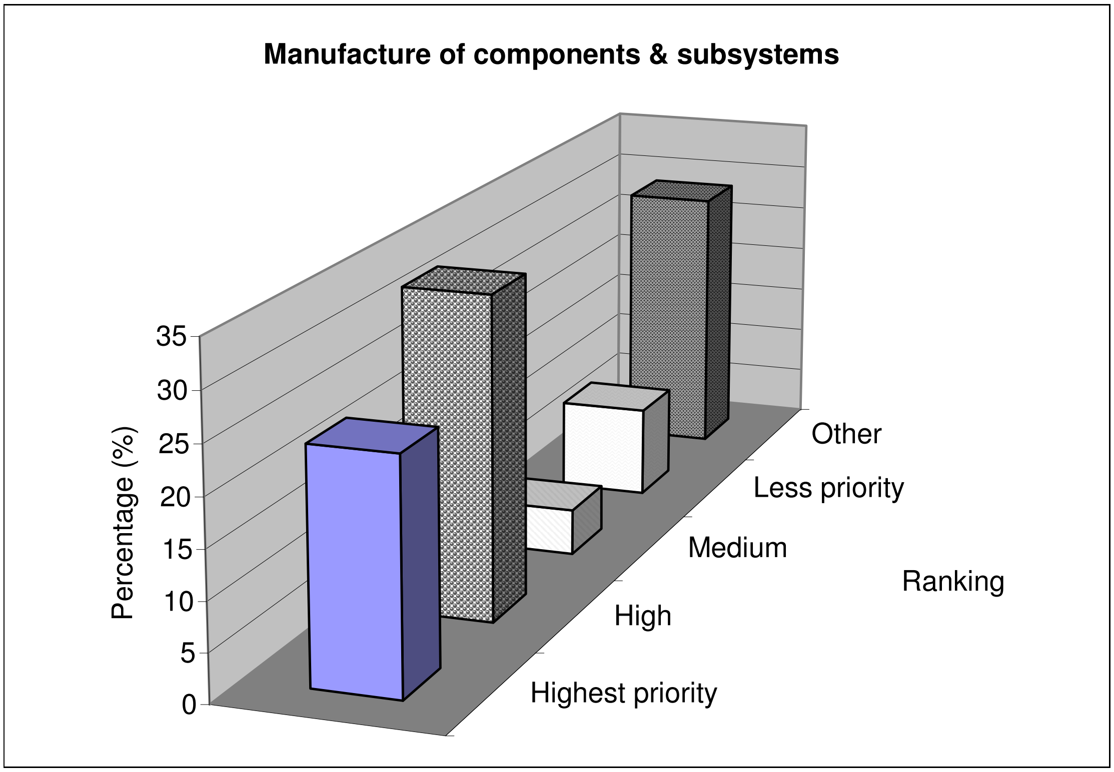

Figure (v)48 Ranking on "Manufacture of components & subsystems" as a competency/capability/skill needed by developing economies for the civil aircraft technology capability-building process

