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.

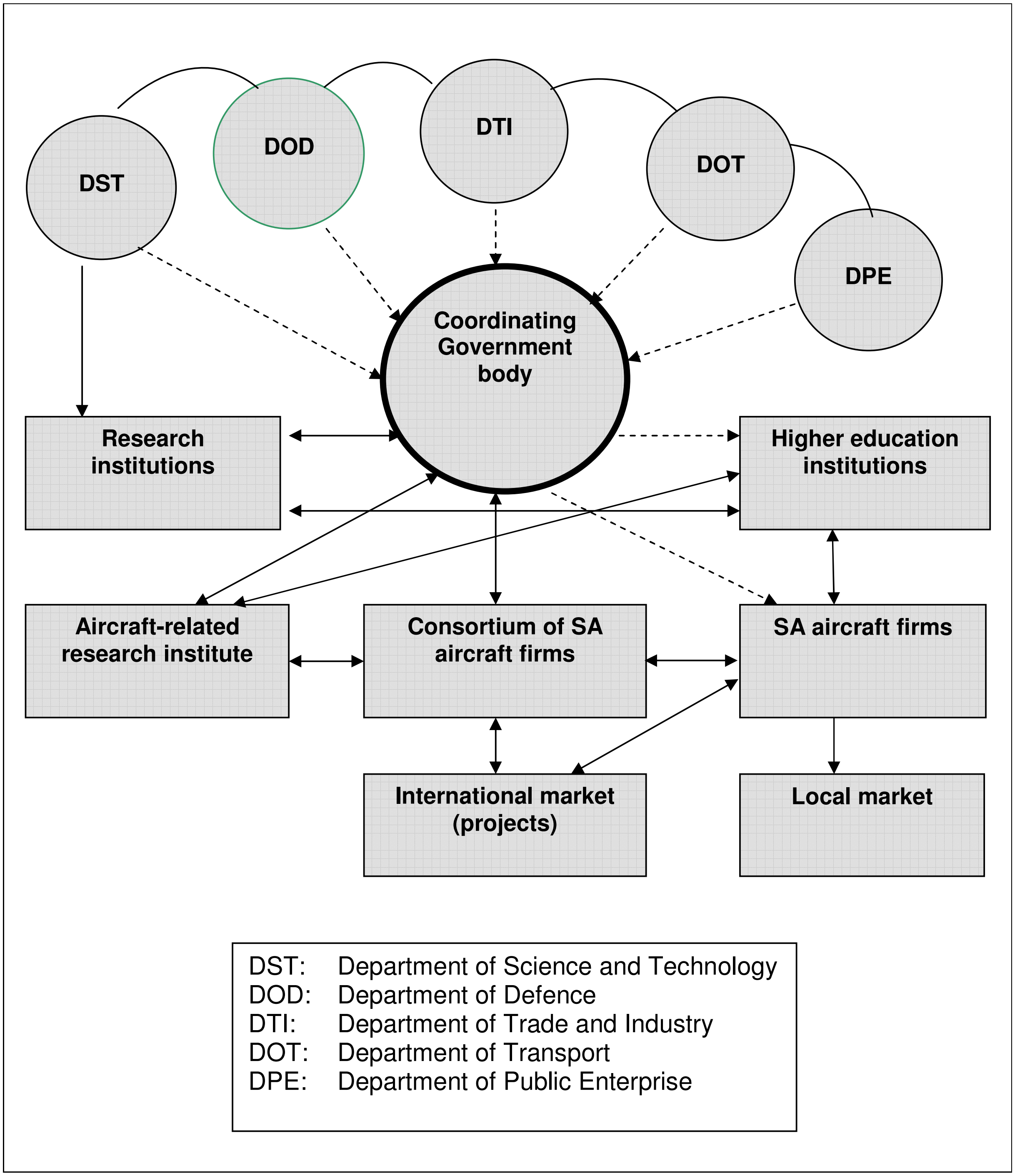

Figure 5.1 Technology capability building through public–private partnerships

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.

