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.

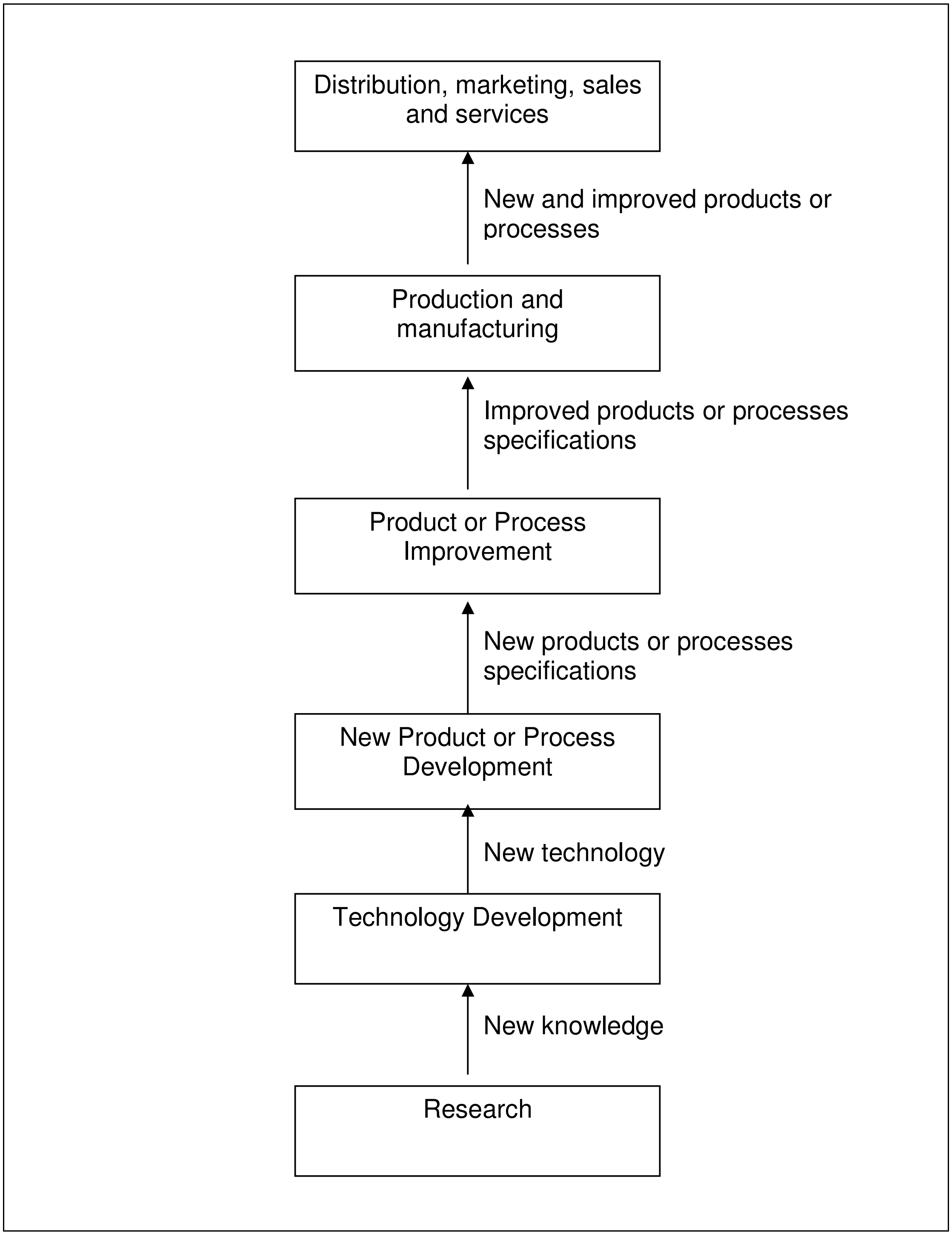

Figure 3.1 The one-directional linear model of the innovation process
Source: Buys (2001; 2002)

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.

