6 DATA GATHERING: DELPHI METHOD

6.1 The Delphi Method

The Delphi method is an established research methodology aimed specifically at exploring the expected future of novel and evolutionary phenomena. The technique obtains a group of experts' most reliable consensus of opinion (Dalkey & Helmer, 1963) by allowing them to express their own views on a topic, while taking into account the other participants' views by means of controlled feedback.

The method is based on the premise that well-informed individuals, drawing on their insights and on prior experience, are better equipped to predict the future than theoretical approaches or extrapolation of trends (Cuhls, 2003). The responses to a series of questionnaires are anonymous. Participants are also provided with a summary of opinions from a previous round before answering the next questionnaire. It is believed that such a consensus process will converge the group toward the 'best' response.

The midpoint of responses is categorised statistically using the median score. In each succeeding round of questionnaires, the range of responses by the panelists will presumably decrease and the median will move toward what is deemed to be the 'correct' answer.

The Delphi technique is well suited to situations where no or very limited historical data is available (Gupta and Clarke, 1996). The method is used mainly to assess long-term issues. As the procedure is aimed at identifying statements (topics) that are relevant for the future, it reduces the tacit and complex knowledge to a single statement and makes it possible to pass judgement.

Using the Delphi technique in conjunction with other methodologies, such as scenarios, technology lists, etc., might prove interesting. This specific method is of particular interest where subjective and complex judgements as opposed to precise quantitative results are of interest (Eto 2003).

It should however be noted that the Delphi technique would be unsuitable in more complex issues where the themes cannot be reduced much or where thinking and discussions in alternatives are the key objective (Eto 2003).

The chief users of the Delphi technique are companies, particularly strategy departments. The Delphi study is a formalised and traceable method that enjoys an amount of credibility with policy-makers. The method has been used in a vast number of technology forecasting studies (Mulder et al. 1996, Scott 2001, van Dijk, 1990), government foresight programmes, such as the UK Department of Trade and Industry's Foresight Programme (Department of Trade and Industry, 2000) and a study on German S&T policy issues (Cuhls, 2001).

6.1.1 Advantages of using the Delphi method

The anonymity of participants and the use of questionnaires avoid those problems commonly associated with group interviews, for example, specious persuasion or deference to authority, impact of oral facility, reluctance to modify publicised opinions as well as band wagon effects (Martorella, 1991, p.84).

The formalisation of the methodology, the amount of data, the number of experts involved and the fact that diverging opinions are partially hidden behind the main converging one, are all factors that contribute to the Delphi method being considered a popular and credible approach for policy makers. As the Delphi process forces group members to consider the problem under study logically and to provide written responses, the consensus reached by the group reflects reasoned opinions (Murry and Hammons, 1995).

Delphi surveys employ group decision-making techniques by involving experts in the field. Group decisions carry greater validity than those made by an individual (Brooks, 1979).

It may also be very difficult to bring a group of people together. Opinions and contributions can consequently be received from a group of experts who may be geographically separated from one another (Murry and Hammons, 1995).

The isolated generation of ideas also results in a high quantity of ideas (Delbecq and Van der Ven, 1974). Physically reading through the question forces one to think and respond with high quality ideas. As participants are forced to think of solution themselves and cannot react on answers from others in a group, the search behaviour is proactive (Delbecq and Van der Ven, 1974).

The judgements made in a Delphi study allows for analyses, rankings and priority-settings. As with other well-formalised methods, it forces people to think about the future. It provides participants with the opportunity to think in greater depth and to gather further information between the rounds.

6.1.2 Disadvantages of using the Delphi method

A number of disadvantages exist in applying the Delphi technique (Forlearn, 2006):

- Delphi studies are difficult to perform well. They are both fairly time-consuming as well as labour intensive and require external expert preparation. Delphi studies can therefore prove expensive
- care has to be taken over group effects. As in all panels or expert groups, the opinions will reflect the set of participants involve. A narrow set of criteria for these may thus lead to unrepresentative views or miss out important sources of knowledge. Single opinions that might be of special value are also pooled and normally ignored. Only the accumulated results are published to preserve anonymity. As anonymity has to be respected, it is often difficult to obtain reasons for dissenting answers later on
- some participants drop out during the process, especially after the first round. In addition, although further qualitative assessment of Delphi inquiry may produce

useful information, this step is often not carried out due to lack of time. It is often difficult to convince people to answer a questionnaire twice or more and incentives may be needed, e.g. providing the experts with the result of the study. The dropout rate increases after the second or third round, resulting in the majority of current studies being limited to preparation and two rounds

- because a topic generation procedure is needed, a Delphi survey is in essence always a mix of methods. Because the group never meets, there is also a degree of difficulty in assessing and utilising the expertise of the group fully (Murry and Hammons, 1995); and
- the danger also exists that greater reliance will be placed on the results than might be warranted. It is thus important to note that a consensus does not necessarily mean that the correct answer, opinion or judgement has been found. Instead, the method and results should be used as a means of structuring group discussion and raising issues for debate.

6.2 Selection of the Expert Panel

A crucial aspect of conducting a successful Delphi study is the selection of the respondents. Much care was consequently taken in recruiting the panel.

Dalkey, Rourke, Lewis & Snyder (1972) reported a definite and monolithic increase in the reliability of group responses with increasing group size. Reliability, with a correlation coefficient approaching .9, was found with a group size of 13. Debecq, Van de Ven & Gustafson (1975) suggest using the minimally sufficient number of respondents. Following these recommendations, a panel of 14 experts was selected for the Delphi study conducted in the research project.

Linstone and Turoff (1975) list applications where the heterogeneity of the participants must be preserved to assure the results' validity.

The experts for this study were selected with care with the specific goal in mind to ensure heterogeneity in terms of the role they play in the South African R&D system. Experts were thus selected to be representative of the three R&D performing sectors in the economy selection also took place on the basis of the different role their organisations play within the three sectors. Care was taken to include experts from all three of the R&D sectors in the South African R&D system namely the Higher Education System, Public sector and the Private sector.

- 5 individuals were selected from the Higher Education Sector. It was ensured that individuals were from different institutions namely University of Pretoria, Wits, Stellenbosch, and University of Cape Town. These individuals also play very different roles at each one of these universities
- From the Public sector 5 individuals were selected. All of these individuals hold very senior positions at their organizations (HSRC, DTI, SPII, NECSA, DST). The role of each of these organizations is very different within the South African R&D system.

- From the Private sector 5 individuals: Innovation Hub, 2 Entrepreneurs, Independent Innovation consultants, MD of a technology company. Many of these industry experts also play advisory roles to senior government officials.

A sensitivity analysis was conducted (See appendix I). It was found that no reason could be found to believe that sub-aggregations exist to adversely affect the reliability of the responses. It can be concluded that heterogeneity was found in the responses from the individuals in the expert panel.

The following lists the names of the experts selected to serve on the expert panel.

Table 6-1: Expert Panel for Delphi Method

Name	Position	Sector
De Wet, Gideon	Academic and Innovation Expert (Stellenbosch)	HES
Marcus, Roy	Director of Da Vinci Institute (Wits)	HES
Pouris, A	Director of Institute of Technological Innovation at the University of Pretoria, Ministerial Advisor on Indicator for S&T	HES
Jeenah, Mohammed	University of Pretoria	HES
Kahn, Michael	Human Sciences Research Council, Head of R&D Survey	HES/Public
Potgieter, Johannes	Department of Trade and Industry. Head of strategy	Public
Suleman, Areef	SPII Champion	Public
Adams, Rob	Chair person Innovation Fund, CEO of NECSA	Public
Paterson, Adi	Director of DST	Public
Sawers, Jill	Manager at Innovation Hub	Industry
Botha, Anthon	Industry Expert: Techoscene – business consulting in innovation, technology and the commercialisation of innovation	Industry
Verhaege, Audrey	Independent Innovation Consultant	Industry
Aberdein, Darryl	Innovation consultant and Industry Expert	Industry
Bester, Coen	Entrepreneur, Senior executive at Brainworks	Industry
Ahlers, Johann	Defence sector expert (R&D), Scientific advisor of Minister f Defence	Industry

6.3 Development of the Questionnaires

Delphi rounds of questionnaires continue until a predetermined level of consensus is reached or no new information is gained. This study was undertaken in two rounds. This approach was judged to be the correct balance between striving for a useful consensus and ensuring that a significant proportion of participants completed the study.

6.4 The First Round Questionnaire

The initial questionnaire was developed with a combination of closed and open-ended questions.

The questionnaire was aimed mainly at establishing the appropriateness of using patents and papers as a measure of R&D output in the South African R&D system. The open-ended questions posed requested respondents to expand on a list of alternative proxies to measure R&D output in the SA R&D system. An open-ended question regarding issues the South African R&D system will be facing in the next 20 years was also posed.

The following table contains the questions included in the first round survey sent to the panel of experts.

Table 6-2: First Round Survey

Delphi method Questionnaire: Round 1

Could you please answer the following questions? This should only take about 5-10 minutes of your time. If you could fill this form out and return it to me as soon as possible it will be greatly appreciated.

Sector: Higher Education Sector (HES)

1.1 Scientific paper output is a good measure of R&D output in the HES (1 agree - 6 disagree)
Please answer the question by selecting a number indicating your opinion on a scale from 1 (you agree) to 6 (you disagree)

1.2 What other proxies can be used for measuring the outputs gained from R&D in the South African HES?
Please answer the question by naming some alternatives to measuring R&D output in the HES in SA.

1.3 What are the general hurdles facing the SA HES R&D system in the next 20 years?
Please answer the question by naming some possible threats to South Africa's R&D capacity in its HES.

Sector: Public sector
2.1 Scientific paper output is a good measure of Basic and applied Research output in the Public Sector (1 agree - 6 disagree)
Please answer the question by selecting a number indicating your opinion on a scale from 1 (you agree) to 6 (you disagree)

2.2 Patent counts are a good measure of Experimental Development output generated in the Public Sector (1 agree – 6 disagree)
Please answer the question by selecting a number indicating your opinion on a scale from 1 (you agree) to 6 (you disagree)

2.3 What other proxies can be used for measuring the outputs gained from R&D in the SA Public sector?
Please answer the question by naming some alternatives to measuring R&D output in the Public sector in SA.

2.4 What are the general hurdles facing the SA Public sector R&D system in the next 20 years?
Please answer the question by naming some possible threats to South Africa's R&D capacity in its Public sector.

Sector: Private sector
3.1 Patent counts are a good measure of R&D output in the SA Private Sector (1 agree - 6 disagree)
Please answer the question by selecting a number indicating your opinion on a scale from 1 (you agree) to 6 (you disagree)

3.2 What other proxies can be used for measuring the outputs gained from R&D in the SA Private sector? *Please answer the question by naming some alternatives to measuring R&D output in the Private sector in SA.*

3.3 What are the general hurdles facing the SA Private sector R&D system in the next 20 years? *Please answer the question by naming some possible threats to South Africa's R&D capacity in its Private sector.*

Feedback from the questionnaires were analysed and used to develop a second questionnaire. The following section provides a brief discussion on the feedback received from the first round questionnaire.

