TOWARDS THE SIXTH GENERATION OF R & D MANAGEMENT

By

ALEX KWAKU KENSEN

DISSERTATION

submitted in partial fulfilment of the requirements for the degree

MASTERS

in

ENGINEERING MANAGEMENT

in the

FACULTY OF ENGINEERING

at the

UNIVERSITY OF JOHANNESBURG

Supervisor: Prof JHC Pretorius

Co-supervisor: Prof L Pretorius

JUNE 2014

Abstract

It is apparent that understanding the link between the role of innovation in competitiveness and economic development is essential. This is because innovation ultimately holds the key to addressing the most pressing social and human challenges of nations. In the past, some organizations viewed research and development (R & D) as an intangible process that is difficult to manage and measure. However, the upsurge in enabling technologies such as the internet is changing such perceptions of managing R & D processes, which is now moving from a technology-oriented model to one that is more interactive and collaborative. Moreover, organizations that have a clear understanding of R & D management have great successes in exploiting it to speed up the commercialization of new technologies that enable them to achieve numerous competitive benefits such as first-to-market advantages, greater market shares for their innovations, premium prices and dominant designs relative to their counterparts. While it is evident that there is increased focus on fine-tuning R & D management processes, the majority of these efforts were confined to the USA, Europe, Asia and other developed economies, with limited developments in the less developed economies like those in Africa.

This dissertation explores the five generations of R & D management practices and attempts to predict the best practices that managers will adopt in the R & D sixth generation. The findings suggest that the sixth generation will be characterized by greater multi-disciplinary approaches emphasizing cross-functional communication, collaboration, as well as greater inclusion of stakeholders such as suppliers, customers and partners in the full life cycle of R & D process.

Key terms – Research and development (R&D); sixth generation R & D; collaboration; open innovation; case studies.

ACKNOWLEDGEMENTS

The author will like to acknowledge Prof. JHC Pretorius and Prof. L Pretorius for their guidance and inputs into this study.

LIST OF ACRONYMS & ABBREVIATIONS

CIS	-	Community Innovation Survey
GHz	-	Gigahertz
IC	-	Integrated Circuit
ICT	-	Information, Communication and Technology
IM	-	Innovation Mill
IP	-	Intellectual Property
PDAs	-	Personal Digital Assistant
R&D	-	Research and Development
NPD	-	New Product Development
ROI	-	Return on Investment
SIG	-	Special Interest Group
SWOT	-	Strengths, Weaknesses, Opportunities and Threats
WAN	-	Wide Area Network

TABLE OF CONTENTS

1. CHAPTER 1: ORIENTATION

Important trends in organizing, conducting and managing research and development (R & D) have emerged over the last two decades, together with a steady increase in R & D and innovation efforts and outputs (Busom & Fernadez-Ribas, 2008). According to Holt & Jayawama (2009), end-users of products are becoming increasingly aware of the capabilities of people at the forefront of R & D and this has resulted in customers' demand for quality products. This view is further emphasized by Miotti & Sachwald (2002) who argue that both supply and demand for innovative technology have surged at global levels as a result of the upswing of a knowledge-based global economy. Miotti et al (2002) further state that since the late 1980s, the role of innovation as a tool of differentiation coupled with the rising pace of technological advancement have contributed to make companies aware of their innovative capabilities. This has driven many firms to allocate increasing amounts of resources to R & D in order to fast track the pace of new product development (NPD) as well as the diversification of their technological capabilities.

This has furthermore has resulted in new R & D management practices such as various internal organizational changes and the building of complex networks to deal with growing outsourcing and various types of technological partnerships. Incumbents may use strategic alliances to enter new product or technological fields in order to enable them to expand their knowledge sources with limited resources. Busom et al (2008) examine the impact of the participation of firms and R & D partnerships and pointed out that the most common of such partnerships occur between customers and suppliers, followed by those between firms within the same industry and by universities and other institutions.

Calderini & Garrone (2001) have divided R & D investments into two broad activities, namely basic research activities and applied research activities. Basic research activities involve the type of research directed towards the exploration of new scientific principles and at fostering the knowledge base that will ultimately be utilised as input in applied research. Basic research endeavours could be characterised as generic because they are not directed at any particular commercial application, are loosely appropriable and generally yield long term gains. Applied research activities on the

other hand are geared towards transforming generic scientific and technical knowledge into specific commercial and marketable applications. Unlike basic research activities, applied research is short-term, highly appropriable and typically produce short-term returns. Malerba & Orsenigo (1996) define appropriability as the ability of innovators to protect their innovations from imitation, and therefore reap profits from their innovations. However, the argument by Calderin et al (2001) on basic research characteristics cannot be entirely valid. This is because a number of innovations continue to emanate from basic research. An example is the invention of the integrated circuit (IC) by Nobel Prize winner Kilby (2000). Although Kilby's invention had elements of fundamental applied research, it can also be classified as basic research because of its nature. In his Nobel Lecture in 2000, Kilby (2000) stated that what people have derived from his invention of the basic IC circuit transcends anyone's imagination. He further summed up the fundamental nature of his invention by stating that: "[I]t feels like the beaver told the rabbit as they stared at the Hoover Dam, 'No, I didn't build it myself. But it's based on an idea of mine!'" This foregrounds the fundamental nature of the inventions of the IC circuit that stemmed from basic research.

Examining the two categories, Garrone et al (2001) express the idea that basic research by nature is carried out by scientists while applied research is carried out by technologists. They are of the view that it is difficult for researchers from the 'school' of applied research to switch to the basic research stream. Classifications of R & D vary depending on the angle from which it is approached. Kim & Oh (2002) argue that it is necessary to consider different types of R & D activities while classifying. Certain scholars divide the innovative/inventive activities of firms into two – research and development. Some attempt to categorize R & D activities into three, namely, basic research, applied research and experimental research while others suggest classifications based on more than three categories – basic research, applied research, product development and manufacturing process R & D. Lastly, there is a further proposition of five categories or levels of research, namely basic research, exploratory research, applied research, product development and product improvement.

A cursory look at these classifications make them appear different. However, a common thread of routines, practices and characteristics runs through all the various R & D activities. Taking the most common elements from these classifications, Kim et al

(2002) suggest three-layered R & D types; basic research, applied research and commercial research. Table 1 shows the characteristics of this classification:

Table 1: R & D and their characteristics

	Basic R&D	Applied R&D	Commercial R&D
Characteristics	Experimental research: Observation of facts; Requires individual research and concentration	Core technology development based on basic R & D; Basis of commercial products	Commercial product development; Evaluated by market success
Time frame	Over 10 years	5-10 years	1-5 years
Applicability	High Generic	Medium	Low Applicable only to specific products and processes
Example	Research into the fundamental attributes of carbon dioxide	Development of substitutes for Freon refrigerant	Development of energy-saving multipurpose refrigerator

Source: Kim et al (2002) - R&D characteristics

The management of R & D takes various forms. A number of companies, even if engaged in multinational manufacturing and marketing of their products, made use of centralized research facilities that are strategically located to enable easy access to external knowledge sources such as leading universities, public research institutions as well as competitors' spillovers. The rationale behind this strategy was that, since knowledge is an intangible asset, it could be transferred at no cost by its proprietors when necessary. This is equivalent to saying that production and researching are subject to different location factors. However, a series of factors over the last two decades have forced the rapid modifications of such R & D management strategies even for multinational firms (Campi & Bella, 1998:241 -242). These factors include:

- The increased competition in the global market;
- The growing diversification of even the most basic commodities resulting in the growing need to tailor products to local market specifications;
- Increasing R & D contributions in the value chain of any product;
- Attractive incentives offered by the governments of many countries to attract foreign investments in cutting-edge industries and/or research facilities in order

to add to the advancement of indigenous technological bases. Sometimes firms may be induced to set up local adaptive R & D programmes by government regulations. There are two schools of thought about government industrial policies: Either internal investments in R & D are considered to fast-track economic growth, or foreign R & D units are viewed as a negative factor that does not contribute to the innovative capability and general welfare of host countries.

- Easy availability of well trained and educated personnel in many countries other than the few traditionally regarded as the most developed (Campi & Bella, 1998:241 -242).

Gerybadze & Reger (1999) argue that while it is clear that the focus on R & D management and R & D related studies is increasing, these studies have been geographically concentrated on multinational corporations from the US, with increasing intensity from Asia, while European companies have lagged behind. Meanwhile, within Europe, the R & D internationalization processes of Scandinavian and British firms have been more documented than related activities of firms from continental Europe. However, there is limited documentation of innovation activities in Africa.

According to Porter, Furman and Stern (2000), although every country undertakes R & D activities in one way or the other, a small number of geographical locations tend to dominate in certain types of innovation. A typical example is in the biotechnology arena. Although there are pockets of biotechnology researches throughout the world, more than 75% of all biotechnology pharmaceutical patents emanate from the United States (Porter et al, 2000). According to Porter et al (2000), innovation intensity depends on a number of factors such as the marriage between private sector strategy and government policies. A healthy competitive spirit prevails when the public and private sectors unite to promote a productive environment for innovation. African countries are somehow lagging in the innovation frontier. However, South Africa was reported to have a higher than expected innovation capacity index, given its overall economic development (Porter et al, 2000) who argues that a country's national innovative capacity can be divided into several areas as follows:

