MANAGING INNOVATION IN THE CONSTRUCTION INDUSTRY

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The candidate confirms that the work submitted is her own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

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Abstract

Many years of research on innovation has proved that innovation is the linchpin for the survival and growth of organisations. Moreover, scholars have spotted the importance of innovation in the construction industry. This research was an investigation into the management of innovation for the facilitation of the design and maintenance of a favourable environment in order to increase the potential of organisations to innovate. Supported by the notion of equifinality in open systems where an end state can be reached by many potential means, actions that facilitate innovation need to be organisation specific. Towards this end and being in line with the Schumpeterian perspective, this text emphasises the importance of increasing organisations' potential to innovate. A generic holistic model of innovation and a generic system for depicting innovation practice in organisations, both developed applying grounded theory techniques, are initially introduced. Then, they are combined together to illustrate a generic mechanism of innovation. This generic mechanism of innovation was applied using a survey within the specific context of the construction industry in the UK. The generic mechanism of innovation was systematised within a software program developed, named InnoAct. InnoAct can be used as a tool, which can be customised according to individual organisational characteristics, for evaluating and monitoring the innovation potential of organisations and for providing alternative scenarios which can facilitate the decision making process towards increasing the potential to innovate. Finally, a procedure using Program Logic Modelling was developed for facilitating the systematic evaluation of organisational performance towards innovation. The proposed procedure can be used to provide trainers and researchers with a new perspective in the study of innovation management and alert managers and policy makers of their need to take appropriate actions to increase performance towards innovation and, in effect, increase economic growth.

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Abbreviations

A

AIP	Actual Innovation Potetnial
APEC	Asia Pacific Economic Cooperation

C

CIB	Construction Industry Board
CoPS	Complex Product Systems

D

DTI	Department of Trade and Industry

E

EM	Expectation Maximisation
ERP	Enterprise Resource Planning

F

FIT	Frequency of occurrence, Intensity of strength of the given effort, Targeted at a specific market or audience

G

GDP	Gross Domestic Product
GERD	Gross Domestic Expenditure for Research and Development

H

HR	Human Resources
HRD	Human Resource Development
HRM	Human Resources Management

I

ICT	information and communication technologies
IIP	Ideal Innovation Potential

K

KM	Knowledge Management

M

M4I	Movement for Innovation
MADM	Multiple Attribute Decision Making
MAR	Missing At Random
MAUT	Multi-Attribute Utility Theory
MCAR	Missing Completely At Random
MNAR	Missing Non At Random

N

NAIP	New Actual Innovation Potential of an organisation
NAO	National Audit Office,
NFTA	North American Free Trade Agreement

O

OECD	Organisation for Economic Co-operation and Development

P

PLM	Program Logic Model
PPP	Public Private Partnership

R

R&D	Research and Development
RBV	Resource Based View
RIP	Residual Innovation Potential

S

SD	standard deviations
SAW	Simple Additive Weighting
SMART	Specific, Measurable, Action oriented, Realistic, Timed

T

TQM	Total Quality Management

V

V&V	Validation and Verification
VBA	Visual Basic for Applications

"An innovation is rarely the product of a solitary genius, beavering away in splendid isolation; rather, it is invariably the culmination of a collaborative endeavour."

H.-J. Lamberti, Deutsche Bank AG

CHAPTER 1: INTRODUCTION

The purpose of this chapter is to introduce the key aspects of this research (research problem, aim, objectives, research scope and limitations) and outline the features and the structure of the thesis.

Specifically this chapter:

- Presents the background to the thesis outlining the importance of the construction sector and the calls for change that makes innovation be of significant importance;
- Describes the evolution of research on innovation management and highlights what has been the focus of research in the area of innovation management until recently;
- Presents the grand theories that provide the theoretical basis of the research;
- Demonstrates the research problem identified in the area of innovation management whose solution this work sought to address;
- Specifies the aim and objectives of this research providing a useful basis upon which the entire thesis can be evaluated;
- Presents the scope of this research highlighting the boundaries of the research in terms of industry sector, time and economic setting;
- Outlines the research limitations and the shortcomings providing the context of the models developed;
- Describes the structure of the thesis summarising the organisation of the contents and the relationship between the different chapters; and
- Summarises what this chapter has achieved and how it leads to the next chapter.

1.1 Background

The construction industry is considered as the lynchpin of development in achieving wealth and quality of life in every economy. There is a relationship between a firm's profitability or future success and its ability to innovate within the construction industry. Therefore, construction organizations need to improve their competitive advantage and respond to changing technology and thus they can only survive and proliferate through innovation, (Brennan and Dooley, 2004).

Design and construction markets currently face many drivers for increased project performance, including new materials of construction, new facility designs involving greater complexity and requiring increased quality, shorter schedules, and decreased investment. The internal dynamics of construction organizations, the external environment in which they operate and the strategic resources that they have, must be such, that they can respond to change by adapting their orientation to reflect, and be able to respond in a demanding and most competitive environment (Steele and Murray, 2000).

This research presents a new and holistic approach for managing innovation. This holistic approach attempts to move from partially capturing innovation to encapsulating its multidimensionality. It takes into account the fact that innovation can be distributed across many actors, has socioeconomic and political influences, and is affected by practices in each organisational discipline Organisations need to address all of those challenges holistically using an integrative approach and by developing their ability to reflect on the calls for change by increasing their potential towards innovation. The management of innovation is the 'vehicle' for creating competitive advantage and increasing performance that can lead to proliferation and growth.

Organisations are called upon to refocus and adjust in a process of continuous improvement and transformation and to use their internal capabilities and resources to change. Given that the overall performance of construction industry is interdependent of a variety of factors and innovation adoption rates depends on the internal, external environment and strategic resources, this research contributes in the area of construction industry offering new theoretical and practical insights for facilitating innovation adoption and improvement in performance. Innovation can be the key for an organisation to respond to those challenges and successfully exploit new ideas, implement new practices and new procedures and turn them into economic benefit.

1.2 The evolution of research in innovation management

Management of innovation has evolved over time and an understanding of innovation models can be achieved through examining the evolutionary stages of research in this area. Interest in innovation research can be seen to have started in the 1950s when new industries emerged and industrial activity expanded (Niosi 1999 and Rothwell 1994). This new technologically intensive era of research, known as the "technology push" period was dominated by focusing on Research and Development (R&D) and the continuous production of new products for the market, while paying little attention to the market's real needs (Tidd 2006). Conceptual models in innovation research during this period have depicted innovation as technologically driven (technology push models). These models limited innovation management to the organisations' ability to invest in R&D activities, which could lead to radical changes and disregard incremental changes.

In the mid 1960s, the market revealed the need to approach innovation differently and reallocated the interest from the creation of new products to identifying the market 'need'. Increased competition in the market's environment changed the focus from increasing productivity to strategic marketing. This so-called "marketing pull" period was characterised by marketing pull models that focussed on market driven R&D activity and led to incremental changes in products or processes to meet customer requirements (Tidd 2006).

In the early 1970s, constrained resources enforced minimisation of cost (Rothwell 1994) and a radically different way of managing the innovation process was introduced (Niosi 1999 and Rothwell 1994). This so-called "coupling elements" period focused on the interaction of R&D and marketing strategies so as to yield more commercially successful results. This research period showed that innovation could be better managed by increasing competency on many elements and activities, paying attention to the interaction of the different elements and the feedback loops between them (Rothwell 1994). However, the multidimensional approaches to innovation management tended to consider organisations as independent entities and did not account for the interactions with the external environment and its financial stability that could directly influence the innovation potential of organisations as recently seen after the 2008 global economic crisis.