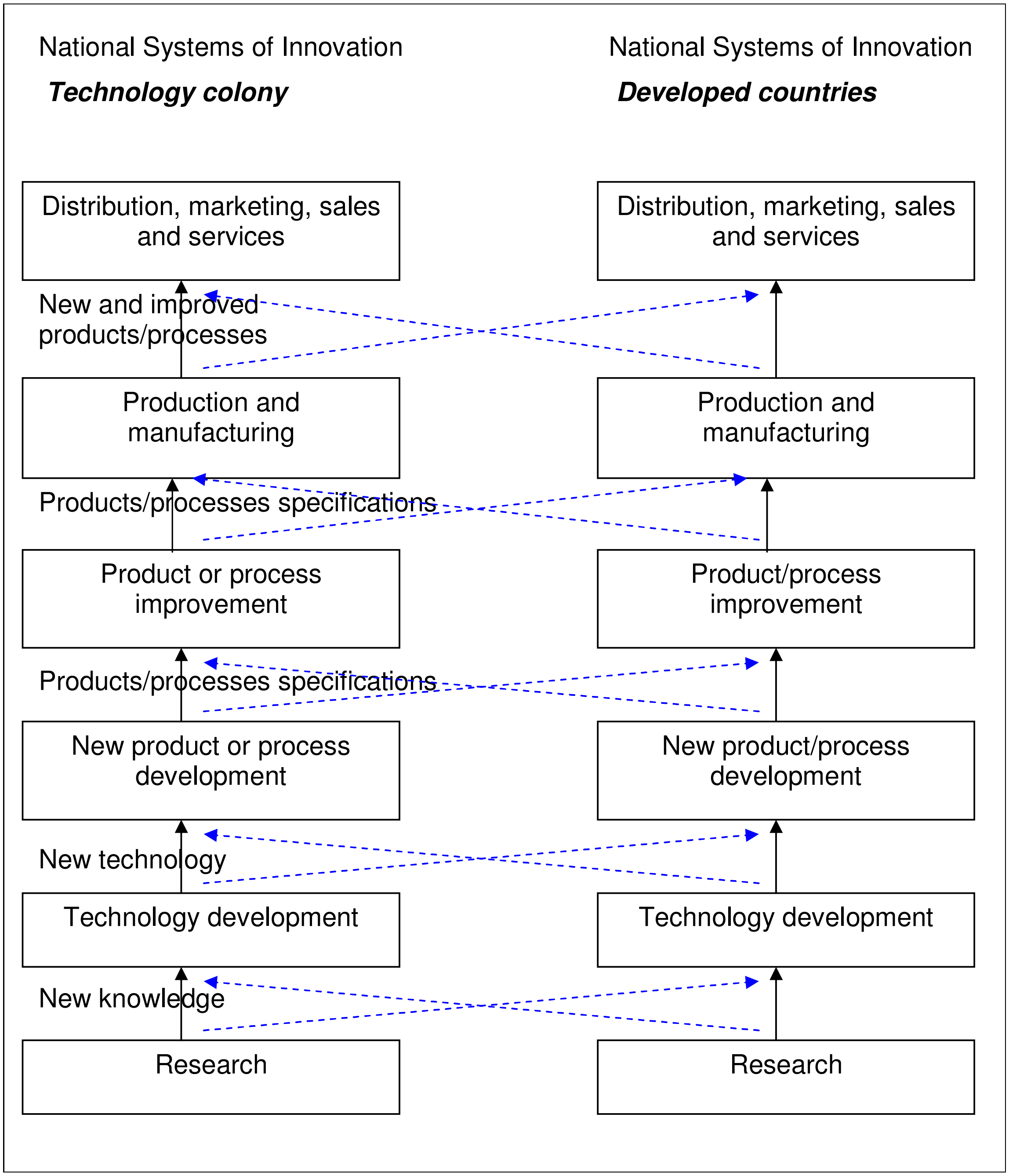

Figure 3.2 Five-stage backwards integration process of national systems of innovation
Source: Adapted from Buys (2001)

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.