6.4.1 Feedback from the first round questionnaire (HES)

6.4.1.1 Round one: R&D output in the HES

The following is a graphic representation of the respondents' feedback on the applicability of scientific output counts as a proxy for R&D output in the South African HES. Respondents were asked to rate the following statement as indicated: **Scientific paper output is a good measure of R&D output in the HES (1 agree - 6 disagree).**

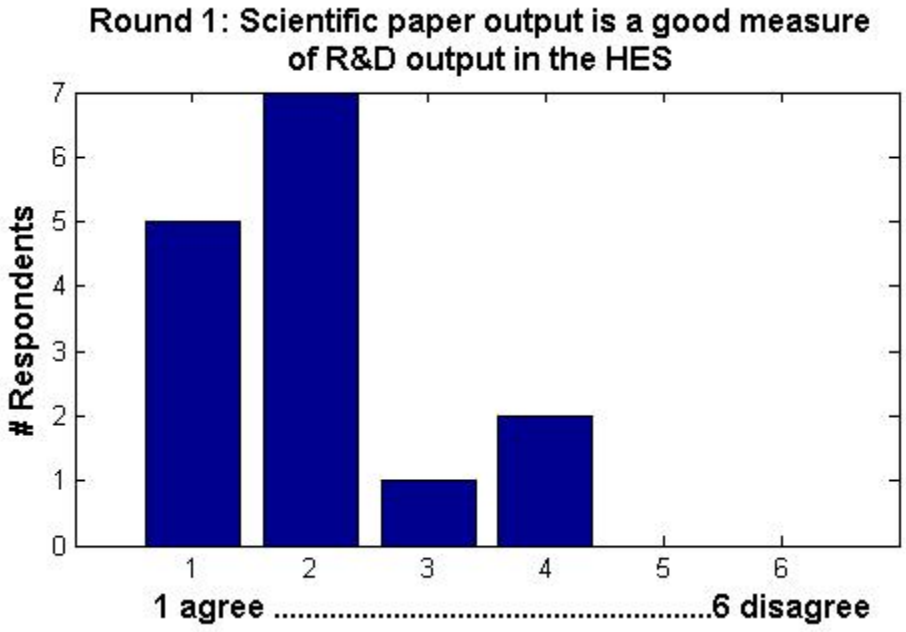


Figure 6-1: Respondent Feedback on the Applicability of Scientific Output in the HES

6.4.1.2 Round one: Alternative proxies for R&D output in the HES

The following question was posed to the expert panel: **What other proxies can be used for measuring the outputs gained from R&D in the South African HES?**

The following is a list with categories and issues belonging to the categories developed from feedback received from the expert panel:

Table 6-3: Proxies for the Measurement of R&D Output in the HES

Category	Proxies
R&D input as a measure of possible R&D outputs	• R&D expenditure in the HES • Percentage funding sourced from private sector • Percentage funding for R&D sourced from government sector • Research grants attracted for R&D projects (both from South African as well as international sources)
Direct measures of R&D output	• Patents filed by universities • Registered designs • Conference papers • Technology licences granted
Nature of R&D projects	• Percentage large multidisciplinary projects with multiple researchers from different fields of science • Number of single researcher projects vs collaborative research projects (number of projects with more than one researcher)
Knowledge captured in equipment	R&D equipment capital stock value in Rand
The training of human resources as an output of R&D	• Number of Masters and PhD theses (as an R&D output) • Training of human resources in terms of the number of PhD and Masters students as an output gained from R&D projects
Quality of R&D outputs	• Excellence and international recognition gained from R&D outputs, i.e. prizes won and key note address invitations for conferences • Number of citations received by South African authors from ISI journals (can be used to identify centres of excellence)
Commercialisation of R&D	• Number of commercialisation projects • Size (in Rand) of commercialisation projects • ROI of commercialisation investment • Venture capital available to HES • Licence revenues (income generated from licensing) • Spin-offs from R&D projects in HES

6.4.1.3 Round one: Hurdles faced in the HES (next 20 years)

The following question was posed to the expert panel: **What are the general hurdles facing the SA HES R&D system in the next 20 years?**

The following is a list with categories and issues belonging to the categories developed from feedback received from the expert panel:

Table 6-4: Hurdles Facing the HES in the Next 20 Years

Issue Category	Examples of Issues Faced in this Category
Lack of funding for R&D in the sector	Poor prospects in terms of funding and the maintenance of R&D infrastructure
Nature of R&D projects	Lack of multidisciplinary research projects
Poor linkages pose a threat to future capacity and relevance of R&D system	• Poor linkages between researchers resulting in lack of knowledge sharing between researchers • Poor linkages between researchers and industry: industrial participation low between HES and private sector
Inability to retain and rejuvenate human	• Poor prospects of the rejuvenation of human resources by, for instance, training new PhDs due to low enrolment in S&T courses in universities

resources stock in the system	• Brain drain phenomenon with the following contributing factors: ❑ uncompetitive salaries offered to human resources in the system; and ❑ lack of career development opportunities for young researchers • Students studying outside South Africa due to lower recognition of South African universities
Threat to future quality of human resources	• Threat to future quality of human resources – the quality of students studying in HES poor from poor secondary education system • Quality of education deteriorating, resulting in a low quality of graduates leaving university • Lack of good remuneration and career opportunities will cause the quality of researchers in the system to deteriorate
Current human resources policies and the possible affect on future R&D capacity: BEE	• Racial quotas and the lack of female and black human resources for R&D to reach representative work force • Lack of funding for deserving students from the previously advantaged group
Difficulty of successful R&D policy alignment with national priorities	• Balancing local relevance with international cutting edge topics • Balancing funding of R&D and training with basic needs delivery
Weak IP protection policies in HES	Weakness in IP protection policies of universities, causing them to loose out on millions of Rands in terms of intellectual property.

6.4.2 Feedback from the first round questionnaire (public sector)

6.4.2.1 Round one: R&D output in the public sector

The following is a graphic representation of the respondents' feedback on the applicability of scientific output as well as patent counts as a proxy for R&D output in the South African public sector. Respondents were asked to rate the following statements as indicated:

Statement 1: Scientific paper output is a good measure of basic and applied research output in the public sector (1 agree - 6 disagree)

Statement 2: Patent output is a good measure of experimental development output in the public sector (1 agree - 6 disagree)

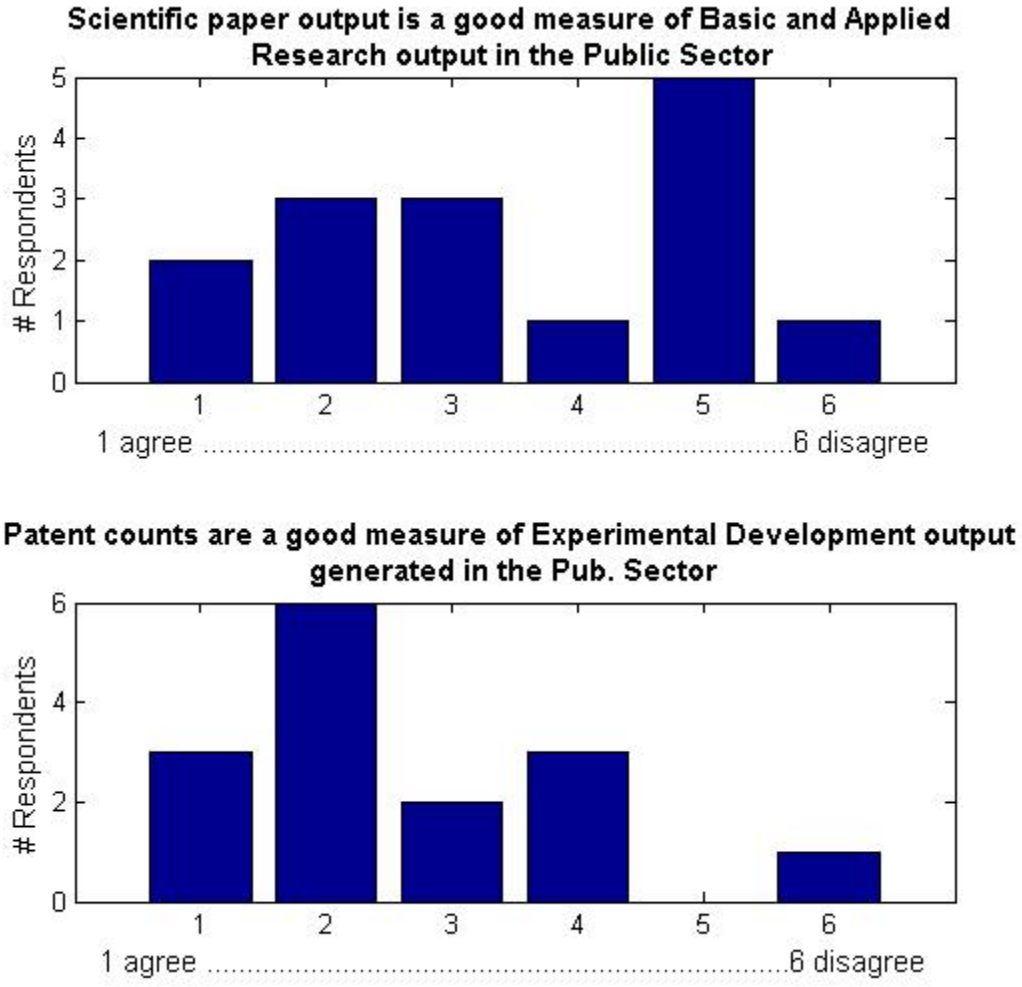


Figure 6-2: Respondent Feedback: Indicators for R&D Output in the Public Sector

Visual analysis yielded that the respondents did not reach consensus regarding the use of scientific paper output as a measure of basic and applied research output in the public sector. Two schools of thought were formed, where one group regarded scientific output as an appropriate proxy and the other did not.

The feedback gathered from the respondents therefore concluded that the majority of the respondents regards patent output as an appropriate proxy for experimental development output generated in the public sector.

6.4.2.2 Round one: Alternative proxies for R&D output in the public sector

The following question was posed to the expert panel: **What other proxies can be used for measuring the outputs gained from R&D in the South African public sector?**

The following is a list with categories and issues belonging to the categories developed from feedback received from the expert panel:

Table 6-5: Alternative Proxies for R&D Output in the Public Sector

Category	Proxies
R&D input as a measure of possible R&D outputs	• R&D expenditure in the public sector • Percentage funding sourced from private sector • Research grants attracted for R&D projects (from South African as well as international sources)
Direct measures of R&D output	• Registered designs • Technology licences granted • Synthesis reports • Statistical surveys • Prototypes • Products • Policy documents on policy changes and policies developed based on R&D results for the successful alignment with government direction setting and declared missions • Number of knowledge transfer conferences
Knowledge captured in equipment	R&D equipment capital stock (value in Rand)
Commercialisation success of R&D	• Number of commercialisation projects • Size (in Rand) of commercialisation projects • ROI of commercialisation investment • Licence revenues (income generated from licensing) • Spin-offs from R&D projects in public sector • Percentage of contract income in any financial year from new products/services created in the past two years or an equivalent measure
Transfer of technology as an output of R&D projects in the public sector	• Number of products developed in private sector using technology developed in projects at science councils • Number of collaborative projects with industry
Linkages	• Number of public/private sector partnerships in R&D domain • Number of collaborative projects with international partners

6.4.2.3 Round one: Hurdles faced in the public sector over the next 20 years

The following question was posed to the expert panel: **What are the general hurdles facing the SA public sector R&D system in the next 20 years?**

The following is a list with categories and issues belonging to the categories developed from feedback received from the expert panel:

Table 6-6: Hurdles Facing the Public Sector in the Next 20 Years

Issue Category	Examples of Issues Faced in this Category
Lack of government funding to public sector to develop R&D and technology platforms	• Lack of funding. Government funding should be adequate to develop technology platforms for transfer to the private sector. • Not supporting a competitive R&D infrastructure: Earning income from consultancy work should have lower priority and not be used to sustain research institutions. • Too much bureaucracy in administration of system and funding to

	research projects
Nature of R&D projects	Lack of multidisciplinary research projects
Inability to retain and rejuvenate the researchers stock in the system	• Losing human resources to private sector or to other countries; losing human resources through the brain drain phenomenon • Lack of adequate rewards systems – uncompetitive salaries • Lack of rejuvenation of human resources – low numbers of graduates are interested in science as a career
Deterioration of quality of human resources working in R&D	• Poor quality of graduates entering the system • Lack of good remuneration and career opportunities will cause the quality of researchers in the system to deteriorate • Inability to overcome mentorship across cultures
Current BEE policies will have a negative affect on quality and R&D capacity	Representativity: Racial quotas rather than competence as functional goals of policy instruments.
Lack of direction and leadership in science policy	• Lack of coherent NIS, based on credible foresight. • Continuous refocusing on the short term, not having a long range strategy ('flavour of the month' approach followed by government, e.g. will want to shift R&D focus to alternative sources for energy after recent problems at Eskom)

6.4.3 Feedback from the first round questionnaire (private sector)

6.4.3.1 Round one: R&D output in the private sector

The following is a graphic representation of the respondents' feedback on the applicability of patent counts as a proxy for R&D output in the South African private sector.

Respondents were asked to rate the following statements as indicated:**Patent output is a good measure of R&D output in the Private sector (1 agree - 6 disagree)**

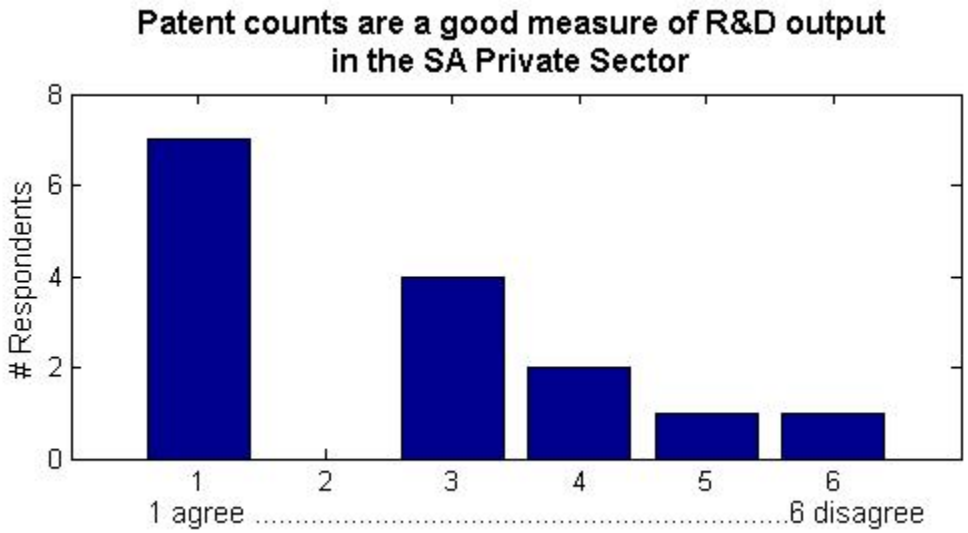


Figure 6-3: Patents Counts as a Measure of R&D Output Created in the Private Sector

The feedback gathered from the respondents concluded that the majority of the respondents regard patent output as an appropriate proxy for experimental development output generated in the private sector.