In the early 1980s until the early 1990s, innovation research was characterised by an increased focus on strategic alliances and networking activity between companies (Rothwell 1994). Performance and market share were related to the speed in development. The Japanese ‘Just in Time’ model introduced the concept of parallel development and integration of activities and it was seen as enabling a more rapid and efficient innovation process. However, this goal-oriented model has been considered to be restrictive because it minimises the importance of managing unexpected changes, which could also include other opportunities for exploitation.

The current generation of innovation research is identified to have started in the early 1990s and is dominated by focusing on the elements identified within the previous generations such as strategic networking, time-based strategies, better integration of product design and manufacturing, organisational flexibility and adaptability (Rothwell 1994). Attention now is also given to the linkages with the globalised market environment and the world economy, and how they directly affect innovation within organisations. In this period, some conceptual models of innovation management depict innovation as new product development only – they disregard the linkages with the process of innovation and are therefore considered to only be partial models. Other models associate innovation competences with capabilities of human resources in R&D teams only, thereby, reducing the capacity of organisations to benefit from all employees’ creativity (Tidd 2006).

The exploration of the evolution of research in innovation management and its key outputs, as discussed above, led to the identification of the grand theories that are relevant to innovation management. The grand theories provided better understanding in the wider topic of innovation and contributed in the identification of the theoretical construct of this research.

1.3 The grand theories and the theoretical construct

In order to depict the theoretical construct to this research the grand theories that are relevant to the field of managing innovation were identified. Those grand theories were the systems theory, the diffusion theory and the strategic resources theory.

1.3.1 The systems theory

The systems theory approach has dominated the management and organisational theories, as opposed to the traditional approach which concentrated on task and structure, and the human relations theory approach which concentrated on people (Jackson, 2000). The 'holism' of the systems approach provided insights into organisations examining them as 'wholes' and not looking at different disciplines in isolation (Jackson, 2000). In systems theory, a system can represent a situation by describing the following basic characteristics: elements and relationships.

Elements are the representation of the phenomena that the observer agrees that exist in order to describe the system and gain insight. An element can be denoting behaviour in the way that a characteristic of that behaviour in terms of quality or property can change. A relationship exists between two elements if the behaviour of its characteristics are either influenced or controlled by others. Any characteristic ascribed to an element or a relationship is termed attribute of that element (e.g. colour, texture, size) or that relationship (e.g. intensity, speed). The attribute changes of the elements and their relationships are of prime interest. Feedback on the influence that an element has on other elements through a series of relationships is the effect of the initial influence that feeds back to itself (Flood and Carson, 1993). It is obvious that it is almost impossible to change an element of a system without creating chained changes in other elements that interface or interact with the first element.

The system of an organisation is also examined in relation to its environment, which contingency theorists argue has direct influence and interdependence (Jackson, 1991). There are two types of systems; closed and open systems. In closed systems, the boundaries of the system are defined in a theoretical construct in an absolute manner such as the relationships of elements in the system while elements outside the system do not exist. In open systems, conversely, exchanges of e.g. materials, information, and or energy occur across boundaries. In a business organisation system, an organisation always interacts and exchanges information with the environment in which it operates and therefore business organisations are better represented as open systems.

According to systems theory, organisations form a complex system of interrelated processes meaning that if in an organisational context a business process changes it creates a challenge for changing other business processes to facilitate the first change. Innovation as an improvement process needs a lot of other changes in other business processes and elements to facilitate its improvement (Jackson, 2000). Furthermore, incremental improvements occurring during the innovation process need to be diffused throughout the organisation system and challenge other possible elements that interact with the initial incremental improvement within the internal environment of the organisation as well as the external environment.

1.3.2 The diffusion theory

The term ‘diffusion’ refers to the phenomenon of the spread in space or acceptance in a human environment, over time, of some specific item or pattern (Gomulka, 1990). The term ‘diffusion’ is used in physics to describe the spread of matter, in anthropology to describe the spread of an idea or a pattern of culture, in sociology to describe the spread of a practise, and in economics to describe the spread of a product or a method. All of these different areas of study use the notion of diffusion to identify factors that can influence (facilitate or resist) the process of spread, discover the precise relations between these factors and the rate of spread within a given environment (Gomulka, 1990).

The diffusion of innovations theory defines diffusion as the process by which an innovation is communicated through channels over time among members of a social system (Rogers, 2003). In an organisational context, the diffusion of innovations theory suggests that there are contextual factors that affect the diffusion of innovations (Rogers, 2003; Askarany, 2005; Askarany and Smith, 2008). Those factors include: 'characteristics of innovations' e.g. relative advantage, complexity, compatibility, observability and trialibility of innovation/s, 'characteristics of adopters' e.g. organisational size, organisational structure, organisational culture, organisational strategy, and other influential factors related to particular country or environment e.g. the level of development of a country, the local regulations and policies, communication channels, infrastructure provision (Askarany and Smith, 2008).

Facilitation, acceleration and sustainability of the innovation diffusion process is a necessity for organisations to be able to survive within the fast changing environments and respond to the continuous call for change (Hivner, Hopkins and Hopkins, 2003). In order to capture the diffusion process and the factors that can impact the acceleration of diffusion of any incremental improvements in the open system of an organisation, it is necessary to gain understanding on whether organisations are making the most out of what is impacting the innovation process.

1.3.3 The resource based theory

The resource based theory views organisations as a combination of resources and capabilities based on what the organisation has (Lagnevik, 2003). Resources are defined as: 'all assets, capabilities, organisational processes, firm attributes, information, knowledge, etc. controlled by the firm that enable the firm to conceive of and implement strategies that improve its efficiency and effectiveness' (Daft, 1983). The Resource Based View (RBV) contributions to organisational performance have been relevant to various different fields of study including human resource management (attraction, development, motivation, and retention of people) (Wright, Dunford and Snell, 2001), economics and finance (performance, innovation activity), entrepreneurship (understanding market opportunities, coordination of resources), marketing and internationalisation of business (Barney *et al.*, 2001).

1.4 Research Problem

As shown in Section 1.2 the exploration of the evolution of research in innovation management and innovation models reveals the tendency to approach the management of innovation in a limited way, as a result of partially encapsulating important factors (Tidd 2006). However, the review of the grand theories as seen in Section 1.3 reveals that organisations are complex systems of interrelated disciplines and processes and innovation is an improvement process that needs to be facilitated, through diffusion processes and the use of resources, and by changes in other business processes (Askarany & Smith 2008). In the context of the 'holism' of the systems approach, organisations as ‘wholes’ need to manage innovation by focusing on all of the different disciplines examined in relation to their environments, which have direct influence and interdependence (Jackson 1991). The grand systems theory, diffusion theory, and resource based theory constitute the theoretical background of the research and raise the importance of key issues in studying the management of innovation. A holistic approach towards conceptualising innovation provides the opportunity to understand and manage innovation more effectively within specific contexts.

The fragmented nature of the construction industry, as demonstrated in detail in Chapter two, and the large number of actors involved in the delivery of a project reduces the opportunities for changes as they may have implications on the processes of other industry actors. However, a wide range of factors that affect the development of products, processes and services in the construction industry can impact the changing process, and construction organisations need to respond to those changes if they are to survive and grow. Chapter two also demonstrates that there are continuous and urgent calls for change in the construction industry. Construction organisations have to deal with an ever changing environment where globalisation forces, the world market economy, climate change and new technologies are continuously changing the rules, calling for immediate realigning of capabilities and resources to meet rapid changes. Furthermore, it is now generally recognised, within the construction industry, that there is a relationship between an organisation’s efficiency and growth and its ability to innovate (Manseau and Shields, 2005).