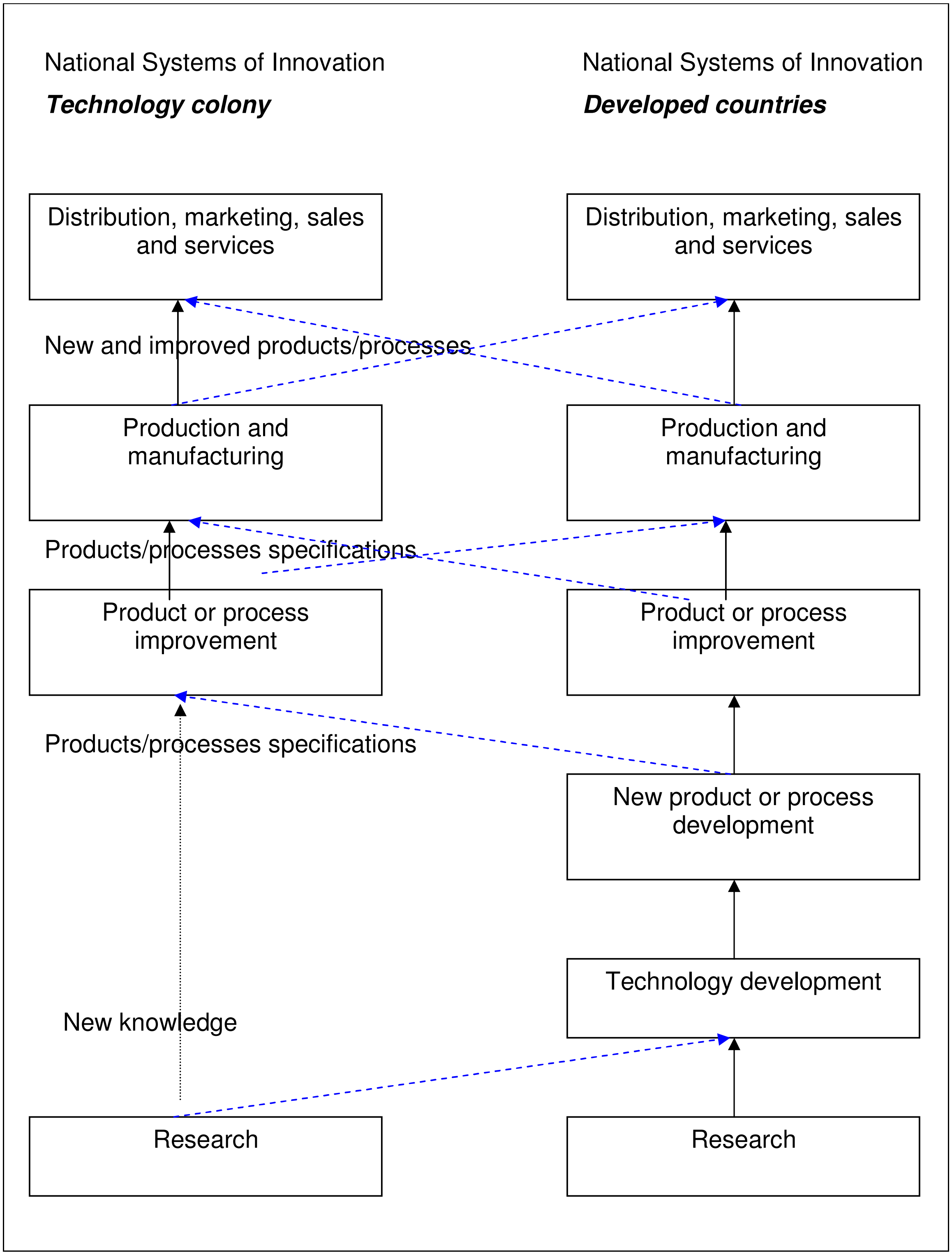

Figure 3.3 Stage III backwards integration of national systems of innovation
Source: Adapted from Buys (2001)

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.

