Sources and Patterns of Innovation in the CSIR, A National Research Council in South Africa

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Abstract
This article reports on the findings of a research project that was conducted to determine the sources of innovation, and the patterns of behavior that led to innovation in a National Research Council. The study was conducted at the CSIR in Pretoria and the results have shown that certain sources of innovation more frequently led to outputs that are considered to be innovative. The study was based on a survey amongst both present and previous researchers of the CSIR. Some results are presented and conclusions were made based on the results. The study was limited to the CSIR and did not include other National Research Councils in South Africa. The CSIR is arguably the most prominent of Research Councils in SA and although it has been in existence for sixty years, no specific effort was made to research the historic trends in innovation over this period.

1.0 Background

1.1 Introduction and Historical Background

The area of interest for this research proposal is the sources of innovation as found in a Science Council in South Africa. The study was limited to the CSIR. There is an increasing amount of pressure on the CSIR from stakeholders to supply innovative solutions to both short- and long term problems unique to the South African and African environments. In response to these pressures, the organisation is actively investigating possible policies and approaches that will ensure improved delivery of the required scientific and technological outputs. A broad base of SET excellence is seen as a prerequisite to achieving the desired objectives, and it was recognised that changes to the corporate structure and culture may be necessary to achieve the required goals.

The CSIR has had a mandate to concentrate on Scientific and Industrial Research since 1945. It has survived through periods where basic research was done utilising funds obtained from government grants, as well as through periods where its continued existence was ensured largely by means of contract development, together with sound corporate and financial management. During 2004 and 2005 the CSIR embarked on a widespread transformation initiative called “The Beyond 60 Process” that resulted in a new organizational management model and a structure aimed at the improvement of in depth scientific knowledge and technological skills.

1.2 Research problem

It has been a concern for several years now that South Africa appears to remain a Technology Colony, despite efforts to improve the industrial outputs obtained from

technological innovation. Research and development have often been cited as the logical area of technology acquisition from which to expect innovation leading to new products and services. Unfortunately in South African industries there are few players with long term R&D strategies that can be used to investigate the sources of innovation over a suitably long period of time.

1.3 Research objectives and questions

This research project attempted to identify, analyse, classify and evaluate such sources in a way that will provide some insight into the challenges of improving the innovative processes at work in this type of organization. Although much literature exists on the topic of industrial innovation leading to innovative and competitive products in the market place, little was found specifically related to the role played by sources of innovation in Research Councils. The following questions were considered:

- What are the identifiable sources leading to innovation in a research environment like the CSIR?
- What patterns of behavior and organizational aspects support innovation in a typical Research Council?

The starting point or basic premise of the investigation is that improved delivery of results can be achieved if a better understanding is gained of the factors giving rise to significant innovation. These factors can collectively be called “sources” of innovation. The final objective of the research is to provide guidelines on how technology managers (and knowledge managers), can ensure that they spend the optimum time and funds on the sources of innovation that are the most likely producers of innovations.

2.0 Theoretical Framework

2.1 Theory and research review

2.1.1 Definitions

Definitions of innovation abound in the available literature. The following definitions were found to be of value for this research project:

- Innovation is the introduction to the market of a new or changed product or process. Innovation entails a combination of scientific, technological, organizational, financial and commercial activities (Blankley and Kaplan, 1997).
- Innovation is new ideas plus action or implementation which results in improvement, gain or profit (Gundling, 2000).
- Innovation is the introduction of change via something new, as opposed to invention, which is the creation of a new device or process, where inventions were not the innovations implemented (Rouse, 1991). Inventions can remain unused.

2.1.2 Classification of types of innovations

Gundling (2000) reported on innovation as a major contributing factor to the long term successes of the 3M Company in the USA. He identified three types of innovation, namely:

- Type A, the most radical type that gives birth to a new completely business or industry
- Type B, the type that changes the basis of competition,

- Type C, a product line extension which produces an incremental advance

This classification was chosen for the study. Clarke and Wheelwright (1993) in their textbook on the management of product development, in essence describes the same three types.

2.1.3 Mechanisms of innovation

Gundling also defined five mechanisms (or "openings") that leads to innovation, namely:

- *A bridge beyond previous accomplishments*, the most direct path to innovation, i.e. provision of an extended life for a product or process.
- *A pattern of association,* which leads to a new product from application of knowledge from other products, e.g. cellular phones derives from handheld two-way radios.
- *Stimulation from an outside source*, e.g. using inputs from mechanical engineering to improve structural stability of optical products.
- *A reversal of previous assumptions,* e.g. rather design for less power consumption from a battery than using a larger battery to increase the mission time of handheld electronic devices.
- *A new combination of technologies* not used together before to create an innovation.