Managing innovation in the construction industry has been one of the main research interests in recent years and an important issue addressed by many researchers. Gann and Salter (Gann and Salter, 2000) have explored the management of innovation in project based service enhanced forms of enterprise and demonstrate that the ability to bring cultural changes while maintaining engineering and technical expertise is the blue print for competing in international markets. Langford and Male (Langford and Male, 2001) recognised innovation as a source of competitive advantage in construction that can be brought from: innovation in materials that rests outside of the contractor's control; in the production process; in the 'organisation' of production that is related with the level and type of subcontracting; in financial management; and in codes and standards that can achieve technology transfer. Langford and Male (Langford and Male, 2001) classified innovation in construction into four categories: technological innovation, organisational innovation, product innovation and process innovation. Manseau and Seaden (Manseau and Seaden, 2001) offered an international analysis on the instruments that the governments are using to promote innovation in construction. Jones and Saad (Jones and Saad, 2003) suggested that innovation in the construction sector remains impeded due to the limited response to factors such as: awareness of the need to change; responsiveness to internal and external change; linkages within and between organisations; strategic holistic and systematic approach; culture conducive to learning and innovation; and commitment. Egbu (Egbu, 2004) explored the importance of knowledge management and intellectual capital in organisations and introduced a holistic approach involving many factors towards achieving effective knowledge management. Miozzo and Dewick (Miozzo and Dewick, 2004a) explored the relationship between the organisational networks and innovation in construction and suggested that performance in construction industry depend upon inter-organisation cooperation. Inter-organisation cooperation according to Miozzo and Dewick (Miozzo and Dewick, 2004a) includes the relationship of contractors with subcontractors or suppliers of materials, the government, universities, architects, engineers, clients and international collaborations. Manseau and Shields (Manseau and Shields, 2005) studied the role governments and state organisations play, as clients, in supporting construction innovation. They elaborated on the importance of construction sector to the economy and also on the relationships of the actors involved in the construction process. Taylor and Levitt (Taylor and Levitt, 2005) also studied systemic innovation in terms of inter-organisational networks and demonstrate how networks adopting systemic innovation that exhibit strong relational stability, network-level interests, fluid boundaries, and the existence of an agent for network level changes perform comparatively better than other networks.

In spite of the large amount of research in the area of innovation management during the past fifty years, there is much less knowledge about why and how innovation occurs than what it leads to. Although it is well established that innovation is an organisational phenomenon and include a wide variety of factors playing an important role towards innovation, a holistic approach in addressing the totality of the factor does not exist. Furthermore, the general understanding of why innovation can emerge from all those factors, how it operates at the organisational level environment and how it is integrated into other systems/environments remains fragmentary. Moreover, particularly in the construction sector, the vast majority of research contributes to understanding innovation in the sector level and the project level to the detriment, of the construction organisation as being the unit of analysis (Reichstein, Salter and Gann, 2008). Further conceptual and applied research is needed in this area (Fagerberg, Mowery and Nelson, 2005).

The discussion above illustrated the research problem providing the background to this research. The aim and objectives of this research are presented in the following sections.

1.5 Research aim and objectives

Arising from the evolution of research, the grand theories principles and the research problem as demonstrated in the sections 1.2, 1.3 and 1.4 above, this research was undertaken with the following aim and the objectives.

1.5.1 Research Aim

The aim of this research was to investigate the management of innovation for facilitating the design and maintenance of a favourable environment in order to increase the potential of organisations to innovate.

1.5.2 Research objectives

In order to be able to accomplish the aim of the research, the following research objectives were pursued:

Objective 1: To develop a generic holistic model of innovation;

Objective 2: To develop a generic system for depicting innovation practice and describe the generic mechanism of innovation for the construction industry in the UK;

Objective 3: To apply the generic mechanism of innovation to the specific context of the construction industry in the UK for exploring innovation practice and describing the specific mechanism of innovation for the UK construction industry;

Objective 4: To model the generic mechanism of innovation;

Objective 5: To systematise the generic mechanism of innovation;

Objective 6: To develop a generic systematic procedure for facilitating the management of innovation; and

Objective 7: To evaluate the proposed systematic procedure.

The objectives of the study were achieved through a complex iterative process that involved:

- Literature Review
- Primary data collection through a questionnaire survey
- Statistical data analysis using the Statistical Package for Social Scientists (SPSS)
- Interpretation of the analysis results;

- Mathematical modelling;
- Computer programming using Microsoft Visual Basic for applications; and
- Program logic modelling.

1.6 Scope of the research

The scope of the research in this thesis can be described under four headings: industry sector, time, economic setting and specification of the approach in managing innovation.

1.6.1 Industry Sector

The construction sector is formed from many different disciplines and as such, many different actors that play a distinguished role in the construction process. The different actors that can be involved in the construction process can be: architects, building contractors, builders, building materials suppliers, chartered surveyors, civil engineering consultancies, mechanical/electrical contractors, property developers, interior designers. This research is designed to address all actors since innovation is viewed as an essential element in all disciplines and activities are often integrated and complementary.

1.6.2 Time

The time of the study was set in June 2006 when the primary data collection was undertaken. That period was characterised by an intense construction activity in the UK which commenced with the International Olympic Committee awarding the 2012 Olympic Games to London on the 6th July 2005. The total budget for the construction of the Olympic venues was £7 billion and the construction activity was accelerated at that time. The research was undertaken at a specific time point and is therefore cross sectional. As a cross section study the responses to the survey questionnaire are related to the specific economic conditions and the general economic activity of the construction sector at that time.

1.6.3 Economic Setting

The economic setting of this research is the UK economy. UK is a developed country with a GDP growth rate 2.8% (2009/2010). The choice of the country was based on the ease of access to information and in order to keep the cost of collecting the primary data within manageable limits.

1.6.4 Specification of the approach in managing innovation

Management is defined as the 'process of designing and maintaining an environment in which individuals, working together in groups efficiently accomplish selected aims' (Koontz and Weihrich, 2007, p.5). As such, management involves planning, organising, staffing, leading and controlling functions (Koontz and Weihrich, 2007). The approach of this research in managing innovation is in terms of designing the right environment by increasing the possibilities for innovation to emerge. This research focuses on facilitating the planning, the organisation, the staffing, and the leading functions of managing innovation.

Management is also concerned with productivity that implies efficiency and effectiveness (Koontz and Weihrich, 2007). This research focuses on increasing efficiency and effectiveness of organisations towards innovation with the overall aim to increase growth. The scope of this work is in line with the Schumpeterian perspective of producing innovations that create monopolistic advantages over competitors resulting in profits for organisations (Mueller and Cubbin, 1990). This text continues its emphasis on the importance of innovations towards maximising organisations' potential for increasing growth.

1.7 Research Limitations

Innovation as a process can be seen as a dimension of a socio-technical system. As such, socio-technical systems as described by Sommerville (Sommerville, 2004) include one or more technical systems and also include knowledge of how the systems should be used to achieve some broader goal. Socio-technical systems usually have some defined operational processes, include the operators (people) as inherent parts of the system and are governed by organisational policies and rules but at the same time they can be affected by external constraints such as national laws and regulatory policies (Sommerville, 2004). According to Sommerville (Sommerville, 2004) the characteristics of socio-technical systems, are that they are non deterministic by means that when there is specific input it is not always certain that it will produce the same output. The extent to which the system supports the organisational goals does not only depend on the system itself. As such, the extent to which the organisation system supports innovation does not only depend on the organisation system itself. Socio-technical systems have emergent properties, which are properties of the system as whole and not properties of a part of a system.