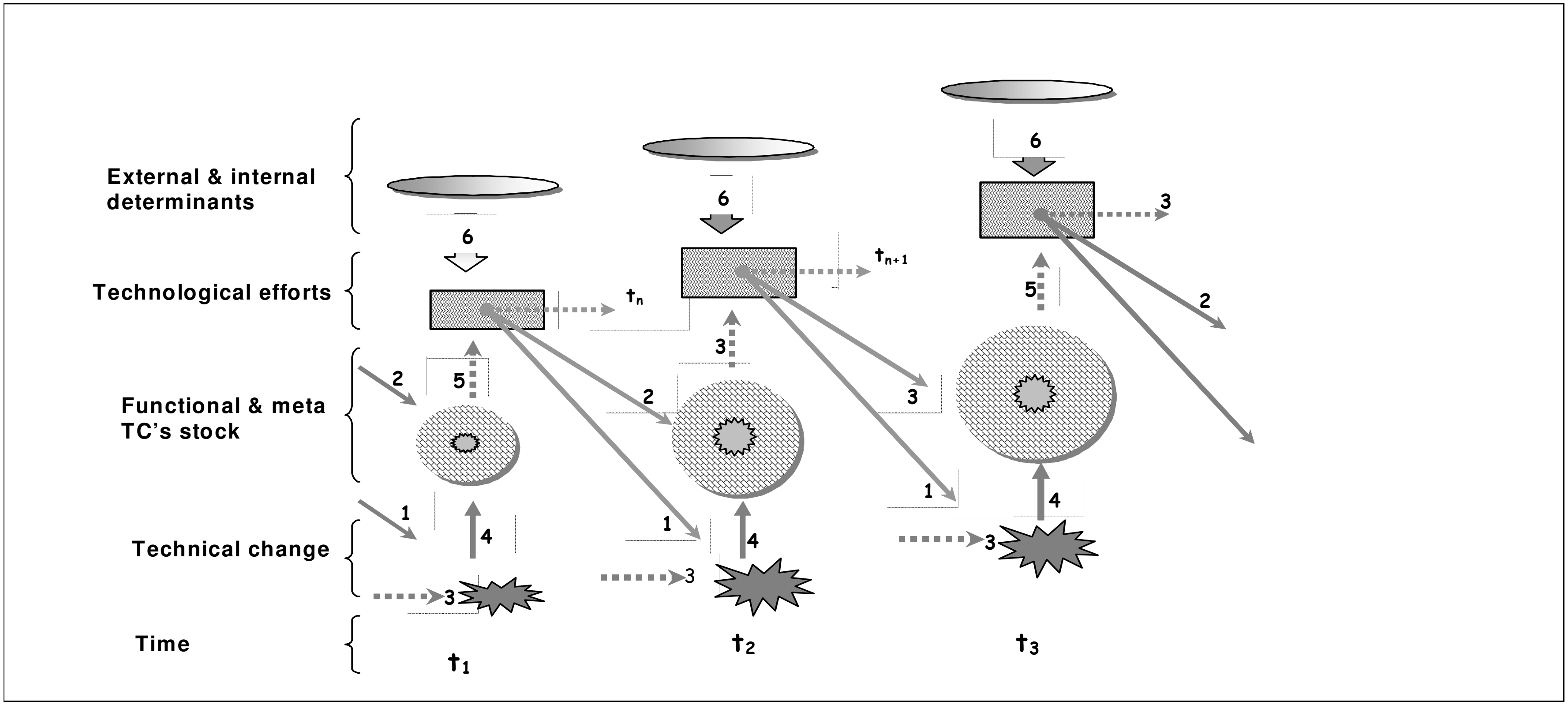

Figure 3.4 Learning process and technical change: Elements and dynamics

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.