6.4.3.2 Round one: Alternative proxies for R&D output in the private sector

The following question was posed to the expert panel: **What other proxies can be used for measuring the outputs gained from R&D in the South African private sector?**

The following is a list with categories and issues belonging to the categories developed from feedback received from the expert panel:

Table 6-7: Alternative Proxies for R&D Output in the Private Sector

Category	Proxies
R&D funding and the availability of funding as a measure of possible R&D outputs	• R&D expenditure in the private sector • Research grants attracted for R&D projects from both South African as well as international sources) • Innovation budget of firms • Growth of venture capital industry
Direct measures of R&D output	• Registered designs • Technology licences granted • Prototypes
Innovation outputs as a result of R&D	• New products, e.g. less than one year old, as a percentage of total product offering • Number of new product launches and significant upgrades • Ratio of own developed products/processes to licensed products/processes
Knowledge captured in equipment	R&D equipment capital stock value in Rand
Commercialisation success of R&D	• Growth in market share locally and globally attributed to innovation • Global market leadership • International sales • Growth in export sales • Percentage of business income in any financial year from new products/services created in the past two years • Number of commercialisation projects • Size (in Rand) of commercialisation projects • ROI of commercialisation investment • Royalties received from intellectual property • Spin-offs from R&D projects in private sector • Jobs created through R&D projects
Linkages and flows	• Inward knowledge intensive FDI • Number of public/private sector partnerships in R&D domain • Number of collaborative projects with international partners

6.4.3.3 Round one: Hurdles faced in the private sector over next 20 years

The following question was posed to the expert panel: **What are the general hurdles facing the SA private sector R&D system in the next 20 years?**

The following is a list with categories and issues belonging to the categories developed from feedback received from the expert panel:

Table 6-8: Hurdles Facing the Private Sector over the Next 20 Years

Issue Category	Examples of Issues Faced in this Category
Lack of research culture in SA	• Companies do not realise the importance and benefits of R&D to maintain competitiveness • South African mindset: to import value added rather that to add the value through R&D. Some of our largest companies are just distribution and sales centres for American and Japanese companies.
Lack of funding and fiscal incentives from government to foster R&D culture in companies	• Lack of R&D investment incentives • Lack of tax incentives from government – financial support to convince companies to take risk and help them overcome their short term against long term perspective. • Better tax breaks in other countries. Globalisation of research leading to loss of local capacity • Lack of export incentives • Lack of support for commercialisation of R&D • Lack of funding for local R&D by multinationals
Nature of R&D projects	Lack of multidisciplinary research projects
Inability to retain and rejuvenate the researchers stock in the system	• Lack of rejuvenation of human resources: low supply of skilled R&D personnel – not enough science and technology graduates to conduct R&D • Lack of adequate rewards systems - uncompetitive salaries • Losing human resources to private sector or to other countries – retention of HR through brain drain phenomenon
Deterioration of quality (skill level) of human resources working in R&D	• Poor quality of graduates entering the system • Poor quality of graduates • Lack of knowledge and business intelligence • Management of technology skills
Current BEE policies will have a negative affect on quality and R&D capacity.	• Representativity: racial quotas rather than competence as functional goals of policy instruments • BEE legislation – many international companies will rather pull out that to share IP through shareholding. • Economic empowerment sapping investment funds from company profits
Poor linkages	• Linkages between research and development not in place: private sector will not invest in R&D projects where the commercial potential is not obvious. Government thus needs to lead in strategic development projects to develop technology platforms from which the private sector can develop new products and processes. • Inability to find global distribution partners – remoteness of market in world terms. We need to develop our manufacturing capability and value-add capability internationally
Lack of direction and leadership in science policy	• Lack of competitive strategies and leadership • Lack of coherent NIS, based on credible foresight, and consequently 'deepening' of the technology colony situation
Communication infrastructure	Bandwidth restrictions

General	Crime/stability in the country

6.5 The Second Round Questionnaire

The second round questionnaire was developed from the feedback received from the first round. See Appendix F for the second round questionnaire. The responses returned from the first round were analysed and applied for the development of the second round questionnaire.

In the second round, feedback was provided regarding the outcome of the first round. Respondents also had the opportunity revise some of their responses made in the first round.

Further analysis was done regarding the open-ended questions posed in the round one survey. After categorising contributors' responses, respondents were asked to rate the seriousness and criticality of hurdles facing the R&D system of South Africa identified in the first round.

Table 6-9: Description of the Ranking Criteria for Issues Ranked by the Experts

Rank	Description
1	Critical issue
2	Serious issue
3	Issue
4	Possible issue
5	Unlikely issue
6	Issue does not exist

The standard deviation is a measurement of the variability in a population. In a normal distribution, 68% of the scores fall within one standard deviation above and one standard deviation below the mean. For the purpose of this study, a decision was made on the level of consensus reached in terms of the standard deviation as described in the following table:

Table 6-10: Decision Criteria for the Level of Consensus Reached in the Delphi Study

Standard Deviation	Level of Consensus Achieved
$0 \leq X < 1$	High level
$1 \leq X < 1.5$	Reasonable/fair level
$1.5 \leq X < 2$	Low level
$2 \leq X$	No consensus

The following sections describe the feedback gathered from the panel of experts in the Delphi study.

The open-ended questions regarding other proxies that could be used for measuring the outputs gained from R&D in the South African HES was not surveyed further in the Delphi study. The questions were posed to respondents mainly to compile a list of

possible alternatives to measure R&D output in the South Africa R&D system.

6.5.1 Feedback from the second round questionnaire (HES)

6.5.1.1 Round two: R&D output in the HES

Respondents had the opportunity revise their opinions of the applicability of using scientific output as a measure of R&D output in the HES. As one respondent dropped out from the first round to the second, his/her first round answer was used in the second. The revised version of the expert opinions (after the second round) is represented in the following graph:

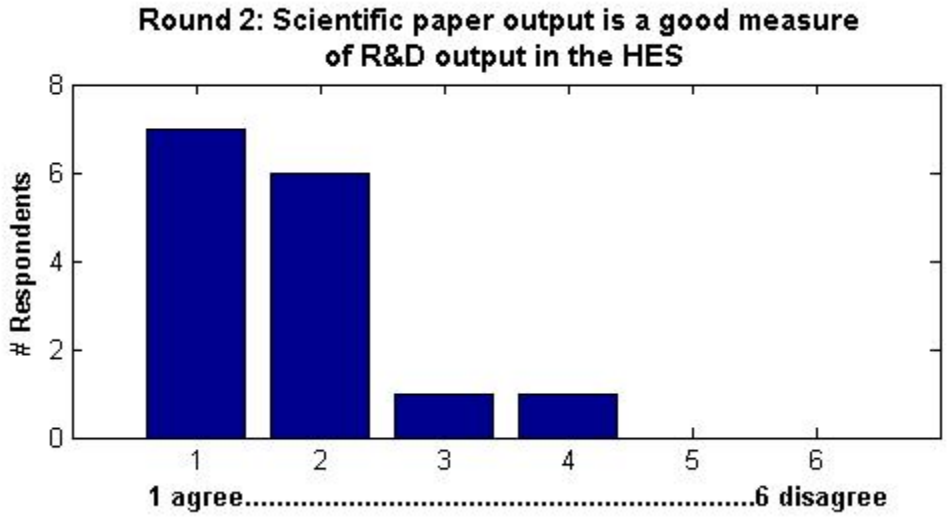


Figure 6-4: Second Round Feedback: Measure of R&D Output in the HES

A further analysis was done to facilitate a comparison of the movement of opinion and the level of agreement of the group. The following graph is a representation of the movement of group opinion, measured in terms of the mean, and the level of consensus, measured in terms of the standard deviation, from round one to round two. It is noted that both group opinion and the level of agreement have moved slightly.

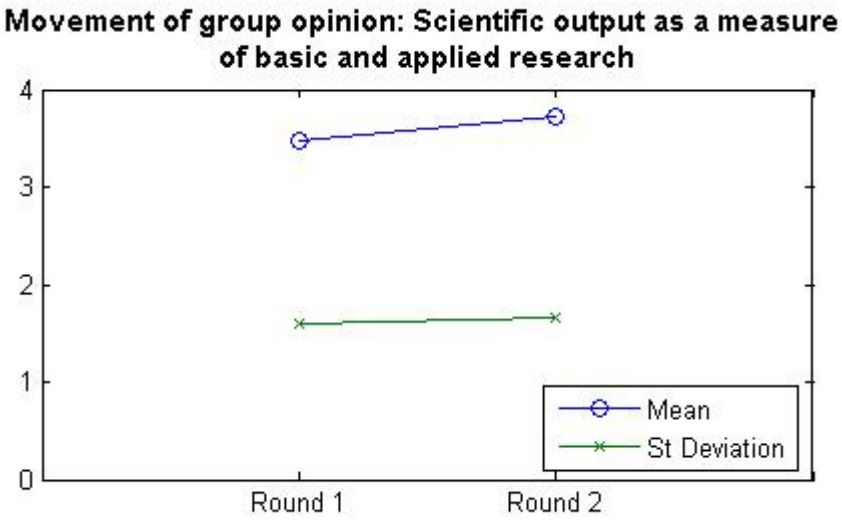


Figure 6-5: Group Opinion for Using Papers to Measure R&D Output in the HES

It can be concluded that a relatively high level of consensus was reached (standard deviation = 0.85), which indicates that the experts in general agree that scientific paper output is a good measure of R&D output generated in the South African HES (mean = 1.73).

Based on the feedback gained from the expert panel, it can therefore be concluded that scientific paper output can be used as a proxy for R&D output in the development of the HES model.

6.5.1.2 Round two: Hurdles faced in the HES over the next 20 years

The following question was an open-ended question posed to the expert panel in the first round survey: **What are the general hurdles facing the SA HES R&D system in the next 20 years?**

A list of issues was compiled from the experts' responses in the first round.

In the development of the second round survey the ideas generated in the first round questionnaire were categorised. In the second round survey, respondents were asked to rate issue categories on a scale from 1 to 6 where 1 indicates that it is a critical issue and a rating of 6 indicates that the issue does not exist. The following is a brief summary of the group opinion after the second round:

Table 6-2: Summarised Issues Rankings for R&D in the HES

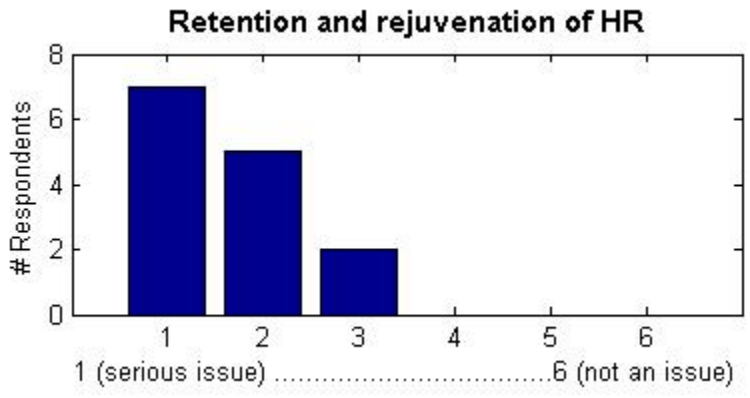
Issue Category	Median	Mean	Mode	St. Dev
1. Inability to retain and rejuvenate human resource	1.50	1.64	1.00	0.72

stock in the system				
2. Lack of funding for R&D in the HES	2.00	2.29	2.00	1.10
3. The lack of female and black researchers for R&D to reach representative work force	2.00	2.71	2.00	1.48
4. The deterioration of quality of human resources working in R&D in the sector	2.50	2.43	1.00	1.12
5. Poor linkages pose a threat to future capacity and the relevance of R&D performed in the system	2.50	2.43	3.00	0.82
6. Lack of multidisciplinary research projects	3.00	3.29	2.00	1.53
7. Difficulty of successful R&D policy alignment with national priorities	3.00	3.29	3.00	0.96
8. Weak IP protection policies in HES	3.00	3.36	3.00	1.34
9. Inadequate funding of equipment	3.50	3.14	4.00	0.99

The issues listed in Table 6-2 will be discussed in more detail in the following sections.