The non deterministic behaviour of a socio-technical system means that the system behaviour depends on the system operators that are the people who do not always react in the same way. Furthermore, interaction of the system divisions may create new relationships that can change its emergent behaviour. Innovation, as an organisational goal is supported by the system divisions and the extent to which it is supported also depend on the stability of those goals, the relationships and conflicts between the organisational goals and how people interpret these goals. New management may reinterpret the innovation goal which can then lead to a ‘failure’.

The emergent properties that innovation can bring to the organisation depend highly on the complex relationships of the organisation’s divisions and thus they can only be evaluated when those divisions are integrated and functioning. The organisation divisions are interdependent and failure in one division can be propagated into the system and affect the operation of other divisions. It is often difficult to predict how an organisation’s division failure propagates and the consequences that it may have to the other divisions. The overall socio-technical system reliability also depends upon the probabilities of the technical systems to fail and how long the repair can take and the probability of the operator to make an error. The entire above are closely linked. A failure in one of the divisions can have a spurious effect on the outputs of the organisations independently of the input sometimes. The management of innovation is thus dependent on the organisation's divisions, on the people who run the organisation and how they operate together while performance on innovation is hard to assess and can only be measured when the system is operational.

1.8 Structure of the thesis

The structure of the thesis aims at maintaining the story line created by the position that there is need in using a holistic approach to address why and how innovation occurs. This can be achieved by identifying the mechanism of innovation in the construction industry using as the unit of analysis construction organisations in the UK. Such improvement can be brought about using the proposed procedure. The structure of the thesis is presented in the paragraph below.

A general introduction of the research project as well as the research problem, the aim and the objectives of this research is presented in Chapter 1 entitled "Introduction". In Chapter 2, entitled "Innovation in the Construction Industry" the nature of the construction industry is explored, the concept of innovation in the construction industry is presented, and the major reforms and drivers for innovation are demonstrated. In Chapter 3, entitled "Research Philosophy and methods" the research design and methodology adopted is explained. In Chapter 4, entitled "A generic holistic model of innovation", the first objective of the research that refers to the development of a generic holistic model of innovation is addressed. Chapter 5, entitled "A generic system for depicting innovation practice", addresses the second objective of the research that refers to the development of a generic system for identifying innovation practises in the construction industry in the UK. In Chapter 6, entitled "Exploring Practices of Innovation in the Construction Industry in the UK", the practices adopted by the construction industry are explored. Chapter 7 entitled "Modelling the mechanism of innovation" addresses the fourth objective of the research that refers to the development of a mathematical model and describes the integration of the factors identified to affect innovation and the innovation practices. Chapter 8, entitled "Systematising the management of innovation", addresses the fifth objective of the research that refers to the development of a computer application that can operationalise the mathematical model. Chapter 9, entitled "The Program Logic Model", addresses the sixth objective of the research that refers to the development of a generic proposed procedure for facilitating the management of innovation in the construction industry. Chapter 10 entitled "Evaluation and Implementation of the Program Logic Model" addresses the seventh objective of the research that refers to the testing and the assessment of the potential usefulness of the PLM. Finally, Chapter 11 entitled "Conclusion and recommendations" demonstrates the contribution of the research to knowledge and identifies the issues that require further work.

1.9 Summary

This chapter has described the lack of a holistic approach in the area of managing innovation and highlighted the need to identify how and why innovation occurs in the construction industry. It has also described the boundaries within which this research was undertaken and identified the context of the contents of this thesis. This chapter has provided the outline of the entire thesis and highlighted the relationship between the different chapters.

This chapter has also demonstrated the research problem that is established on the grand theories that provide the theoretical construct and the way innovation management has been addresses until recently by other scholars. The next chapter explores innovation in the construction industry providing more details on the nature of the construction industry, the concept of innovation and the major reforms and drivers for innovation within the industry.

CHAPTER 2: INNOVATION IN THE CONSTRUCTION INDUSTRY

The construction industry is a major driver of activity in an economy and as such is considered a crucial industry for achieving wealth and quality of life. In parallel, during recent decades innovation has been identified by many nations as an important factor for economic growth and wealth creation (Crosthwaite, 2000, p. 138; Murray and Langford, 2003; Manseau and Shields, 2005; Research and Markets, 2010). This chapter:

- Discusses the nature of the construction industry under the headings: types of products, nature of delivery, product life cycle and projects actors;
- Explores the concept of innovation and its scope in the construction industry; and
- Identifies the major reforms and innovation drivers for the construction industry.

2.1 The nature of the construction industry

The construction industry includes various actors (e.g. clients, materials and components suppliers and contractors), and offers a wide range of products and services (e.g. house-buildings, commercial properties, infrastructure, industrial structure and/or general subcontracting materials or services). The construction industry is mainly comprised by many small organisations and a high labour intensity. It is highly dependent on public regulations and public investments and is thus used as an indicator for macroeconomic trends, restricted in periods of economic expansion and stimulated especially in periods of recession (Research and Markets, 2010). It has been described by various authors under the following dimensions:

- type of products;
- nature of delivery;
- product life cycle; and
- project actors.

2.1.1 Types of products

The construction process can be traced back throughout the history of humanity, when the construction of shelters to protect humans from the natural environment was the ultimate need. In ancient Greece public buildings, civil works, great temples and private houses reveal even today the building processes and specifications used then. A constant demand for the evolution of structural and design standards so as to increase the comfort within all kinds of structural systems has led to a radical change in construction practices in recent times. Human needs for high quality standards of living, use of technologically advanced materials and processes, and information and communication technologies (ICT) have changed the types of products needed to be more in alignment with cultural and population characteristics (size, growth, density, distribution, age, gender and ethnicity) (Ashworth, 2006).

The types of products in the UK construction industry can be segmented into four main sectors: house building (private and public residential buildings), infrastructure (rail, highways, airports, etc.), industrial construction (energy factories, agriculture, manufacturing, etc.) and commercial construction (hospitals, education, hotels, department stores, offices etc.). The largest sector in the UK construction industry is the commercial construction sector (the repair and maintenance sector is not included) and is followed by the house-building sector (Research and Markets, 2009).

All types of structures are forced into continuous reformation due to changes relating to demand and human wellbeing. Today's construction industry calls for structures that are designed to meet the different client requirements, policy regulations, and environmental concerns and at the same time host a wide range of invented facilities like: heating, ventilation and cooling systems; fire and security; and elevation systems which have gradually become a necessity (Manseau and Shields, 2005). These necessities have enforced the construction process to continuously change and innovate.

2.1.2 Nature of delivery

The construction industry is characterised by high complexity with interconnected systems and a small change to an element within the system may lead to large changes to other elements of the same system or to other integrated systems (Ball, 1988; Gann & Salter, 2000; Slaughter, 1998). As such, construction can be viewed as a complex systems industry and construction projects can be seen as complex systems that are high cost and are formed by many interconnected and often customised parts including control units, sub-systems, and components, designed in a hierarchical manner and for specific customers (Hobday, 2000). In complex systems industries, changes within the production process or to the materials used by an organisation have to be implemented in a project and not just within the organisation that brings about the change (Manseau and Shields, 2005).

Moreover, each project is unique, and each construction site has different ground and climate characteristics. Even similar designs have to address these different site conditions thus making each project unique. Manseau & Seaden (2001) particularly stress that although there have been many positive initiatives towards industrializing the process of construction though prefabrication, modularisation standardisation and other manufacturing-type production techniques, due to the variable site requirements, the durability of the product, and the impact on the surrounding community, the construction industry remains unique and significantly different in its characteristics from other industrial sectors.

The complexity and the project based nature of each project increase the difficulty to apply knowledge gained to projects constructed elsewhere. The nature of work in the construction sector implies that firms have to manage ‘networks’ of highly ‘complex interfaces’ that influences the opportunity for changes to be applied widely elsewhere (Gann and Salter, 2000).