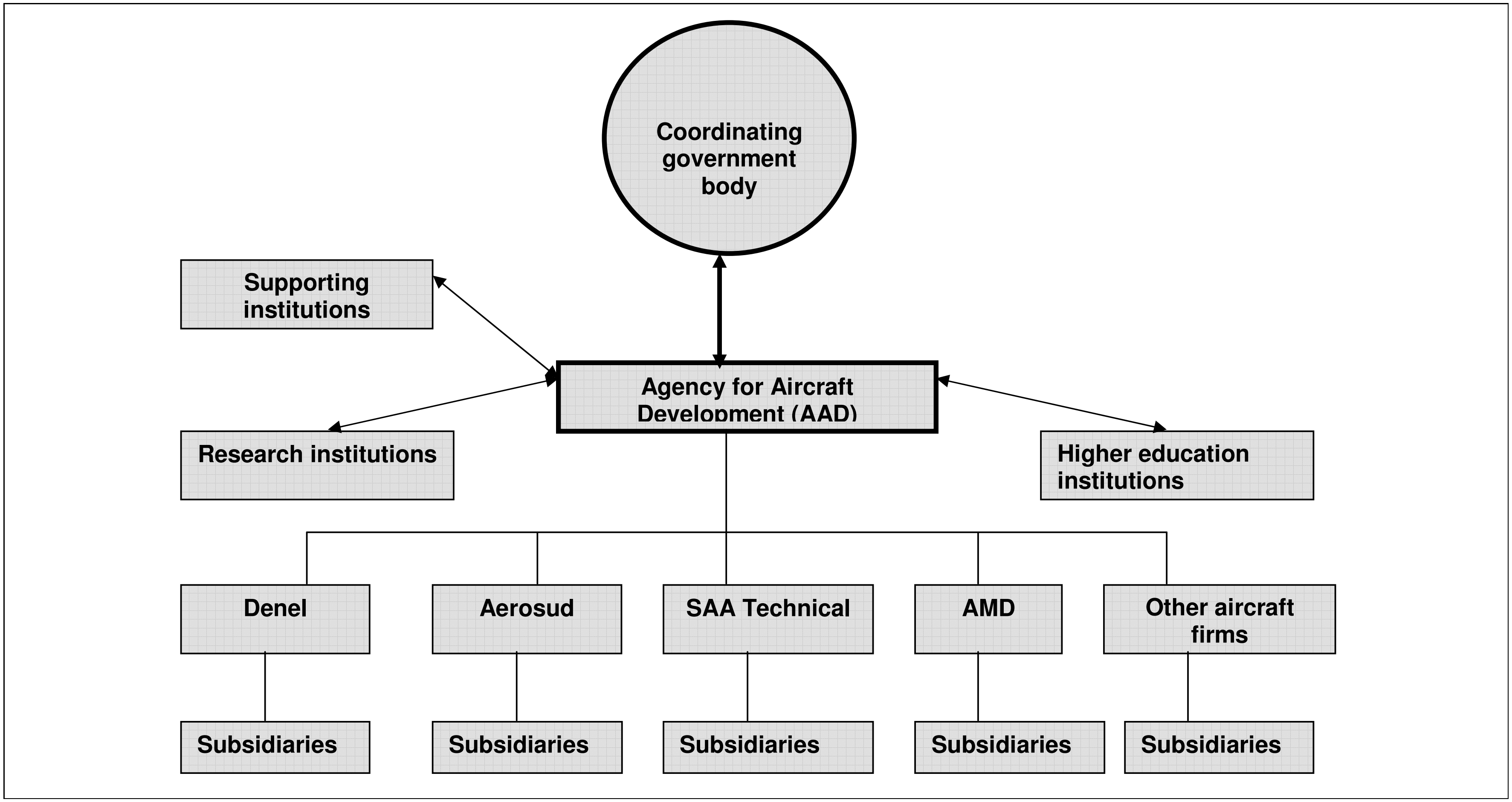

Figure 5.2 Institutional structure for the development of national aircraft technology

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.