1. Inability to retain and rejuvenate human resources stock in the system

This question relates to poor prospects of the rejuvenation of human resources due to issues, such as low enrolment in S&T courses in universities, the low number of PhDs graduating from universities as well as the notorious brain drain phenomenon. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:

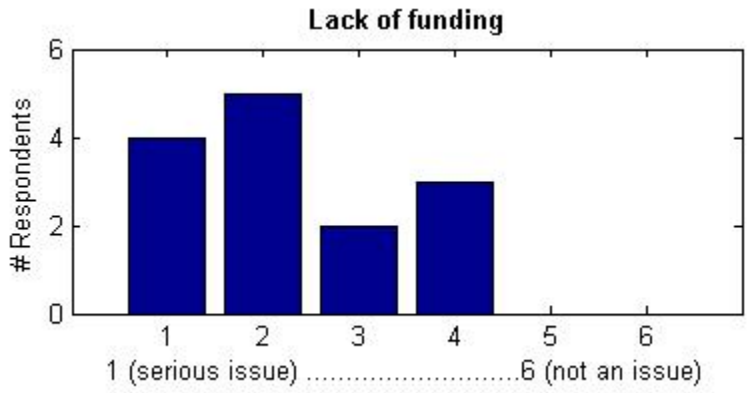


Median: 1.5
Mean: 1.64
Mode: 1
Stdev: 0.72

A high level of consensus (standard deviation of 0.72) was achieved regarding this issue. The aggregated expert opinion is that the South African HES's inability to retain and rejuvenate the human resources stock in the system will pose a major hurdle to the system in the next 20 years. A substantial percentage of the respondents (50%) rated this as a critical issue (rank = 1) facing the HES R&D system.

2. Lack of funding for R&D in the HES

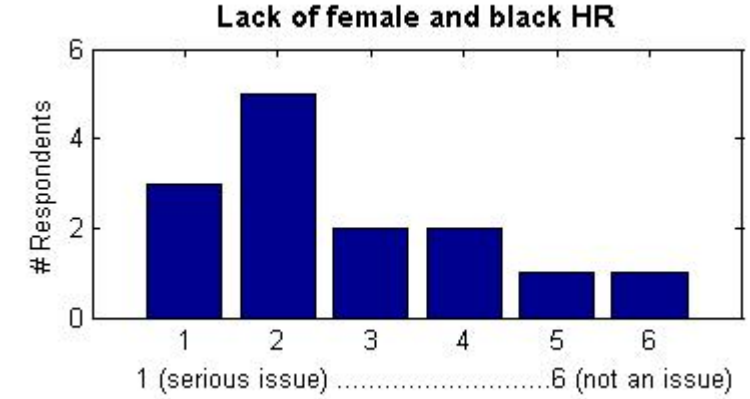
This issue relates to poor prospects in terms of funding for the maintenance of the R&D infrastructure in the HES in the next 20 years. The following is a graphic representation of feedback received from the expert panel regarding the perceived issue's level of criticality:



Median: 2
Mean: 2.29
Mode: 2
Stdev: 1.10

A reasonable level of consensus (standard deviation of 1.10) was achieved regarding this issue. Experts reached a reasonable level of agreement regarding a lack of adequate funding for R&D projects over the next 20 years. The aggregated expert opinion is that the lack of enough funding for R&D projects will be a major issue affecting the system in the next 20 years.

3. The lack of female and black researchers for R&D to reach representative work force
This issue relates to a perceived hurdle posed to the sector in the next 20 years regarding the persisted shortages of female and black researchers necessary to reach a representative work force. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:



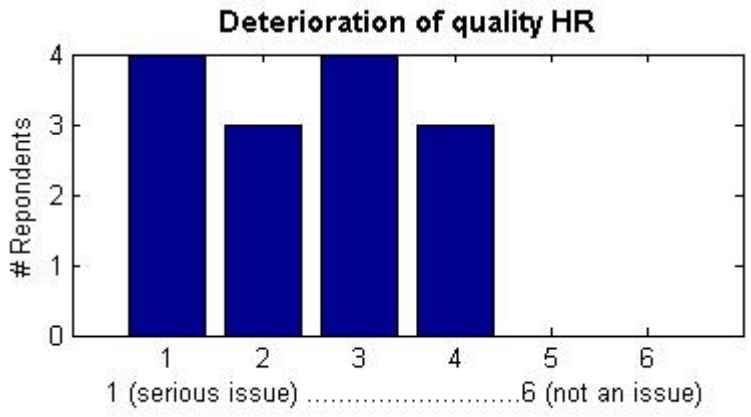
Median: 2
Mean: 2.71
Mode: 2
Stdev: 1.48

A low level of consensus was achieved regarding this issue with a standard deviation of 1.48. Experts fail to agree wholly on whether shortages in female and black researchers will pose a hurdle to the R&D sector in the following 20 years. Although the mean computed expert opinion is fairly low at 2.71, a substantial amount of experts rated this as an important issue (8 experts rated it to be of level 1 and 2). This indicates that the lack of female and black researchers to reach a representative work force might remain a hurdle to the system in years to come.

4. There deteriorating quality of human resources working in R&D in the sector

This question relates to a perceived threat to the future level of quality of human resources working in the HES. This threat could stem from multiple reasons, including, amongst others, poor quality students entering the HES, a perceived deterioration of the quality of education, resulting in a low quality of graduate leaving university and a lack of good remuneration and career opportunities, which could result in the level of quality of researchers in the system deteriorating.

The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality.

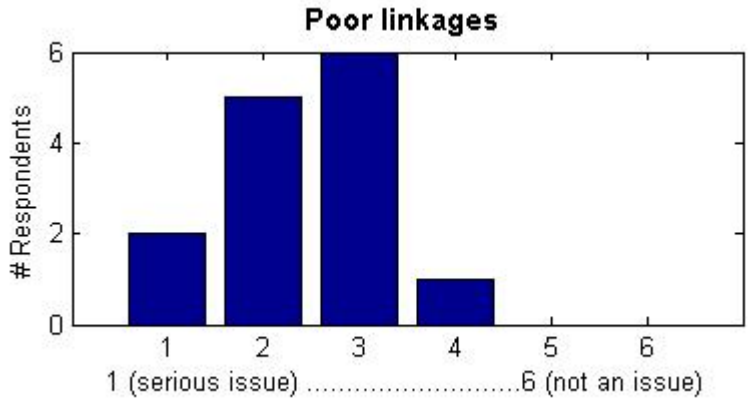


Median: 2.50
Mean: 2.43
Mode: 1
Stdev: 1.12

A reasonable level of consensus was achieved with a standard deviation of 1.12. Expert opinion indicates that the HES faces a deterioration of the quality of human resources working in the sector. A substantial amount of the respondents (50%) rated this as a critical issue or major issue (ranking 1 or 2) facing the HES in the next 20 years.

5. Poor linkages pose a threat to future capacity and the relevance of R&D performed in the system

This perceived issue relates to poor linkages between researchers and the industry, resulting in low industrial participation between the HES and the private sector. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:

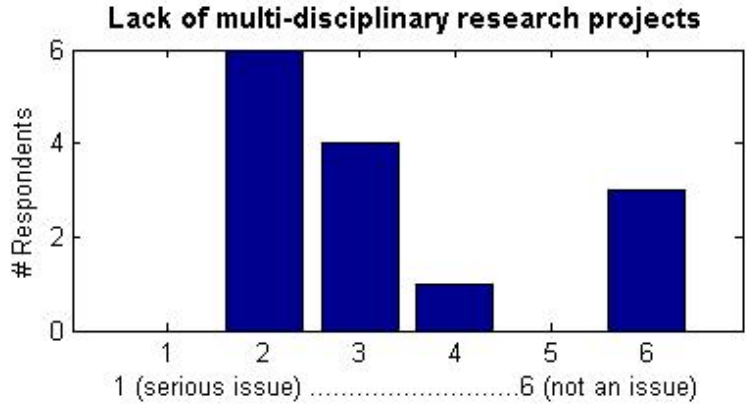


Median: 2.50
Mean: 2.43
Mode: 3
Stdev: 0.82

A high level of consensus was achieved regarding this issue with a standard deviation of 0.82. Although some of the respondents rate the issue as critical (2 respondents rated it to be of level 1), 11 of the respondents rated the issue to be of level 2 and 3 of criticality. Such a rating indicates that although the issue was not perceived as highly critical, it remained an area of concern that should receive the necessary attention to ensure the future relevance of R&D performed in the sector.

6. Lack of multidisciplinary research projects

This issue relates to a perceived hurdle posed to the sector in the next 20 years regarding a lack of multidisciplinary research projects. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:

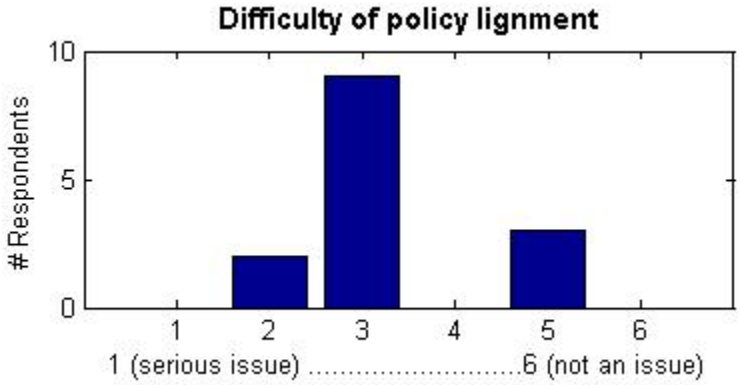


Median: 3
Mean: 3.29
Mode: 2
Stdev: 1.53

A low level of consensus was achieved regarding this issue with a standard deviation of 1.53. There seems to be two schools of thought regarding this issue. Three respondents believed this not to be an issue at all. A substantial amount of the respondents, i.e. ten, however agreed that this should be viewed as an area of concern and that a lack of multidisciplinary research projects might pose some degree of problems to the R&D system in the following 20 years to come.

7. Difficulty of successful R&D policy alignment with national priorities

Respondents were asked to provide their opinion regarding the criticality of issues of the effect that balancing funding of R&D and training with basic needs delivery will have on the system in the next 20 years. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:

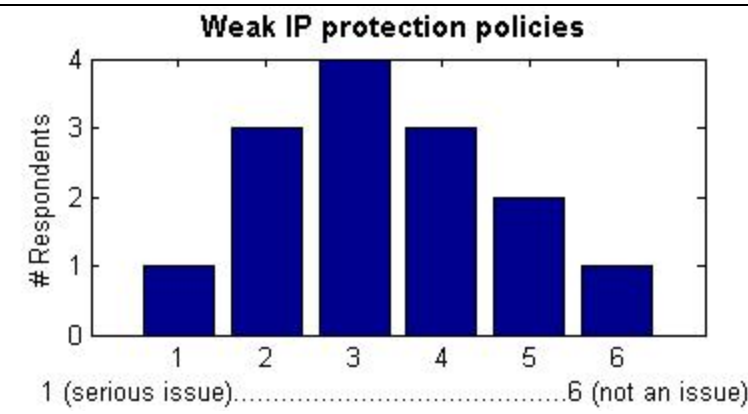


Median: 3
Mean: 3.29
Mode: 3
Stdev: 0.96

A high level of consensus was achieved with a standard deviation of 0.96. Respondents agreed that although this was not a critical issue, it had to be viewed as an area of concern.

8. Weak IP protection policies in HES

Respondents were asked to comment on the level of criticality of a perceived issue that the HES has weak IP protection policies of universities, thus causing them to loose out on millions of Rands. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:



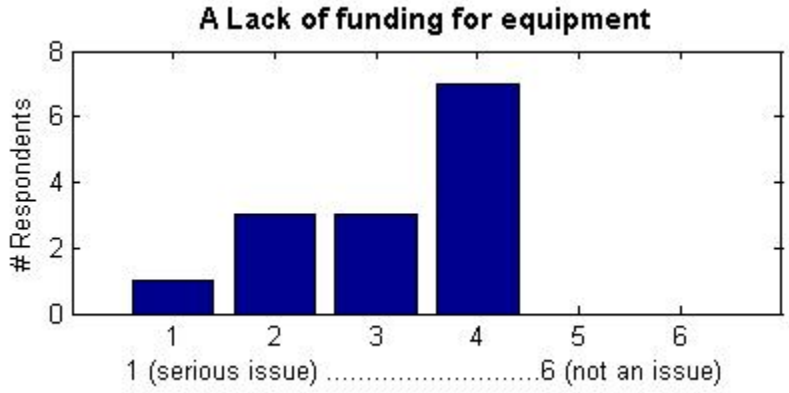
Median: 3
Mean: 3.36
Mode: 3
Stdev: 1.34

A fair level of consensus was reached with a standard deviation of 1.34. Respondents agreed to some extent that the IP policies of universities should be seen as an area of concern (mean of 3.36).