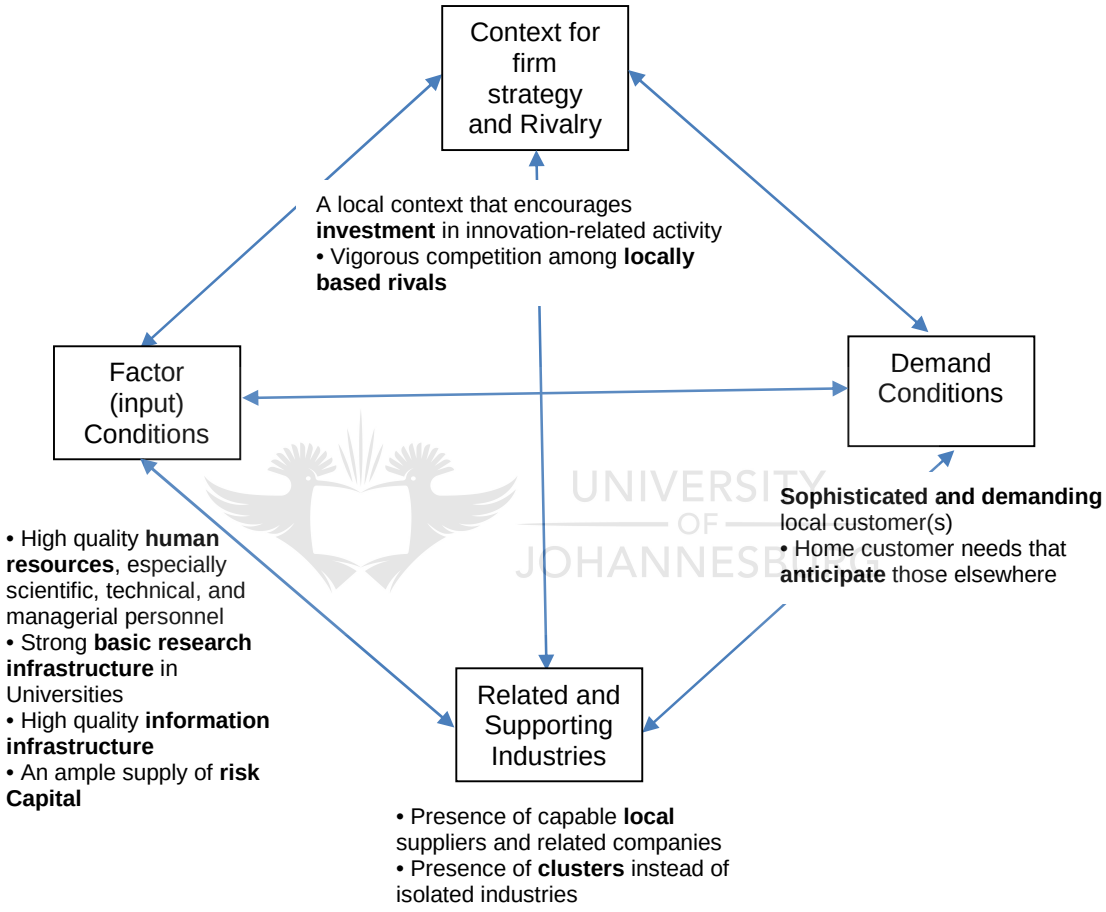
1. National innovative capacity: This depends on the presence of a country's underlying innovation infrastructure and interlinked factors which contribute broadly to innovativeness throughout the economy. The underlying innovative infrastructure includes a nation's overall science and technology policy environment, the established mechanisms for supporting basic research and higher education as well as the cumulative stock of technological know-how upon which novel ideas are developed and commercialized.

2. A country's innovative capacity depends on the specific innovation atmosphere in the nation's commercial and industrial clusters. It is a country's prevailing microeconomic condition associated with its commercial and industrial clusters that determine whether firms participate or respond to technological opportunities and innovate at the international frontier.

3. National innovative capacity depends on the intensity of the linkages between common innovation infrastructure and specific clusters. The productivity of a strong national innovation infrastructure is higher when targeted mechanisms or establishments, such as a strong domestic university system and funding mechanisms for new ventures carry ideas from the common infrastructure into commercial utilization.

Porter et al (2000) depiction of the innovation orientation of national industry clusters is presented in Figure 1:

Figure 1: The innovation orientation of national industrial cluster



Source: Porter et al (2000) – National innovation cluster

R & D is a voluntary economic investment activity that drives development, growth, invention and technological advancement. Past investigations into R & D management have mostly focused on developed economies with the general presumptions of similar institutional settings, work etiquettes, and choices of motivation incentives by profit driven firms in other parts of the world. It is thus generally assumed that R & D decisions actually made in these other places would be efficient (Zhao, 2003). Zhao (2003) has further argued that managing R & D requires the correct form of business organization in order to encourage innovation while controlling any associated risks. The way businesses are structured is a major factor (X-factor) that accounts for Pareto-efficiency in their productivity. According to Zhao (2003), research of Liebenstein (1966) entitled 'Allocative efficiency vs. "x-efficiency" stated that, when the X-factor affects the production of the firm's conventional goods only, the firm is statically X-inefficient; but when it is of consequence for the rate of innovation process, the firm is dynamically X-inefficient. X-inefficiency refers to the failure of a productive unit to utilize the resources it commands fully and hence attain its efficiency namely the maximum level of output possible under the prevailing resources and circumstances (Liebenstein & Maital, 1994). Liebenstein et al (1994) further stated that, the 'X' in the term 'X-inefficiency' denotes the somewhat mysterious nature and origin of the phenomenon. A firm's capacity for R & D commercialization is an important measure of its dynamic X-efficiency. Various studies have shown the positive impact of privatization on reducing static-inefficiency of formerly state-owned enterprises. However, little is known of the effect of marketization on the dynamic X-inefficiency of R & D institutes in a transition economy (Zhao 2003).

Currently, to this author's knowledge, there is very little research on, or any organization established for the purpose of monitoring R & D management activities on the African continent. Furthermore, there is no comprehensive body of literature published in scholarly journals on managing R & D in Africa. Other continents such as Europe, and Asia have organizations like The Community Innovation Survey (CIS) – which is a European–wide firm-level survey organization focusing on innovation and R & D (Busom & Fernadez-Ribas, 2008) – and many others that extensively monitor and document R & D activities and trends in various economic sectors.

The lack of coordination, planning, monitoring and management of R & D activities in Africa is a contributing factor to the widening digital divide between the developed and developing economies on the continent. Considering the already constrained environments within which researchers in Africa have to operate, local firms within the continent are lagging behind in product development and other innovations that emanate from R & D activities. Many firms therefore find themselves in an increasingly difficult position as they attempt to promote their exports, attract capital investment, transform their economy and gain competitive advantage (Simon, 2004). Set against this backdrop, this study sets out to explore the various generations leading to the sixth generation of R & D management.

1.1. Study Objective

The main objective of this study is to investigate the current generation of sixth generation of R & D management. The basic research questions that motivate this study are:

- What were the trends in R & D management in the previous R&D generations?
- What will characterize the sixth generation of R & D management strategies?

In order to investigate these issues, the author developed a conceptual framework for R & D management based on one developed by Nobelius (2004). This framework has been successfully explored in a number of R & D management evolution models and has been found to be robust.

1.2. Contribution of this study

This study will have important implications for both future research and practice. First, in terms of research, this study will be one among a few (if any) which examine the R & D management model in South Africa. Thus, it will contribute to filling the knowledge gap on R & D management dynamics while highlighting the major factors (i.e. environmental, technological and organizational) that influence the adoption of sixth generation R & D management strategies among researchers (Kendall, Tung, Chua, Ng, Hui & Tan, 2001). Secondly, the result of this study could serve as guideline for future studies that aim at examining the R&D management phenomenon in South Africa. In light of this, it must be emphasized that this study only deals with the trends

towards sixth generation R&D management strategies, which has been the primary research focus of many recent studies in many countries.

1.3. Outline

The rest of the research document is outlined as follows: Chapter 1 presents the introduction to this study on R&D management. Chapter 2 focuses on literature review and theoretical foundation which highlighted past studies on the issue relating R&D management trends up to current adopted practices in R&D among researchers. The research design is next presented in chapter 3 which consists of the design of the study, and the analysis of data that reveals the best fitted dynamics of R&D management routines among R&D managers. Next in chapter 4, the author presents the findings and discussions which took an in-depth look at the factors that could trigger the transition into the sixth generation of R&D management. Finally conclusions, managerial implications and future research directions are presented.

1.4. Research and design methodology

There has been little empirical work done in examining the different generations of R & D management. This is mainly due to the difficulty in recognizing and making sense of the inconspicuous, multiple, open-ended and dynamic variables. Thus exploratory case studies have been used in this research to address this complexity by directing the focus on mechanisms, i.e. what was done and how, instead of how many, how much and frequency (Holt et al, 2009). Yin (2003) argued that multiple cases studies offer a greater range of evidence as well as providing a single set of cross-case conclusions.

This research mainly focuses on understanding the factors behind changes in R & D management, and thus explores more recent practices leading up to the sixth generation of R & D management. The outline of this research is as follows:

1. Step one involves an evaluation of the core literature on R & D management from database searches.
2. Step two involves extensive reading up of articles in journals from the database searches. The author started with a systematic search of all articles related to R & D management. The key words and phrases used include research and development,

R & D, new product development and innovation. Due to the large number of journals available on topics related to R & D, the author had to limit those to be included in this study to those that are specific to R & D management (Candelin-Palmqvist, Sandberg and Mylly, 2012).

3. The various results and findings from all the literature were then compiled to form the conclusion of this research. It may thus be assumed that the extensive consultation of various findings and conclusions have enhanced the trustworthiness of the findings of this research.

1.5. Limitations of the study

First, it should be noted that this study is a static view of the constant and rapid evolution of R & D management dynamics (Kowtha & Choon, 2001). However, it gives a good overview of the status quo with respect to R & D management evolution and highlights some issues that managers and decision-makers can use in formulating R & D management strategies and policies (Scupola, 2003). A further limitation may arise from the specificity of the aim of this study. While this helped in narrowing the focus of the study, it may also result in the generalization of the findings across all R & D management setups. However, this creates an opportunity and need for further studies in this field (Lancastre & Lages, 2005).