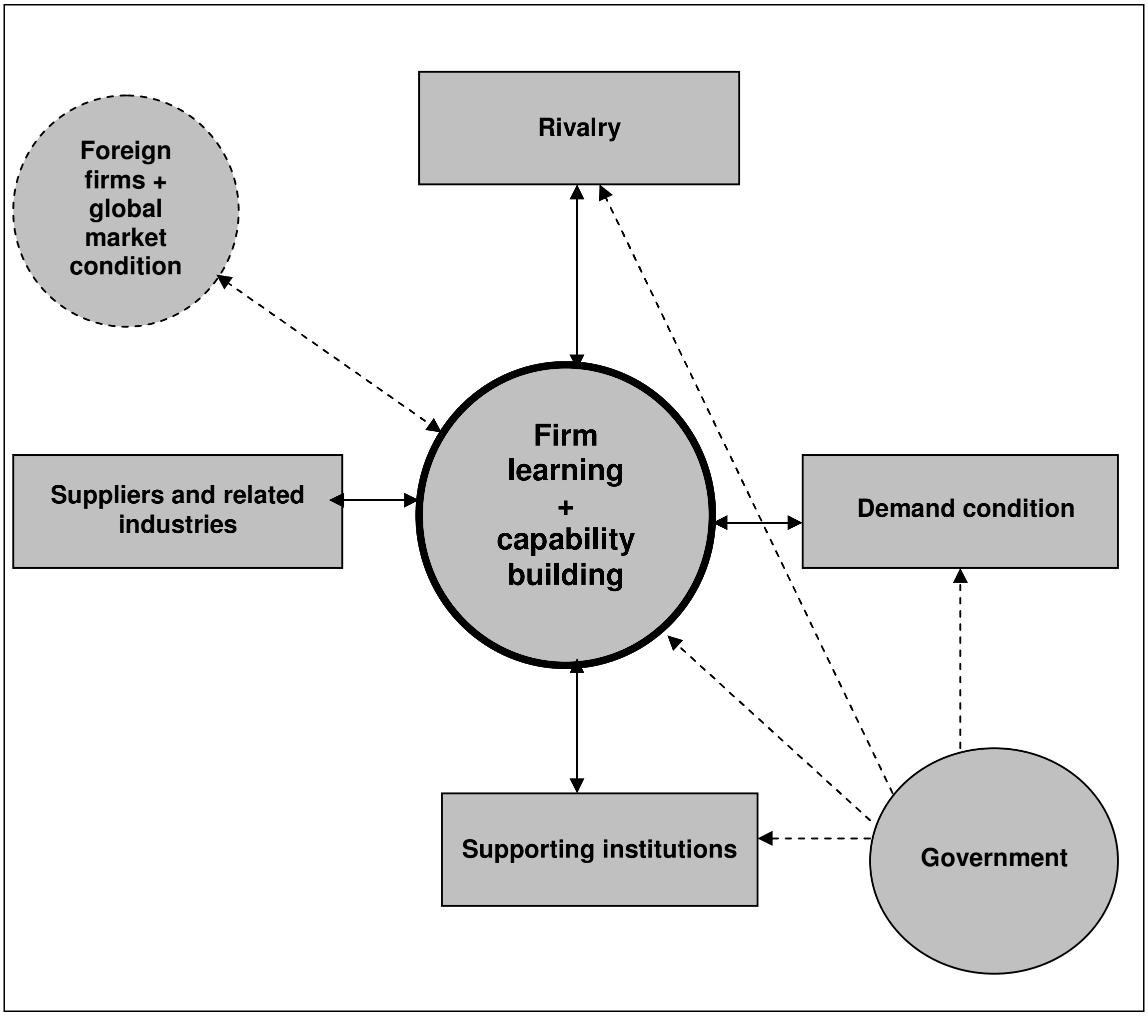

Figure 2.3 National factors in capability building
Source: Hwang (2000)

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.