9. Inadequate funding of equipment

Respondents were asked to comment on the level of criticality of a perceived issue that there will be a shortage of funding for research equipment in the HES in the next 20

years. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:



Median: 3.5
Mean: 3.14
Mode: 4
Stdev: 0.99

A reasonably high level of consensus was reached with a standard deviation of 0.99. The experts seemed to agree to a large extent that the inadequate funding of equipment should not pose a major hurdle to R&D in the HES over the next 20.

6.5.2 Feedback from the second round questionnaire (public sector)

Respondent had the opportunity to revise their opinions of the applicability of using scientific output and patents as a measure of R&D output in the public sector.

6.5.2.1 Round two: Basic and applied research in the public sector

Respondent had the opportunity to revise their opinions of the applicability of using scientific output as a measure of basic and applied research output in the public sector. The revised version of expert opinions (after the second round) is graphically represented in the following graph:

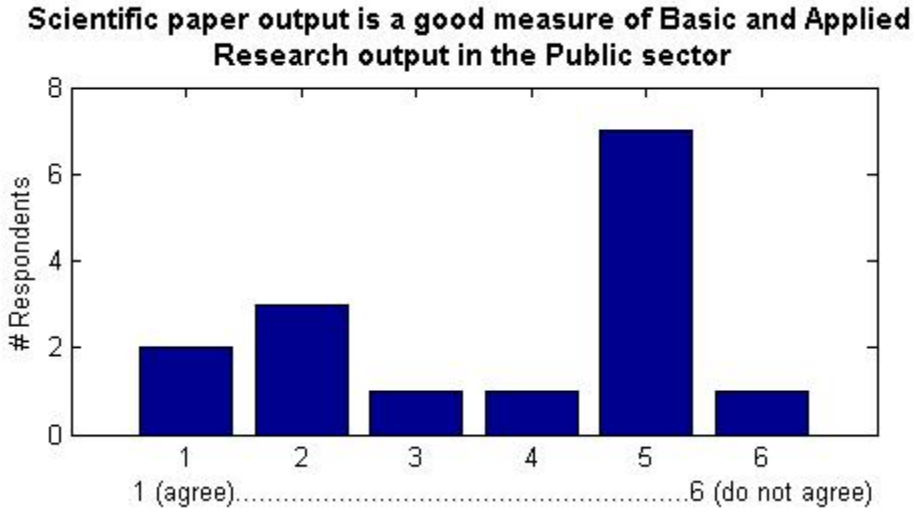


Figure 6-6: Second Round Feedback: Measure of Basic and Applied Research in the Public Sector

A further analysis was done to facilitate a comparison of the movement of opinion and

the level of agreement of the group. The following graph provides a graphic representation of the movement of group opinion (measured in terms of the mean) and the level of consensus (measured in terms of the standard deviation) from round one to round two.

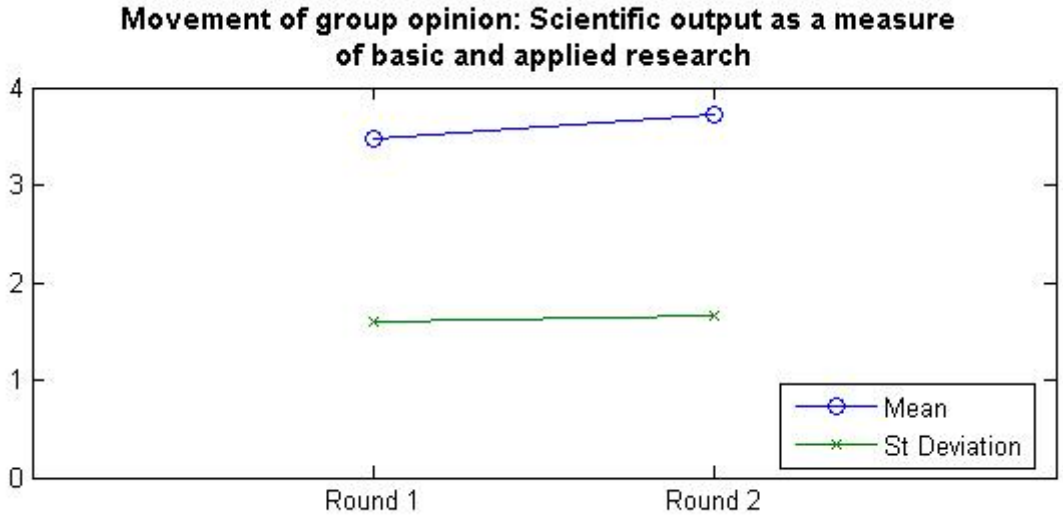


Figure 6-7: Group Opinion: Measure for Basic and Applied Research Output in the Public Sector

It can be concluded that a slightly higher level of consensus was reached (standard deviation =1.59 to 1.65) after the second round. On the Likert scale of 1 to 6, where 1 indicates that the responded agrees with the statement and where 6 indicate that the respondent disagrees, the mean was 3.73. The mean moved from 3.47 to 4.73 after the second round.

The mode and median for the feedback gained from the expert panel was both 5, which indicates that the aggregated expert opinion is that scientific publication output is not an adequate measure of basic and applied research output in the public sector.

However, it appears that there might be two schools of thought in the expert group. A substantial number of the experts, i.e. six, agreed to some extend that scientific publication output could be used as a proxy for basic and applied research output in the public sector.

6.5.2.2 Round Two: Experimental development in the public sector

Respondent had the opportunity to revise their opinions of the applicability of using patent output as a measure of experimental development in the public sector. The second round responses received from the expert panel is represented graphically in the following figure:

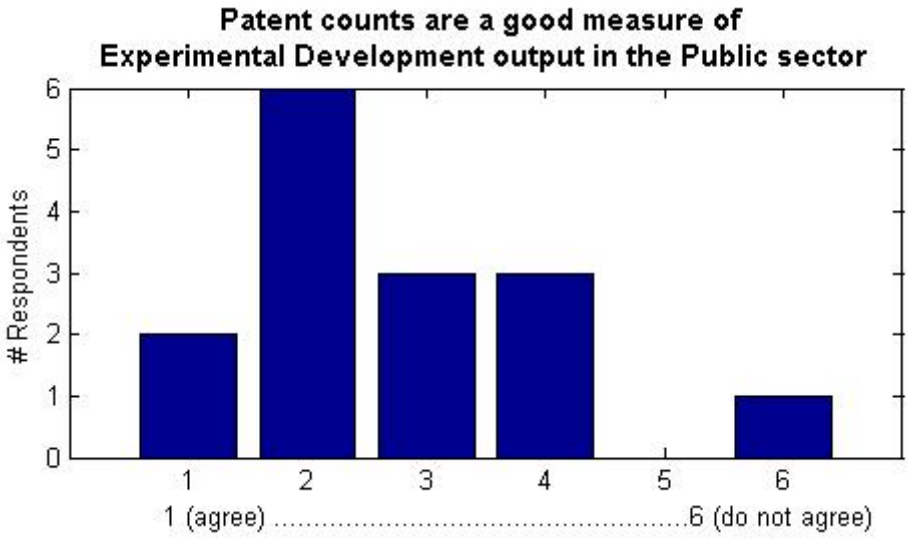


Figure 6-8: Measure of Experimental Development Output in the Public Sector

The responses yielded that the mode is 2, which indicates that the respondents view this measure as a valid proxy for measuring experimental development output in the public sector. From the 12 respondents, only four ranked above 3, which would indicate that they do not agree. We can therefore conclude that patent output is a relatively good measure of experimental development output in the South African public sector. This approach naturally also has its weaknesses, which is reflected in the mean rating of 2.92 by the expert panel.

The comparison of movement of opinion and the group's level of agreement was also analysed further. The following graph represents the movement of group opinion, measured in terms of the mean, and the level of consensus, measured in terms of the standard deviation, from round one to round two.

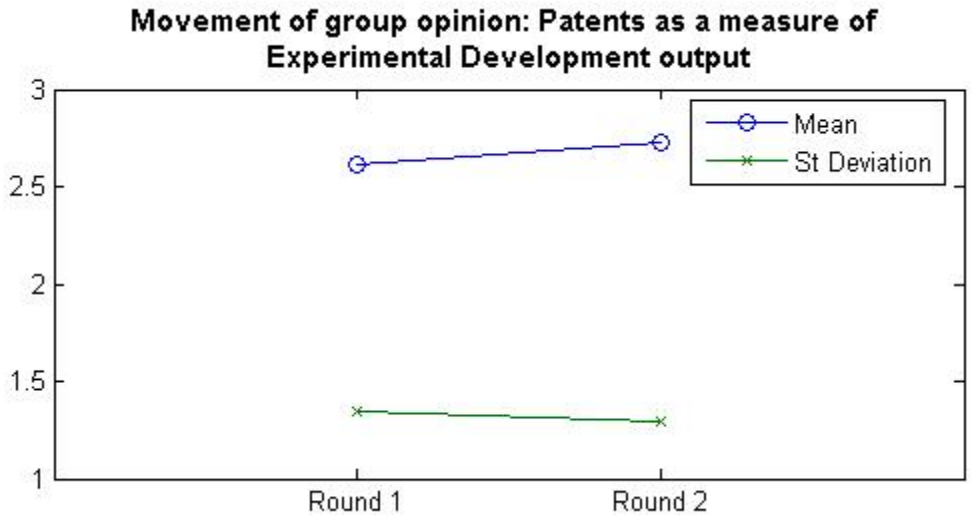


Figure 6-9: Group Opinion: Experimental Development Output in the Public Sector

The graph concludes that the group opinion has shifted from a mean ranking of 2.61 to 2.73. By the second round, a slightly higher level of agreement was reached with a standard deviation moving from 1.35 to 1.29. We can therefore conclude that the expert panel agrees to a reasonable level that patent output is an acceptable measure of R&D output generated in the public sector. The statement thus holds that patent output could be an appropriate proxy for experimental development output in the public sector model.

6.5.2.3 Round two: Hurdles faced in the public sector (next 20 years)

The following question was an open-ended question in the first round survey: **What are the general hurdles facing the South African public sector R&D system in the next 20 years?** A list of issues was compiled from the experts' responses in the first round.

The ideas generated in the first round questionnaire were categorised when developing the second round survey. In the second round survey, respondents were asked to rate issue categories on a scale from 1 to 6, where 1 indicates that it is a critical issue and a rating of 6 indicates that the issue does not exist.

Table 6-3: Summarised Issues Rankings for R&D in the Public Sector

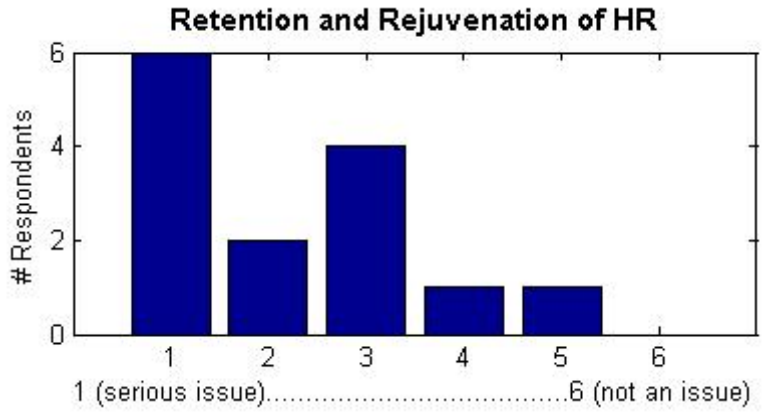
Issue Category	Median	Mean	Mode	St. Dev
1. Inability to retain and rejuvenate the researchers stock in the system	2	2.21	1	1.26
2. Lack of government funding to the public sector to develop R&D and technology platforms	2	2.43	2	1.12
3. Deterioration of quality of human resources working in R&D	2	2.43	2	1.12
4. A lack of direction and leadership in science policy	2	2.79	2	1.42
5. Current BEE policies having a negative effect on quality and R&D capacity	2.5	2.86	1	1.64

Table 6-3: indicates that all the issues raised have a median of 2 and a mean above 2 and below 3. The expert panel thus rated all these issues as relevant to some extent to the future of the public sector R&D system. The issues listed in Table 6-3: are discussed in more detail in the following sections.

1. Inability to retain and rejuvenate the researchers stock in the system

This perceived issue relates to the public sector's inability to retain and rejuvenate the human resources stock due to any of the following issue raised by the respondents: losing HR through brain drain phenomenon; low numbers of graduates interested in science as a career; and the lack of adequate rewards system in the public sector.

