IMPACT OF CHANGING BUSINESS STRATEGY ON R&D PORTFOLIO

BONGINKOSI NGQULUNGA
PhD Student, University of Pretoria,
Graduate School of Technology Management,
Department of Engineering and Technology Management,
South Africa
bonginkosi.ngqulunga@implats.co.za

DAVID WALWYN
Professor, University of Pretoria,
Graduate School of Technology Management,
Department of Engineering and Technology Management,
South Africa
david.walwyn@up.ac.za

ABSTRACT

Knowledge begins life as a public good available to all (non-rival and non-excludable), and as an input into the generation of additional knowledge is made, it subsequently becomes artificially scarce as countries grants intellectual property rights to stimulate investment in the production of private knowledge goods (Maskus and Reichman, 2004). However, patent policy has strongly sought to protect intellectual property rights and investment made by innovation rather than by strengthening the tradability of R&D inventions in a market thereby ensuring economic growth (Troy, 2012). Changes in the external and internal business environment may induce a redirection of company strategy, which can result in the destruction of a company's valuable intellectual assets (people and knowledge), generated through formal R&D investment. These intellectual assets may be of value to both the company and society, and their termination of projects as a consequence of the re-shaping of company R&D portfolios may result in the destruction of knowledge useful to society.

The objective of this research is to establish the extent to which uncertain business environment induce changes in R&D portfolios, and as a consequence destroy shareholder value. Develop an R&D PPM methodology which can be used to mitigate the risk of the destruction of valuable intellectual assets as a consequence of changes in business strategy. This research study investigates four important aspects: 1) What is the likelihood of a change in business strategy that will impact negatively on an R&D project portfolio value? 2) What is the extent of the impact of changing business strategy on R&D portfolio value (this is equivalent to the benefit that will be gained by ensuring that R&D portfolio value is not reduced by changes in business strategy)?, 3) What steps are being taken by companies to avoid destruction of shareholder value and maximize social return on investment in the event of R&D portfolio changes, and; 4) What portfolio management methodology can be used to mitigate the risk of portfolio value destruction as identified in questions above?

The population was drawn from South African R&D intensive manufacturing companies, this population includes medium-sized enterprises as well as large organisations listed on the Johannesburg stock exchange. Data was collected using an online instrument and telephone interviews during this study phase while the questionnaire was developed for Phase one of the study and to be further developed and refined of item wording and structure for use in Phase two and three.

The analysis of the findings of the Phase 1 of this study show manufacturing companies are affected by changes in business strategy. Private R&D outputs can be divided into those that lead to new company innovation (new

products, processes and services), those that have value but are discontinued due to change in company strategy or lack of funds, and those that have no immediate value. Many companies are sitting on huge reservoirs of new knowledge which is never revealed. This knowledge has intrinsic value. It should be possible to create an alternative means of publication which will allow public access. The ultimate argument is that the overall return on private R&D could be improved if these outcomes are freely available, especially if there is a change in strategy and the projects are discontinued for non-technical reasons. Uncertain business environment and consequent changes in company strategy have a negative influence on R&D portfolio value.

Keywords: Project portfolio management, business strategy, research and development projects, dynamic capabilities, innovation, uncertainty, spillovers and social return on investment.

INTRODUCTION

According to Cooper, Edgett and Kleinschmidt (2002), project portfolio management (PPM) is a dynamic decision process, whereby a business' list of active projects is constantly revised and updated. In this series of actions, new projects are assessed, carefully chosen and ranked; current projects may be expedited, aborted or de-prioritized and resources are allotted and re-allotted to active projects. The portfolio decision process is characterized by uncertain and dynamic business environment, changing information, dynamic opportunities, multiple goals and strategic fit considerations, interdependence among projects, and multiple decision makers and locations (Cooper *et al*., 2002). The portfolio decision process comprises of a number of decision making processes within the business, including periodic reviews of the total portfolio of all projects (looking at all projects holistically, and against each other); It also makes Go/Kill decisions on individual projects on an on-going basis, and develops a new business strategy, complete with strategic resources allocation decisions (Cooper *et al*., 2002).

Generally organizations are aiming for self-sustaining success while allotting limited resources to costly R&D activities; the probable consequence is extended patent portfolios (Wang, Vanhaverbeke and Roijakkers, 2012). According to Chesbrough and Vanhaverbeke (2011) survey, approximately eighty five per cent of large company's patents are by no means used in any of the holders' businesses, or are used to deter potential competitors and most innovations and intellectual property (IP) sit on the shelf unexploited; from a public goods perspective, unexploited patents represent a large unexploited source of knowledge that could be used to construct new companies and economic growth if there were an efficient approach to 'activate' these unexploited patents in other companies.

A Japanese Patent Office survey conducted in 2007 found that almost 50% of Japanese patents were unused, with a global R&D annual spend of $1.6 trillion in 2014, this means that at least $800 billion of knowledge never enters the public domain. This waste of scarce corporate resources is significant; from society's perspective, the loss is even worse; if organizations irrefutably do not use various technologies they are creating, or license-out these technologies to other organizations for the purpose of commercialization, then the knowledge covered by the temporary monopoly are not ever brought to market. Thus, society never gets to experience the use of these new inventions, and policy-makers also endow organizations to impede anyone else from using the technology until the patents expire; More importantly, considerable effort has to be put into commercializing the unexploited technology/knowledge through spin-offs or through licensing to other companies in other markets (Wang *et al*., 2012).

By tradition, patent policy has strongly sought to protect IP rights and investment by innovation rather than by strengthening the tradability of R&D inventions in a market; Courts and regulators, including even governments, have mainly been involved in generally expanding and strengthening the ownership of novel and useful knowledge (Troy, 2012). According to Troy (2012) the increase of IP licensing activities and the increasing alertness of the commercial potential of IP rights and technologies, indicate that patents more and more become a source of profit for businesses and institutions of higher education. Patents are not only exchanged to prevent costly litigations and conflicts from overlapping patent rights, but, it is recognized that patent trades allow for revenues from royalties and a decline in costs of R&D endeavours when companies acquire and exploit technologies outside the firm (Chesbrough, 2006).

According to Wang *et al*. (2012), for the open innovation process, allocation of resources will shift from the focal corporation to the developer community and external partners, such as joint ventures and university research. In this way, scarce portfolio resource allocation efficiency will be gained at two levels. At the firm level, innovating firms, using an open innovation model, can manage the innovation community successfully over different time horizons by leveraging internal and external innovators (Grand, von Grogh, Dorothy and Swap, 2004). Active R&D resource sharing mostly widens firms' R&D reach and greatly lessens needless duplication. From the society's perspective, open innovation provides greater scope for jointly configuring and re-configuring the best ideas and business model, while presenting the most suitable business models for commercialization (Chesbrough, 2006; Backer, 2008). The efficiency of PPM, in dynamic environments, could be valued by estimating the degree to which the portfolio fulfils its objectives: strategic alignment/fit, balance across projects, and value maximization (Martinsuo and Lehtonen, 2007). In this study, PPM efficiency concerns organizational members' estimate of the degree to which the projects together, as a portfolio, thrive in accomplishing the portfolio objectives. This efficiency should include extracting value from those projects which have been aborted, and yet have value embedded in them.

RESEARCH PROBLEM

Changes in the external and internal business environment may induce a redirection of company strategy, which can result in the destruction of a company's valuable intellectual assets (people and knowledge), generated through formal R&D investment. These intellectual assets may be of value to both the company and society, and their termination of projects as a consequence of the reshaping of company R&D portfolios may result in the destruction of knowledge useful to society.

RESEARCH OBJECTIVES

The objective of this research will be to establish the extent to which uncertain business environment induce changes in R&D portfolios, and as a consequence destroy shareholder value. Develop an R&D PPM methodology which can be used to mitigate the risk of the destruction of valuable intellectual assets as a consequence of changes in business strategy.

RESEARCH QUESTIONS

1) What is the likelihood of a change in business strategy that will impact negatively on an R&D project portfolio value?
2) What is the extent of the impact of changing business strategy on R&D portfolio value (this is equivalent to the benefit that will be gained by ensuring that R&D portfolio value is not reduced by changes in business strategy)?
3) What steps are being taken by companies to avoid destruction of shareholder value and maximize social return on investment in the event of R&D portfolio changes?
4) What project portfolio management methodology can be used to mitigate the risk of portfolio value destruction as identified in questions above?

Hypotheses:

H1: Uncertain business environment and consequent changes in company strategy have a negative influence on R&D portfolio value.

H2: Economic output can be increased by releasing the inherent value in unpublished and unexploited research results/knowledge.