2.1.4 Sources of innovation

Sources of innovation are elegantly described by Drucker (1985), and his classification was used for the research conducted. The sources, listed in descending order of reliability and predictability, are:

Internal Sources:

- *The unexpected*, i.e. success, failure or an outside event
- *The incongruity*, between reality as it actually and reality as it is assumed to be or "ought to be"
- Innovation based on *process needs*
- *Changes in industry* structure or market structure

External Sources:

- *Demographics*, or population related changes
- *Changes in perception*, mood and meaning
- *New knowledge*, both scientific and non scientific

Drucker places new knowledge last in his list based on reliability and predictability. This observation from industry or "real life" may not be directly applicable to the environment of a research council, because his emphasis is on sources seen from the perspective of entrepreneurial opportunities provided by innovation. Results from this project do indicate that this aspect is not irrelevant in the context of a research council. He also comments on the very limited value of a single bright idea; for the purposes of this project it was decided to include this variable in the survey. He states that it belongs in the appendix due to our lack of understanding of it, yet it should be appreciated and rewarded; he states that to discourage patents is both short-sighted and deleterious.

2.1.5 Technology acquisition:

Khalil (2000) describes the different forms of new technology acquisition and it was decided to investigate the relationships between new technology acquisitions

and innovation, especially in the light of the views of Drucker that new knowledge does not play a major role in the process of innovation. It was found that internal research and development is the dominant source of technology acquisition in the CSIR.

2.1.6 Patterns associated with innovation

When patterns of behaviour that leads to innovation were sought, it was found that environmental aspects like company culture can be either conducive to innovation, or it can be a very limiting factor (Gundling, 2000). Even within organizations with the required culture and "innovative environments", disciplined approaches to innovation, as well as systematic procedures and processes are found (Rouse, 1991 and1992), Kelly & Littman (2001); Gundling (2000).

2.2 Theories and models

Theories and models for innovation largely draw on the body of knowledge available in the fields of technology management and development management. Clark and Wheelwright (1993) provide an extensive strategy for development that systematically handles most aspects of innovation. Rouse (1991) provides planning strategies based on the approach advocated by the American management association, as well as a structured methodology. Drucker (1985) gives three conditions which seem obvious but often go disregarded:

- *Innovation is work*. It requires knowledge and ingenuity, but it becomes hard, focused, purposeful work making very great demands on diligence, persistence and commitment
- *To succeed, innovators must build on their strengths*. The attempted innovation must fit the individuals and the company involved.
- *Innovation is an effect in economy and society*, a change in the behavior of customers, of teachers, and of people in general. Innovation must be close to the market, indeed market driven

2.3 Hypothesis

The basic premise of the investigation is that improved delivery of innovative results can be achieved if a better understanding is gained of the factors giving rise to significant innovation. If the sources of innovation are identified, the optimum utilization of each source can be achieved through the application of technology management. The secondary objective of the research is to provide insight to technology managers (and knowledge managers), to enable them to spend the optimum amount of time and funds on the sources of innovation that are the most likely producers of innovations.

3.0 Methodology

3.1 Research strategy and instruments

The question arose whether detailed knowledge of the sources and patterns of innovation can lead to management actions that will optimize the outputs obtained from innovative activities in the CSIR. A research proposal was prepared and the project was executed during 2005. A literature study was conducted to identify a suitable listing of sources of innovation as well as the parameters relevant to sources and patterns of innovation. For practical reasons it was decided to make use of a survey amongst present CSIR employees as well as some thirty five

former CSIR researchers that were known to have been involved, and who could be traced. The research survey was designed to address the aspects of interest, and after workgroup discussions with colleagues and improvements to the survey, it was encoded to be used on the World Wide Web, and subjected to a trial amongst colleagues. A total of twenty eight innovations that roughly spanned the period of 1955 to 2005 were investigated. The results from the survey was automatically captured in a database via the internet and then processed for analysis and interpretation.

3.2 Data Collection

The respondents were requested to complete a questionnaire for each innovation witnessed. The entire questionnaire focused on the characteristics of a single innovation. No responses were received duplicating an innovation covered by another response. The questionnaire was designed to gather data regarding the following aspects:

3.2.1 Requirements satisfied by the innovation:
Five requirements were identified and surveyed.
3.2.2 Phases in the life cycle of products and systems affected by the innovation:
Seven phases as defined in the systems engineering discipline were surveyed.
3.2.3 Professions, subject areas and branches of science involved:
Eleven subject areas were provided to choose from
3.2.4 Type of innovation:
The three types of innovation listed earlier were surveyed
3.2.5 Mechanisms of innovation:
The five mechanisms or openings leading to innovation were provided and the most relevant one that lead to the innovation had to be selected.
3.2.6 Aspects of company culture:
Thirteen aspects attributable to company culture was provided to be rated.
3.2.7 Sources of innovation:
The seven sources mentioned earlier were listed and the most relevant one had to be chosen.
3.2.8 The influence from a bright idea had to be rated.
3.2.9 The influence from six types of technology acquisition had to be rated
3.2.10 The results of the innovation had to be indicated as one or more of five possible outcomes.

3.3 Data Analysis

It should be noted that certain innovations influenced several parameters, hence the percentages in several results add up to more than one hundred percent

3.3.1 Requirements satisfied by innovations

It is clear from the sample data that the requirements for products were the most dominant requirement served by the innovations.