The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:

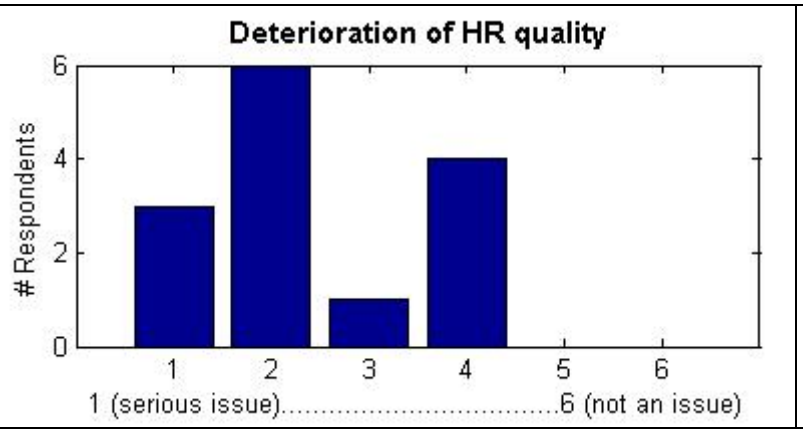


Median: 2
Mean: 2.21
Mode: 1
Stdev: 1.26

A fair level of consensus was achieved regarding this issue with a standard deviation of 1.26. The aggregated expert opinion is that the South African public sector's inability to retain and rejuvenate the human resources stock in the system will pose a hurdle to the system in the next 20 years. It must also be mentioned that six out of 14 respondents ranked this as a critical issue facing the system.

2. Deterioration of quality of human resources working in R&D

This question relates to a future threat to the level of quality of human resources working in the HES. This issue can be ascribed to multiple sources, including poor quality students entering the system as well as a lack of good remuneration and career opportunities, resulting in the level of quality of researchers in the system to deteriorate. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:



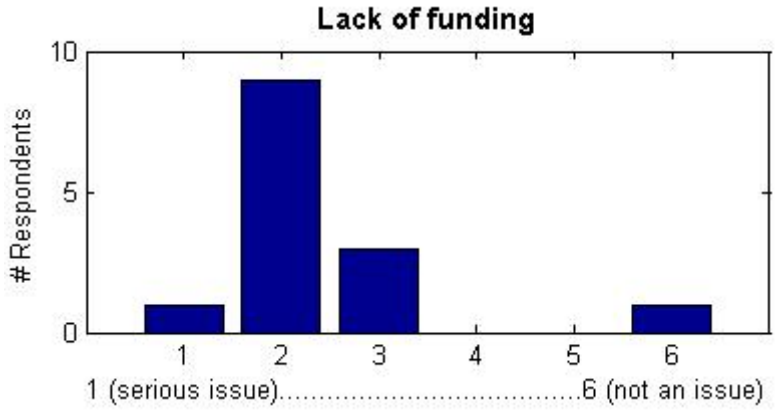
Median: 2
Mean: 2.43
Mode: 2
Stdev: 1.12

A reasonable level of consensus was achieved with a standard deviation of 1.12. A substantial amount of the respondents (>50%) rated this a critical or major issue (ranking 1 or 2) facing the public sector in the next 20 years. The experts' opinion gathered indicates that there is a deterioration of quality in human resources in the system, which could pose a threat to the R&D capacity in the public sector in the next 20 years.

3. Lack of government funding to public sector to develop R&D and technology

platforms

This issue relates to a perceived issue that science councils have poor prospect for receiving sufficient government funding to sustain them fully. The rationale is that consultancy work should have a lower priority and should thus not be used to sustain research institutions. The hurdle foreseen for the next 20-year period is therefore that science councils might not receive adequate funding from government, which would, in turn, force these institutions to continue placing a high priority on work. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:

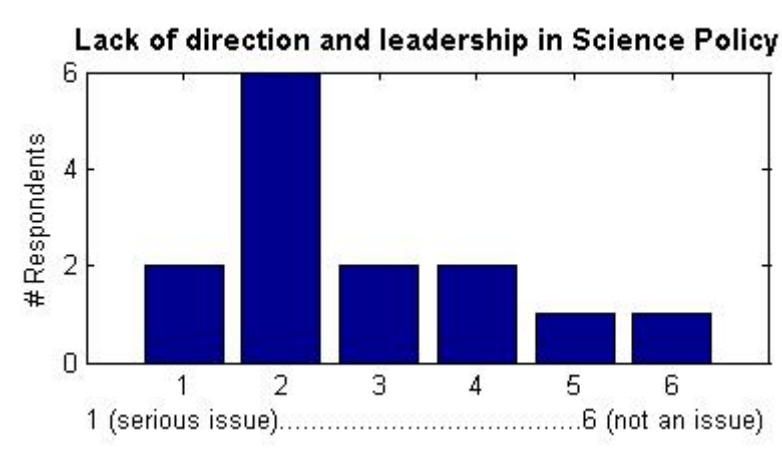


Median: 2
Mean: 2.79
Mode: 2
Stdev: 1.42

A reasonable level of consensus was achieved. Experts reached a reasonable level of consensus with a standard deviation of 1.13 regarding the existence of a major hurdle facing the HES regarding a lack of adequate government funding for R&D in the public sector.

4. There is a lack of direction and leadership in science policy

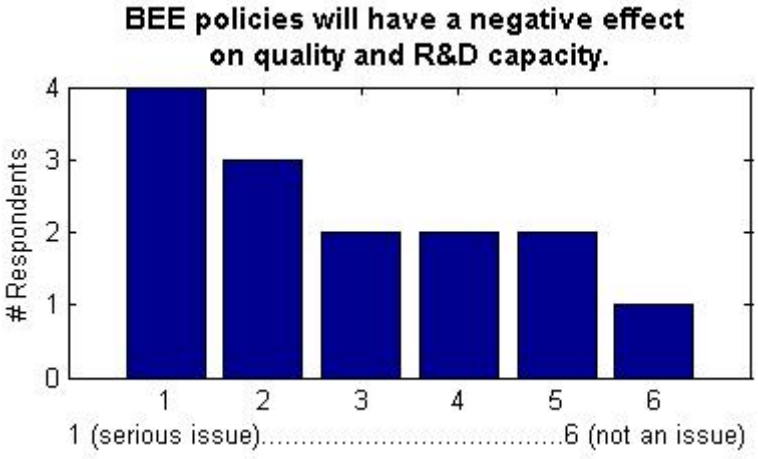
This perceived issue relates to a perception that, based on credible foresight, there is a lack of a coherent NIS, which could result in a continuous refocusing on the short term, i.e. 'flavour of the month' approach. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:



Median: 2
Mean: 2.79
Mode: 2
Stdev: 1.42

A fair level of consensus was achieved with a standard deviation of 1.42. An overall feeling that there is a lack of direction and leadership in science policy was recorded. A substantial amount of the respondents (>50%) rated this a critical or major issue (ranking 1 or 2) facing the public sector in the next 20 years. The median value ranking of this as a hurdle facing the public sector is 2.

5. Current BEE policies will have a negative effect on quality and R&D capacity
This issue relates to a perception that representativity receives too much attention and that racial quotas rather than competence are used as functional goals of policy instruments. This issued could ultimately impact negatively on the R&D system. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:



Median: 2.5
Mean: 2.86
Mode: 1
Stdev: 1.64

A low level of consensus was achieved with a standard deviation of 1.64. The respondents' feedback was inconclusive regarding the future effect of BEE policies on system performance. This is illustrated by the wide spectrum selection ranging from 1 to 6. It is however also evident that more than 50% of the experts do view this as a critical issue facing the public sector in years to come (9 respondents ranked this as an issue with criticality 1 to 3).

6.5.3 Feedback from the second round questionnaire (private sector)

6.5.3.1 Round two: R&D output in the private sector
Respondent had the opportunity to revise their opinions of the applicability of using scientific output as a measure of R&D output in the private sector. The revised version of expert opinions (after the second round) is represented in the following graph:

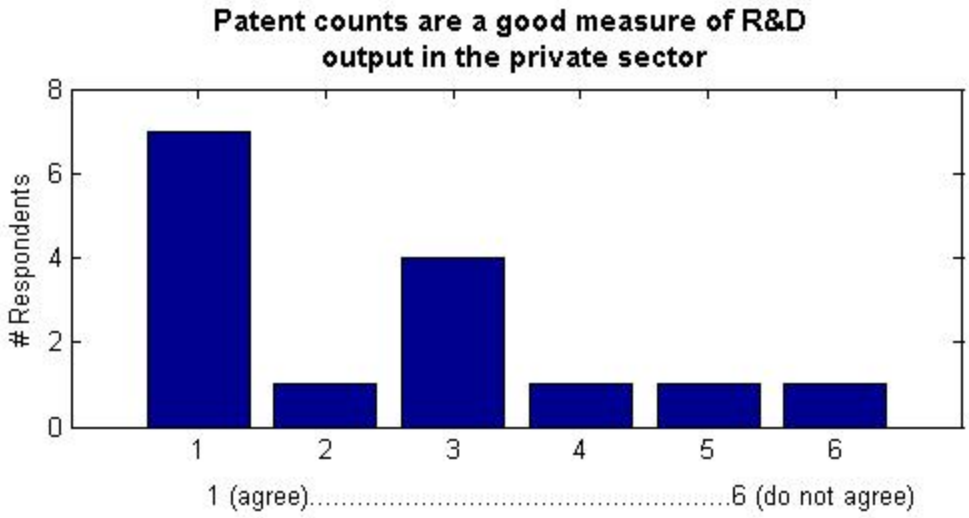


Figure 6-6: Response Graph - Measurement of R&D in the Private Sector

The comparison of movement of opinion and the group's level of agreement was analysed further. The following graph represents the movement of group opinion, measured in terms of the mean, and the level of consensus, measured in terms of the standard deviation, from round one to round two.

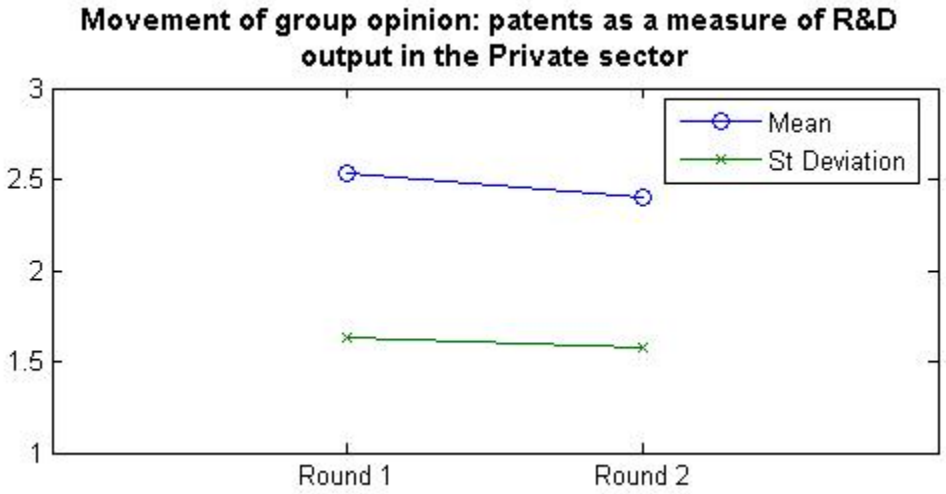


Figure 6-7: Movement of Group Opinion - Patents to Measure R&D Output

After the second round, a small improvement in the level of consensus was reached (standard deviation =1.63 to 1.58). In round one, the mean was 2.53, which decreased to 2.40 after round two.

The response graph (Figure 6-6) indicates that the mode is 1, with seven of the fourteen respondents agreeing (rank = 1) that the use of patent output is a good measure of R&D output in the private sector. From the 12 respondents, only three ranked above 3, which translates to an indication of a poor measure. We can therefore conclude that patent output is a relatively good measure of experimental development output in the South African private sector. This approach naturally also has its weaknesses, which is reflected in the mean rating of 2.40 by the expert panel.

6.5.3.2 Round two: Hurdles faced in the private sector (next 20 years)

The following question was an open-ended question in the first round survey: **What are the general hurdles facing the South African private sector R&D system in the next 20 years?** A list of issues was compiled from the experts' responses in the first round.

The ideas generated in the first round questionnaire were categorised when developing the second round survey. In the second round survey, respondents were asked to rate issue categories on a scale from 1 to 6, where 1 indicates that it is a critical issue and a rating of 6 indicates that the issue does not exist.