According to Miller (2002) the consequences of inefficient PPM are a higher level of project failures, voluminous projects for available resources, and the inability to reject them. Not all rejected projects have no value, hence the 2nd hypothesis. Rejection of projects may be caused by a changing strategic direction/fit, portfolio balance, limited resources, and new opportunities. Therefore, this leads to an argument which states that, for a

truly efficient project portfolio management in an uncertain and dynamic framework, value has to be extracted from aborted projects, as not all of them have no value.

R&D projects investment is huge, estimated for 2014 to be more than $1.6 trillion; the United States, China, and European Union remain the most committed regions to R&D, with a combine total of nearly 92% of all global spending (Battelle, *R&D magazine*, 2014). Much of public R&D is published, while most of private R&D is not published due to companies protecting their interests, which is not in the interests of public good. According to Walwyn (2010), South Africa sits with extensively used gauge to mirror the research intensity within a national economy of 0.9 which is gross domestic expenditure on research and development (GERD), expressed usually as a percentage of gross domestic product (GDP), which is not competitive enough to transition the country to knowledge economy. Since the world credit crisis started, the economic output has been taking strain and private companies are sitting with unexploited research results, to the detriment of economic growth.

Private R&D outputs can be divided into those that lead to new company innovation (new products, processes and services), those that have value but are discontinued due to change in company strategy or lack of funds, and those that have no immediate value. Many companies are sitting on huge reservoirs of new knowledge which is never revealed. This knowledge has intrinsic value (all knowledge has value). It should be possible to create an alternative means of publication which will allow public access. Companies could be incentivised to reveal this knowledge or a legal framework could facilitate this process. This would create massive additional economic value at little additional cost. Creating economic value from R&D project research results requires a value chain from R&D to a final product or service in the hands of a customer.

RESEARCH AND DEVELOPMENT MANAGEMENT

The significance of R&D for the future competitiveness of a firm is well accepted and also frequently mentioned in connection with the development of industrial nations (Gupta and Wilemon, 1996). The constant support of R&D activities, as well as the continuous improvement of processes within NPD, is widely recognised as a vital prerequisite for a company's future success (Bartezzaghi *et al*, 1997; Caffyn, 1997; Wheelwright and Clark, 1992). Nowadays, successful R&D depends not only on the development of technologically superior products, but also on the improvement of management processes and procedures which might turn into the true new core dynamic capabilities of R&D-intensive companies. It is therefore essential to foster the capability of learning from each and every single R&D project. One way of encouraging such learning in R&D is to conduct post-project reviews of aborted R&D projects. If such knowledge is lost, future projects can suffer from past mistakes being repeated. It is also argued that post-project reviews can have a positive impact on the learning capacity of R&D units, as they have the potential to contribute to the development and continuous improvement of R&D management processes (Abel-Hamid, 1990; Huber, 1996).

The term R&D comprises not only activities in scientific research, but also the development of new products. In other words, research provides the fundamental knowledge, whereas development tries to turn such knowledge into new and innovative products (Dumbleton, 1986; von Zedtwitz, 1999).

Table 1: Global R&D spending forecast.

	2012 R&D Spending	2012 R&D as % of GDP	2012 R&D GERD PPP Billions U.S. $	2013 R&D Spending	2013 R&D as % of GDP	2013 R&D GERD PPP Billions U.S. $	2014 R&D Spending	2014 R&D as % of GDP	2014 R&D GERD PPP Billions U.S. $
Americas	34.5%	2.5%	$485	34.0%	2.4%	$489	33.9%	2.5%	$504
U.S.	32.0%	2.8%	$447	31.4%	2.8%	$450	31.1%	2.8%	$465
Asia	37.0%	1.8%	$561	38.3%	1.9%	$596	39.1%	1.9%	$633
Japan	10.5%	3.4%	$160	10.5%	3.4%	$163	10.2%	3.4%	$165
China	15.3%	1.8%	$232	16.5%	1.9%	$258	17.5%	2.0%	$284
India	2.7%	0.9%	$41	2.7%	0.9%	$42	2.7%	0.9%	$44
Europe	23.1%	1.9%	$350	22.4%	1.9%	$349	21.7%	1.8%	$351
Rest of World	5.4%	0.9%	$81	5.3%	0.9%	$92	5.3%	0.9%	$87
Total	**100%**	**1.8%**	**$1 517**	**100%**	**1.8%**	**$1 559**	**100%**	**1.8%**	**$1 618**

GERD=Gross Expenditures on R&D, PPP=Purchasing Power Parity

Source: Battelle, *R&D Magazine (2014)*

In the beginning of its life knowledge is as a public good accessible to all and as an input into the generation of further knowledge is made, it then becomes artificially scarce as countries grants IP rights to fuel investment in the production of private knowledge goods (Maskus and Reichman, 2004). R&D knowledge production problems are admittedly not necessarily causally connected to its "global" character, the global nature of the production process certainly further limits the level of control regulatory agencies, professional organizations and other bodies are able to exercise; while the globalization of communication practices has repercussions for the development of knowledge governance; enforcing standards becomes even more challenging, particularly due to absence of accountable transnational structures (Lemmens, 2013). Scholars like Lemmens (2013) have argued that R&D pharmaceutical knowledge is a human rights issue being created by access to information as a right to health and right to life a societal issue. The regulation of knowledge goods in general markets impinges on the provision of other public goods like, education, scientific research, health and the environment (Maskus and Reichman, 2004). The developed countries tendency of traditionally urging unrestricted competition on the rest of other countries, to demand strong legal monopolies to safeguard private knowledge goods in international trade, and the predisposition of developing countries to want unrestrained competition with respect to these same knowledge goods, most of which are manufactured at great cost in the technology exporting countries complicates matters (Reichman, 1989).

R&D SPILLOVERS AND THE SOCIAL RETURNS TO R&D

R&D research outputs spur new knowledge about materials, processes, and ways of recombining them to produce new goods and services; in reality, such benefits are impossible to be fully internalized within a business, industry or even a country (Hall, Mairesse and Mohnen, 2010). The R&D executed in an organization can shake the productivity performance of other organizations operating in the same business sector or in other industries, locally and even abroad. An innovation in one firm, business sector, industry or country can trigger new avenues of research, instigate new research projects, or find new uses in other firms, sectors or countries (Hall *et al*., 2010). R&D varies from other forms of investments in numerous respects; the main distinguishing factor is that payoffs from R&D are not restricted to the original investors, but also accrue to other firms, competitors, suppliers, customers and society at large (Sveikauskas, 2007).

Griliches (1992) differentiates between two spillover types; rent spillovers and knowledge spillovers. The rent spillovers ensue when a company or purchaser buys R&D incorporated merchandises or services at charges that do not reveal their user value. This is because of imperfect price discrimination due to asymmetric information and transaction costs, imperfect appropriability and imitation, or mismeasurement of the true value of the transaction due to the lack of hedonic prices. The knowledge spillovers occur when an R&D project produces knowledge that can be useful to another firm in doing its own research. Knowledge is rival and only partially-excludable good. Because of incomplete or weak patent protection, inability to keep innovations undisclosed, reverse engineering and imitation, some of the knowledge and benefits from R&D are not kept within the firm (Hall *et al*., 2010). Various forms of knowledge are useful to other organizations (and so have a social return) even if they no longer pay off to the organization that initiated the research (no longer have a private return). Consumers obtain better or cheaper products (benefit from social returns) even if the private return to businesses

turns out to be small (Sveikauskas, 2007). The notion of knowledge spillovers is very pertinent for growth and development, because it lays the underpinning for further knowledge creation and diffusion. It is imperative at this juncture to distinguish between technology transfer and spillovers. Technology transfer is about trade in technology, which occurs when an agent sale a piece of technology with a price attached to the transaction (Hall *et al*., 2010).

Social returns to R&D are meticulously entangled with that of R&D spillovers; spillovers can be derived from R&D carried out by (1) other firms in the sector, (2) firms in other industries, (3) universities, public research laboratories, and even (4) firms, laboratories, and governments in other nations of the world. Spillovers generate what is called a social return on investment, which is shown to be at least 30% higher than the private return (Sveikauskas, 1981; Goto-Suzuki, 1989; Terleckyj, 1974; Mohnen, 1996). In other words, there is considerable benefit in promoting the dissemination of R&D results outside of the private company. The argument is that the overall return on private R&D could be improved if these outcomes are freely available, especially if there is a change in strategy and the projects are discontinued for non-technical reasons. According to Martinsuo (2012) PPM literature articles can be divided into two categories: 1) Dominantly deliberating the practice of PPM through portfolio managers' activities, and 2) Those dominantly deliberating the context in which such activity takes place. The second part is to be the focus of this research. The relationship between PPM practise and context is obvious in several recent articles (e.g. Martinsuo, 2012; Biedenbach and Müller, 2012; Petit, 2012; Blichfeldt and Eskerod, 2008; and Christiansen and Varnes, 2008).