2.1.3 Product life cycle

Construction firms focus on types of projects that are driven by local or regional demand for infrastructure, commercial buildings and private houses. Once installed, some Complex Product Systems (CoPS) i.e.: intelligent buildings and computer integrated manufacturing systems; further evolve as users expand, optimise, adopt, and operate the system (Gann as cited in Hobday, 2000).

After the long lasting duration of a project expires, facilities are often renovated and modernised rather than demolished and built new as is often the practice with other kinds of products in other industries such as manufacturing (Manseau and Seaden, 2001). New facilities are required in order to use old buildings, although those were not included during the initial design phase.

Novel approaches for converting the use of buildings have to be explored and necessary repairs have to be applied to improve and sustain the structures. Sustainability in current design techniques is the expression of the need to facilitate those future born requirements that emerge over the years, increasing at the same time the complexity of the design phase and the cost of construction.

2.1.4 Project actors

The construction industry as a complex systems industry is comprised of supply network actors, project-based firms, and users; institutional and regulatory actors; and technical support infrastructure actors as illustrated in Figure 2.1 below.

The supply network actors in the construction industry (Manseau and Seaden, 2001, p.3) includes:

- Building materials suppliers who provide the basic materials for construction such as lumber, cement and bricks.
- Machinery manufacturers who provide the heavy equipment used in construction such as cranes, graders and bulldozers.

- Building product component manufacturers who provide the subsystems (complex products) such as air quality systems, elevators, heating systems, windows and cladding.

Project-based firms in the construction industry (Marceau *et al.*, 1999; Carassus, 2004) include:

- On-site service providers involved in new construction, refurbishment and repair works (Carassus, 2004). They include sub-assemblers (specialty trades and installers) who bring together components and materials to create such sub-systems; and developers and facility assemblers (or general contractors) who co-ordinate the overall assembly.
- Client services providers which include facilities/building operators and management who manage property services and maintenance; facilitators and providers of knowledge/information such as scientists, architects, designers, engineers, evaluators, information services, professional associations, education and training providers; and providers of complementary goods and services such as transportation, distribution, cleaning, demolition and disposal (Manseau and Seaden, 2001, p. 3).

Clients are the beneficiaries of the projects and the ultimate end users. The different end users are indicating the details of a project. Each project then needs to be uniquely specified by its developers. As such, all projects are demand driven and therefore difficult to be standardised.

Institutional and regulatory actors who provide the general framework conditions which includes financial and business institutions, government agencies and business/trade general labour regulations and standards.

The technical support infrastructure the educational and R&D institutions, the professional associations and the government agencies that provide the necessary technical R&D and communication support for the construction industry (Manseau and Seaden, 2001, p. 3).

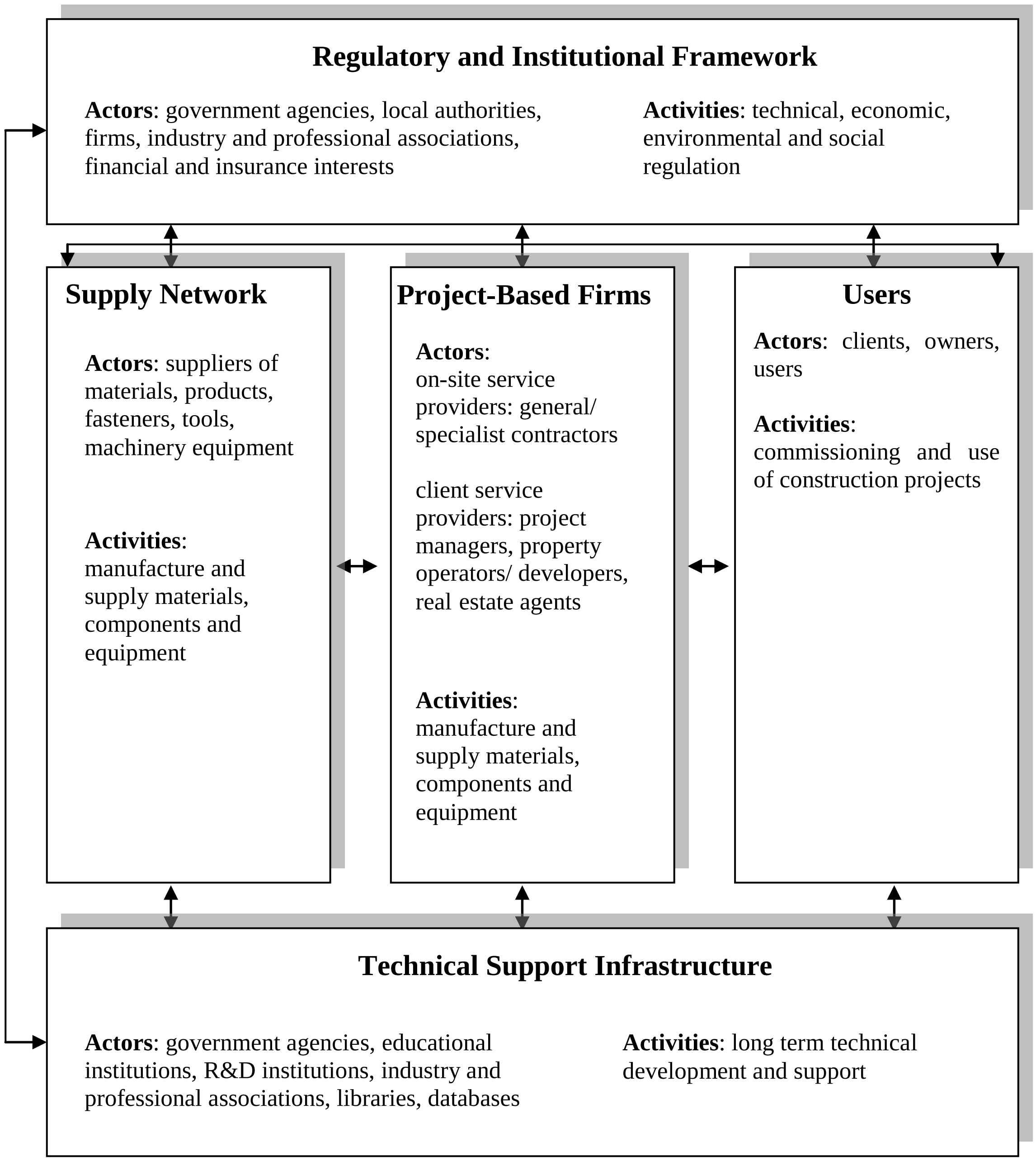

Figure 2.1 Actors in the building and construction project based system, as in Gann and Salter (2000).

A construction project can be viewed as a focusing device which enables different actors to cooperate and agree to the fine details of a complex system's development and production. The project is the driving instrument for realising the market's needs, for coordinating decisions across firms, for enabling buyer involvement, and for matching technical and financial resources through time. The project serves as a communication platform for architectural, design and construction knowledge by integrating the distinctive resources, know-how, and skills of the collaborators (Hobday, 2000). To face these challenges construction firms are led to organise their business activities leading to project-based structures. Project based firms in the construction industry may carry out huge projects where they do not have large span of control as there are many actors involved and may either be in the position of the contractor or the subcontractor. Clients also play a key role in construction innovation since projects are delivered according to their specific requirements and needs, which vary widely, and may address, among others, demand for new materials, novel designs and sustainability criteria. The complicated system and the key actors of the construction sector, described above, implies that innovation in construction may occur in a wide variety of economic and productive arenas through combining technical expertise from other organisations (Gann and Salter, 2000).