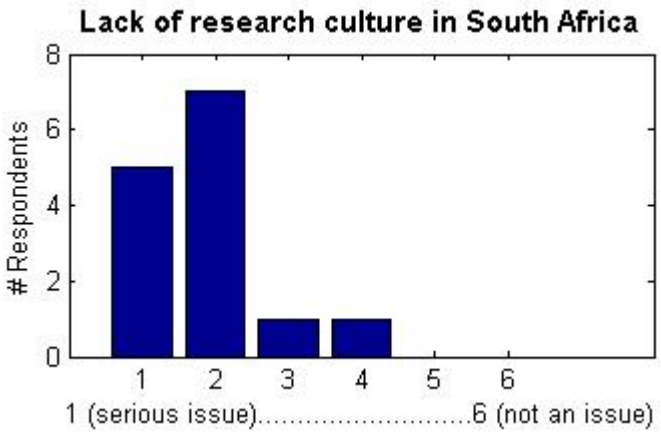
Table 6-4: Summarised Issues Rankings for R&D in the Private Sector

Issue Category	Median	Mean	Mode	St.dev
1. Lack of research culture in South Africa	2	1.86	2	0.83
2. Lack of funding of R&D	2	2.07	2	0.80
3. Restrictive communication infrastructure	2	2.07	2	1.16
4. Inability to retain and rejuvenate the researchers stock in the system	2	2.29	2	1.16
5. Current BEE policies having a negative effect on South Africa's future R&D capacity	2.5	2.93	4	1.53
6. Poor linkages	3	2.64	3	0.61
7. Lack of fiscal incentives from government to foster R&D culture in companies	3	2.71	1	1.58
8. Deterioration of quality (skill level) of human resources working in R&D	3	3.00	3	1.25
9. Lack of direction and leadership in science policy	3.5	3.71	2	1.44

The issues listed in Table 6-4 are discussed in more detail in the following sections.

1. Lack of research culture in SA

Respondents were asked to rank this perceived hurdle facing the private sector in the next 20 years. This related to the perception that companies do not realise the importance and benefits of R&D to maintain competitiveness. In South Africa, the general mindset in the private sector is to import value added rather than to add the value through R&D. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:

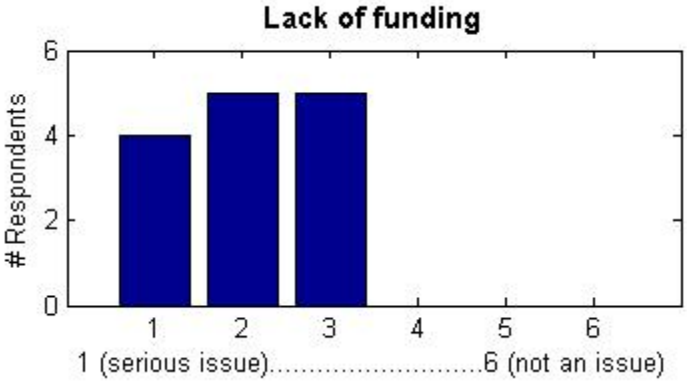


Median: 2
Mean: 1.86
Mode: 2
Stdev: 0.83

A high level of consensus was achieved regarding this issue, with a standard deviation of 0.83. A substantial amount of the respondents (>80%) rated this a critical issue or major issue (ranking 1 or 2) facing the private sector R&D system in the next 20 years.

2. Lack of funding of R&D

Respondents were asked to rank the criticality of the perceived issue that there is a lack of support for commercialisation of R&D and a lack of funding for local R&D. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:

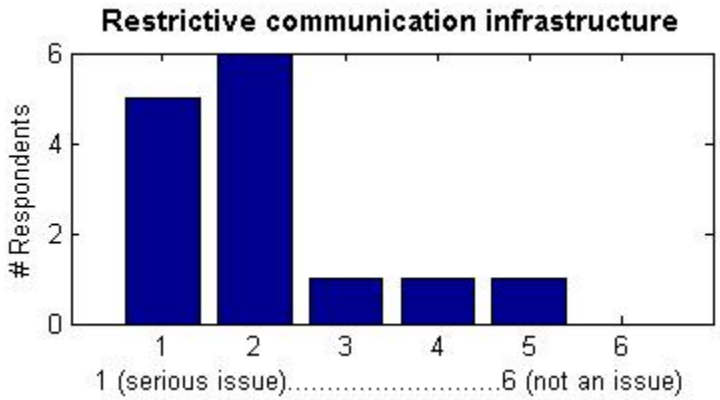


Median: 2
Mean: 2.07
Mode: 2
Stdev: 0.80

A high level of consensus was achieved regarding this issue, with a standard deviation of 0.80. All the respondents rated this as an issue (level 1 to 3). We can therefore conclude that a continued lack of funding for the R&D private sector seems to be a major hurdle facing the sector in the next 20 years.

3. Restrictive communication infrastructure

Respondents were asked to attach a level of criticality to the perceived issue that South Africa has a restrictive communication system. The following is a graph representation of the feedback received from the expert panel regarding the issue's level of criticality:

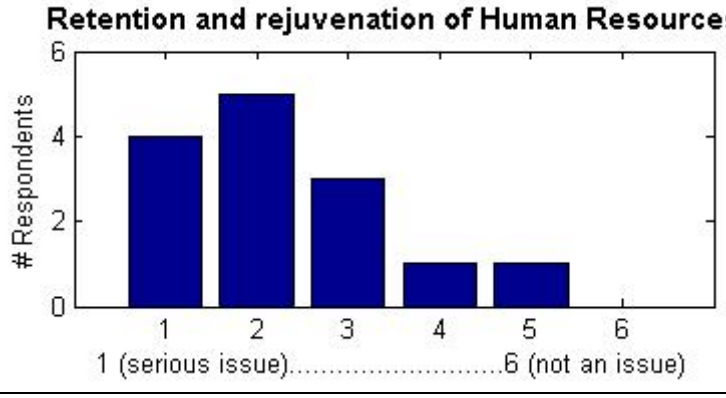


Median: 2
Mean: 2.07
Mode: 2
Stdev: 1.16

A reasonable level of consensus was achieved regarding this issue, with a standard deviation of 1.16. The majority of the respondent (11 out of 14) rated the issue as critical, thus level 1 and 2. We can therefore conclude that a restrictive communication seems to be a major hurdle facing the private sector R&D system in the next 20 years.

4. Inability to retain and rejuvenate the researchers stock in the system

This question relates to a perceived issue that the private sector faces poor prospects regarding the rejuvenation its human resources working in R&D due to issues such as: a low supply of skilled R&D personnel; an inadequate rewards system and the brain drain phenomenon. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:



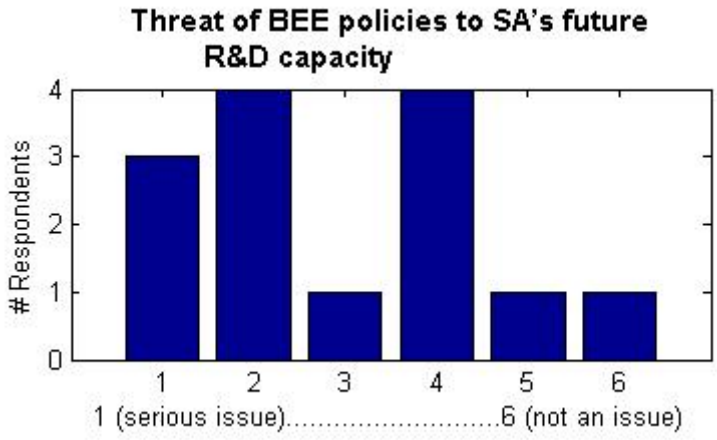
Median: 2
Mean: 2.29
Mode: 2
Stdev: 1.16

A fair level of consensus was achieved regarding this issue, with a standard deviation of 1.16. The majority of the respondent (12 out of 14) rated the issue as critical, thus level 1 to 3. We can therefore conclude that the experts foresee poor prospects for the private sector in terms of its ability to retain and rejuvenate its researchers stock during the next 20 years.

5. Current BEE policies will have a negative effect on South Africa's future R&D capacity

Respondents were asked to attach a level of criticality to the perceived issue that racial quotas rather than competence as functional goals of policy instruments could pose a

threat to the R&D capacity on the private sector. Other possible issues relating to this factor is that economic empowerment is sapping investment funds from company profits. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:

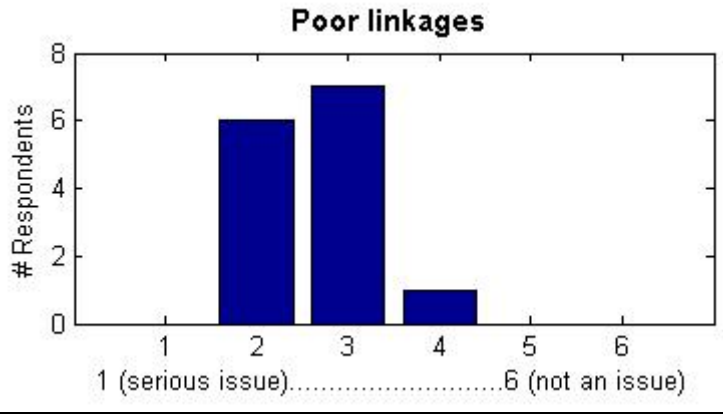


Median: 2.5
Mean: 2.93
Mode: 4
Stdev: 1.53

A low level of consensus was achieved regarding this issue with a standard deviation of 1.53. Although the mean value of the expert opinion rating (2.93) indicates that BEE policies should not pose a major hurdle to the private sector in the next 20 years, a substantial percentage of the respondents (7 out of 14) rated the issue as critical, thus a level 1 and 2. This indicates that a significant portion of the respondents views the issue to be a major concern regarding the sustainability of the R&D capacity in the sector.

6. Poor linkages

The private sector will not invest in R&D projects where the commercial potential is not obvious. Government thus needs to lead in strategic development projects to develop technology platforms from which the private sector can develop new products and processes. Respondents were asked to attach a level of criticality to the perceived issue that poor linkages exist between the private sector and government R&D programmes. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:

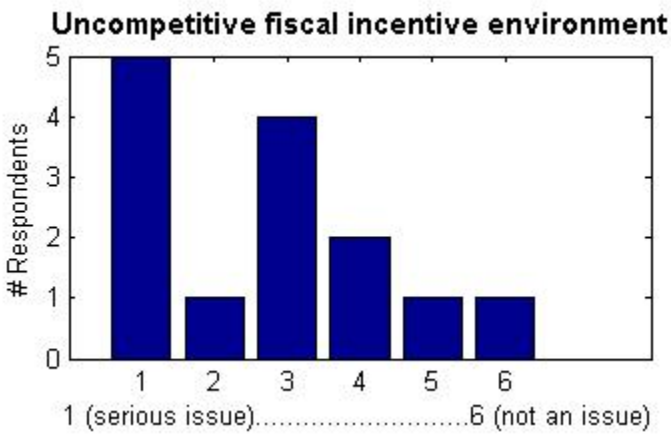


Median: 3
Mean: 2.64
Mode: 3
Stdev: 0.61

A high level of consensus was achieved regarding this issue, with a standard deviation of 0.61. The majority of the respondent (13 out of 14) rated the issue as critical, thus level 2 and 3. We can thus conclude that the expert panel acknowledges the issue that poor linkages exist. Respondents seem to agree that although this issue will continue to play a role in the next 20 years, it should not be viewed as a critical issue. Although this is thus not a critical issue, the experts agree that it could pose hurdles for the system in the next 20 years.

7. Lack of fiscal incentives from government to foster R&D culture in companies

Respondents were asked to attach a level of criticality to the perceived issue that there is a lack of tax incentives from government. Better tax breaks in other countries could result in a loss of R&D capacity as multinationals establish R&D centres where the fiscal environment is more advantageous. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:

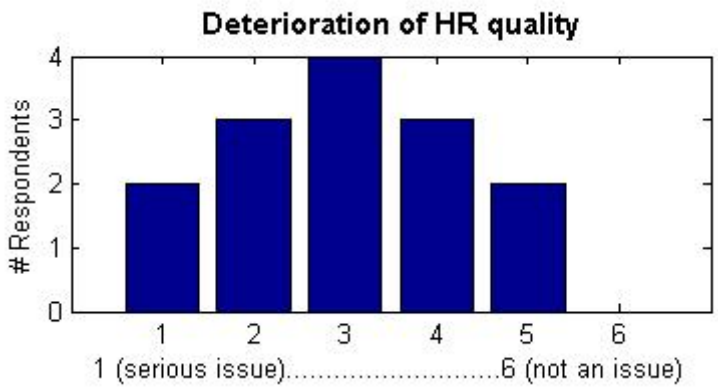


Median: 3
Mean: 2.71
Mode: 1
Stdev: 1.58

A fairly low level of consensus was achieved regarding this issue, with a standard deviation of 1.58. The majority of the respondent (10 out of 14) rated the issue as critical, thus level 1 to 3. We can therefore conclude that the lack of an adequate fiscal incentive scheme could pose a hurdle for the private sector R&D system.