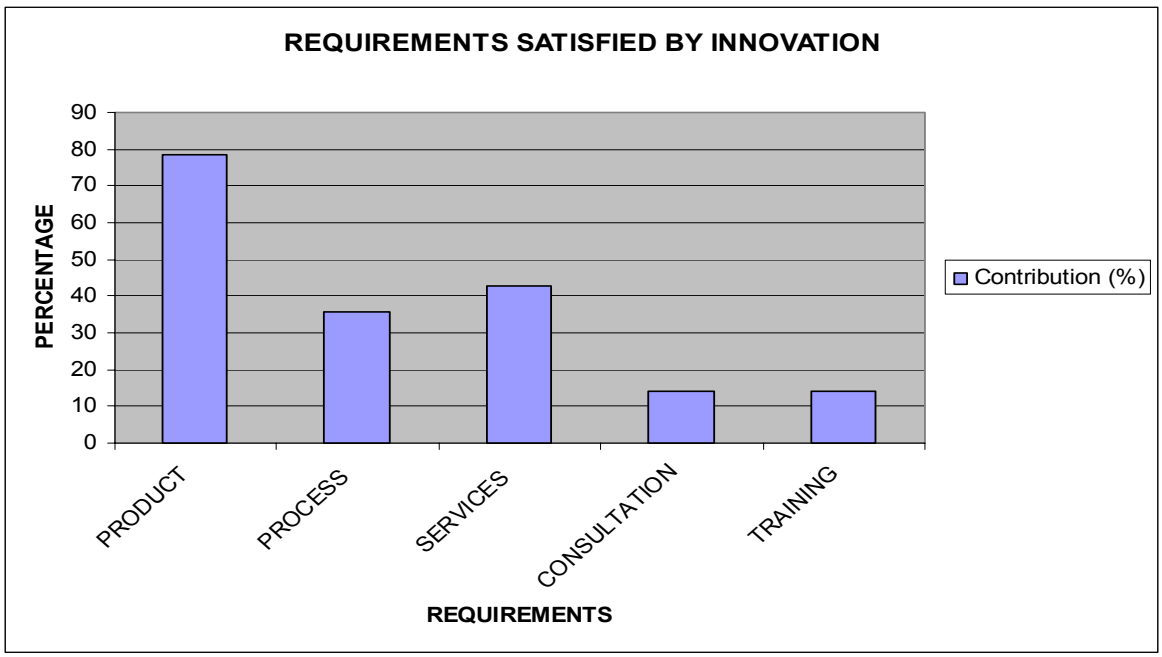


Figure 1: Requirements satisfied by the innovation

3.3.2 Life cycle phases influenced by innovations

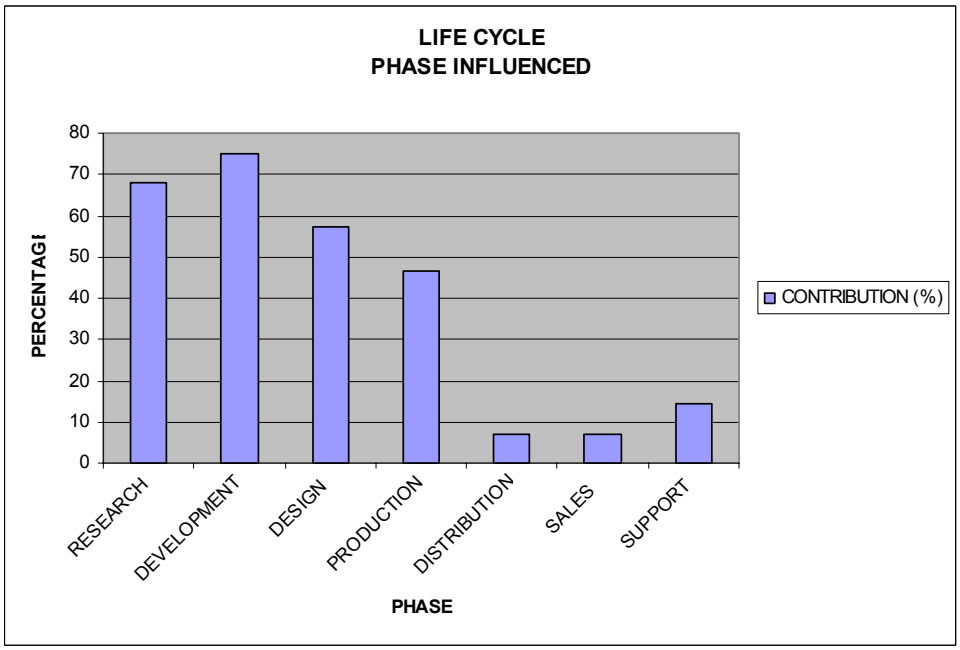


Figure 2: Life cycle phase influenced

From the results of the sample data it can be deduced that most innovations occurred during the development phase, closely followed by research, design and production phases. It should be noted that certain innovations influenced several phases, hence the frequencies of occurrence adds up to a number that is bigger than the total number of innovations reported on.

3.3.3 Scientific activities contributing to innovations

Engineering and technical sciences contributed by far the most innovations, and pure science contributed a much smaller number of innovations.