This research challenges certain assumptions in PPM rationale which have a key impact on how PPM has been studied and executed in organizations; 1) Projects are obedient servants to fulfil business's strategy (Artto and Dietrich, 2004). Nevertheless, innovation projects are frequently used to interrogate the existing business strategy and no longer necessarily limited to one company's strategic interests only (Martinsuo, 2012). This can result in a change of business strategy; hence the "emergent strategy" concept (Srivannaboon, 2006); 2) Most PPM frameworks assume that projects compete for the same limited resources and that all relevant resources are known and controlled by the parent company. However, an increasing number of companies collaborate with external partners in research and development projects (Martinsuo and Lehtonen, 2009), borrowing from open innovation literature; and, 3) Most frameworks assume that companies are completely aware of all internal and external factors swaying project portfolios. Many previous research studies delimit their attention to project portfolios that are well defined and whose environments are stable and well known, even if less well-defined projects are being found in portfolios (Martinsuo, 2012; Blichfeldt and Eskerod, 2008). Many portfolio environments are dynamic, uncertain and poorly known (Petit and Hobbs, 2010; and Petit, 2012).

This study will offer a theoretical framework to maximize project portfolio efficiency or return on investment within dynamic environments. In other words, business strategy can change and hence strategic alignment cannot be guaranteed. Given that this is characteristic of business in dynamic environments, what can we do to avoid the inevitable destruction of stakeholder value as a consequence of changes in business strategy? Mostly, this will translate into reducing the impact of short-term losses whilst maximizing the longer term ones.

The shortfalls in current efficient PPM frameworks are mainly caused by the lack of research undertaken on the rapidly-changing and uncertain business environment in which project portfolios manoeuvre. The checklist and behavioural techniques are characterized by partial gaps, while financial and optimization techniques are perceived to have a definite shortfall. This never provides a comprehensive PPM overview. The interface between projects and the business's strategy may be both *"deliberate*", and "*emergent*" (when they are executed, they create new environments that, in turn, impact and shape the planned strategy) (Milosevic and Srivannaboon, 2006). Scholars have begun researching the projects strategic alignment in further detail (Artto and Dietrich, 2004; Morris and Jamieson, 2005; Srivannaboon and Milosevic, 2004; Shenhar *et al.*, 2007; and Smith *et al*., 2007). Jamieson and Morris (2004) suggested that most of the components which include organisational structures, strategic planning process internal analysis and control systems, have robust associations with projects processes and activities.

Uncertainty can arise from both internal and external sources in a dynamic project portfolio environment. It has been usually documented that the traditional way of project managing focuses more on monitoring, planning, and control (Atkinson, Crawford and Ward, 2006; and Perminova *et al*, 2008). Productivity PPM practices can be

considered as effective and efficient in a climate of uncertainty management by clearly defining objectives, plans and allocating resources. However, this planning is only effective if the project is operating in a stable environment and no unforeseen deviations occur. Nevertheless, in reality, portfolios are affected by multiple factors which change or require adaptation of plans in order to achieve the goals and objectives. At times, the goals and objectives might change during the portfolio life cycle, consequently affecting all the initial planning and effort already undertaken. Accordingly there is an element of dynamism and uncertainty in projects which directly affects the project portfolio and/or its environment.

DYNAMIC CAPABILITIES

Criticism of the resource-based view is derived from practical applicability limitations in the dynamic and uncertain environments (Petit, 2012). The core features are the capability to renew competencies due to a changing and dynamic business environment and the crucial role of strategic management in adapting, integrating and reconfiguring internal and external organizations' resources, skills and functional competencies to tie-up with the requirements of a dynamic and uncertain environment. Dynamic capabilities theory contends that, to develop unique resources or capabilities is no longer enough (as proposed initially by the resource based view) to achieve competitive advantage, but these capabilities and resources must continuously be re-allocated and re-optimized to adapt to dynamic environments (Teece, 2009).

This definition is proposed by Teece (2009:87-88):

> *"…dynamic capabilities refer to the particular capacity business enterprises possess to shape, reshape, configure, and reconfigure assets so as to respond to changing technologies and markets and escape the zero-profit condition. Dynamic capabilities relate to the enterprise's ability to sense, seize, and adapt in order to generate and exploit internal and external enterprise-specific competences, and to address the enterprise's changing environment."*

However, this is what managing a project in dynamic and uncertain environments encompasses (Petit, 2012). The literature has criticized the resource-based view and its practical relevance to organizational research is in question; identifying definitions as a challenge and indicating that the path-dependent nature of the resource-based view, which is evolutionary by nature, is more suitable to relatively unchanging environments. It requires both internal organizational steadiness and external environmental steadiness to be applicable in reality (Killen, Jugdev, Drouin and Petit, 2012). Dynamic capabilities as an extension to the resource based view have taken steps to remedy the identified shortcomings, and have been identified as enabling the organizations/companies to respond to the rapid changes in dynamic and uncertain environments in which companies compete (Teece, 2007). Dynamic capabilities enhance value by re-configuring the present resource base, while the relative ease with which they may be developed or copied restricts their capacity to provide a lasting value independently (Eisenhardt and Martin, 2000). Consequently, the existence of both fundamental resource-based advantages, as well as dynamic capabilities, is essential for an extended term of competitive advantage in dynamic environments (Teece, 2007; and Teece, 2010).

The dynamic capabilities of an organization comprise of tangible and intangible assets, and the knowledge and the processes needed for recognizing new business opportunities and orchestrating its resource portfolio in uncertain and dynamic business conditions (Zahra and George, 2002; Ellonen, Wikstrom and Jantunen, 2009). Project portfolio management is central for most organizations, where the R&D process is crucial for successfully developing innovative products. These industries are embedded in a rapidly-changing environment and characterized as being hypercompetitive (D'Aveni, 1994; D'Aveni, 1998; Wang, 1997; and Liebeskind, Oliver, Zucker and Brewer, 1996). In such uncertain environments, projects serve as powerful vehicles for creating the required flexibility, supported by appropriate dynamic capabilities and structures to allow controllability (Biedenbach and Soderholm, 2008). Existing literature emphasizes that organizations utilize dynamic capabilities to gain competitive advantage (Eisenhardt and Martin, 2000; and Teece *et al*, 1997).

Wang and Ahmed (2007) identified three components of dynamic capabilities namely absorptive, innovative and adaptive. Absorptive capabilities are critical for organizations involved in R&D to apply the latest external knowledge through learning processes (Lane, Koka and Pathak, 2006). Innovative capabilities are essential for

developing products to refine or replace existing products (Subramaniam and Youndt, 2005). Adaptive capabilities are needed for identification and assessment of emerging market opportunities (Wang and Ahmed, 2007). Certain scholars believe that dynamic capabilities are the key to competitive advantage (Ambrosini and Bowman, 2009; Helfat and Peteraf, 2009; Teece *et al*., 1997; Teece, 2007; and Teece, 2010), while certain others argue that dynamic capabilities do not manifest the characteristics of heterogeneity, thus cannot be a source of competitive advantage (Eisenhardt and Martin, 2000; Li and Liu, 2012). Some believe the role of dynamic capabilities is limited and indirect (Wang and Ahmed, 2007); while others believe that environmental dynamism is a-key-driving force of dynamic capabilities (Teece, 2007). Earlier studies in this area focused mainly on firms operating in developed markets, and little had been learnt about what dynamic capability was and its relationship with competitive edge in developing economies. Since there is much dissimilarity between developed markets and transition economies, this narrow focus limits theoretical completeness and creates a gap in the dynamic capabilities literature.

OPEN INNOVATION

In an uncertain business environment where knowledge is widely dispersed, the innovation process has become more complex and there has been a gradual shift from a closed to an open model of innovation. A closed innovation strategy implies that the process of developing new products is undertaken by the firm's internal R&D department (Chesbrough, 2003a). In contrast, an open innovation model refers to a *'...paradigm that assumes that firms can and should use external ideas as well as internal ideas and external paths to market'* (Chesbrough, 2003a). The open innovation model has two dimensions: inbound and outbound (Chesbrough, 2003a). Inbound open innovation refers to leveraging the research and development of external agents and acquiring external knowledge resources from a network in order to develop new products. In contrast, outbound open innovation refers to the commercialisation of internal research and development outputs to external organisations (i.e. licensing, joint ventures, spin-offs).