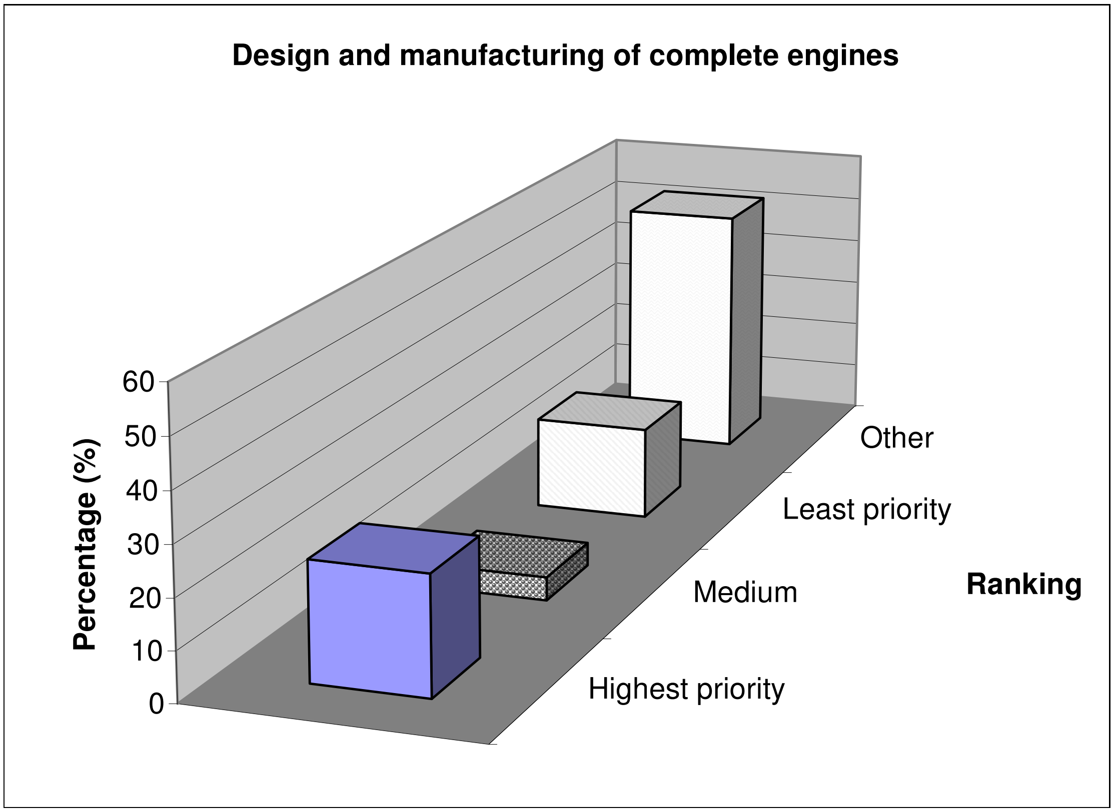

Figure (v)49 Ranking on "Design and manufacture of complete engines" as a competency/capability/skill needed by developing economies for the civil aircraft technology capability-building process

Element **J** (*Full assembling skills for passenger aircraft*) followed with a score of **10%** on *Highest priority*.

Element **I** (*Design and manufacturing skills for passenger aircraft*) scored **24%** on *High priority*.

Element **G** (*Capabilities for interior designs*) scored **19%** on *High priority*.

Element **F** (*Specialists in avionics*) scored **10%** on *High priority*.

Element **H** (*Design and manufacturing skills for helicopters*) scored **5%** on *High priority*.

16. How would you rate the current level of innovation in your firm/country as compared to that of successful firms/countries specifically within the civil aircraft industry?

On average the rating indicated by total responses on the current level of innovation in the countries interviewed varies as follows: *Very strong* (32%), *Strong* (10%), *Moderate* (29%), *Poor* (24%) and *Other* (5%).