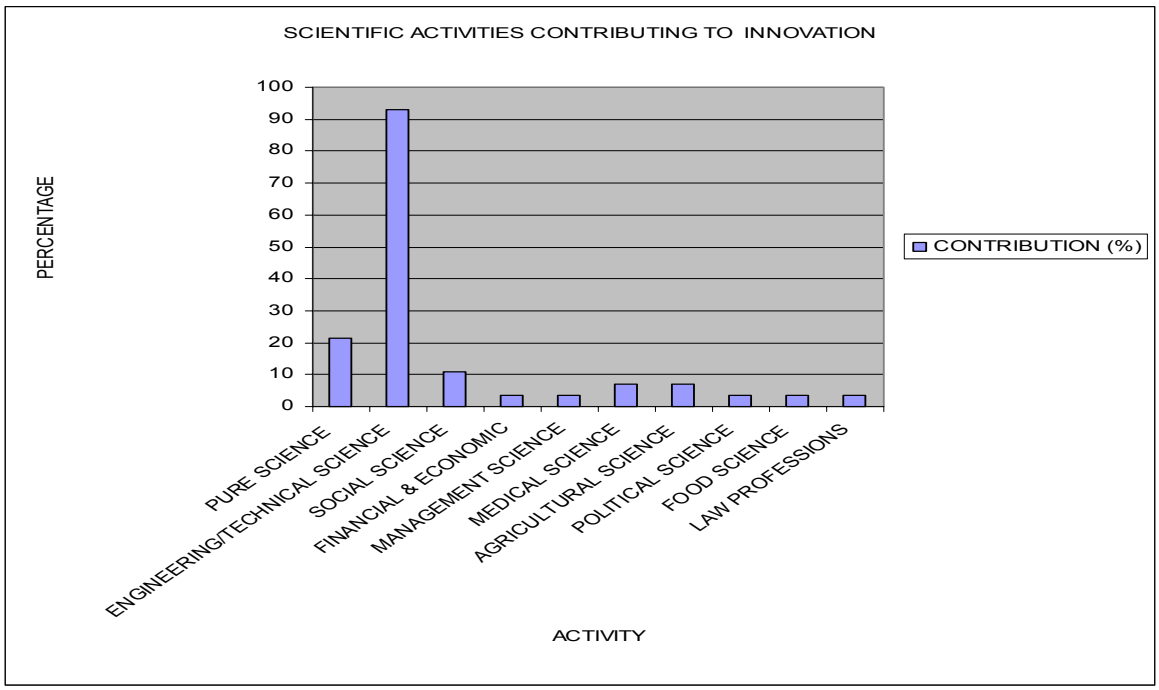


Figure 3: Scientific activities contributing to innovation

3.3.4 Types of innovations

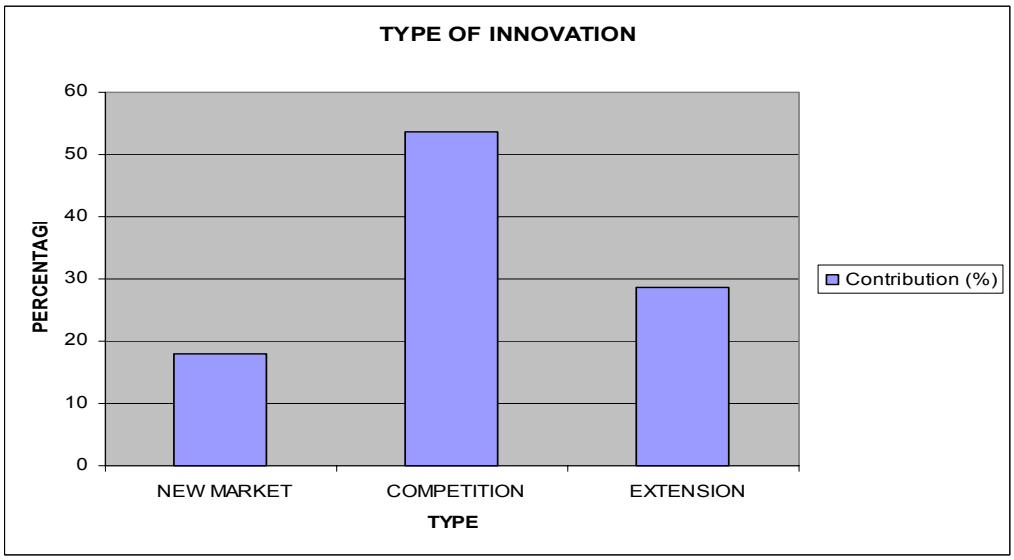


Figure 4: Type of innovation

The dominant type of innovation was the type that provided a better base for competition, followed by the extension of processes or product lines. Innovations leading to new markets or products were the fewest.

3.3.5 Mechanisms of innovation

Patterns of association provided most innovations, closely followed by the combination of different technologies. The other three mechanisms investigated led to few innovations.