The modern knowledge societies are characterized by the growing importance of intellectual property (IP) and knowledge-based technologies which contribute to economic growth and corporate competitiveness. In a "knowledge economy", knowledge has become a significant productive factor, an asset and commodity in its own right through the creation of knowledge-based technologies, as well as the emergence of new markets for technologies, and organizational exchanges (Drucker, 1993; Stehr, 2001). Knowledge "…*is economically relevant if it is utilizable and if it contributes to the value-add of companies and enhances their competitive advantages to ensure the efficient allocation of resources*" (Hayek, 1980: 78). This holds particularly true for technological inventions characterized by novelty and "useful" knowledge (Mokyr, 2002: 1-27). This type of innovative knowledge, which includes instructions and techniques usually stored in technical artefacts, is institutionally protected by patents.

Apart from leveraging external knowledge, the logic of innovation has undergone an additional transformation as firms are opening their boundaries to other partners and are giving access to their intellectual properties portfolio (i.e. outbound open innovation). The need to manage project portfolios well, and to learn from one project to the next, including aborted projects, is of vital importance, as the world becomes more project based and the business environment more dynamic and uncertain (Williams, 2007). In practise, private firms' aborted projects are not reviewed and published at all for various reasons. If they are reviewed, the methods don't account for complexity or try to explain causality, so there is no understanding about what went wrong (or right) and why; while the review process does not include reasons for whether or not to publish, and why, including selling the project knowledge for the purpose of recouping spent capital costs in aborted projects (Williams, 2007).

Organizations must be prepared to invest in the development of an uncertainty culture which supports the application of tools and processes, especially knowledge management that makes the uncertainty management effective (Karlsen, 2011). While PPM capabilities often have common elements, they cannot be transferred or acquired easily, and must be developed over time along maturity paths (Killen and Hunt, 2009).

CONCEPTUAL FRAMEWORK

Management research has increasingly contributed to theory building with respect to business strategy, project portfolio management, innovation and dynamic capabilities ensuring sustainable competitive advantage. Through new business models, companies create and deliver value for customers, and then convert payments received to profits (Eisenhardt and Martin, 2000; Teece, 2010). This research study, is focused on the approaches that help organizations efficiently manage their research and development investment project portfolio in uncertain business environments. Exploring the efficiency of portfolio approaches requires some context for what is considered to be "efficient". This requires examining the results of the portfolio management or the portfolio performance in terms of value maximization, business strategy alignment and portfolio balance.

A conceptual framework is a technique of structuring experiences and providing coherent ways of discerning about relationships, both of which are necessary in the creation of new knowledge (Brennan and Dooley, 2005). Conceptual frameworks are potentially valuable for problem solving in domains that are overly multifaceted and complex (Goodman and Lawless, 1994). They are also necessary in the formation of a world-view. "Everyone has a different world-view; we all have different constructs of reality, our perceptions, connotations, associations, sensations and languages" (Rhodes, 1991). Our interpretation of our world-view is based on our unique perceptual combination of internal (i.e. attitude, personality, etc.); communication and sharing of explicit and tacit knowledge is an important part of the creative process and the generation of creative and innovative ideas, thereby jumping from one conceptual space to the other, thus expanding our world-view (Brennan and Dooley, 2005). Due to rapid changes in research and development projects in the industrial markets (emerging technologies, changing customer needs, emerging and shrinking markets, and accelerating competition), deploying and understanding dynamic capabilities are key portfolio managerial concerns.

Despite the increasing awareness of patent exploitation, "they are kept on the shelf by the corporation throughout the patent's legal life" (Chesbrough, 2006a:3). Topical literature casts light on reasons for unused patents ("sleeping patents"). The number of patents is also used to signal innovativeness because it improves the technological image of companies (Gambardella, Harhoff and Verspagen, 2006). As intangible assets, patents can enhance the value of inventing companies and serves to establish "reputation motive" (Blind et al., 2006; Lerner, 1994).

The conceptual framework consists of six dynamic capabilities:

1. Sensing: Processes to sense, filter, shape, and interpret events and uncertainty;
2. Seizing: Opportunities seized, selection rules, business model used, and decision making protocols;
3. Transforming and reconfiguring: Characterization of changes to project portfolios; preserve competiveness by combining, enhancing, protecting and, where needed, reconfiguring the business's tangible and intangible assets;
4. Absorptive: external knowledge is taken-in;
5. Innovative: business's innovativeness to products and markets linked (Wang and Ahmed, 2007); and,
6. Adaptive: resources and capabilities are aligned (Teece, 2009; Teece, 2010; Petit, 2012; Petit and Hobbs, 2010; Wang and Ahmed, 2007).

The more efficient an organisation is in its PPM of R&D projects, the more efficient will its ability be to pass on social returns which will benefit society and more inventions are developed by the larger community of innovators.

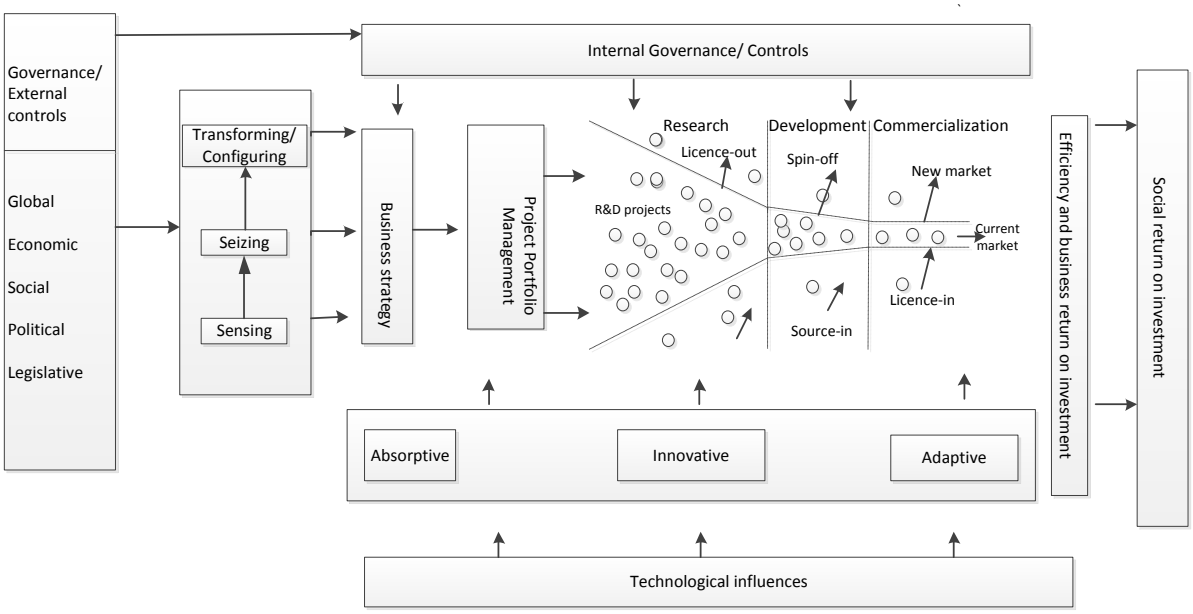

Figure 1: **Proposed conceptual framework.**

The conceptual framework is also characterized by the following:

- Business environment: the market, economic, technological, political, industry type, the rivalry, legal aspects and how dynamic the environment is;
- Business strategy: assumes that the strategy for organization, project portfolio and project is already decided. Will study to understand the vision, mission, and business strategy to assess how dynamic and uncertain business environment is managed;
- Governance: refers to decision structures which are at corporate, portfolio and project level. The government/parliament/congress in terms of influence would be greater in R&D projects which are funded by the state or other government agencies or partners. Rules, directives, organizational control procedures and guidelines. Governance and structure includes how projects are structured, which include functional organization, and alliances with external firms, especially where collaboration is at play;
- Project portfolio management: looks at the characteristics of the portfolio, history and dependencies between projects, as well as review. Refers to a process of selecting and evaluating new projects into the portfolio, and removing others;
- Efficiency and business return on investment: estimating the degree to which the portfolio fulfils its objects; strategic alignment/fit, balance across projects, and value maximization and the return on investment; and,
- Social return on investment: return on investment accrued to society at large.

RESEARCH DESIGN AND METHODOLOGY

The type of research study being undertaken in this project is a theory/model building study. Mouton (2001:176) describes such a study as

"....studies aimed at developing new models and theories to explain a particular phenomenon."

Good theories and models (Mouton, 2001:176): 1) provide causal accounts for the world; 2) allow us to make predictive claims under certain conditions; 3) bring conceptual coherence to a domain of science; and, 4) simplify our understanding of the world. Before selecting a research methodology, it is most important that the questions and data required to answer these questions should match, and this in turn is dependent on the research objectives and the status of the knowledge on the topic (Punch, 2006).