2. CHAPTER 2: LITERATURE REVIEW

This chapter provides critical review of various generations of R & D management strategies leading up to the sixth generation, as well as the predictors of sixth generation strategies among researchers. Research and development is the best known means by which corporations and institutions accumulate and increase their knowledge pool. The most common platforms for conducting R & D include company research laboratories, government research hubs and university laboratories. Within these three research channels, R & D has undergone several metamorphoses. The first phase of R & D change occurred between the early 1950s and mid-1960s. During this era, R & D was conducted in silos within company departments who subsequently hand over their outcomes to the manufacturing sectors. By the late 1960s, a second stage of R & D management emerged in which project management methodologies were employed to control R & D projects. Evolution towards a radically new direction in R & D management emerged between the early 1970s and 1980s. This new approach was more inclusive and integrative than the previous silo approach in that the responsibilities and activities of R & D managers were more linked to other areas within the company such as marketing, operations, engineering, manufacturing, and finance. The integration of all these departments helped in breaking down the isolation of R & D departments (Niosi, 1999).

Paraponaris (2003) argues that transforming R & D management strategies to become more integrative and cutting-edge during the third generation has introduced new organizational problems. One of the major problems concerns the management of knowledge. Knowledge creation through R & D is carried out by means of technological co-operation. It is essential to know how to internalize, diffuse and absorb the knowledge produced within various R & D departments. Several multinational organizations seek to diversify their resources in an attempt to optimize their R & D activities. This optimization applies to the mode of product design, technology construction and customer relations. It also applies to multinational level strategies of combining the diversification and optimization of R & D activities. This is so because since the main aim of multinational strategy is to incorporate diversity rather than endure it. This is in contrast to home office establishments, where a single unit usually engages a number of different sources of knowledge such as technological partnerships,

collaboration with universities and engineering schools. Examples of some of the major diversity dimensions include:

- Diversity as a product of technological globalization: Paraponaris (2003: 96-98) has established that most firms have converted their R & D sites into specialist units, resulting in a decision-making process that is based on an assessment of local technological advantage. The drive towards specialization involves giving a particular subsidiary the responsibility for the development of one or more technologies. This has resulted in a fairly pronounced difference in most firms between the individual sites in terms of their relationship to R & D work, movement within the company, attitudes to evaluation and the definition of research activities on one hand, and development activities on the other hand.
- The necessary diversity within R&D projects: Project-based organizations require the bringing together and management of several specialists in order to work towards an objective or a goal.
- Diversity as context of academic collaboration: The vast majority of this type of collaboration is centered on PhD students. These opportunities go hand in hand with actions located further upstream that involve the establishment of partnerships with a view to influencing curriculum design. Paying considerable attention to the mix of academic and national profiles, firms select their academic partners so that they can participate in the joint development of graduate training.

Paraponaris (2003:96-98) further argues that models of R & D strategies have undergone several metamorphoses over the past couples of decades resulting in the current hybrid structures that combine a market-driven approach with networking practices. The first phase that took place in the 1980s saw firms de-centralizing their R & D activities into strategic business units. Previously, multinationals had been dispersing their activities into various countries while retaining their major R & D operations in the company's home office. This saw R & D activities organized centrally to achieve economies of scale in the context of industrial strategies based on company's technologies. Thus, a central laboratory was assigned the task of developing these technologies by assuming most of the responsibility for coordinating the various ventures with other firms and academic institutions. However, the inadequate understanding of commercial constraints within the system was proposed in

justification of decentralization of R & D resources to operational units charged with the responsibility of developing product policy in a more focused way, and driven by marketing considerations and the technological possibilities. R & D groups were established as a result of this desire to control technology policy through the market. This has resulted in bringing together players involved in the design and development of new products as well as the reduction of lead times. This further resulted in increased diversity within firms.

The second phase occurred in the 1990s. This phase seems to drift into some form of instability, in that, some business units' decision-making autonomy suddenly turned into technological independence from the multinational group. This led to various problems, in that, since each R & D unit was responsible for meeting its needs of commercial control, it became difficult for it to justify its own independent R & D activities. Yet, none of the units had much opportunity to coordinate its activities with others. This resulted in inadequacies in the coordination and diffusion of knowledge. In order to exert greater control over the diversity of results produced by new product development and innovation projects, management redefined the centralization of R & D. At this point, it was impossible to go back to the previous situation; hence many firms decided to set up network-type organizational structures. Corporate laboratories began to be established, distinguishing short-term to medium-term activities from long-term activities and, in particular, to institute knowledge management systems. Paraponaris (2003) argues that this second phase equates to the third generation R & D management strategy.

The risks related to the imitation of new innovations by market participants foreground the need for effective management control systems when such transactions involve investment in new technology. R & D projects are characterized by investigations into new innovations and technologies and require large sunk costs relative to reduced liquidation value. This exposes R & D management to moral challenges and adverse selection problems that are difficult to monitor and control in comparison with other transactions (Bernanke & Gertler, 1989). This sentiment is echoed by Van de Van (1993) who proposed a social system model based on observations of public and private factors over an extended period of time to account for the encouragement and inhibition of investment in technological innovations. This system includes institutional

arrangements, resource endowments and propriety activities that necessitate development and commercialized innovations.

The time, money, risk and other resources incurred by firms in developing new products are inversely related to the progress in building institutional arrangements and resource enrichment for the new technology. Van de Van (1993) further argued that new technologies are rarely developed based on only the single factor of institutional environment that allows and constrains organizations to invent and develop only certain types of technologies and practices. What this means is that changes in institutional setup are expected to translate into substantial differences in strategic formulation, project selection and the success rates of R&D management. This argument is backed by Aasen, Molnvik, Aarlien, Bredesen, Munkejord, Brunsvold & Gundersen (2012), who state that innovation can no longer be seen as a process taking place within boundaries. Zhao (2003) also argues that the result of R & D activity has little value by itself due to the inability of participants to exploit it commercially and the lack of open markets for scientific knowledge and technology. This inability to exploit R & D for commercialization can be attributed to the absence of clearly defined property rights over intellectual rights, since only property rights can offer socially recognized power or authority to those who possess these rights.

In centralized economies where there is a monopoly of R & D financing by either large firms or governments (for example in China), R & D institutes generally do not have clear ownership of the knowledge and technology produced by scientists and researchers who they employ. This makes it difficult for research institutes to sell their know-how in the market. Secure property rights are considered to be vital for encouraging organizations and individuals to put their resources at risk to develop them to their fullest potentials. Thus, a management control system based on weakly defined property rights is a recipe for conflict of interests, operating inefficiencies and the wastage of resources (Zhao, 2003).

In a study on financial implications for R & D management, Haung & Xu (1997) emphasize the need for external financing as a means of providing tighter controls and monitoring. They argue that when the uncertainty of an R & D project is not high, there is no difference between a centralized and decentralized economy in which internal

financing by large firms (or government) is more efficient. Centralized economies do not perform worse than decentralized economies in R & D for heavy technology industries. However, when uncertainty is very high, a centralized economy would be dominated by a decentralized economy because of the lack of effective control mechanisms.

According to Zhao (2003), the state plays an important role in the determination of funding, mission and the internal procedures of R & D organizations in a centralized economy. This type of internal (state) funding systems results in a soft budget constraint. In contrast, market-based financing serves as a control mechanism to prevent conflict of interest and reduce information asymmetry in R & D management systems. Venture capitalists, who are solely interested in investing in successful R & D projects, are exposed to initial adverse selection risks. Hence, investors will seek control rights over the management, and release funds in a stage-gate approach when the project progresses successfully. Budget constraint has a major effect on the economic performance of R & D institutes under centralized versus decentralized economies.

The financial control of R & D management is made up of two parts, namely capital budgeting and project evaluation. Striking the right balance in R & D budgeting presents great challenges to R & D managers. Spending too little could mean leaving potential profit on the table, while spending too much may put constraints on resources. Project evaluation addresses the fact that a typical R & D investment has a high degree of uncertainty, and such uncertainty can be resolved only after the project has been undertaken. The monitoring and interpretation of costs incurred during a project against pre-specified targets is the most common task that R & D managers at all levels have to undertake. Bernstein (1994) argued that successful R & D commercialization endeavors were predominantly associated with enterprises that act as profit and loss centers with decentralized decision making and information distribution.

Post & Mahon (1980) identified two environments that facilitate participation in a strategic alliance for effective R & D management. The first is named task environment, which mainly refers to the sharing of sources of inputs, markets for outputs, competitors and regulators. The second is institutional environment. This includes societal, demographical, economic, political and international parameters within which the

alliance functions. Partnerships operating in highly regulated environments are faced with two main factors that adversely impact their efficiency. One is the need to deal with the operational and technical hurdles of the regulation and the other is the management of political interactions with regulatory authorities. In highly regulated environments therefore, there are restrictions on management's decision on prerogatives and limits on the important role of strategy. As a result, environmental conditions rather than variables subject to managerial control carry greater weight in determining task environment and organizational performance under highly regulated settings.

2.1 Generations of R & D management

According to Zhao (2003), the first generation of R & D management also referred to as push-technology approach spans the 1950s and 1960s. During this time, R & D management was characterized by a lack of strategic frameworks, and activities were organized by scientific or engineering disciplines. Funds were allocated to cost centres without specific profit objectives, resource plans, or budgetary time-frames. Furthermore, there was minimum evaluation of R & D performance other than the R & D function itself as well as little communication between R & D centres.

During the first generation, R & D was organized centrally in order to achieve economies of scale in the context of industrial strategies premised on the technologies at a company's disposal. Thus, a central laboratory would bear the responsibility of developing technologies by assuming all the activities for co-ordinating the series of co-operative ventures with other institutions and universities. The lack of understanding of commercial constraints within the system was put forward in justification of the decentralization of R & D resources to operational units charged with the task of developing product policy in a more focused way, and driven by marketing considerations and technological possibilities. This led to the establishment of R & D groups as a means of controlling technology policies through the market. The players involved in the design and development of new products were thus brought closer together, with great results in terms of reducing lead times to markets. Furthermore, this method of distribution of resources led to increased diversity within firms (Paraponaris, 2003).

The second generation of R & D management, also known as the market-pull approach, gained popularity between the 1960s and 1970s. It saw the start of a strategic framework for R & D at the project level, while seeking to improve communication between R & D and other functions for commercial purposes. The centralized model which characterized the first generation limited opportunities for business collaboration and prevented the diffusion of innovation into the market place. Second generation R & D management attempted to correct these problems by linking R & D to commercial needs on a project by project basis, and through measurement of R & D results in financial terms, such as net present value, ROI, and payback ratio. It took into consideration, the cyclical and iterative nature of R & D projects, which lead to the third generation that was based on the formation of strategic portfolios. The second/third generation of R&D management improved on the first generation through the combination of the emphasis on financial control as well as the separation of centralized and decentralized models of management.