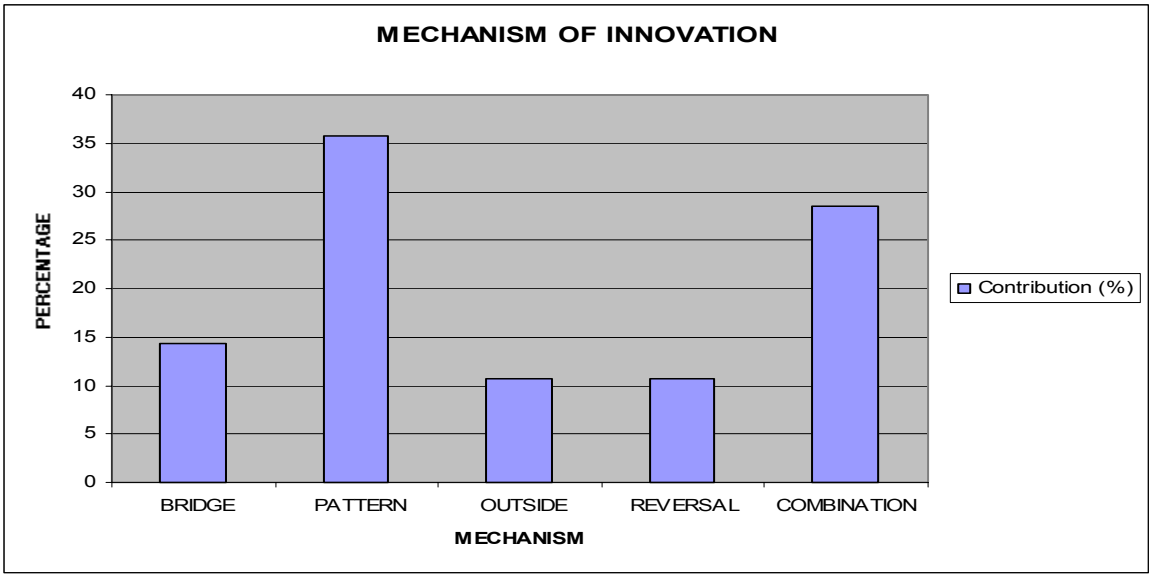


Figure 5: Mechanism of innovation

3.3.6 Effects of organizational culture on innovations

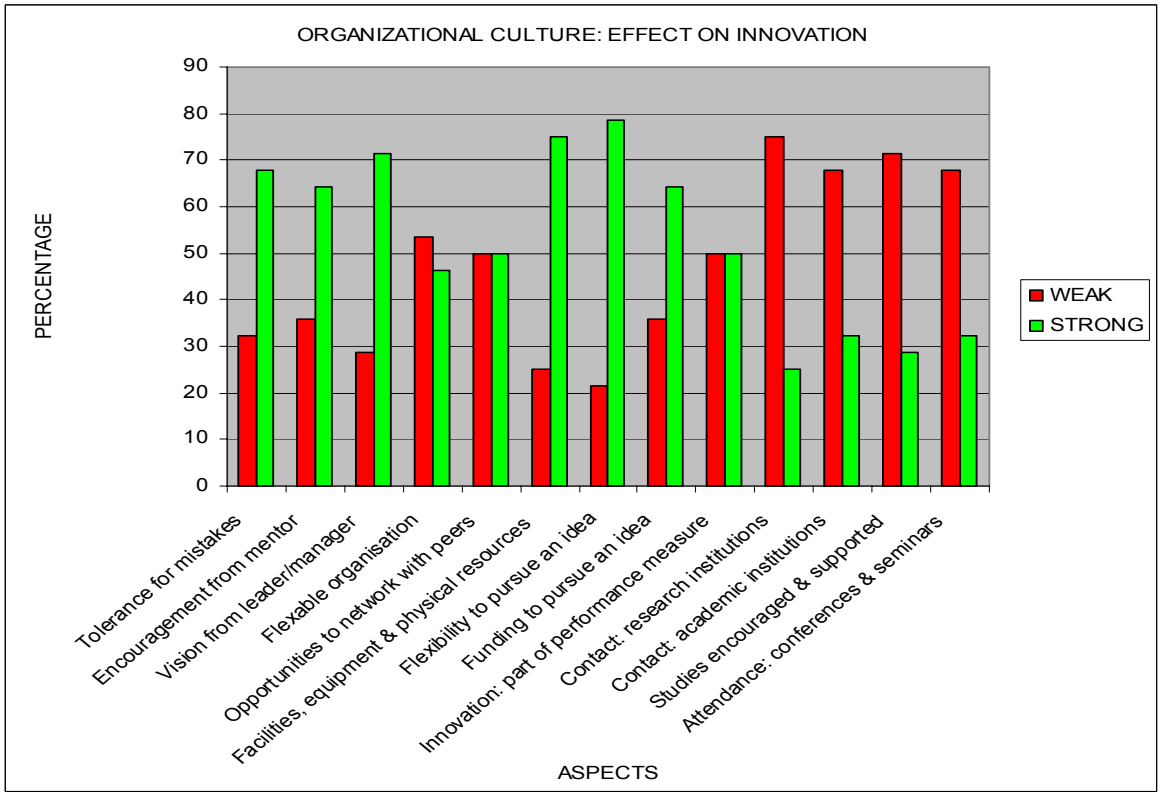


Figure 6: Organisational culture on innovations

The aspects of organizational culture that influenced the innovations, listed in descending order of importance, are:

- Flexibility to pursue an idea
- Availability of facilities, equipment and physical resources
- Vision from a leader or manager
- Tolerance for mistakes
- Encouragement from a mentor