The objective of many scientific enquiries is to develop theories which can be generalized and can explain some form of causality of some phenomenon (Kinloch, 1977; Sutton and Staw, 1995; Weick, 1995b). This is difficult with a case study method only as a main methodology of collecting data. Mixed methodology is pursued

for this research. The conceptual framework, described above, was used to guide and structure the investigation, and will be modified with latest understanding as investigations progresses into Phase 2 and 3.

There are different types of Delphis; the three key types are (van Zolingen and Klaassen, 2003): 1) Classical Delphi; 2) Policy Delphi; and 3) Decision Delphi. The three Delphi types have intersecting characteristics; the primary difference is an emphasis on research objectives (Nielsen and Thangadurai, 2007). The Classical Delphi's main focus is on forecasting significant future developments. The Policy Delphi could be more accurately referred to as a "Strategic Planning and Public Policy" Delphi, since its main purpose is to generate alternative strategies and/or policy alternatives to achieve desirable goals and mitigate against undesirable consequences (Gordon, 2004a). The Decision Delphi engages all categories of relevant decision-makers in conceptualizing and describing problems associated with certain social developments. The aim is to improve the quality of decisions used to resolve social problems (van Zolingen and Klaassen, 2003). The Delphi research method, even though generally ignored by business researchers, has a proven track record in forecasting, public policy and strategic planning (Gordon, 2004a). Its utility is increased through enhancements, e.g. computer-mediated communication, cross-impact analysis and trend impact analysis.

The Delphi process is a structured, group-based information sharing method that generally proceeds through three phases: 1) identification of theses, problems or issues; 2) sharing of perspectives based on experience and knowledge; and 3) synthesis which may include a summary of the degrees of consensus and divergence among group members. Experts from the field/s relevant to the study are encouraged to generate ideas and think creatively as they move through these phases in a collaborative process to expand their horizons, and deepen their understanding of issues. The Delphi method is well suited to comprehensive investigation of complex environments characterized by uncertainty (Ziglio, 1996). It is based on a dialectical enquiry that encourages the sharing and exploring of divergent viewpoints (Nielsen and Thangadurai, 2007). The emphasis is not to secure a single, universal truth, but the range of quality ideas it generates, not only those around which consensus may form, since this may be less important to current investigators; according to Gordon (2004a:12)

"…a useful product of the delphi method is crystallization of reasons for dis-sensus."

A survey strategy is normally associated with the deductive approach and is a common and a popular strategy in business and management research. It allows for the collection of a large amount of data from a sizeable population in an economical way, whereby a sample of subjects is drawn from a population and studied to make inferences about it (Hussey and Hussey, 1997). The word survey normally indicates human respondents and the basic data is gathered by talking to people, either face to face, by means of telephone, over the internet, or by a written questionnaire (Jankowicz, 2005).

Table 2: Four worldviews

Postpositivism	**Constructivism**
• Determination • Reductionism • Empirical observation and measurement • Theory verification	• Understanding • Multiple participant meanings • Social and historical construction • Theory generation
Advocacy/Participatory	**Pragmatism**
• Political • Empowerment issue-oriented • Collaborative • Change-oriented	• Consequences of actions • Problem-centred • Pluralistic • Real-world practice oriented

Source: Creswell (2009)

To accomplish the research objectives by answering the research questions empirically, three phases of study is being followed. Phase I deals with answering research question 1 and 2, addressing a likelihood of a change in business strategy and the impact on R&D portfolio. Phase 2 is dealing with steps taken by companies to avoid destruction of shareholder value and maximize social return on investment in the event of R&D portfolio changes.

Phase 3 will deal with the development of a portfolio management methodology and the validation thereof using a Delphi study.

The study gathered survey data on South African R&D intensive manufacturing companies. Data was collected using an online instrument during phase 1. The questionnaire was developed by researcher and approved by the supervisor before being used in Phase one of the study and to be further refined of item wording and structure for use in Phase 2 and 3. To the extent possible, the questions were based on previous studies of open innovation and portfolio project management practices. Where scales are not available in literature, they are to be developed for the purpose of this research. The population was drawn from South African R&D intensive manufacturing companies, this population includes medium-sized enterprises (SMEs) as well as large organisations listed on the Johannesburg stock exchange (JSE).

R&D managers are considered the most suitable informants for our survey, because they are the most knowledgeable about the innovation-related aspects of their companies, which constitute the main focus of research questions. Nevertheless, in the case of companies devoid of these job titles/functions, the business owner or general manager was asked to participate. In cases where, only the general company email was obtained, the questionnaire was distributed internally from this email. Companies were screened out if they have no innovation-related activities. The online questionnaire resulted in 25000 company e-mails sent to approximately 6000 South African manufacturing companies, based on a rented data base. After several reminders, a total of 172 responses were returned. After screening for inconsistent answers, there were 161 usable questionnaires.

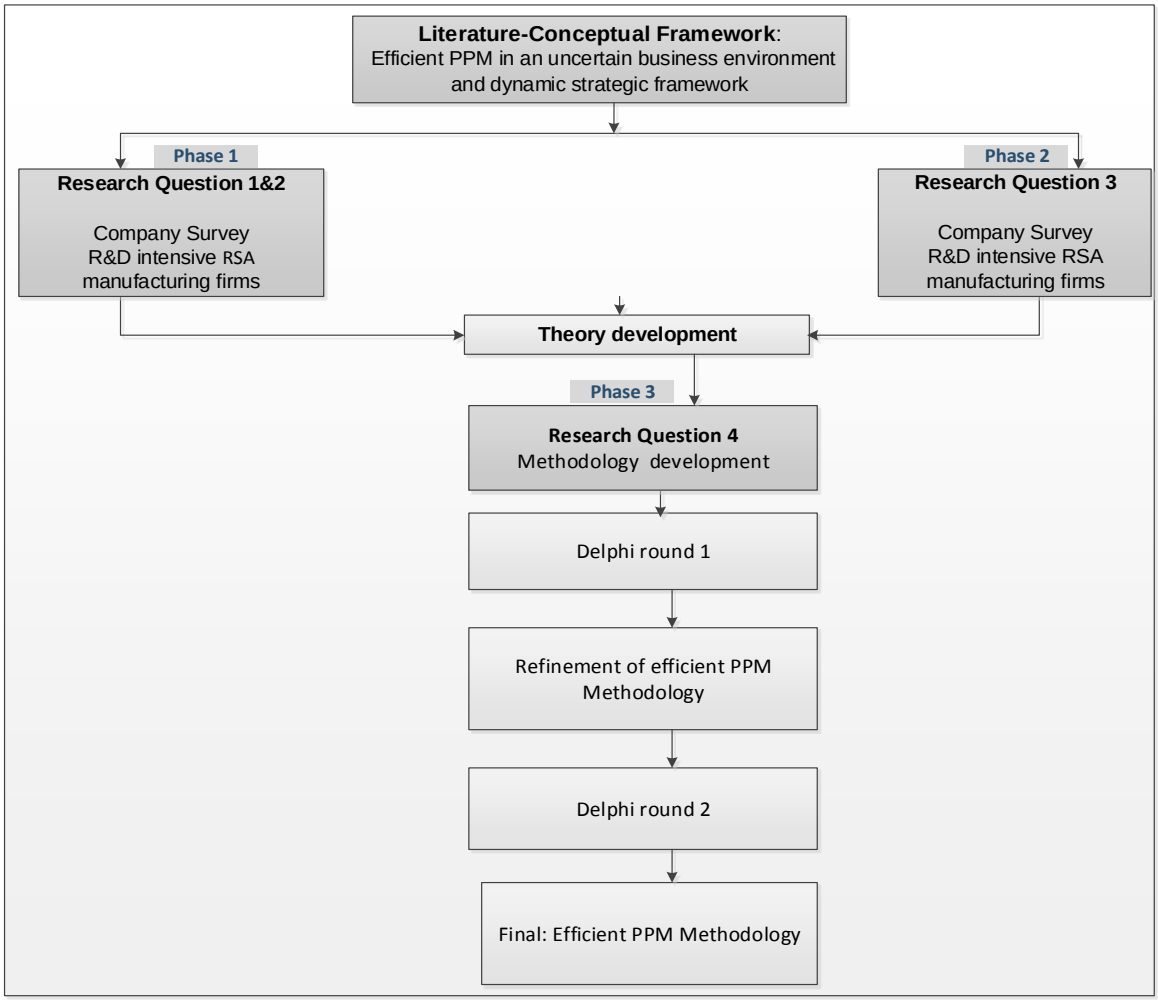

Figure 2: Research design approach and strategy

RESEARCH RESULTS AND CONCLUSION

A principle conclusion of the Phase 1 of this research is that *"internal inventions not being used in a firm's business should be taken outside the company (e.g. through licensing, joint ventures or spin-offs)"*. There is definite benefit in promoting the dissemination of R&D results outside of the private company. The ultimate argument is that the overall return on private R&D could be improved if these outcomes are freely available, especially if there is a change in strategy and the projects are discontinued for non-technical reasons. Uncertain business environment and consequent changes in company strategy have a negative influence on R&D portfolio value. Economic output can be increased by releasing the inherent value in unpublished and unexploited research results/knowledge. The deduction from the analysis, is that for a truly efficient project portfolio management in an uncertain and dynamic framework, value has to be extracted from aborted projects, as not all of them have no value.