According to Niosi (1999), the incorporation of project management into R & D in the post-war period marked the second generation of R & D management. This has somehow lessened the uncertainties associated with R & D management, and increased cost and time controls and accountability. It was during this time that PERT and GANTT charts were introduced in R&D management. However, universities and government R & D laboratories were unchanged by the emergence of new techniques in the larger corporate research units. The third generation R & D management which emerged in the 1970s introduced in-house feedback systems as well as the integration of R & D within corporate strategy; the selection and management of projects somehow formed part of corporations' upper management responsibilities and/or interdepartmental business development groups. Companies gained capabilities to conduct R & D in areas where they had some manufacturing and marketing competencies and in promising areas in which they had strategically decided to build competencies.

The late 1990s saw the emergence of fourth-generation R & D management. Knowledge produced in the universities as well as government research laboratories were positively explored and utilised. The feedback system within R & D management

became streamlined and more complex to manage with the development of technological alliances. The frontiers of the corporation became more porous, as intellectual property (IP) emanating from technical partnerships became partially shared with external agents. The conventional R & D management methods soon became obsolete and new routines emerged to cope with new activities, new knowledge directions and new calibre of employees. In the new business atmosphere, nimble-footedness became the key characteristic of the emerging model of R & D. Through strategic alliances, corporations looked for key complementary assets (in technology, marketing knowledge and financing) through the combination of internal and external resources (Niosi, 1999).

Sofo (2008), Hara, Blomqvist, Koivuniemi & Aijo (2004) offer a framework describing the five generations of R & D management in Table 2 below:

Table 2: Description of five generations of R&D management

R & D Generations	Context	Characteristics
First generation	R&D performed out of curiosity. Black hole demand (1950s to mid-1960s)	**R & D as ivory tower:** Technology-push oriented, seen as an overhead cost, having little or no interaction with the rest of the company or overall strategy on scientific breakthroughs (Nobelius, 2003). A collection and adaptation of Feynman's (1999) lecture cited him as stating that one of the scientific spirits of adventure is the adventure into the unknown, an unknown which must be recognised as being unknown in order to be explored; the demand that the unanswerable mysteries of the universe remain unanswered; the attitude that all is uncertain; to summarise it – the humility of the intellect (Feynman, 1999: 245-257;Sofo, 2008); ***Focus*:** Lack of framework viewing future technologies as the sole domain of R & D; ***Approach*:** Narrow concentration on operational matters such as limiting costs; ***Limitation:*** Research seen as data collection; an expensive activity viewed as an overhead cost; long-term projects excluded; narrow range of responsibilities.
Second generation	Market shares battle (mid 1960s to early 1970s)	**R & D as business:** Market-pull oriented and strategy-driven from the business side, all under the umbrella of project management and the internal customer concept. ***Focus*:** Straight focus where activities were turned into business needs (Sofo, 2008). ***Approach*:** Project-by-project management; silos approach to projects. ***Limitation:*** Lacking cross-functionality; projects seen to be in competition rather than taking a holistic approach (Nobelius, 2003).
Third generation	Rationalization efforts (mid 1970s to mid-1980s)	**R & D as portfolio:** Moving away from individual projects view, and with linkages to both business and corporate strategies. Risk-reward and similar methods guide the overall investments (Nobelius, 2003), ***Focus*:** Strategic and purposeful with strongly focused mission ***Approach*:** Cross-functional pooling and sharing of insights to decide on projects; included portfolios, roadmaps, life cycle aspects across business units; use of partnerships between R & D and general managers; projects developed serially

		***Limitations*:** Dynamic approach created change fatigue, widespread complexity and increase workloads (Sofo, 2008).
Fourth generation	Time-based struggle (early 1980s to mid-1990s)	**R & D as integrative activity**: Learning from and with customers, moving away from a product focus to a total concept focus, where activities are conducted in parallel by cross-functional teams (Nobelius (2003). ***Focus*:** Strategic focus with broader mission for R & D as a leader of technologically enabled discontinuous innovation ***Approach*:** Fourth generation innovation model strives for integration and parallel development; integrates in-house departmental activities so all work simultaneously on projects; integrates customers and partners in the entire conception and development process ***Limitations*:** High demand on time, coordination and communication including risk of slow progress for thoroughness and integration (Sofo, 2008).
Fifth generation	Systems integration (mid 1990s onwards	R & D as network, focusing on collaboration within a wider system – involving competitors, suppliers, distributors, etc. The ability to control product development speed is imperative, separating R from D (Nobelius, 2003). ***Focus*:** A highly strategic network focus including overall organisational and systems integration ***Approach*:** Fifth generation emerging paradigm is a total 'open innovation' system using cross-border information management, knowledge and collaborative approaches ***Limitations*:** Mainly suitable to dynamic business environments; additional resources needed to attend to technology management problems (Sofo, 2008).

Source: Sofo (2008), Blomqvist et al (2004) – Description of management of five R & D generations

Table 2 presents a descriptive analysis of five generations of R & D management. An appreciation of the historical development and perspective of R & D globally provides a contextual framework for the advancement for further alliances among various R & D management efforts worldwide. These provide opportunities for developing a more efficient and highly competitive approach to the next generations of R & D management (Nobelius, 2004). The analysis in table 2 shows a steady progression of R & D management. This progression is characterized by strategic focus a more holistic and multi-disciplinary approach that emphasizes cross-functional communication, collaboration and greater inclusion of community experts and key stakeholders. in R &D throughout the full research cyclical process, that is, from conception to market development, evaluation, reporting and re-conceptualization (Blomqvist et al, 2004). These stakeholders include suppliers, distributors, customers, government and other partners.

Blomqvist et al (2004) argue that the transformational progression in R & D management has led to a concept called 'open innovation' which embraces organizational learning, with collaboration between key customers, suppliers, partners, stakeholders, collaborating companies and universities for radical innovation, risk-taking and market penetration. From Table 2, it can be deduced that the first and second generation of R & D management are characterized by curiosity, an idea elaborated on by Feynman (1999) in a lecture entitled, 'The of the pleasure of finding out things'. This curiosity concerns the detection and correction of inherent problems in managing knowledge and expertise to pursue innovation. For their part, fourth and fifth generation models of R & D management are much more proactive, holistic and inclusive of various stakeholders (Blomqvist et al, 2004).

2.2 Why the new R&D generation emerges

According to Niosi (1999), current business conditions are entirely new, very fast-paced and highly disruptive when compared to the quiet economic climates that dominated the previous generations. The emergence of ICTs is characterized by several new factors:

- New business landscapes have been created by the arrival of new industrial countries and new competitors have arrived in the global marketplace. In this

new business landscape, long-term R & D projects have become more uncertain and risky due to the rapid pace of new innovations. Any nimble-footed newcomer may arrive first to commercially successful results and seize a large share of global market before older, established firms can achieve results in their competing R & D projects. In this environment, companies prefer to develop technological partnerships in order to reduce risk and uncertainty and better monitor other competitors' technological development.

- The rapid pace at which information becomes obsolete has made it very difficult for a single company to keep stock of knowledge. At the same time, the life cycle of products has shrunk, and the race to innovate further has accelerated. In order to achieve rapid results in shorter periods of time, companies went into partnerships to reduce lead time in bringing new products to the market.
- As new technologies are becoming more advanced, users need to be trained in the acquisition of these technologies. Companies who are able to capture the first-mover advantage are more likely to retain their customers. This is so, since after becoming acquainted with a specific innovation/technology, the cost of switching becomes high, and customers tend to stick to the product they have learned to use. This is particularly true in the case of software programmes, telecommunications equipment, etc. Cooperation among research and innovation agents can reduce the lead time to market and allow participating companies gain competitive edge.
- Due to the financial constraints, the governments of various countries are becoming more inclined to allocate their R & D funds to groups of companies or industry-university innovation hubs to better diffuse technical knowledge and reduce cost further. Additionally, governments are currently driving the agenda for government-private R & D partnerships in order to both foster knowledge/technology diffusion and to reduce the financial burden on the public labs.
- New management paradigms, mostly adopted from Japan, tend to emphasize collaboration and not competition. Vertical collaboration between assemblers and suppliers allows for the spread of quality control, just-in-time (JIT) and cooperative research to improve products and reduce production and R & D

costs by all partners. Horizontal collaboration among competitors increases the chance of arriving at results and reduces R & D costs and lead time.

In summary, the new paradigm tends to limit the efficiency of the previous models of R & D while increasing the usefulness of feedback models based on collaboration and flexibility (Niosi, 1999:112-113).

2.3 Summary

The main focus of this chapter was the exploration of the metamorphosis of R & D management practices over time. The driving force behind the migration from one generation to another is the need for efficiency, speed and achievement of best practices in the management of innovations. As the need for faster turnaround times for new products to the market place combines with the need to obtain first-to-market advantage in an intense business competition landscape, enterprises are finding more practical and sustainable ways to manage their R & D strategies, hence the evolutions in R&D management practices. The challenge for companies in this era is to stay profitable in the current tougher-than-ever competitive landscape (Nobelius, 2004). In an attempt to study the sixth generation of R & D management, it is essential to examine the previous R & D management generations, and to interrogate the factors that prompt the adoption of the next generation. The chapter to follow addresses specific case studies that explore the characteristics of the next generation R & D management.

3. CHAPTER 3: CASE STUDIES AND DISCUSSIONS

3.1 Towards the sixth generation

Nobelius (2004) argues that a generation in R & D management is the totality of the different types of approaches as well as evolution that characterizes the particular era. All these possess the single aim of assisting institutions to improve their R & D efficiencies while developing a lingua-franca for researchers and institutions to work with. The advent of internet technology and the current business landscape has introduced several challenges into all facets of innovation management. Rapid access to information through the internet, the fast-paced development of science-based industries, the emergence of multinational companies, freer markets, the need to manage knowledge effectively and the rapid pace at which technologies are being rendered obsolete by both competitors and customers are some of the factors that have introduced new complexities into R & D management. The main goal of management routines is to reduce lead times, improve just-in-time deliveries of new products, minimize the number of unsuccessful projects, improve efficiency, and cut research cost (Niosi, 1999).