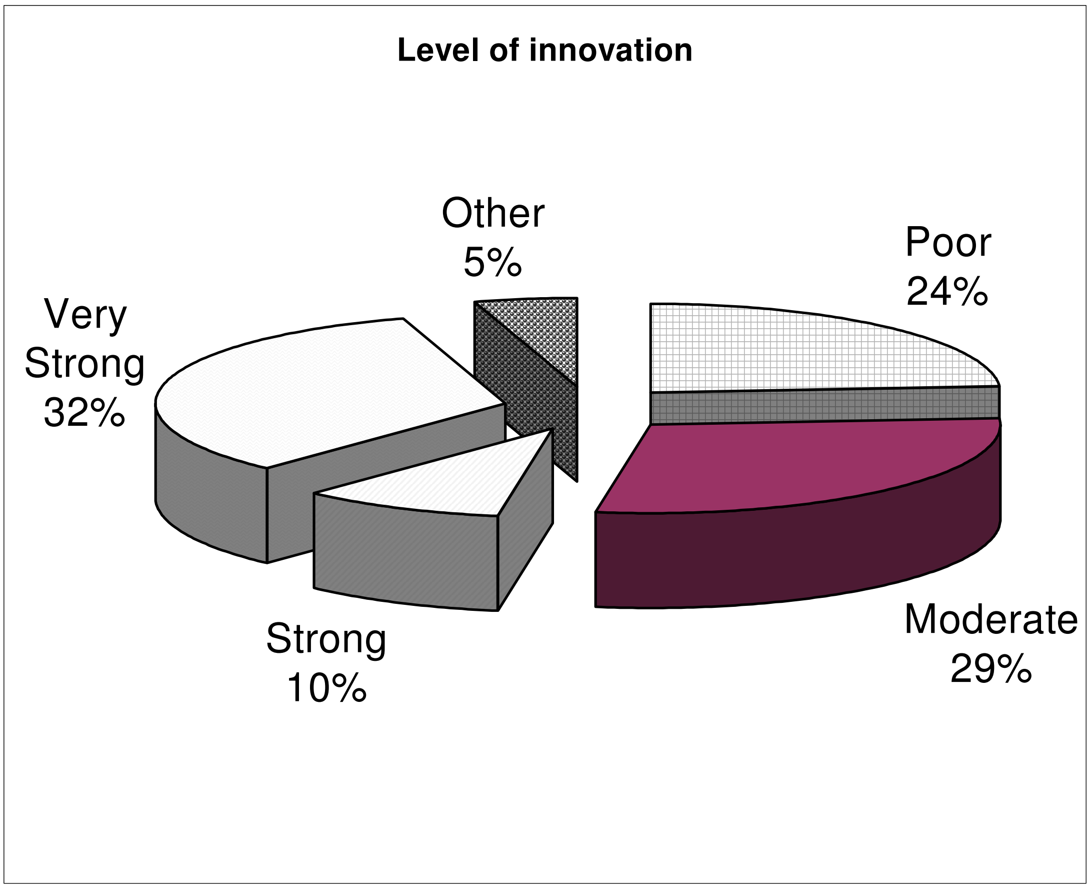

Figure (v)50 The average level of innovation in the countries studied

If the results are broken down further as *Poor* or *Good*, the scores can be graphically illustrated as follows:

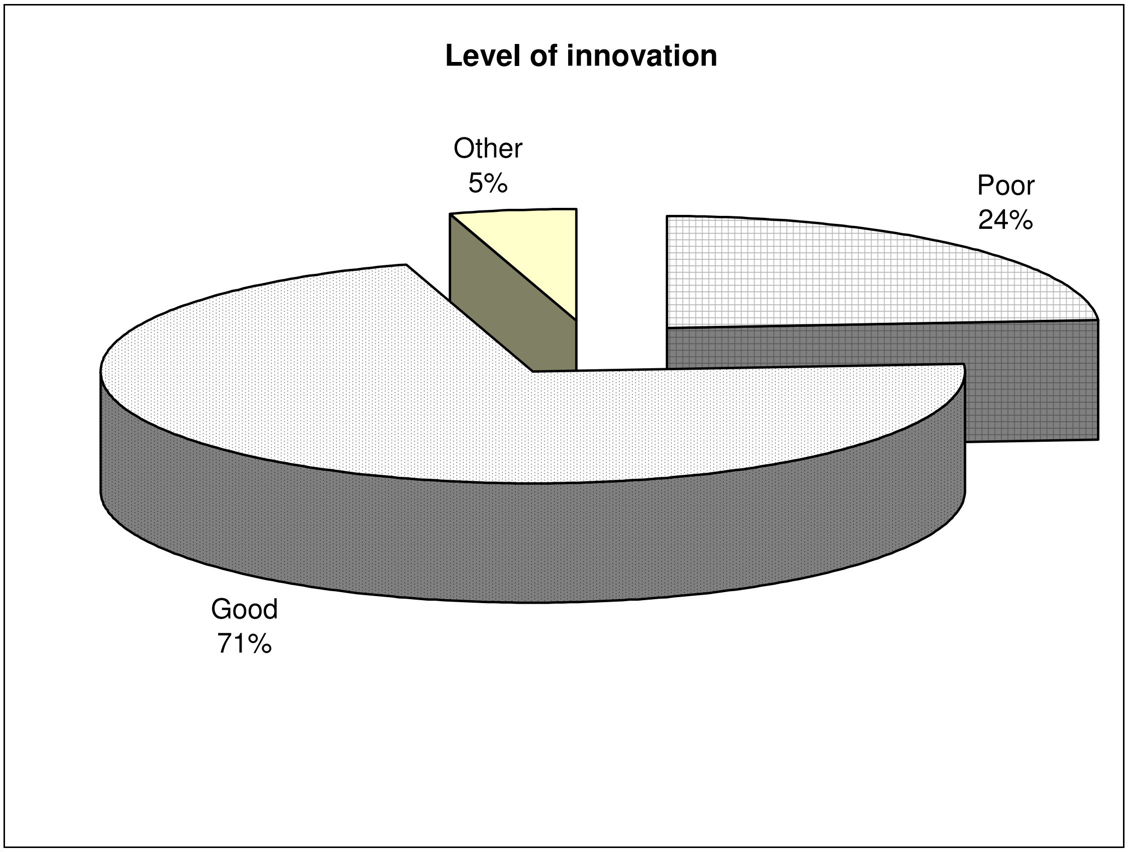

Figure (v)51 A further breakdown of the level of innovation in the countries studied