Table 3: Key drivers of changes in business strategy affecting PPM

	Descriptive Statistics (Bonginkosi revised codes)							
Variable	Valid N	Mean	Median	Lower Quartile	Upper Quartile	Std.Dev.	Confidence SD -95.000%	Confidence SD +95.000%
Non-core innovations in the R&D portfolio	161	3.22981	3.00000	3.00000	4.00000	0.82347	0.74228	0.92476
Changes in the portfolio to align with business stratergy	161	3.53416	4.00000	3.00000	4.00000	0.77484	0.69845	0.87015
Changes in executive/senior management	161	2.95031	3.00000	2.00000	4.00000	0.90692	0.81750	1.01848
Lack of funds within the enterprise for R&D projects in the port	161	2.88198	3.00000	2.00000	4.00000	0.95772	0.86329	1.07552
Lack of funding from sources outside the enterprise	160	2.95625	3.00000	2.00000	4.00000	1.18876	1.07123	1.33550
R&D costs too high	161	3.21118	3.00000	3.00000	4.00000	0.91794	0.82744	1.03085
Lack of qualified personnel	161	2.91925	3.00000	2.00000	4.00000	1.00607	0.90688	1.12982
Information on technology	160	2.87500	3.00000	2.00000	3.50000	0.96966	0.87379	1.08935
Information on markets	161	2.95031	3.00000	2.00000	4.00000	1.07122	0.96560	1.20298
Difficulty in finding co-operation partners for innovation	160	2.85625	3.00000	2.00000	3.50000	1.00843	0.90872	1.13291
Market dominated by established enterprises	159	3.44025	4.00000	3.00000	4.00000	0.98463	0.88700	1.10660
Uncertain demand for innovative goods or services	159	3.16352	3.00000	3.00000	4.00000	0.94717	0.85326	1.06450

Table 4: Enterprise's level of knowledge and experience

	Descriptive Statistics (Bonginkosi revised codes)							
Variable	Valid N	Mean	Median	Lower Quartile	Upper Quartile	Std.Dev.	Confidence SD -95.000%	Confidence SD +95.000%
Most of the staff in our firm is highly skilled and qualified	161	3.72670	4.00000	3.00000	4.00000	0.96816	0.87271	1.08725
Our firm invests substantially in training	160	3.83750	4.00000	3.00000	4.00000	0.89644	0.80781	1.00709
Most of the time our firm is ahead of our competitors in developing and launching r	161	3.59627	4.00000	3.00000	4.00000	0.91773	0.82725	1.03061
Our firm has the ability to adapt other firms technologies	159	3.79245	4.00000	4.00000	4.00000	0.73841	0.66520	0.82988
Our firm innovates as the result of R&D carried out within our own firm	161	3.94409	4.00000	4.00000	4.00000	0.76033	0.68536	0.85385
Our firm innovates as the reult of R&D carried out outside of our own firm	160	3.41250	4.00000	3.00000	4.00000	0.92748	0.83577	1.04196
Our firm innovates as the result of R&D carried out within and also outside our own f	160	3.81875	4.00000	3.50000	4.00000	0.75960	0.68450	0.85337
Our firm has considerable resources and own knowledge resources for technological	159	3.81761	4.00000	3.00000	4.00000	0.92678	0.83489	1.04158
Our firm is able to introduce into the market innovations that are completely novel c	160	3.67500	4.00000	3.00000	4.00000	0.98766	0.89000	1.10957

Table 5: Use of other knowledge sources

Variable	Descriptive Statistics (Bonginkosi revised codes)							
	Valid N	Mean	Median	Lower Quartile	Upper Quartile	Std.Dev.	Confidence SD -95.000%	Confidence SD +95.000%
Employing key scientists and engineers (including poaching from other organizations)	161	3.06832	3.00000	2.00000	4.00000	1.06726	0.96203	1.19854
Acquiring key information at conference and workshops organized by industry associations	161	3.43478	4.00000	3.00000	4.00000	1.00487	0.90580	1.12848
Reverse engineering at technological knowledge embedded in products/developed produced by o	160	2.83125	3.00000	2.00000	3.00000	0.97916	0.88235	1.10025
Knowledge embedded in organisational processes or routines of other firms	161	3.06832	3.00000	2.00000	4.00000	0.94289	0.84993	1.05887
Publications in technical and scientific papers by other firms	161	3.24844	3.00000	3.00000	4.00000	1.06084	0.95625	1.19132

Table 6: External technology acquisition and exploitation

Variable	Descriptive Statistics (Bonginkosi revised codes)							
	Valid N	Mean	Median	Lower Quartile	Upper Quartile	Std.Dev.	Confidence SD -95.000%	Confidence SD +95.000%
Regularly search for external ideas that may create value for us	161	3.94409	4.00000	4.00000	4.00000	0.78460	0.70724	0.88111
We have a sound system to search for and acquire external technology and intellectual proper	161	3.56521	4.00000	3.00000	4.00000	0.91366	0.82358	1.02604
We often acquire technological knowledge from outside for our use	161	3.58385	4.00000	3.00000	4.00000	0.89134	0.80345	1.00097
We tend to build greater ties with external parties and rely on their innovation	161	3.37267	4.00000	3.00000	4.00000	0.97992	0.88330	1.10045
We welcome others to purchase and use our technological knowledge or intellectual property	161	2.78260	3.00000	2.00000	4.00000	1.17098	1.05552	1.31501
We make it a formal practice to sell technological knowledge or intellectual property in the ma	161	2.41614	2.00000	2.00000	3.00000	1.10994	1.00051	1.24647
We have a dedicated unit (i.e gatekeepers promoters) to commercialize knowledge assets (e.g	161	2.63354	2.00000	2.00000	4.00000	1.20254	1.08398	1.35046
We are proactively managing outward knowledge flow	157	3.15923	3.00000	2.00000	4.00000	1.11808	1.00659	1.25758

Table 7: Likelihood of a change in business strategy that will impact negatively on R&D project portfolio value?

Variable	Descriptive Statistics (Bonginkosi revised codes)							
	Valid N	Mean	Median	Lower Quartile	Upper Quartile	Std.Dev.	Confidence SD -95.000%	Confid e SD +95.00
Our organisation will keep an R&D project as part of the portfolio even if it is not aligned with business strategy	161	2.59627	2.00000	2.00000	3.00000	1.15314	1.03944	1.294
In our organisation it is likely that a change in business strategy will impact negatively on an R&D project portfolio va	161	3.16149	3.00000	2.00000	4.00000	0.98679	0.88950	1.108
What is the likelihood that an uncertain business environment and consequent changes in company strategy have a r	161	3.40372	4.00000	3.00000	4.00000	0.98981	0.89222	1.111
What is the likelihood that changes in the external and internal business environment may induce a redirection of co	161	3.31677	4.00000	2.00000	4.00000	1.06900	0.96361	1.200

The spillovers generate the so called social return on investment, which is shown to be at least 30% higher than that of the private return. In other words, there is considerable benefit in promoting the dissemination of R&D results outside of the private company. The ultimate argument is that the overall return on private R&D could be improved if these outcomes are freely available, especially if there is a change in strategy and the projects are discontinued for non-technical reasons. Uncertain business environment and consequent changes in company strategy have a negative influence on R&D portfolio value. Economic output can be increased by releasing the inherent value in unpublished and unexploited research results/knowledge.

Key drivers of changes in business strategy were the strategic alignment drivers and market drivers. Most South African manufacturing firms are carrying out R&D within and also outside the companies. The organizations that have some R&D capabilities within seems to benefit more from the absorption innovations form outside. Most firms in country are acquiring technologies from external sources. Not all rejected projects have no value, hence the rejection of projects may be caused by a changing strategic direction/fit, portfolio balance, limited resources, and new opportunities. Therefore, this leads to a deduction which states that, for a truly efficient project portfolio management in an uncertain and dynamic framework, value has to be extracted from aborted projects, as not all of them have no value.