Nobelius (2004) further argues that there is the need for R & D management to take the following into consideration – interoperability, industrial design, environmental issues, and manufacturability and after market factors. The challenge facing R & D managers is the ability to cooperate effectively, and to coordinate and interact with diverse key players outside the conventional departments (such as marketing & manufacturing functions, suppliers, customers, distributors, competitors as well as government regulations). There is also the need for efficient and effective commercialization of new products (e.g. just-in-time (JIT) deliveries of right qualities and quantities).

According to Nobelius (2004), the need to incorporating these factors into the R & D context is driven by the ever-changing complexities of new products and technologies. The demand to cooperate with more players is largely driven by larger technological investments and rational specialization, and the need for effective and efficient commercialization of new technology is driven by rate-of-return, payback period and benefits of first-to market competitive advantages. In view of all these increasing complexities, coupled with the globalization of technologies, the next revolution in R

& D management will inevitably take on a new set of management routines that will produce a newly defined and identifiable generation. It has therefore been predicted that the sixth generation of R & D management will lean towards similar routines, viz greater complexities which will result in even more issues being integrated into R & D management as well as more sophisticated involvement of diverse actors. As a result of the diversity of technical and commercial considerations coupled with the diversity of actors, the effective and efficient management of diversity will be one of the main challenges of the sixth generation of R & D management. Holt and Jayawarna, (2009) emphasize the multi-faceted and complex nature of R & D by arguing that it is far from being a homogenous activity and can be described differently by various professionals (e.g. scientists, engineers, technologists, etc.) within the same R & D organization. Each discipline has its own interests and perspectives on the nature of knowledge and how a quality system should be employed. Within such complex and multi-discipline environments and differing attitudes, a one-size-fits-all set of routines cannot serve the entire spectrum, implying that each discipline must be utilized in a specific and limited way to have the desired beneficial outcome. Based on this, the sixth generation of R & D will need to fine-tune the consolidation of knowledge within R & D units, creating synergies among the sundry professional groups and making individual units' competencies more transparent, explorable and exploitable. Management of knowledge, quality and competencies within the next generation of R&D will take a solid form in terms of:

- The documentation of R & D personnel competencies, with attempts to match these competencies to jobs considered to be essential (job chain) in the innovation chain. The documents will act as management tools that will enable R & D managers to create some form of dashboard for the R & D organization they attempt to achieve. These will act as reference points for making comparisons between the various units and jobs.
- The co-ordination of actors (networking practices) will also form one of the major elements of the next generation of R & D (Paraponaris, 2003). In view of the increasing complexity and multi-disciplinarity of research where speed and innovative product combinations constitute major competitive strengths, firms' R & D management strategies in the sixth generation will involve actively knit networks of complementary assets and resources (Miotti and Sachwald, 2003).

- Introduction of flexibility into research facilities through integration of effective communication links within the network of all players (Holt et al, 2009).

Much of the breakthrough innovations in the next generation of research will not be a result of a single company's research efforts. Instead, breakthroughs will be based on joint efforts from informal networks of smaller players driven by common interest (Nobelius, 2004). According to Busom et al (2008), new trends in the way R & D is managed and conducted have emerged over the last 20 years, along with steady increase in R & D and innovation effort and output.

The literature on management has identified three forms of R & D cooperation, namely;

1) Horizontal cooperation, i.e. between competing firms, which stresses the importance of the degree of product market competition;
2) Vertical cooperation, i.e. between suppliers or customers, and
3) Institutional cooperation, i.e. with universities and research institutions (Belderbos, Carree, Diederen, Lokshin and Veugelers, 2004).

Belderbos et al (2004) further argue that the type of partnership adopted by a firm for a particular R & D project depends on the goal to be achieved. However, the main goal of vertical cooperation with suppliers has been linked more to cost reduction, relating to the tendency of firms to focus on core competencies and to outsource activities to suppliers and/or develop close collaborative arrangements with suppliers to reduce cost. This sentiment is echoed by Busom et al (2008) who argue that customers' and suppliers' partnerships are the most frequently adopted by firms. This is followed by firms within the same enterprise group and then by universities or other higher educational institutions.

Busom et al (2008) further states that several hypotheses have been proposed to explain incentives that firms have to cooperate with other firms or public research organizations. Four broad categories have been identified. One school of thought emphasizes that in order to develop firms' complementary intangible assets .i.e. tacit knowledge and experience which cannot be easily copied and monitored through market-based transactions, cooperation agreements may be establish as a safeguard. A

second hypothesis views research collaborations as a means to share risks and costs as well as exploit the benefit of economies of scale and scope in R & D. A third stream of hypothesis emphasized the importance of incoming and outgoing knowledge spillovers. However, while partnerships may improve learning capabilities among the alliance, outgoing spillovers may occur when knowledge that is generated by the firm leaks out and benefits other firms. These spillovers may pose a serious concern when a firm's appropriability mechanisms are not watertight, hence the reduced drive to carry out some R & D projects. Lastly, the fourth hypothesis predicts R & D cooperation may take place when it enables partners in the alliance to leverage their competitive position in the product market place. In conclusion, studies have shown that incoming spillovers, outgoing spillovers, firm size, cost and risks associated with R & D affects firms' decision to partake in any form of partnership.

3.2 Elaboration on the elements of sixth generation managerial approach

Ghemawat (1999) argues that the more concentrated an industry, the more likely for competitors in these industries to recognize their mutual interdependence and hence restrain their rivalry. This section elaborates on some of the important managerial elements that will characterize the sixth generation of R & D using two case studies. Under the sixth generation model, organizations will develop methods to share IP and engage in various forms of collaboration that are new to R & D management practices. The first case study describes an initiative called the Innovation Mill (IM) that was established through collaboration among three Finland-based companies, namely Nokia Corporation, Technoplis and Tekes. This initiative was analysed and described by Hossain (2012). The second case study describes the development of Bluetooth technology and the formation of the SIG.

3.3 Case Study 1: The Nokia Innovation Mill (IM)

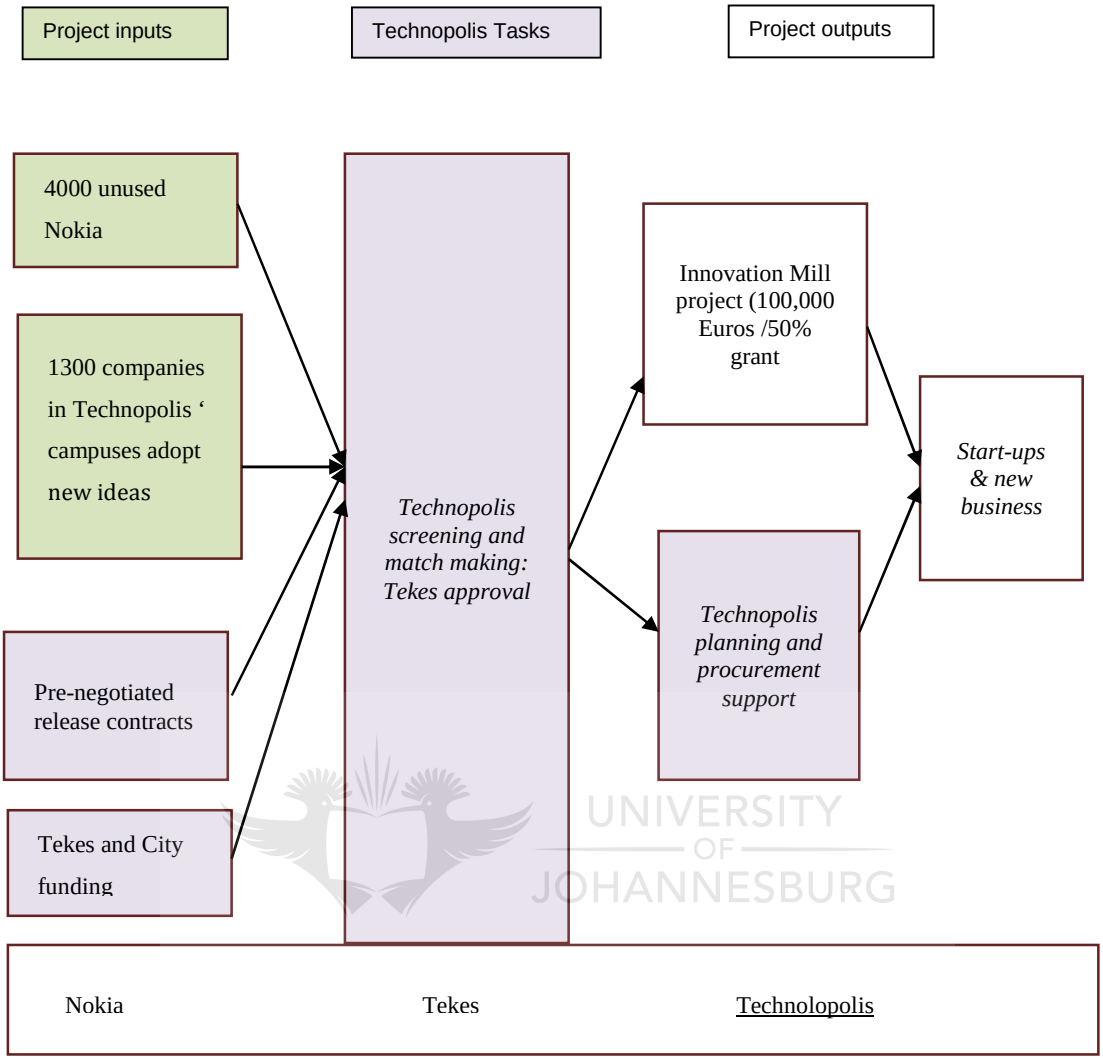
Nokia Corporation is a market leader in the mobile phone sector while Technopolis specialises in providing business environments and services for knowledge-intensive organizations. Tekes for its part is a government funding agency for Technology & Innovation, and specializes in financing R & D and innovations in Finland. Each of these organizations has a large number of employees. Tekes finances industrial R & D

projects, universities and other R & D institutes (Hossain, 2012). The purpose of IM is to encourage Finland's innovation sector in the information, communication and technology (ICT) sector in developing globally competitive products and services. Although the collaboration is among these three companies, the custodian of IM is Nokia. Nokia makes available the ideas that do not form part of their core business and make them available to companies throughout Finland who might have the capability to turn these ideas into innovative products and services. The patents of these ideas are then transferred to the companies who are able to convince their innovation boards of their ability to convert these initial ideas into innovative products and services successfully. This is a unique example of open innovation which will characterise the sixth generation of R & D management. The IM initiative has created a unique R & D model that fosters collaboration among Finish companies, an element that is predicted to be prevalent in the next generation R & D and that might indeed be one of its main characteristics. Hossain (2012) cited other companies like Cisco, Dell, Nokia and Motorola that have acquired ideas through similar partnership engagements with other companies.