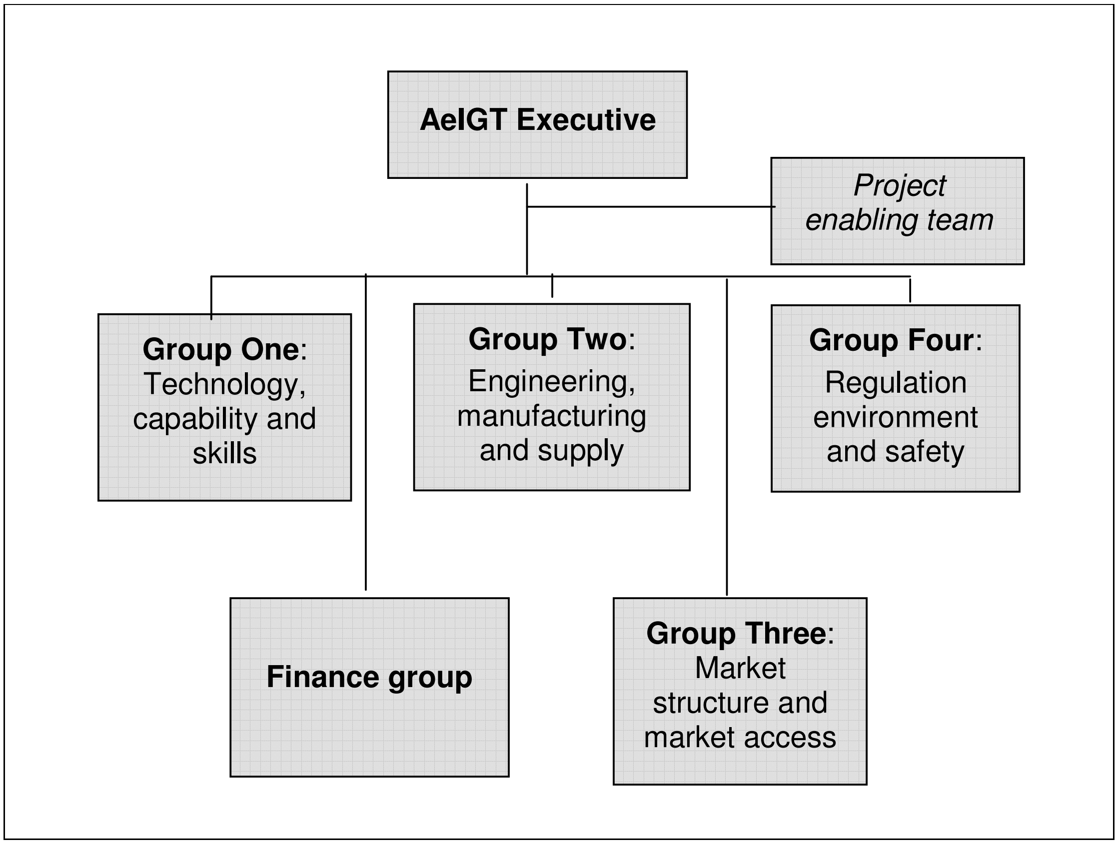

Figure 3.5 Aerospace Innovation and Growth Team (AeIGT) organisation
Source: DTI (UK), 2003. Independent report by Aerospace Innovation and Growth Team (AeIGT) on the future of the UK aerospace industry (June 2003)

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.

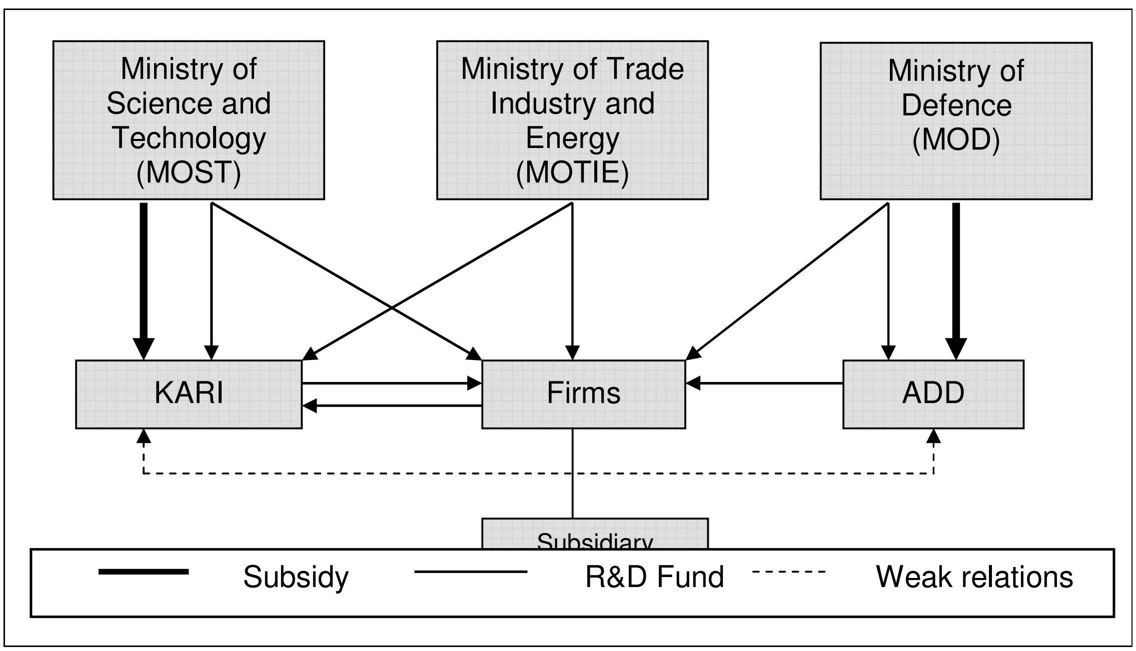

Figure 3.6 The national R&D mechanism on the South Korean aircraft industry
Source: Hwang, 2000 (adapted from Lee and Hwang, 1992)

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.