ACKNOWLEDGEMENTS

Conducting PhD research parallel to a full-time job is always challenging, frequently frustrating and sometimes even impossible. Therefore, it is even more important to have a small circle of people who support this PhD process in different ways from the very beginning. The person I want to mention is my PhD supervisor, Professor David Walwyn who has been my pillar of strength through his academic advice and enthusiasm thus far. I would also like to thank Impala Platinum (Implats) for funding. Lastly, I would like to thank my family for their unending support and their never-ending belief in my capacity to finish this PhD.

REFERENCES

Abel-Hamid, T. K. 1990. The elusive silver lining: how we fail to learn from software development failures. *Sloan Management Review*, 32(1), 39-48.
Ambrosini, V. and Bowman, C. 2009. What are dynamic capabilities and are they a useful construct in strategic management? *International Journal of Management Reviews*, 11(1): 29-49.
Artto, K. and Dietrich, P. 2004. *Strategic business management through multiple projects.* NJ: John Wiley and Sons.
Atkinson, R., Crawford, L. and Ward, S. 2006. Fundamental uncertainties in projects and the scope of project management. *International Journal of Project Management,* 24 (2006)**,** 687-698.
Backer, 2008. Open innovation in global networks, OECD, Paris.
Bartezzaghi, E., Corso, M., Verganti, R. 1997. Continuous improvement and inter-project learning in new product development. *International Journal of Technology Management*, 14(1), 116-138.
Battelle, *R&D magazine,* 2014. 2014 global R&D funding forecast. *Battelle the business of innovation.*
Biedenbach, T. and Soderholm, A. 2008. The challenge of organizing change in hypercompetitive industries: A literature review: *Journal of change management,* 8(2), 123-145.
Biedenbach, T. and Müller, R. 2012. Absorptive, innovative and adaptive capabilities and their impact on project and project portfolio performance. *International Journal of Project Management.* 30 (5), 621–635.
Blichfeldt, B.S., Eskerod, P. 2008. Project portfolio management – there's more to it than what management enacts. *International Journal of Project Management* .26, 357–365.
Blind, K., Edler, J., Frietsch, R. and Schmoch, U. 2006. Motives to patent: Empirical evidence from Germany. *Research Policy*, 35(5): 655-672.
Brennan A. and Dooley, L. 2005. Networked creativity: a structured management framework for stimulating innovation Technovation. 25 (2005) 1388–1399.
Caffyn, S. 1997. Extending continuous improvement to the new product development process. *R&D Management*, 27(3), 253-267.
Chesbrough, H. 2003a. Open Innovation: *The new imperative for creating and profiting from technology*: Boston: Harvard Business School Press.
Chesbrough, H. 2006. Open Business Models: How to Thrive in the New Innovation Landscape. Boston, MA: Harvard Business School Press.
Chesbrough, H. and Vanhaverbeke, W. 2011. *Open innovation and public policy in Europe.* ESADE Business School & the science, Business innovation board AISBL.
Christiansen, J.K. and Varnes, C. 2008. From models to practice: Decision making at portfolio meetings. International Journal of Quality and Reliability Management 25 (1), 87–101.
Cooper, R., Edgett, S., Kleinschmidt, E., 2002. Portfolio management: fundamental to new product success. In: Belliveau, P., Griffin, A., Somermeyer, S. (Eds.), The PDMA Toolbook for New Product Development. John Wiley & Sons, New York.
Creswell, J.W. 2009. Research Design. 3rd ed. California: Sage Publications, Inc.
D'Aveni, R.A. 1994. Hypercompetition: Managing the Dynamics of Strategic Manoeuvring. New York: Free Press.
D'Aveni, R.A. 1998. Waking up to the new era of hypercompetition. The Washington Quarterly, 21, 183–195.
Dietrich, P. and Lehtonen, P. 2005. Successful management of strategic intentions through multiple projects. Reflections from empirical study. *International Journal of Project Management*, 23(2005), 386-391.
Drucker, P. 1993. *Die postkapitalistische Gesellschaft*. Düsseldorf: ECON.
Dumbleton, J. H. 1986. Management of high-technology, Research & Development. Elsevier, Oxford.
Eisenhardt, K. M. and Martin, J. A. 2000. Dynamic capabilities: What are they? *Strategic Management Journal*, 21(10/110), 1105-1121.
Ellonen, H., Wikstrom, P. and Jantunen, A. 2009. Linking dynamic-capability portfolios and innovation outcomes. *The international journal of technological innovation and technology management.* 29(11), 753-762.
Gambardella, A., Harhoff, D. and Verspagen, B. 2006. *The Value of Patents*. NN.
<http://www.ffii.se/erik/EPIP2006/Alfonso%20Gambardella_Value%20of%20
Patents.pdf; 02/10/2010>.
Ghauri, P.N. and Gronhaug, K. 2001. Research methods in business studies: A practical guide, 3rd ed., Prentice-Hall, London.

Goodman, R.A., Lawless, M.W. 1994. Technology and Strategy—Conceptual Models and Diagnostics. Oxford University Press, Oxford.
Gordon, T.J. 2004a. The Delphi method. In: Glen, J.C., Gordon T.J. (Eds.), Futures research methodology. American council for the nation's university millennium project, Washington, D.C.
Grand, S., von Grogh, G., Dorothy, S. and Swap, W. (2004). Resource allocation beyond firm boundaries: a multi-level model for Open Source innovation, Long Range Planning. 37(6) 591-610.
Griliches, Z. 1992. The search for R&D spillovers, *The Scandinavian Journal of Economics* 94: 29-47.
Gupta, A.K. and Wilemon, D. 1996. Changing patterns in Industrial R&D Management. *Journal of Product Innovation Management*, 13(6), 497-511.
Hall, B. H., J. Mairesse, and Mohnen, P. 2010. Returns to R&D and productivity. In Hall, B. H. and N. Rosenberg (eds.), *The Handbook of the Economics of Innovation, Volume 2*. Amsterdam: Elsevier.
Hamel, G. 1991. Competition for competence and inter-partner learning within international strategic alliances. *Strategic Management Journal*, Summer Special Issue, Vol. 12, pp. 83-103
Hayek, F. (1980): *Individualism and economic order*. Chicago u.a.: University of Chicago Press.
Helfat, C., and Peteraf, M. A. (2009). Understanding dynamic capabilities: Progress along a development path. Strategic Organization, 7(1), 91–102.
Hussey, J. and Hussey, R. 1997. *Business Research: A practical guide for undergraduate and postgraduate students.* London, Macmillan.
Huber, G. P. 1996. Organizational learning: a guide for executives in technology-critical organizations. International Journal of Technology Management, Special Publication on Learning, 11(7/8), 821-832.
Jankowicz, A.D. 2005. *Business Research Projects.* 4th edition, London: Thomson Learning.
Japan Patent Office, *Overview of the Result of the 2008 Survey of Intellectual Property-Related Activities*. Cited in Japan Patent Office, *Open Innovation and Intellectual Property*, 2010, p. 18.
Karlsen, J.T. 2011. Supporting culture for efficient project uncertainty management. *International journal for managing projects in business.* 4(2), 240-256.
Killen, C.P. and Hunt, R.A. 2009. Project portfolio management maturity model for dynamic environments. Modernisation in project management.
Killen, C.P., Jugdev, K., Drouin, N. and Petit, Y. 2012. Advancing project and portfolio management research: Applying strategic management theories. *International Journal of Project Management*, 30(2012), 525-538.
Kinloch, G.C. 1977. *Sociological Theory: Its development and major paradigms,* New York: Montreal, McGraw-Hill.
Lane, P. J. and Koka, B. and Pathak, S. 2006. The reification of absorptive capacity: a critical review and rejuvenation of the construct. Academy of Management Review Vol. 31 (4) 833-863.
Lemmens, T. 2013. Pharmaceutical knowledge governance: *A human rights perspective. Global health and the law*.
Lerner, R. (1994). Revolutions Revisited. *Two faces of the politics of enlightenment*.
Li, D. and Liu, J. 2012. Dynamic capabilities, environmental dynamism, and competitive advantage: Evidence from China. *Journal of Business Research*.
Liebeskind, J.P., Oliver, A.L., Zucker, L. and Brewer, M. 1996. Social networks, learning and flexibility: Sourcing scientific knowledge in new biotechnology firms, Organizing Science, 7(4): 428-443.
Love, J. H., Roper, S. and Bryson, J. R. 2011. Openness, knowledge, innovation and growth in UK business services. *Research Policy*, 40(10): 1438-1452.
Martinsuo, M., Lehtonen, P. 2007. Role of single-project management in achieving portfolio management efficiency. International Journal of Project Management 25 (1), 56–65.
Martinsuo, M., Lehtonen, P. 2009. Project autonomy in complex service development networks. International Journal of Managing Projects in Business 2 (2), 261–281.
Martinsuo, M. 2012. PPM in practice and in context. *International journal of project management*,
Maskus, K.E. and Reichman, J.H. 2004. The globalization of private knowledge goods and the privatization of global public goods. Journal of international economics law. 7(2), 279-320.
Meskendahl, S. 2010. The influence of business strategy on project portfolio management and its success – a conceptual framework. International Journal of Project Management 28 (8), 807–817.
Miller, R. 2002. A framework for analysing the development and delivery of large capital projects, Cleland, D. and Pinto, J. (eds.), PMI.
Milosevic, D. and Srivannaboon, S. 2006. A theoretical framework for aligning project management with business strategy, *Project Management Journal,* ABI/INFORM Global, 98-110.