3.4 The Innovation Mill

The IM is a classic example of the combination of knowledge management, collaboration and open innovation, a scenario that is predicted to characterise sixth generation R & D management. Open Innovation was a term initially coined by Chesbrough (2005) and is a notion that entails collaborative endeavour while dealing with the issue of intellectual property rights. Nokia Corporation, a leader in the mobile phone market with a large global footprint with a large number of employees, has numerous business ideas and internal projects which have to be discontinued or cancelled at some point due to many reasons, although these projects/ventures may have significant commercial potential. Nokia Corporation then decides that these unused prospects should be passed onto businesses to utilize. It therefore started the IM, a three year programme, with the aim of developing unused commercial potentials. Figures 2&3 depict the model.

Figure 2: Stakeholders of IM and their inter-relations



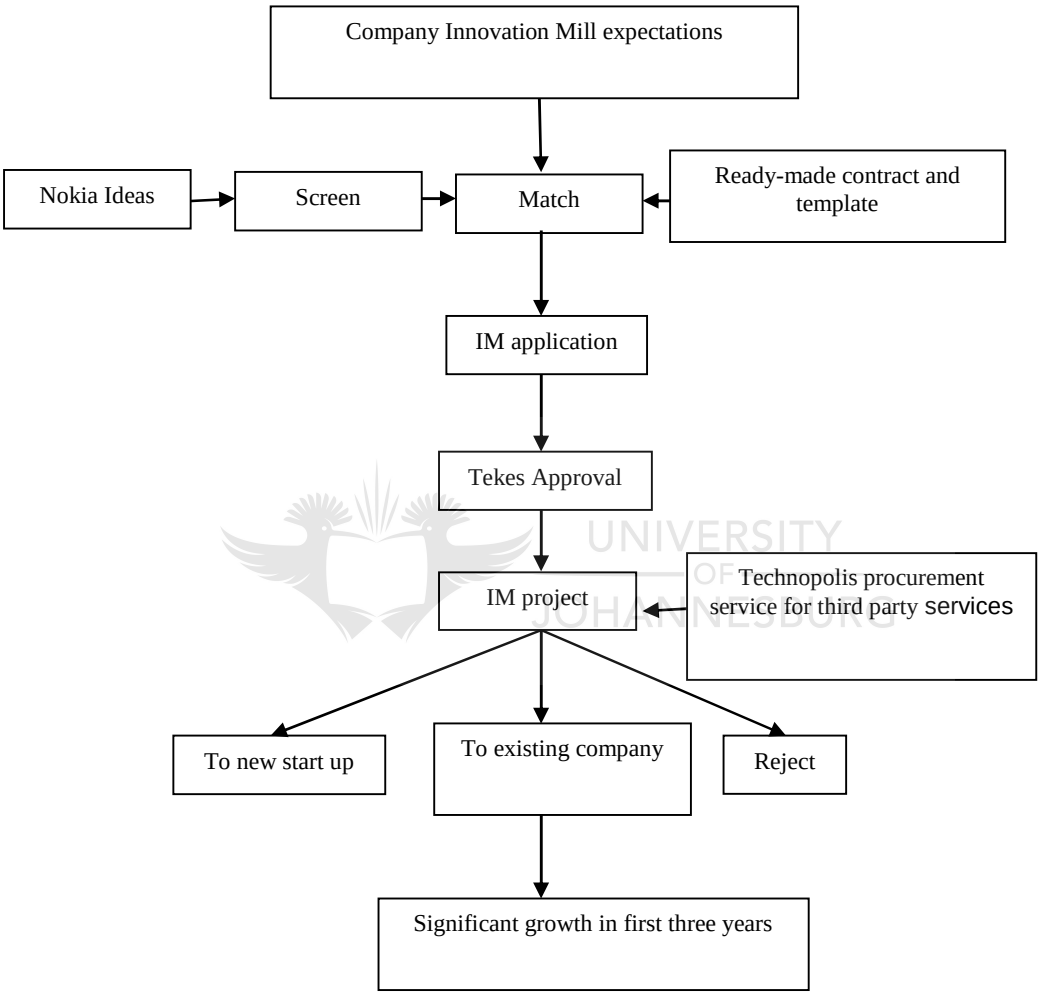
Source: Hossain (2012) - Stakeholders of IM and inter-relations

3.5 IM Process

Figure 3 depicts the innovation mill process. It shows the systematic IM process of managing R & D and innovation from the beginning of idea generation to making commercial success. Each idea is carefully screened and project-managed with stakeholder participation in a synchronous manner from conception to completion. Potential companies, Nokia and other stakeholders sign non-disclosure agreements for mutual co-operation. Technopolis helps potential companies prepare a project plan. In this case, a business plan should include the impact of the project on business and growth among other things. There are two main aspects – technical and commercial – considered when evaluating these projects.. Technical aspects include technical

specifications for the new product, user interface, interface design, systematic test design, demo and production plans. Commercial plans include market study, competitor analysis, SWOT analysis, sales and marketing plans, business plan, project plan, financial plan, partnership negotiations, contract and other legal studies and planning. Tekes then decides which projects qualify for funding (Hossain, 2012).

Figure 3: Schematic diagram of Innovation Mill process



Source: Hossain (2012) – Innovation Mill Process

3.6 Summary of Managerial implication Sixth generation R & D management – IM

IM is a unique example of open innovation that is predicted by Nobelius (2004) to characterize sixth generation R & D management. According to Hossain (2012), the open innovation concept generally comprises spin-off, licensing inbound or outbound flows of knowledge, technology and information. Thus companies consider open innovation with the objective of gaining competitive advantage or market leadership in their business. However, the IM initiative goes beyond the idea of gaining competitive advantage by making available ideas, funds and support whilst at the same time fulfilling its social responsibility role. This case study is selected because it has the hallmarks of the sixth generation of R & D management. The framework of Nobelius (2004) predicted open innovation and collaboration as some of the key characteristics of this generation and the IM initiative demonstrates these characteristics.

3.7 Case study 2: Bluetooth development and evolution

The development and the evolution of Bluetooth technology has a number of sixth generation R & D management features (Nobelius 2004). Bluetooth is a wireless communication technology that enables inter-communication between devices. Some of its common functions include data synchronization between devices such as cellular phones and computers or different computers, or cellular phone to cellular phone and connecting to the internet. It has very wide applications and works in the unlicensed 2.4 GHz frequency band. Unlike most devices, Bluetooth allows devices to automatically connect to each other. Bluetooth is named after a Danish king who ruled from 940 to 985 AD. During the time of his rein, Bluetooth was reported to be the one who facilitated the unification of Denmark and some parts of Norway into a single kingdom.

Ericsson began researching into short-range wireless technologies that could be used between their cellular phones and peripheral devices. In 1998, Ericsson, Nokia, IBM, Toshiba and Intel formed a coalition called the Special Interest Group (SIG). These companies were chosen because of their leadership in their respective technological fields. Ericsson and Nokia are leaders in the mobile phone technology field, IBM and Toshiba are leaders in laptop computing technologies while Intel's leadership resides in the digital signal processing technology. Each of these companies has a large number

of employees, thus in four short years, the original five companies in the SIG turned into a group with 1500 personnel (Yen, Shih and Dursch, 2004).

The original aim of Bluetooth was to clear all the cables that tie down the complex world of computing and communicating technologies. Every computer or communication device (monitors, keyboards, mouses and printers) is tied down by cables at the back. For instance, a. This creates mazes of cables that users have to go through each day, making it very confusing for users as more plug-in devices are added. This is where Bluetooth came in. The developers immediately realised that Bluetooth technology has more capabilities than merely connecting peripheral devices. It is versatile in terms of application, allowing other types of wireless network connections. Up to eight devices can connect through Bluetooth, forming a small network called a piconet. When more than eight devices need to be involved in the connection, a number of piconets can be connected together to form a network called a scatternet (Yen et al, 2004). Bluetooth technology came with the following advantages (Yen et al, 2004):

- It has great versatility and is very easy to use. Bluetooth frees up the end-user from being tied down by wires. With the increasing need to connect several devices at once, wireless connection through Bluetooth technology has eliminated the complication that a wired connection would have created.
- Not only does Bluetooth allow seamless and wireless communications, it also allows devices to be connected automatically, making it very user-friendly.
- Other added advantages include enhanced security features.

Table 3 shows the history and evolution of Bluetooth technology.