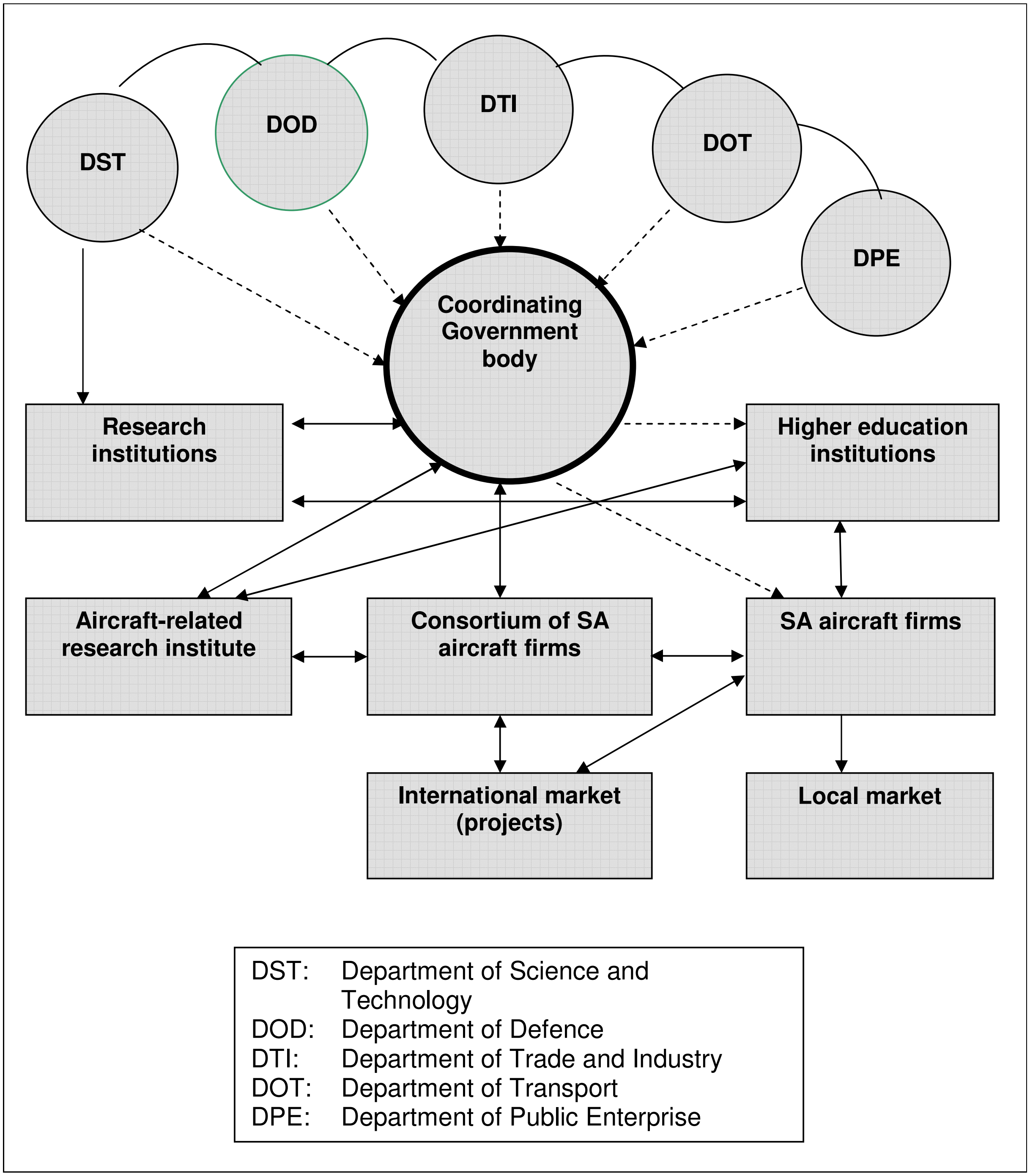

Figure 5.1 Technology capability building through public–private partnerships

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.

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