3.3.7 Sources of innovation

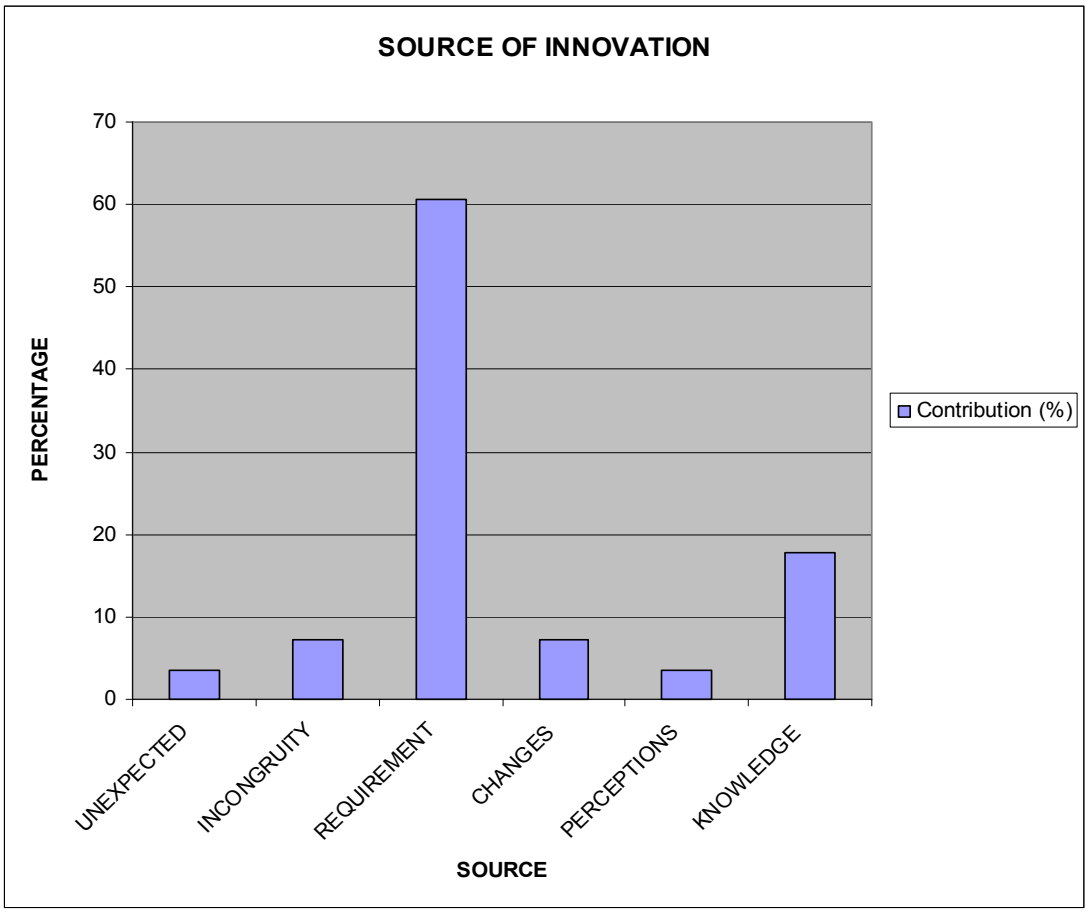


Figure 7: Source of innovation

The most prominent question of this study provided a very definite result, namely that a requirement in the market of clients or of stakeholders is what drives innovation at the CSIR.

The requirement for products and processes is by far the most important source of innovation found in the sample surveyed, proving the wisdom of “necessity is the mother of invention”. The only other source that made a significant contribution, although its contribution was more than three times lower, was the availability of new knowledge; this source was rated as the least important by Drucker (1985).

3.3.8 Influence of a single bright idea on innovations

Approximately 78% of respondents rated the influence of this parameter as strong or very strong, while only 22% rated it as weak or very weak.