The discussion above shows that the construction industry is highly fragmented. The nature of the construction process allows firms which are mainly small in size to control only small sectors of the construction process and depend highly on the network and the cooperation developed among the members of the network. Divisions and the different actors that struggle for advantage demonstrate that novel approaches need to be adopted for managing more effectively the delivery of projects.

2.2 The concept of innovation

The nature of the construction industry as described in the previous section reveals that the industry is complex and highly fragmented, project-based, and is characterized by short term partnering between organisations which are not necessarily located in the same region and acting at varying levels of project maturity. Based on those characteristics it is not surprising that the industry is also known for its conservative culture with a relatively high resistance to change (Research and Markets, 2010). However, new technologies and materials that promise to increase efficiency within a wide spectrum of an organisation’s activities and manufacturing processes emerge, and construction organisations are called to adopt them and innovate in order not to be left behind.

Innovation in the construction industry can be understood by exploring: general definitions of innovation, the organisational context of innovation and the scope of innovation within the construction industry.

2.2.1 General definitions of innovation

Schumpeter (Schumpeter, 1934) was one of the first to state that, economic development which resulted from continuous structural and economic change was the outcome of innovation as a driving force. Schumpeter conceptualized innovation as 'a continuous struggle between entrepreneurs who are advocating novel solutions and the social inertia' (as cited in Fagerberg, 2003, p. 6). Schumpeter focused on innovation as developing and implementing a new idea (Van de Ven *et al.*, 1999). Schumpeter's later studies emphasized the importance of co-operative entrepreneurship in achieving rewarding innovations (Fagerberg, 2003).

In the Innovation Report (DTI, 2003) of the Department of Trade and Industry, innovation is defined as the successful exploitation of new ideas which may be entirely new to the market or involve the application of existing ideas that are new to the innovating organisation or often a combination of both. This definition suggests that innovation involves the creation of new designs, concepts and ways of doing things, their commercial exploitation, and subsequent diffusion through the rest of the economy and society.

The Australian National Training Authority (ANTA, 2002) captures the essence of innovation from an overall perspective defining innovation as a new idea or a new use of an old idea which adds value for the end user.

2.2.2 Organisation context of innovation

'Innovativeness' is the term to describe a measure of the degree of 'newness' of an innovation. 'Highly innovative' products are seen as having a high degree of newness and 'low innovative' products are seen as having low degree of newness (Garcia and Calantone, 2002, p.112). The degree of newness depends on *whose* perspective this newness is being viewed from and *what* is new. Although the majority of research takes a firm's perspective toward newness, other research looks at new to the world (Song, Montoya-Weiss, as cited in Garcia and Calantone, 2002), new to the adopting unit (Ettlie, Rubenstein as cited in Garcia and Calantone, 2002), new to the industry (Colarelli as cited in Garcia and Calantone, 2002), new to the market (Meyers & Tucker; Kleinschmidt & Cooper as cited in Garcia and Calantone, 2002), and new to the consumer (Atuahene-Gima as cited in Garcia and Calantone, 2002). In the work of Damanpour and Gopalakrishnan (Damanpour and Gopalakrishnan, 1998) the term 'innovativeness' is referred to 'the rate of adoption i.e. the number of innovations the organisation adopts within a given period'. Building on the previous work of defining innovativeness, an organisation's perspective of innovativeness can be conceived as a measure of increasing its innovation mentality.

On a broader level, the Organisation for Economic Cooperation and Development categorizes innovation in the Oslo Manual on the basis of international research across a number of industries (Anderson and Manseu, 1999). That research has revealed that innovation across sectors does not occur at the same rate or speed. Sectoral analysis of innovation provides a rich source of information in determining factors contributing to innovation and success of some organisations compared to others. Heterogeneity of innovations is not only realized in different organisations but also in different divisions of the organisations (Brown, 2000). Therefore the analysis of the contextual factors within specific industries may result in different factors playing a key role to innovation (Brown and Maylor, 2005). However, sometimes it seems that organisations across sectors may adopt good innovation practices occurring in different sectors in order to innovate fast and successfully (Brown and Maylor, 2005).

Other research of Schumpeter, Lundvall and Nelson (as cited in Fagerberg, 2003) used the spatial approach to analyze innovation on the basis of systems approach and interdependencies within countries or regions. The systems perspective of analyzing innovation includes the interactions of the involved actors of the system and the nature of complementary components where the absence of one results in the slowdown of the growth of the whole system.

Some literature describes innovation as: ‘new products’, ‘new processes, ‘new sources of supply’, ‘exploitation of new markets’ and ‘new ways to organise business’ (Anderson and Manseu, 1999; Fagerberg, 2003). Innovation is also described in other literature as ‘incremental’ or ‘radical’ changes. *Incremental innovations* most often appear as small changes in the already developed products or systems. It is the exploitation of further knowledge of the already existing knowledge base having a low breadth impact (Koberg, Detienne and Heppard, 2003; Manseau and Shields, 2005). *Radical innovations ‘is a completely new concept’* (Manseau and Shields, 2005) and creates a new market with new competitors, new firms and new customers. According to Garcia and Calantone (Garcia and Calantone, 2002) radical innovations often address a demand not previously recognised by consumers.

In a wider context, innovation does not occur in isolation from products or processes or services but is the simultaneous ongoing improvement of all levels of the organisation’s ability to innovate (Pisano, 1997; Brown and Maylor, 2005). Innovation can occur as incremental or radical changes, can involve many actors and is influenced by the different environmental setting (e.g. country or sector) in which it emerges. It is therefore necessary that organisations organise, reorganise, and, if necessary, entirely readjust, transform and reinvent themselves in order for innovation to occur.

2.2.3 Scope of innovation in the construction industry

The scope of innovation in the construction industry has also been researched by various authors (Tatum, 1987; Toole, 1998; Seaden and Manseau, 2001). In Seaden &

Manseau (Seaden and Manseau, 2001, p. 186), construction industry literature sources show a variety of definitions for innovation:

- 'Application of technology that is new to an organisation and that significantly improves the design and construction of a living space by decreasing installed cost, increasing installed performance, and/or improving the business process' (Toole, 1998);
- 'The successful exploitation of new ideas, where ideas are new to a particular enterprise, and are more than just technology related – new ideas can relate to process, market or management'(Construction Research and Innovation Strategy Panel, 1997);
- 'Apply innovative design, methods or materials to improve productivity' (Civil Engineering Research Foundation (Civil Engineering Research Foundation, 1993);
- 'Anything new that is actually used' (Slaughter, 1993); and
- 'First use of a technology within a construction firm' (Tatum, 1987).

Different concepts of innovation are understood by different actors involved in the construction of projects and the definitions are widely debated. Slaughter (Slaughter, 1998) conceptualizes innovation in the construction industry as the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change. The focus of this research is based on the definition by Slaughter who captures innovation in an overall context addressing where innovations can occur i.e. in processes, products and systems and underlines the novel change that has to be performed in the organisation in order to improve.

Innovation in the construction industry can take many forms. Slaughter (Slaughter, 1998) characterizes innovation according to whether it is 'incremental' (small, and based on existing experience and knowledge), 'radical' (a breakthrough in science or technology), 'modular' (a change in concept within a component only), 'architectural' (a change in links to other components or systems), or 'system' (multiple, integrated innovations).

In the construction sector most construction innovations occur in the production of materials and manufacturing of components where R&D was performed for developing those innovations (Manseau and Shields, 2005). Such innovations are easier to disseminate to contractors since they don't need readjusting other sections of the work. However innovation of managerial and organisational methods are also important (Manseau and Shields, 2005).