Table 3: History and evolution of Bluetooth technology

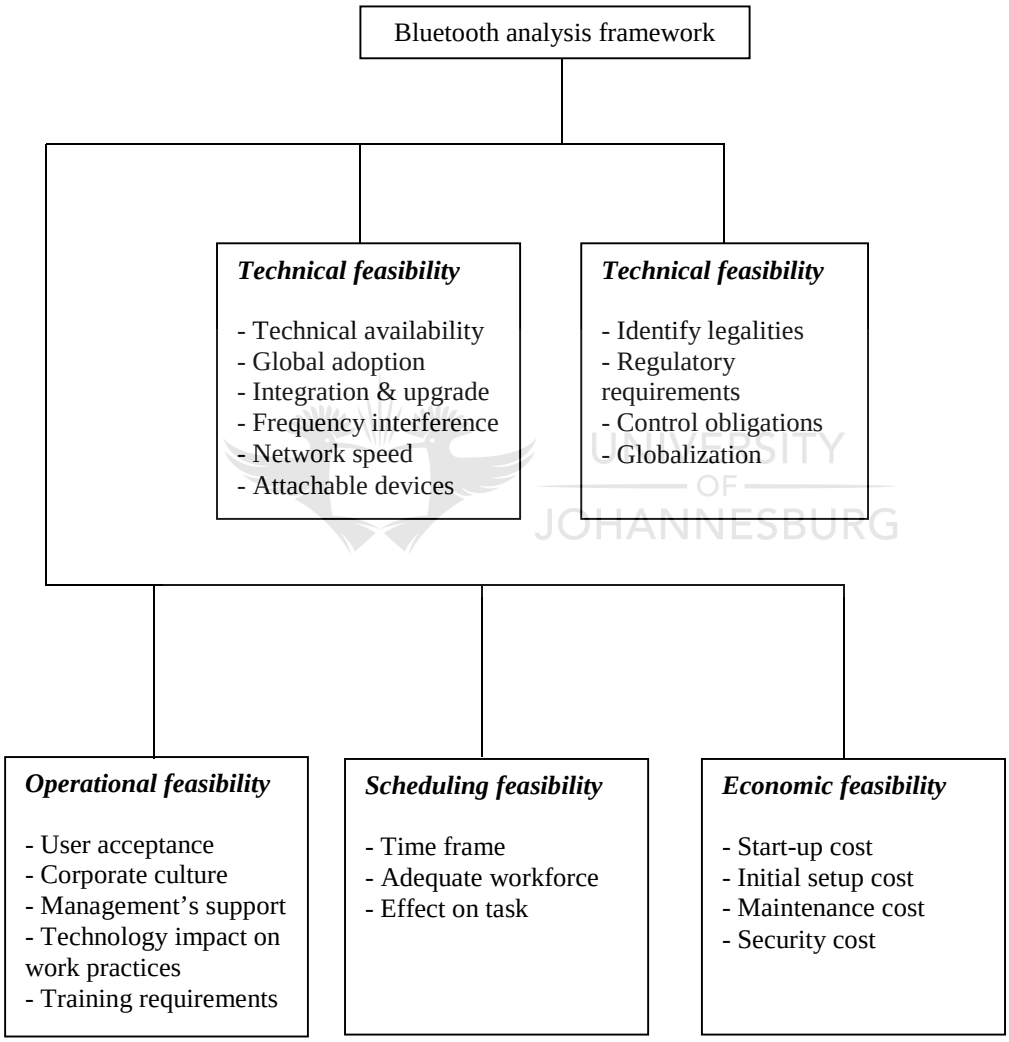
Year	Cycle of Evolution	Major development	Lessons learned
1996	Introduction	Ericsson started research on a short-range wireless solution for peripheral devices	Capability and versatility of Bluetooth begins to be realised by its developers and users.
1998-2000	Growth	SIG research coalition was formed	Bluetooth began showing more potentials with growing support and many more uses are being explored, however, security concerns are emerging.
2000-2003	Maturity	Versatility of Bluetooth is explored. Bluetooth is used in conjunction with other wireless standards such as Wi-Fi.	2.4GHz band may become too overcrowded, questions being asked if there is a need for newer solutions.
2003-current	Current/future	Once more commercial and consumer market support is well established, prices started dropping.	Popularity of the Bluetooth technology is rapidly increasing and price drop is rapid.

Source: Yen, Shih and Dursch (2004)

3.8 Bluetooth analysis framework

The continuous R & D into Bluetooth technology is broadening its scope of use. What really makes Bluetooth such an important standard is its world-wide adoption and acceptance. Yen et al (2004) provided the following framework that identifies the various areas of which organizations need to consider in deploying Bluetooth technology.

Figure 4: Bluetooth adoption framework for corporates



Source: Yen et al (2004)

- *Technical feasibility* – Initially, Bluetooth was simply a device that enabled people to talk on their Bluetooth enabled phones hands-free. Now its applications have been extended to many areas such as communications with PDAs, computers, laptops, cars, watches, and internet connections to name a few (Yen et al, 2004).
- *Economic feasibility* – Companies that wish to deploy the Bluetooth platform need to take the economic aspects of deployment into account. Most companies still have wired networks. Adopting a wireless technology like Bluetooth will reduce companies' operational cost in the long run. However, the initial setup cost will be high since companies will have to initially ensure that their devices are Bluetooth ready.
- *Legal feasibility* – The deployment of Bluetooth has both legal and security implications. Thus it is important for businesses to identify any legal requirements there may be. Businesses then needs to assess their capacity to meet these requirements. Since Bluetooth is also a universal standard, business practices and laws need to be taken into account when setting up in different countries, especially for multi-national companies. Security concerns on the Bluetooth platform needs to be taken seriously as well during set up.
- *Operational feasibility* – Despite its ease of use, user acceptance of Bluetooth platforms need to be taken into consideration. Some of the factors that come into play are corporate culture, leadership involvement and the management of the new technology rollout. Training requirements of employees need to be considered.
- *Scheduling feasibility* - The deployment of Bluetooth technology needs to be carefully project-managed in order to establish the various milestones for its rollout. This calls for management involvement in order to reduce or eliminate employee frustrations during the adoption of the technology.

3.9 Summary of managerial implications for sixth generation R & D management

Bluetooth SIG

The formation of the SIG enables inter-industry collaboration and rapid global acceptance, adoption and standardization of a new innovation. Furthermore, both Ericsson and Intel were first to identify the choice of opening up the intellectual

property as a basis of fast tracking the global presence of an innovation (Nobelius, 2004). This has created a new product that has been formed through collaboration between more than a thousand companies that voluntarily came together with the common goal of developing a wide area wireless network (WAN). This technology quickly caught on to become a global standard for wireless personal area networks. The benefit of becoming part of the Bluetooth SIG includes:

- Gaining access to a royalty-free license to develop products based on the same technology;
- Gaining access to Bluetooth technology;
- Enabling a member organization to influence the direction and development of the Bluetooth specification;
- Offering potential partners co-development opportunities.

The increasing complexity of new innovations continuously demands that more issues be taken into account to enable the sustainability of the innovation. Some of these include interoperability with other technologies, industrial design, portability, universality, versatility, environmental concerns, conformity to global standards and marketing considerations. All these demand cooperation and interaction with more of both internal/external as well as commercial/industry key players such as suppliers, customers, competitors, distributors and even non-competitors, for an innovation to be sustainable (Nobelius 2004).

Both case studies demonstrate the need to create an environment for collaboration and idea sharing among different organizations to develop new products. This strengthens the idea that successful innovations do not necessarily need to come from one company alone. The success of both the Bluetooth and the Innovation Mill case studies demonstrate that the next generation of R & D approaches may be characterized by network-based settings where open innovation, idea sharing, joint research efforts, and cross-industrial commitment could become the norm.

3.10 Summary

This chapter narrowed the focus of the research from broadly examining various R & D generations and their characteristics to the more specific characteristics that are predicted to be dominant in the sixth generation. Two case studies were used to demonstrate these predicted characteristics. Major attributes identified in the two case studies are R & D partnerships, open innovations, and collaborations among major industrial players in fast-tracking new products to the market. The next chapter comments on the future of R & D management practices.

4. CHAPTER 4: CONCLUDING REMARKS

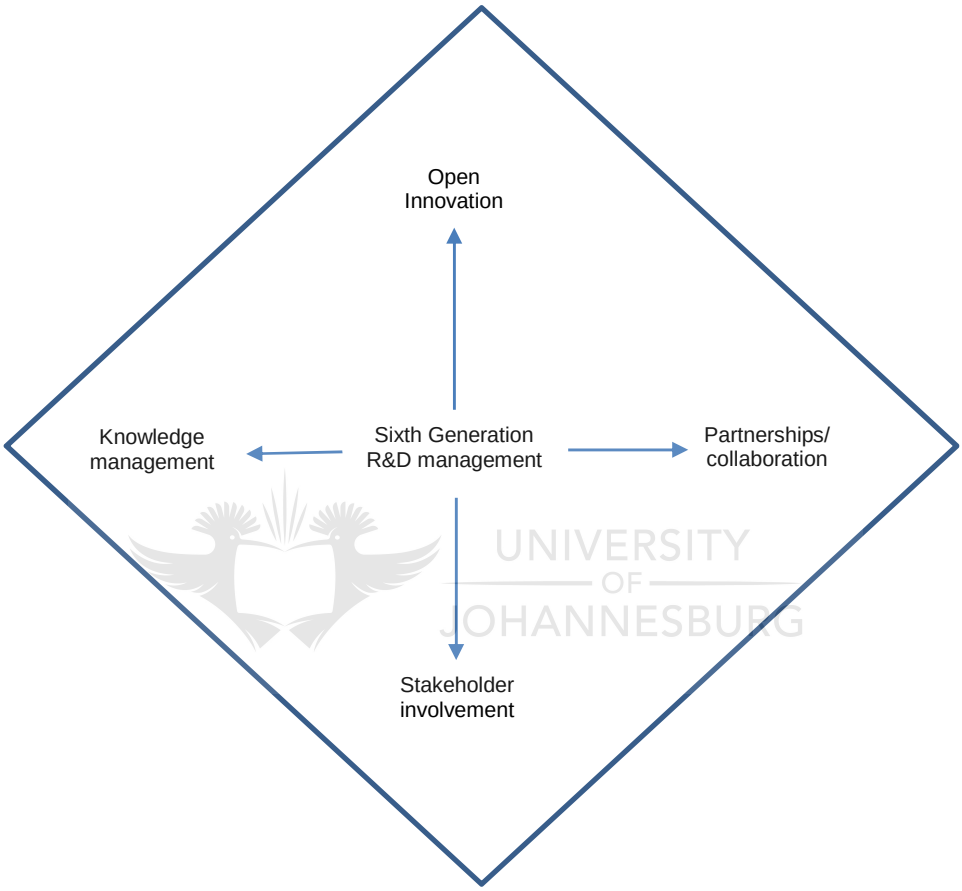
The main goal of R & D management is to achieve maximum efficiency for organizing and controlling efforts applied to its core activities. According to Sofo (2008), analysis shows that the transformation of R & D management is increasingly characterized by greater multi-disciplinary approach emphasizing cross-functional communication, collaboration, greater inclusion of stakeholders such as suppliers, customers and partners in the full life cycle of R & D management process. That is, from conception to market development, evaluation, reporting and re-conceptualization. The sixth generation of R & D will be characterized by inclusiveness of various stakeholders and partnership endeavors. This is in clear contrast to the previous R & D generations which were more characterized by individual companies or entities trying to develop new propriety products single-handedly.