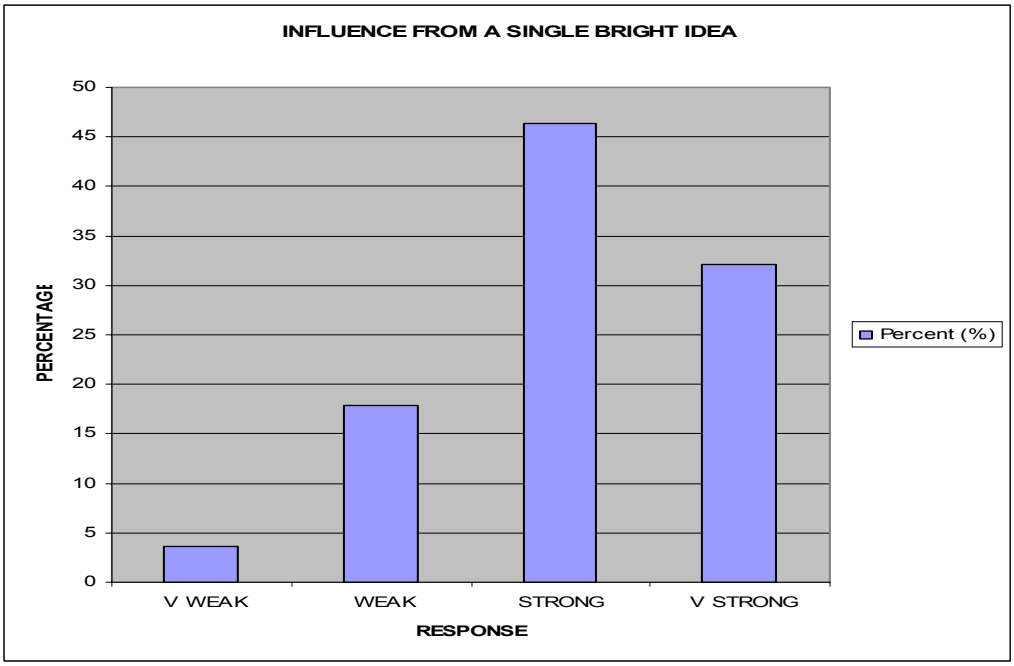


Figure 8: Influence from a single bright idea

3.3.9 Technology acquisition leading to innovations

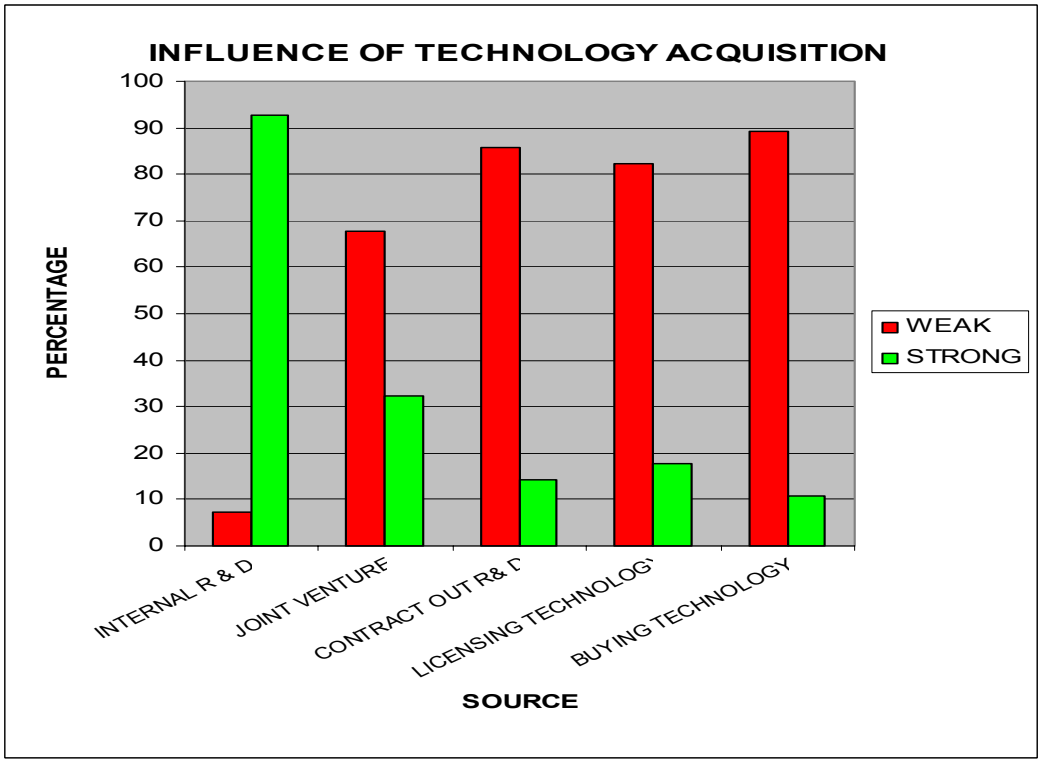
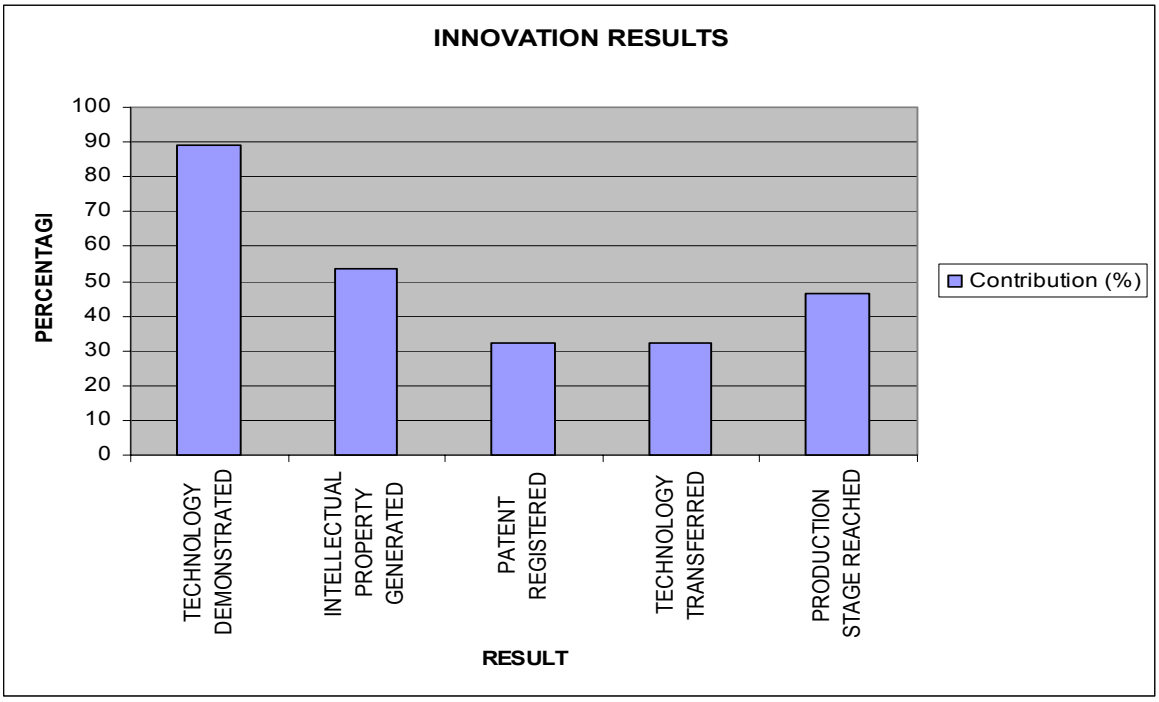