The increasing and complex demand of future construction projects will drive a fragmentation of the design and construction industry into two main types of organisations: those that are innovative and able to adapt and change, and those that remain traditional. Strong current drivers clearly indicate this trend. Increased understanding and application of the knowledge relating to the innovation process can provide an essential distinctive competence for the innovative organisations (Sexton and Barrett, 2003).

2.3 Major reforms and innovation drivers in the UK construction industry

The importance of innovation in the UK construction industry can be traced from the calls for new methods, practices, etc. These calls can be clearly seen from published construction reports and initiatives or macro level environment forces.

2.3.1 Construction reports and initiatives

A review on the reports that have been published since World War II is revealing that construction industry has been continuously encouraged to change and improve its performance. The most important reports and their drivers are presented in Table 2.1.

Table 2.1 Important Reports 1944-2002

Report	**Theme**	**Driver**
Simon 1944	Placing of public	Constructors want less bureaucratic

	contracts	tendering in Government contracts. Escape from competitive tendering.
Phillips 1949	Organisation and efficiency of the building industry	Public clients seek better performance from the industry through improvements in labour productivity and the management of the construction process.
Emmerson 1962	Greater integration of the design and the construction process	Constructors want a continuous stream of work less dependent on open tenders and incomplete design information.
Banwell 1964	Management of the building process	Constructors look to Government to regulate the planning of contracts. Public contracts negotiable.
What is wrong on site? (Tavistrock 1965 and 1966, Large industrial sites 1970)	Industrial relations on Large sites	Clients want better control of projects and industrial relations in particular.
Wood 1975	Placing of public contracts via package deals	Constructors want more negotiated work and final contracts. Architects alarmed.
Faster Building for Industry, NEDO 1983	Productivity in building factories and warehouses	Property developers (clients) want US construction times for UK.

Faster Building for Commerce, NEDO 1988	Productivity in commercial construction	Property developers (clients) want faster construction times for office blocks.
Latham 1994	Relationships between the parties to the construction process	Both clients and constructors gain: clients through better performance, constructors through better cash management.
Technology Foresight 1995	Return to an industry planning model not seen since 1960s	Political, social and technical alignment of a changed agenda set by Government. Prepares the ground for Egan.
Egan 1998	Performance and productivity of the industry	Clients want and get greater authority over the constructors.
Egan 2002	Accelerating increase in performance	Clients want leadership and integrated teams.

Source: Table adapted from Murray and Langford (2003).

Although all the reports have indicated the need for change, important issues such as procurement, relationships and performance were recurring themes indicating that little change has been achieved. The analysis that follows focuses on the reports published after 1990s, when a very deep economic recession had already started in 1989 and the interaction of the construction industry with the general economic conditions came into focus.

In 1994, the report *Constructing the Team*, by Sir Michael Latham (Latham and Great Britain Department of the Environment, 1994) was published. The report focused on the issue of achieving the client's satisfaction, raising the importance of cooperation and teamwork, and reviewing procurement and contractual arrangements. The key recommendations made in the Latham report focused on:

- the benefits of partnering arrangement between the contractor and the client on the basis of reducing disputes and hostility by acting as a team;
- resolving delayed payment disputes of contractors and subcontractors by motivating clients to use trust funds;
- the settlement of disputes by arbitration to remove the costs of litigation;
- the development of a central public sector registry of qualified contractors and consultants where clients could search tenders only from this list in the context of encouraging long term relationships and partnering; and
- the use of standard tender documents, contracts and simple forms of minor works documentation.

Significant change in legislation that prompted major amendments to standard form construction contracts was the outcome of the Latham report. Namely, the Housing Grants, Construction and Regeneration Act 1996 came into effect. Redesign of the Act and changes concerning late payments and dispute resolution came into effect in 1998 (Murray and Langford, 2003). Partnering became more popular especially for large and more complex projects as a means of reducing the greater risks and the possible disputes. Overall, the report encouraged a cultural change in the industry.

In 1995, the Technology Foresight report, *Progress through Partnership*, was published. The report focused on the need to recognise the importance of the UK research and its link to national wealth. The need to align the Government initiatives, the industry and academia was in the focus and the six key challenges identified were (Murray and Langford, 2003):

- to reduce cost, add value, and sharpen international practice;
- to consider more the environmental and social consequences;
- to strengthen technological capability;
- to improve education and training;
- to upgrade existing buildings and infrastructure; and
- to re-engineer basic business processes.

The report stressed the importance of increasing funding for research into innovation and recognised that innovation is the dominant force for change, survival and growth. The report proved to be influential as research gained more importance and became an instrument of policy. Research was forwarded to the needs of the industry in increasing efficiency and improving management techniques (Murray and Langford, 2003).

The next major reflection to the need for change was improving the quality and performance of the UK construction industry articulated in Sir John Egan's report (Egan, 1998), *Rethinking Construction*. The report stressed the need for a change in style, culture and processes focusing on key drivers of committed leadership, on the customer, on the integration of process and the team around the project, and on a quality driven agenda. The report led to initiatives for achieving the ambitions of modern construction industry and proposed annual targets of improvement. The report key recommendations were:

- constructing excellence to establish new thresholds of performance based on cross industry networking and collaboration - introduction of independent and objective assessments of performance indicators for measuring project and organisational performance;
- lean construction/off-site focusing on a sustained programme for improvement and for the production and delivery of components such as off site prefabrication requiring new relationships between these supply chain members and new ways of working - typically, this involves CAD, standardised products, computer modelling of erection/installation of components, off-site fabrication, use of sub-assemblies, JIT delivery in 'bundles' by plot or floor etc;
- supply chain management focusing on long term relationships and improvement throughout the supply chain introducing the culture of partnering; and
- project collaboration systems that can allow for real time exchange of information, drawings, specifications, time scales and budgets, and are used to increase the data flow, reduces errors, and 'as-built' records are stored electronically.

The Egan report proposed annual targets for increasing performance in the processes of construction. Those targets were: to reduce capital costs by 10%; reduce construction time by 10%; reduce defects by 20%; increase predictability of project costs and time estimate by 10%; increase productivity by 10%; and increase turnover and profits by 10 % (Egan, 1998). Clearly, the Egan report has been the more cited report in construction, and influenced the ability of the organisations to predict significant savings and improve quality. However, it was concluded that the rate of take-up the Egan report recommendations for the construction organisations should have been more rapid (Murray and Langford, 2003).

After the Latham and Egan reports the report published by the National Audit Office 'Modernizing construction' (NAO, 2001) concluded the impact and benefits gained from changes initiated by the earlier reports. The report stressed the important influence that procurement regulation has towards implementing new initiatives and recommended that procurement rules (the most economically advantageous tender wins) should not be hindering changes in construction.

In 2002 the *Accelerating change* report was published, after the Strategic Forum for Construction chaired by Sir John Egan (Strategic Forum for Construction, 2002). The report provided key measures to accelerate change in the construction industry. The forum determination was to respond to the decline of the construction industry's ability to retain a skilful workforce and increase education courses in construction related applications (Strategic Forum for Construction, 2002). Key recommendations of the report addressed client leadership, integrated teams, health and safety and people issues. More specifically the report focused on:

- clients, who should have the ability to acquire independent advice on projects and should be supported by the industry and the government on that;
- team working, integration of activities by different actors in the industry and long term supply chains, that require the active participation of the clients;
- the industry actors competences, that should be available to clients in order to keep them aware of the services expected;

- health and safety performance, that should be of major importance throughout the project phases, and cases of fatal accidents should be published;
- new project actors, that should be able to participate in integrated teams;
- training on collaboration and supply team integration, that should be made available to SME's;
- pay and conditions of work, that should draw the attention of employers in employing the best people in the industry; and
- taking initiatives on sustainability issues in all areas of construction (processes, component materials, etc.).