Mohnen, P. 1996. R&D externalities and productivity growth, *OECD STI Review* 18: 39-66.
Mokyr, J. 2002. *The Gifts of Athena. Historical Origins of the Knowledge Economy*.
Princeton: Princeton University Press.
Morris, P. W. G. and Jamieson, A. 2005. Moving from corporate strategy to project strategy. *Project Management Journal*, 36(4), 5-18.
Morse, J. 2003. Principles of mixed methods and multi method research design. In A. Tashakkori & C. Teddlie (Eds.), Handbook of mixed methods in social and behavioural research (pp. 189-208). Thousand Oaks, CA: Sage.
Muller, R., Martinsuo, M., and Blomquist, T. 2008. Project portfolio control and portfolio management performance in different context. *Project management journal.* 39(3), 28-42.
Nielsen, C. and Thangadurai, H.C. 2007. "Janus and Delphi oracle: Entering the new world of international business research", *Journal of international management 13: 147-163.*
Perminova, O., Gustafsson, M. and Wikstrom, K. 2008. Defining uncertainty in projects - a new perspective. *International Journal of Project Management,* 26**,** 73-79.
Petit, Y. 2012. Project portfolio management in dynamic environments: organizing for uncertainty. *International Journal of Project Management*. 30, 539-553.
Petit, Y. and Hobbs, B. 2010. Project portfolios in dynamic environments: Sources of uncertainty and sensing mechanisms. *Project Management Journal*, 41(4), 46-58.
Project Management Institute, 2008. *A Guide to the Project Management Body of Knowledge (PMBOK),* PMI.
Project Management Institute (PMI). 2008. *The standard for portfolio management.* Newtown Square, PA. PMI.
Punch, K.F. 2006. *Developing effective research proposals,* Second edition, London, UK.
Reichman, J.H. 1989. *Intellectual property in international trade: Opportunities and risks of a GATT connection*. 22 Vand. J. Transnational L.
Rhodes, J. 1991. Conceptual Toolmaking Expert Systems of the Mind. Blackwell, Oxford.
Roper, S. and Arvanitis, S. 2012. From knowledge to added value: A comparative, panel-data analysis of the innovation value chain in Irish and Swiss manufacturing firms. *Research Policy*, 41(6): 1093-1106.
Shenhar, A. (2004), Strategic Project Leadership: Towards a strategic approach to Project Management. *R&D Management*, 569-578.
Shenhar, A. and Dvir, D. 2004. *How projects differ and what to do about it. Handbook of Managing Projects*, NJ: John Wiley & Sons. Inc.
Shenhar, A.J., Milosevic, D., Dvir, D. and Thamhain, H. 2007. *Linking Project Management to business strategy*. Project Management Institute (PMI), Inc.
Shih, F. 1998. Triangulation in nursing research: issues of conceptual clarity and purpose.
Journal of Advanced Nursing, 28(3): 631-641.
Smith, G., Pearson-Taylor, J., Anderson, D. and Marsh A. 2007. Project valuation, capital investment and strategic alignment – Tools and techniques at Anglo Platinum. *The Journal for the Southern African Institute of Mining and Metallurgy,* 107, January 2007.
Srivannaboon, S. 2006. Linking Project Management with Business Strategy, *Project Management Journal*, ABI/INFORM Global, 88-96.
Srivannaboon, S. 2006. *Towards a contingency approach: Tailoring project management to achieve competitive advantage*. PICMET Proceedings, Istanbul, Turkey.
Srivannaboon, S. and Milosevic, D. 2004. *The process of translating business strategy in project actions.* Project Management Research. PMI, 175-192.
Stehr, N. 2001. *Wissen und Wirtschaften*. Frankfurt a. M.: Suhrkamp.
Subramaniam, M. and Youndt, M. A. 2005. The influence of intellectual capital on the types of innovative capabilities. *Academy of Management Journal*, 48(3): 450-463.
Sutton, R.I. and Staw, B.M. 1995. "What Theory in not", *Administrativ*e science quarterly, vol. 40, no. 3.
Sveikauskas, L. 1981. Technology inputs and multifactor productivity growth. *Review of Economics and Statistics* 63: 275-282.
Sveikauskas, L. 2007. R&D and Productivity Growth: A Review of the Literature. BLS working papers. U.S. Department of Labor. U.S. Bureau of Labor Statistics. Office of Productivity and Technology.
Teece, D.J., Pisano, G., and Shuen, A. 1997. Dynamic capabilities and strategic management. Strategic Management Journal 18, 509–533.
Teece, D.J. 2007. Explicating dynamic capabilities: The nature and micro foundations of (sustainable) enterprise performance. *Strategic Management Journal*, 28(13), 1319-1350.

Teece, D.J. (2009). *Dynamic capabilities and strategic management-organizing for innovation and growth.* New York, NY: Oxford University Press.
Teece, D.J. 2010. Technological innovation and the theory of the firm: The role of enterprise-level knowledge, complementarities, and (dynamic) capabilities. *Handbooks in Economics, Volume 01.*
Terleckyj, N. 1974. Effects of R&D on the Productivity Growth of Industries: An Exploratory Study, National Planning Association, Washington, 1974.
Tharp J. 2007. *Align Project Management with Organizational Strategy.* PMI Global Congress Proceedings – Budapest.
Troy, I. 2012. Patent transactions and markets for patents dealing with uncertainty. *ZuidamUithof Drukkerijen, Utrecht*.
Van Zolingen, S.J. and Klaassen, C.A. 2003. Selection processes in a Delphi study about key qualifications in senior secondary vocational education. Technological Forecasting and Social Change 70 (4), 317-340.
Von Zedtwitz, M. 1999. Managing interfaces in international R&D. Dissertation Nr. 2315 der Universität St. Gallen, Difo-Druck OHG, Bamberg.
Walwyn, D. 2010. *Determining research and development expenditure targets based on an affordability Index*. Pretoria: Department of Engineering and Technology Management. University of Pretoria.
Wang, Q. 1997. R&D/marketing interface in a firm's capability-building process: evidence from pharmaceutical firms. *International Journal of Innovation Management.* 1 (1) 23-52
Wang, C.L. and Ahmed, P.K. 2007. Dynamic capabilities: A review and research agenda. International Journal of Management Reviews, 9(1), 31–51.
Wang, Y., Vanhaverbeke, W. and Roijakkers, N. 2012. Exploring the impact of open innovation on national systems of innovation – A theoretical analysis. Technological Forecasting & Social Change 79 (2012) 419-428.
Ward, S. and Chapman, C. 2003. Transforming project risk management into project uncertainty management. *International Journal of Project Management*, 21, 97-105.
Weick, K.E. 1995b. "Sources of order in under-organized systems. Themes in recent organizational theory' in *Organizational theory and inquiry: The paradigm revolution.* Y. S. Lincon (ed.). Beverly Hills, CA: Sage.
Wheelwright, S., Clark, K. 1992. Revolutionizing Product Development: Quantum Leaps in Speed, Efficiency, and Quality. Free Press, New York.
Williams, T. 2007. Post project reviews to gain lessons learned. Project Management Institute, Inc.
Zahra, S. A. and George, G. 2002. Absorptive capacity: a review, reconceptualization and extension. *Academy of Management Review*, 27(2): 185-203.
Ziglio, E. 1996. The Delphi method and its contribution to decision-making. In M. Adler & E. Ziglio (Eds.), *Gazing into oracle: The Delphi and its application to social policy and public health.* London, England: Jessica Kingsley.