Figure 9: Influence of technology acquisition

The only type of technology acquisition that played a significant part in the innovations surveyed was internal research and development. The joint venture did provide some influence on innovations, but it seems to be insignificant in relation to own research and development.

3.3.10 Results of innovations



The outcomes resulting from the innovation are represented in all the categories considered. They are listed, in descending order of importance:

- Technology demonstrated
- Intellectual property generated
- Production stage reached
- Technology transferred
- Patents registered

3.4 Hypothesis testing

The first research question, viz.: “What are the identifiable sources leading to innovation in a research environment like the CSIR?” has been adequately answered by the following results of the research project:

- Requirements for products or processes are the dominant sources of innovations
- A single bright idea influences the occurrence of an innovation very strongly
- The requirements for products were the most dominant requirement served by the innovations.
- Engineering and technical sciences contributed by far the most innovations, and pure science contributed a much smaller number of innovations.
- The only type of technology acquisition that played a significant part in the innovations surveyed was internal research and development

The second question, viz.: “What patterns of behavior and organizational aspects support innovation in a typical Research Council?” is answered by the following results:

- Patterns of association provided most innovations, closely followed by the combination of different technologies
- The dominant type of innovation was the type that provided a better base for competition, followed by the extension of processes or product lines
- Several aspects of company culture influences innovativeness very strongly, namely: Flexibility to pursue an idea; Availability of facilities, equipment and physical resources; Vision from a leader or manager; Tolerance for mistakes; Encouragement from a mentor.

The hypothesis forwarded at the outset of this research project was: “Improved delivery of (innovative) results can be achieved if a better understanding is gained of the factors giving rise to significant innovation. If the sources of innovation are identified, the optimum utilization of each source can be achieved through the application of technology management.” The above results provided by the research can be used to take management action, but the hypothesis can only be rigorously proved once the outcomes of the management actions, implemented in response to the information, are assessed.

The secondary objective of the research was “to provide insight to technology managers (and knowledge managers), to enable them to spend the optimum amount of time and funds on the sources of innovation that are the most likely producers of innovations.” The results show clearly that certain sources performed better for the innovations surveyed; yet it should be noted that these outcomes are based on historical data, and in a rapidly changing global business environment it may be prudent to make decisions to exploit other sources as well as the dominant sources of the past.

4.0 Conclusions

Research results

The research project provided clear results that give insight into the daunting task of improving innovativeness. Some results do not support the notions forwarded by the literature, indicating that the Research Council environment may be different from the “real world” environments of industry and commerce.

Implications and contributions

The results from this study provides an understanding of the sources and patterns of innovation as found in the CSIR prior to 2005 and can contribute to decisions regarding technology management at the CSIR, an example of a Research Council.

Recommendations

It is recommended that this study is repeated after a period of three to five years to evaluate the possible changes in results due to the recent changes in the organization; a repetition of the study may also serve to further support the hypothesis formulated prior to this study.

The results regarding the sources of innovation should be used to decide whether the less prominent sources should be exploited more, or whether priority should be given to supporting the identified prominent source.

References

Blankley W. (FRD) & Kaplan D. (ISP), *Innovation Patterns in South African Manufacturing Firms,* Foundation For Research Development and Industrial Strategy Project, October 1997

Clark Kim B., Wheelwright Steven C., *Managing New Product and Process Development,* The Free Press, New York, 1993.

Drucker Peter F., I*nnovation and Entrepreneurship,* Butterworth Heinemann, Woburn, MA, 1985

Gundling, E., *The 3M way to Innovation: Balancing People and Profit*, Kodansha International, Tokyo, 2000.

Kelly & Littman, *The Art of Innovation:* HarperCollinsBusiness, 2001.

Khalil Tarek, *Management Of technology: The Key to Competitiveness and Wealth Creation,* McGraw-Hill, 2000.

Rouse William B., *Design for Success: A Human-centered Approach to Designing Successful Products and Systems,* John Wiley & Sons, New York, 1991.

Rouse William B., *Strategies for Innovation: Creating Successful Products, Systems and Organizations,* John Wiley & Sons, New York, 1992.

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