8. Deterioration of quality (skill level) of human resources working in R&D

This question relates to a future threat to the level of quality of human resources working in the private sector. Respondents were asked to comment on the level of criticality of the perceived issue that the quality of human resources working in R&D will deteriorate. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:

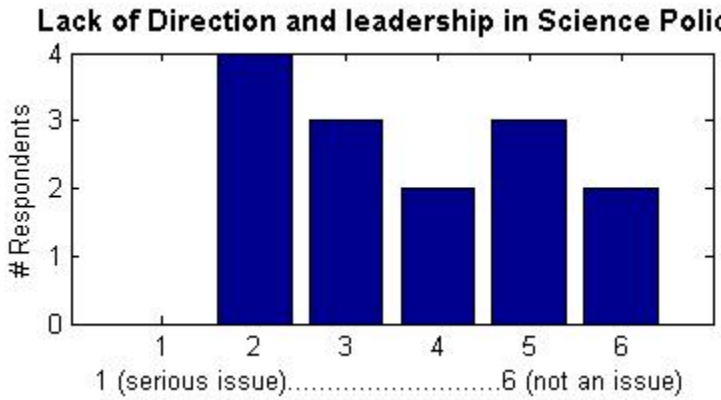


Median: 3
Mean: 3.00
Mode: 3
Stdev: 1.25

A fair level of consensus was reached with a standard deviation of 1.25. Respondents agree to some extent that a deterioration of quality and skill levels of human resources in the private sector might be seen as an area of concern (mean of 3).

9. Lack of direction and leadership in science policy

Respondents were asked to comment on the level of criticality of the perceived issue that there is a lack of a coherent science policy for the private sector. The following is a graphic representation of the feedback received from the expert panel regarding the issue's level of criticality:



Median: 3.5
Mean: 3.71
Mode: 2
Stdev: 1.44

A fair level of consensus was achieved with a standard deviation of 1.44. Respondents seem to agree that although this issue will continue to play a role in the next 20 years. The experts also agree that although this is not a critical issue, it must be viewed as an area of concern (mean 3.5).

6.6 Interpretation of Findings

In the past, the Delphi methodology suffered a high level of criticism. The fact that participants are not allowed to discuss the issues raised or to elaborate on the views

provided has been accused of weakening the process (Walker & Selfe 1996, Goodman 1987). This issue also arises in the application of the Delphi methodology in this thesis.

In the first round, experts were asked to list hurdles facing South Africa's R&D system in the following 20 years. In the second round survey, the respondents were asked for their opinion on the seriousness of statements made regarding issues facing the South African R&D system.

The three main R&D sectors in South Africa's R&D system, namely the HES as well as the public and private sector, were treated separately. The following is a short summary of the issues and their levels of criticality as well as the level of consensus achieved in the Delphi study.

6.6.1 The HES

The following table summarises the aggregated respondents' opinion regarding the level of criticality of issues facing the R&D system in South Africa's HES over the next 20 years:

Table 6-5: Summary Table of Hurdles Facing the HES in the Next 20 Years

Issue category	Median	Mean	Mode	St. Dev
1.Inability to retain and rejuvenate human resources stock in the system	1.50	1.64	1.00	0.72
2. Lack of funding for R&D in the HES	2.00	2.29	2.00	1.10
3. Lack of female and black rresearchers for R&D to reach representative work force	2.00	2.71	2.00	1.48
4. Deterioration of quality of human resources working in R&D in the sector	2.50	2.43	1.00	1.12
5. Poor linkages posing a threat to future capacity and the relevance of R&D performed in the system	2.50	2.43	3.00	0.82
6. Lack of multidisciplinary research projects	3.00	3.29	2.00	1.53
7. Difficulty of successful R&D policy alignment with national priorities	3.00	3.29	3.00	0.96
8. Weak IP protection policies in HES	3.00	3.36	3.00	1.34
9. Inadequate funding of equipment	3.50	3.14	4.00	0.99

The level of consensus achieved by the group is measured by considering the standard deviation of opinion. It can be concluded that an overall reasonable level of agreement exists regarding the issues in the system.

An exception is the respondents' opinion on a future lack of female and black researchers in the HES (st. deviation is 1.48). This issue can therefore be identified as an area of further discussion and debate. Respondents also failed to agree (st. dev 1.53) on the criticality of the issues posed to the system during the next 20 years through a perceived

lack of multidisciplinary research in the sector.

The discussion in Section 6.5.1.2 and the summary in Table 6-5 concluded that the most pressing issues facing the South African HES are:

- poor prospects for retaining and rejuvenating the human resources stock in the next 20 years
- poor prospect for adequate funding for R&D in the HES in the next 20 years
- a deterioration of quality of human resources in the system in the next 20 years; and
- a lack of female and black researchers for R&D to reach a representative work force.

These specific issues are also closely interlinked with the research questions posed in this thesis. However, this research question focuses on the effect of R&D expenditure on the development of an R&D capacity in the system. The scenarios consequently focuses mainly on answering questions regarding the effect of R&D expenditure on the future R&D capacity of the R&D system.

The following scenarios were developed to be tested on the system models. The objective was to tests the effect that some of these issues might have on the system in the next 20 years. To facilitate an answer to these questions, scenario tests were developed and tested on the system model regarding the hurdles foreseen by experts. Table 6-6 provides a short summary of the scenarios developed to be tested on the system model of R&D in the HES:

Table 6-6: Scenarios Developed for the HES Model

Base Case: Experts foresee a lack of adequate funding for R&D projects in the HES for R&D projects. How could a constant/unchanging investment in the South African HES affect its ability to produce R&D output and absorb knowledge?
Scenario 1: Experts foresee a lack of adequate funding for R&D projects in the HES for R&D projects. How could a decreasing level of investment in the South African HES affect its ability to produce R&D output and absorb knowledge?
Scenario 2: Experts foresee a deterioration of the quality of human resources in the system. How could the introduction of dedicated researchers in the system (science chairs) influence system performance in the development of centres of excellence?
Scenario 3: How could delayed reaction to the decay of R&D capacity influence the system and the cost to rebuild lost capacity?
Scenario 4: How could the introduction of better time management skills in academic and research personnel influence system performance?

6.6.2 The Public sector

The following table summarises the aggregated respondent opinion regarding the level of criticality of issues facing the R&D system in South Africa's public sector R&D system

over the next 20 years:

Table 6-7: Summary Table of Hurdles Facing the Public Sector in the Next 20 Years

Issue category	Median	Mean	Mode	St. Dev
1. Inability to retain and rejuvenate the researchers stock in the system	2	2.21	1	1.26
2. Lack of government funding to public sector to develop R&D and technology platforms	2	2.43	2	1.12
3. Deterioration of quality of human resources working in R&D	2	2.43	2	1.12
4. Lack of direction and leadership in science policy	2	2.79	2	1.42
5. Current BEE policies having negative effect on quality and R&D capacity	2.5	2.86	1	1.64

The level of consensus achieved by the group is measured by considering the standard deviation of opinion. It can be concluded that an overall reasonable level of agreement exists regarding the criticality of issues raised in the first round. The exception is the respondent opinion on the negative effect current BEE policies might have on quality and R&D capacity in the public sector (st. deviation is 1.64). This issue can therefore be identified as an area of further discussion and debate.

The discussion in Section 6.5.2.3 and the summary in Table 6-7 concluded that the most pressing issues facing the South African Public sector are:

- poor prospects for retaining and rejuvenating the human resources stock in the next 20 years
- poor prospect for adequate funding for R&D in the public sector in the next 20 years; and
- a deterioration of quality of human resources in the system in the next 20 years.

These specific issues are also closely interlinked with the research questions posed in this thesis. However, this research question focuses on the effect of R&D expenditure on the development of an R&D capacity in the system. The scenarios consequently focuses mainly on answering questions regarding the effect of R&D expenditure on the future R&D capacity of the R&D system.

To facilitate an answer to these questions, scenario tests were developed and tested on the system model regarding the hurdles foreseen by experts. Table 6-8 provides a short summary of the scenarios developed to be tested on the system model of R&D in the public sector:

Table 6-8: Scenarios Developed for the Public Sector Model

Base Case: Experts foresee a lack of adequate funding for R&D projects in the public sector. How could a constant/unchanging investment in the South African public sector R&D system affect its ability to produce R&D output and absorb knowledge?

Scenario 1: Experts foresee a lack of adequate funding for R&D projects in the public sector. How could a decreasing level of government investment in the South African public sector R&D system affect its ability to produce R&D output and absorb knowledge?

Scenario 2*:* Experts foresee a lack of adequate government funding for R&D projects in the public sector to enable it to attach less priority to consultancy work. How could moving away from the framework autonomy policy influence the system?

Scenario 3: How could an increasing/decreasing level of investment from government combined with a movement away from framework affect the system's ability to produce R&D output and absorb knowledge?

6.6.3 The Private sector

The following table summarises the aggregated respondents' opinion regarding the level of criticality of issues facing the R&D system in South Africa's private sector R&D system over the next 20 years:

Table 6-9: Summary Table of Hurdles Facing the Private Sector in the Next 20 Years

	Median	Mean	Mode	Stdev
1. Lack of research culture in South Africa	2	1.86	2	0.83
2. Lack of funding of R&D	2	2.07	2	0.80
3. Restrictive communication infrastructure	2	2.07	2	1.16
4. Inability to retain and rejuvenate the researchers stock in the system	2	2.29	2	1.16
5. Current BEE policies will have a negative effect on South Africa's future R&D capacity	2.5	2.93	4	1.53
6. Poor linkages	3	2.64	3	0.61
7. Lack of fiscal incentives from government to foster R&D culture in companies	3	2.71	1	1.58
8. Deterioration of quality (skill level) of human resources working in R&D	3	3.00	3	1.25
9. Lack of direction and leadership in science policy	3.5	3.71	2	1.44

The level of consensus achieved by the group is measured by considering the standard deviation of opinion. It can be concluded that an overall reasonable level of agreement exists regarding the criticality of issues raised in the first round.

The exception is the respondent opinion on the negative effect that current BEE policies might have on quality and R&D capacity in the private sector (st. deviation is 1.53). This issue can therefore be identified as an area of further discussion and debate.

Another issues that respondents failed to agree on was the level of criticality that an

uncompetitive fiscal incentive environment will have on the private sector in the next 20 years.

The discussion in Section 6.5.2.3 and the summary in Table 6-9 concluded that some of the most pressing issues facing the South African Public sector R&D system are:

- a lack of a research culture poses a hurdle for the development of an R&D capacity in the next 20 years
- poor prospect for adequate funding for R&D in the public sector in the next 20 years
- a restrictive communication infrastructure; and
- poor prospects for retaining and rejuvenating the human resources stock in the next 20 years.

These specific issues are also closely interlinked with the research questions posed in this thesis. However, this research question focuses on the effect of R&D expenditure on the development of an R&D capacity in the system. The scenarios consequently focuses mainly on answering questions regarding the effect of R&D expenditure on the future R&D capacity of the R&D system.

The following scenarios were developed to be tested on the system models. The objective was to tests the effect that some of these issues might have on the system in the next 20 years. To facilitate an answer to these questions, scenario tests were developed and tested on the system model regarding the hurdles foreseen by experts. Table 6-6: provides a short summary of the scenarios developed to be tested on the system model of R&D in the private sector:

Table 6-10: Scenarios Developed for the Private Sector Model

Base Case: Experts foresee a lack of adequate funding for R&D projects in the private sector. How could a constant/unchanging investment in the South African private sector R&D system affect its ability to produce R&D output and absorb knowledge?
Scenario 1: Experts foresee a lack of adequate funding for R&D projects in the private sector. How could an increase/decreasing level of investment in the South African private sector R&D system affect its ability to produce R&D output and absorb knowledge?
Scenario 2: Experts rank a lack of an R&D culture as one of the biggest restrictions for the future development of the private sector's R&D capacity. Through fiscal incentives, a policy can be introduced to help foster an R&D culture in the private sector. This scenario was developed to find an answer to the following research question: How could the introduction of fiscal incentives influence R&D expenditure and the ability to produce R&D output and absorb knowledge?
Scenario 3: Experts rank a lack of an R&D culture as one of the biggest restrictions for the future development of the private sector's R&D capacity in the next 20 years. Scenario 3 examines and compares the model's predicted output for different levels of responsiveness from the private sector to tax incentive schemes in conjunction with varying delays of the private sector to react to these incentives

6.7 Conclusion

An analysis of the results section yields a conclusion that a reasonable overall level of agreement exists regarding the group opinion. The aggregated group opinion introduces two similar and repetitive themes regarding the most pressing issues in all three of the R&D sectors surveyed. These themes centre on issues regarding human resources working in R&D as well as the availability of funding.

A very low level of agreement (and consequently uncertainty) exists regarding the effect of BEE policies on the future capacity of the system. The issue presented the lowest level of consensus in all three sectors surveyed. This is therefore an issue that warrants further investigation.

In general, a sufficient level of consensus was achieved in the second round survey.

It must be remembered that the existence of a consensus does not necessarily mean that the correct answer, opinion or judgement has been identified. The real significance this study's outcome must be kept in mind, i.e. it assisted in identifying areas, in this case, hurdles faced by the South African R&D system, that the group of experts considered important.