This research has reviewed a number of available literature on the characteristics of various generations of R & D management. The argument is that the attempt to predict the routines that will dominate the sixth generation of R & D management based on the literature of the previous five generations from the literature reviewed in this study. In broader terms, this study has offered several contributions which can serve as basis for future research. Firstly, this study has demonstrated the fundamental theoretical framework of the last five generations of R & D management and has shown the usefulness of this framework in the context of the fast-paced development of new innovations. The discussion in this study could serve as a starting point for future research models on the evolution of R & D management.

Previous studies on R & D management are mainly conducted in either Europe or America. Furthermore, there is limited research undertaken to predict the R & D management practices that will be adopted in the sixth generation. This study will therefore serve as a contribution to the work started by Nobelius (2004) in predicting the likely prevailing management practices in the next R & D generation. Throughout this study, attempts have been made to explore the factors that will facilitate migration to the next generation of R & D management. By studying the different streams and generations of research on R & D management, the author suggests that partnerships/collaborations, focus on knowledge management and open innovation will

dominate the sixth generation of R & D management. This prediction is in line with Nobelius's (2004) assertion that it will be difficult for a company to create successful and sustainable innovation single-handedly. This assertion is backed by Sofo (2008) who expresses a similar view in the form of a framework (see Figure 5) of the next generation of R&D management.

Figure 5: Framework for sixth generation R &



Source: Sofo (2008)

Berchicci (2012) observes stated that the conventional paradigm of having a company's core R & D activities exclusively in-house is becoming less prevalent, while current models of innovation suggest how firms are opening up their R & D borders to harness external knowledge. Adoption of an open R & D system will enable a firm to outsource projects or technologies which might previously have no clear pathways to commercialization. The IM case study points to this fact. By exposing R & D projects or technologies to external partners, these projects find their way to markets faster. It further allows firms to in-source external ideas through the integration of suppliers, customers and external knowledge sources to augment the firm's innovativeness while

keeping up with novel developments so that the firm can increase learning acquired from partnerships (Berchicci, 2012), (Aasen, Molnvik, Aarlien, Bredesen, Munkejord, Brunsvold & Gundersen, 2012).

The Bluetooth SIG case firmly supports this notion of open innovation. Chesbrough (2005) defined open innovation as the use of purposive inflows and outflows of knowledge to speed up internal innovation while broadening the markets for external use of innovation respectively. Chesbrough (2005) further stated that open innovation is a model based on an assumption that firms can exploit both internal/external ideas and paths to the market, while they shape up to their technology. Markets are changing so rapidly because of new technologies, hence, ideas that are not captured and promptly implemented soon fade away. It has thus become an important issue for corporate strategists to act on ideas swiftly and convert them to commercial products (Hossain 2012).

Successful R & D activities are vital for national as well as firms' sustainable competitive advantage. The transition from one generation of R & D management to the next is not a tangible process. Furthermore, R & D management activities within firms is made up of a mixture of routines from more than one generation. Moreover, R & D managers need to be guided by operational environments and contexts (e.g. geographical location, government legislation, country, prevailing R & D practices in the area and industry) when attempting to adopt specific R & D practices geared at making a transition to the sixth generation. It is therefore imperative for R & D managers to be able to design and adapt the latest and most proven management strategies in order to maintain a competitive edge.

5. REFERENCES

1. Aasen TMB, Molnvik MJ, Arlien R, Bredesen R, Munkejord ST, Brunsvold A & Gundersen T. 2012: Innovation in heterogeneous CCS Research Centre: Managerial and Organizational Challenges. *Energy procedia 23(2012):296 - 305.*

2. Belderbos R, Carree M, Diederen B, Lokshin B & Veugelers R. 2004: Heterogeneity in R & D Cooperation Strategies. *International Journal of Industrial Organization 22(2004): 1237 - 1263.*
3. Bernanke B & Gertler M. 1989: Agency costs, net worth and business fluctuations. *American Economic Review* 79(1): 14-31.
4. Berchicci L. 2013: Towards an open R & D system: Internal R & D investment, external knowledge acquisition and innovative performance. *Research Policy 42(2013) 117-127.*
5. Blomqvist K, Aijo T, Hara V & Koivuniemi J. 2004: Towards networked R & D management: The R & D approach of Sonera Corporation as an example. *R & D Management 34(4): 591-603.*
6. Busom I & Fernadez-Ribas A. 2008: The impact of firm participation in R & D programmes on R & D partnerships. *Research Policy 2008(37)*: 240-257.
7. Calderini M & Garrone P. 2001: Liberalization, industry turmoil and balance of R&D activities. *Information Economics and Policy 2001(13) 199-230.*

8. Campi C & La Bella A. 1998: Analysis of the interaction between regional R&D productivity and the investment strategies of multinational enterprises. *Technological Forecasting and Social Change 1998(58): 241-249.*
9. Candelin-Palmqvist H, Sandberg B & Mylly U. 2012: Intellectual property rights in innovation management research: A review. *Technovation 2012: 1-10.*
10. Chesbrough H, 2005: Open Innovation: A new paradigm for understanding industrial innovation. *(2005)1-27.*
11. Feynman R. 1999: *The pleasure of finding things out.* 2nd edition. London: Penguin Books.
12. Gerydadze A & Reger G. 1999: Globalization of R&D: recent changes in the management of innovation in transnational corporation. *Research Policy*. 1999(*28): 251-274.*

13. Ghemawat P. 1999: *Strategy and the Business Landscape:* 1st edition. Addison Wesley: Longman, Inc.
14. Holt R & Jayawama D. 2009: Knowledge and quality management: An R&D perspective. *Technovation 2009(29): 775-785*.
15. Hossain M. 2012: Open Innovation Mill: Utilization of Nokia's Non-Core Ideas. *8th Procedia – Social and Behavioral Sciences 58(2012) 765-765*.
16. Kendall JD, Tung LL, Chua KH, Ng CHD, Hui K & Tan SM. 2001: Receptivity of Singapore's electronic commerce adoption. *Journal of Strategic Information Systems 10(2001): 223-242*.
17. Kilby JS. 2000: Turning potential into realities: The invention of the integrated circuit. *Nobel Lectures Dec. (2000): 474-485*.
18. Kim B & Oh H. 2001: An effective R&D performance measurement system: survey of Korean R&D researchers. *The International Journal of Management Science 30(2002): 19-31*.
19. Kowtha NR & Choon TWI. 2001: Determinants of website development: a study of electronic commerce in Singapore. *Information and Management 39(2001):227-242*.
20. Lancastre A & Lages LP. 2005: The relationship between buyer and a B2B e-marketplace: Cooperation determinants in an electronic market context. *Industrial marketing management (2005): 1 - 16.*
21. Liebenstein H & Maital S. 1994: The organizational foundations of X-inefficiency: A game-theoretic interpretation of Argyris' model of organizational learning. *Journal of Economic Behaviour and Organization 23 (1994):251-268.*
22. Malerba F & Orsenigo L. 1996: Schumpeterian patterns of innovation are technology-specific. *Research Policy 25(1996): 451-478.*
23. Miotti L & Sachwald F. 2003: Co-operative R & D: Why and with whom? An integrated framework of analysis. *Research Policy 32(2003): 1481-1499.*
24. Niosi J. 1999: Fourth-generation R&D: From linear model to flexible innovation. *Journal of Business Research 45: 111-117*.
25. Nobelius D. 2004: Towards the sixth generation of R & D management. *International Journal of Project Management 22(2004): 369-375.*
26. Paraponaris C. 2003: Third-generation R&D and strategies for knowledge management. *Journal of knowledge Management 7(5): 96-106*.

27. Post JE. & Mahon JF. 1980: Articulated turbulence: The impact of regulatory agencies on corporate response to social change. *Academy of Management Journal 5: 399-407.*
28. Porter ME, Furman JL & Stern S. 2000: National Innovative capacity.
29. Scupola A. 2003: The adoption of Internet commerce by SMEs in the south of Italy: An environmental, technological and organizational perspective. *Journal of Global Information Technology Management 6(1): 52-71*.
30. Simon JS. 2004: Critical success factors for electronic services: Challenges for developing countries. *Journal for Global Information Technology Management 7(2): 31-53*.
31. Sofo F. 2008: Reflections on China and a six-dimensional framework for managing research and development: *Journal of Knowledge Management 1(1): 28-42*.
32. Van de Van A. 1993: The emergence of an industrial infrastructure for technological innovation. *Journal of Comparative Economics 17: 338-369*.
33. Yen DC, Shih D, Dursch A. 2004: Bluetooth technology: an exploratory study of the analysis and implementation frameworks. *Computer Standards & Interfaces 26(2004):263 - 277.*
34. Yin, R. K. 2003. *Case study research: Design and methods:* 4th edition. Thousand Oaks, CA: Sage.
35. Zhao R. 2003: Transition in R & D management control system: Case study of biotechnology research institute in China. *Journal of Technology Management Research 14(2003): 213-229.*