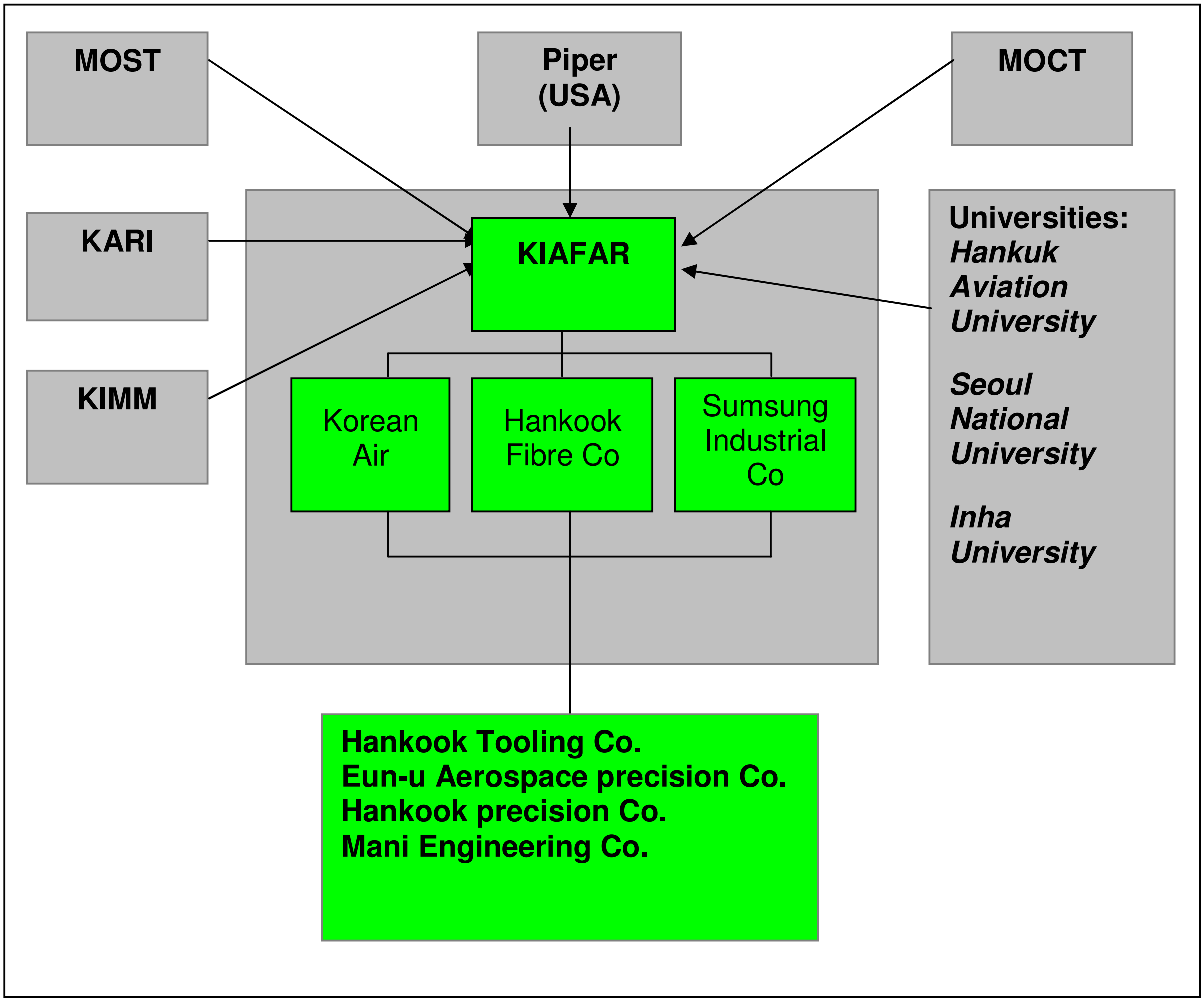

Figure 3.7 Institutional structure (framework) of the Chang Gong-91 project
Source: Hwang (2000)

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).

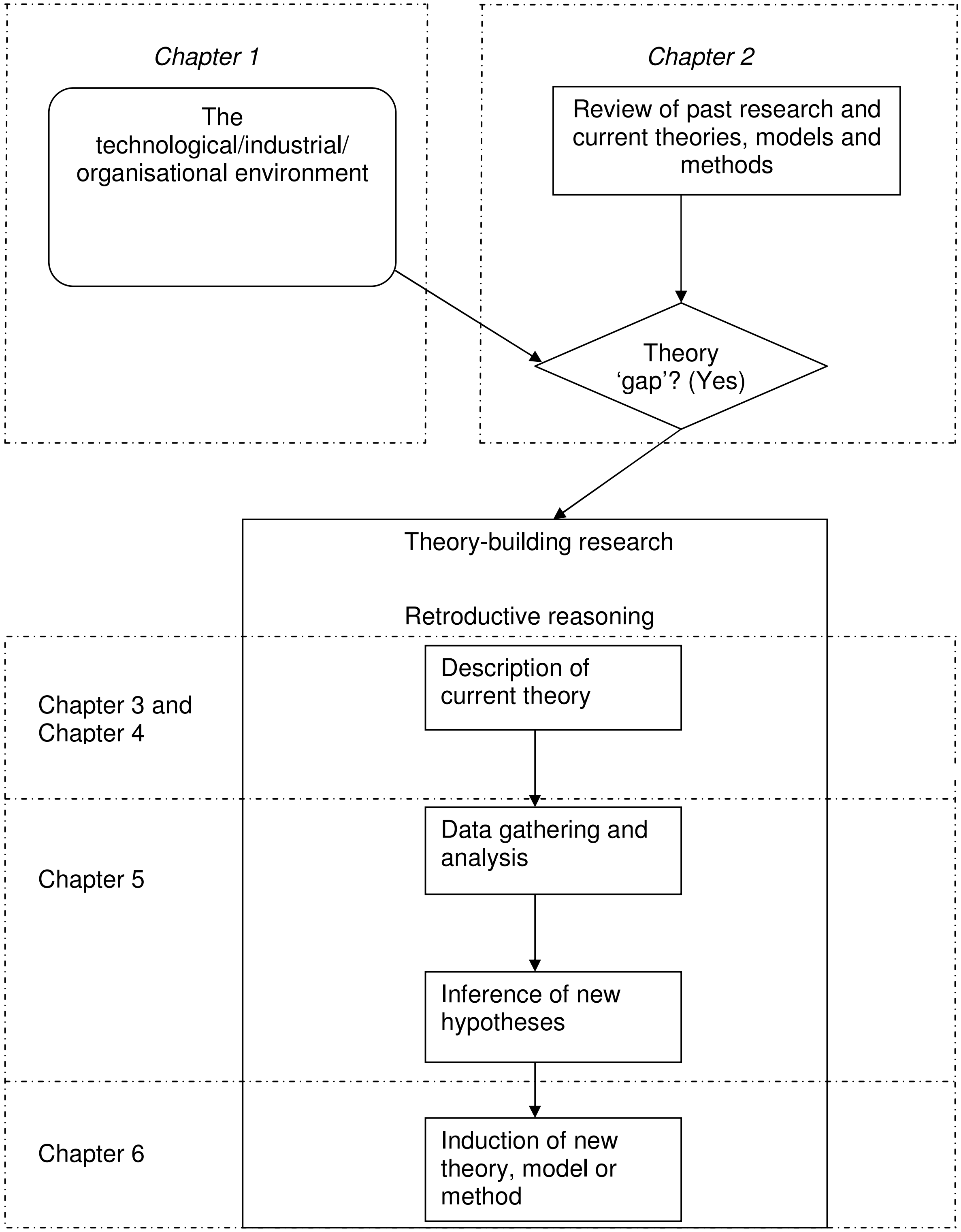

Figure 4.1 Research logic for theory-based research
Source: Adapted from Buys (2005: 62)

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

<table>
<tr><th colspan="2">Country</th><th>No of participants</th></tr>
<tr><td colspan="2">France (Firms)</td><td>7</td></tr>
<tr><td colspan="2">Brazil (Firms)</td><td>2</td></tr>
<tr><td rowspan="3">South Korea</td><td>Research institutes</td><td>5</td></tr>
<tr><td>Government</td><td>1</td></tr>
<tr><td>Firms</td><td>6</td></tr>
<tr><td colspan="2">Total</td><td>21</td></tr>
</table>

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.