The impact of the *Accelerating Change* report to the construction industry was the greater use of integrated teams and supply chains (House of Commons, 2008).

Another important document, which referred to the wider UK business sector, was the Innovation White Paper, published in 2008 by the Department for Innovation, Universities and Skills. The paper set out the aim of making Britain 'the best country in the world to run an innovative business or public service' (Department of Innovation Universities & Skills, 2008). The paper focused on the changing face of innovation, which was initially regarded as a simple process of investment in fundamental research leading to commercialisation by farsighted management in the industry. However today, it is recognised that users are increasingly innovating independently or in collaboration with businesses or public services, thus creating new sources of innovation. The paper also focused on the recognition that the government should create the conditions for innovation by ensuring macroeconomic stability, open competitive markets and support businesses in order to facilitate them to innovate. The paper further stressed the need for strategies for unlocking the human potential towards innovation and drive regeneration, and recognised spatial properties of innovation in the UK. All the above should be fostered following the recognition that innovation is an international endeavour as businesses are internationalising their R&D supply chains and customer bases.

The review on the reports show that the sector recognises the need to change and modernise, and although changes in the construction process occur slowly, the reports created a range of initiatives, as described in the following paragraph, related to the organisation, the client leadership, the procurement and management of projects, integration of the supply chain and the industry, teamwork and cooperation, design and sustainability, and health and safety (Langford and Murray, 2003).

After Sir Michael Latham report (Latham and Great Britain Department of the Environment, 1994), certain initiatives were launched to act complementary to the changes the construction industry was forced into. In 1995, the Construction Industry Board (CIB) was established to deliver Latham's agenda. The Construction Best Practice program was created to introduce the required knowledge and skills needed to implement changes. In 1997, the Design-Build-Foundation launched, aimed at representing the whole construction industry supply chain by bringing together clients, designers, consultants, contractors, and manufacturers. The Building Down the Barriers initiative launched by the Construction Minister in 1997, developed an integrated approach for the supply chain and introduced procurement method called Prime Contracting (Preece, Moodley and Smith, 2003). The recommendation of the Egan report for creating a group of dynamic people inspired by the need for change in the construction industry so called in the report 'Movement for Change' was followed by the formation of the Movement for Innovation (M4I) in 1998. In 2001, the Construction Clients' Charter was launched to define the expected minimum standards in procurement methods and promote cultural change on issues of client leadership, team integration, partnerships, life quality and respect for people. The necessity of the active role of the clients and their performance in facilitating the construction processes are evaluated in order to initiate corrective actions. In 2002 the Government established the *Strategic Forum for Construction* which role is to measure and monitor progress in key areas of focus (client leadership, procurement, integration of the supply chain and the industry, teamwork and cooperation, design and sustainability, and health and safety) resulting from the earlier published reports and accelerate change. In 2003, Constructing Excellence was formed to drive the changing agenda and improve the construction industry's performance.

The need for change is revealed by the vigorous activities and initiatives launched to drive change. Although, as stated in Jones and Saad (Jones and Saad, 2003), the industry is so fragmented that the issues of Egan and Latham reports still remain a challenge. A concluding outcome from all the reports and initiatives is that internal industry-level reformation has been continuously encouraged for more than fifty years now. However, such a reformation can be facilitated by increasing the industry's ability to change and to reflect upon the need for the greater integration of the construction process, greater investment in IT, more investment in Research and Development (R&D), and increased staff development within a wider environment in which the construction industry operates. This external environment can enable or hinder the changing process, and can be influenced by the performance of the overall economy.

Reports and initiatives were important drivers for change but not the only ones. Factors at the macro level are driving construction towards increased performance and innovation.

2.3.2 Macro level environment forces

The macro level environment forces calling for innovation can be demonstrated from the globalisation and the opening of the markets, the continuous increase of CO_2 emissions and climate change and the 2008 credit crunch.

2.3.2.1 Globalisation

Construction markets around the world are being liberalised and deregulated and this brings opportunities for expanding operations. Firms can locate all or part of the production process or service wherever the economic advantage is greatest. Large international contractors are seeking both growth in operations and geographical diversification (Manseau and Shields, 2005).

UK-based firms also face competition from firms in countries with relatively low labour costs and where education and skill levels are high. For example, hourly labour costs in

South Korea are just over half the labour costs in UK, but the proportion of graduates in the working age population is almost identical (DTI, 2003). UK-based businesses find it increasingly difficult to compete on low costs alone in labour intensive industries exposed to international competition. Therefore the challenge for businesses is to compete on the basis of unique value and innovation (DTI, 2003).

Development of information and communication technologies along with the development of trade agreements (NAFTA, APEC, European Union, etc.) have also opened up new markets, and faster global communications mean that consumers learn about new ideas and products faster than ever before (Manseau and Shields, 2005). In times of the emergence of new markets and new marketing channels, there are additional pressures on managers and executive boards to generate returns in order to keep investors' interest. Furthermore, many more firms are now being forced to make the transition from operating in niche markets to environments of wider competition and, amongst other implications for the firm of such a change, there are those of the innovation process (Brown and Maylor, 2005).

Coherency in policies and regulations is far more a necessity, revealed especially after the global downturn of 2007/08 where the EU governments confronted the huge challenge of managing the immediate effects of falling demand and constrained credit, while also equipping the European economy for recovery (Department for Business Innovation & Skills, 2009). Coherency in EU competition rules by national competition authorities, and coherent regulations for markets, consumers and employees are also required to improve the underlying capacity of economy and innovation within the EU and also at a global level.

The global environment in which organisations operate bring powers that are forcing construction organisations to seek ways to improve their performance, analyse their strengths and weaknesses and explore new, innovative ways for making profits and surviving the global arena. Those new challenges are followed by the current need to reflect to the calls for greener construction in order to reduce CO_2 emissions.

2.3.2.2 Climate Change

Major changes occur in the construction industry driven by the climate conditions. Demand is shifting towards more functional buildings (with greater concern for user satisfaction and environmental friendly facilities), more sophisticated equipment for sustainable buildings such as intelligent devices for better control of energy efficiency or indoor environment, improved working/living conditions and more respect for environmental constraints (Manseau and Seaden, 2001).

Science and technology are providing new opportunities for construction to compete based upon exploiting knowledge, skills and creativity to produce technologies, materials and services that are more valuable. Materials industries are being transformed, producing totally new environmentally friendly materials. The speed of changing technology and the extent to which new products and services and new clients can change market conditions indicates that the challenge to innovate is urgent and continuous.

Furthermore, the challenge of climate change and rising energy costs calls for a comprehensive response towards sustainable development and the reduction of CO_2 emissions. The construction sector is among the major exploiters of natural resources. Its significant contribution to the current unsustainable development of the global economy (Spence and Mulligan, 1995) urges it towards the need for immediate action and alignment with the Kyoto protocol (United Nations, 1998) for reducing CO_2 emissions and the Lisbon Agenda (Official Journal of the European Union, 2007) for sustainable growth. The UK government's commitment to sustainable growth (Department for Environment Food and Rural Affairs, 2008) introduced a new era of procurement rules, new materials, sustainable methods of transportation, energy efficient building structures powered with alternative sources of energy.

The construction industry has to deal with more strict rules and regulations with the involvement of government and regional authorities. The continuous update of the regulations and building specifications such as the Housing Act (Office for Public

Sector Information, 2004), the Energy Performance of Building Regulations (Office for Public Sector Information, 2007), and the Climate Change Act (Office for Public Sector Information, 2008) requires firms to be instant-ready to adapt and integrate the new regulations which lately often originate from environmental protection and sustainability. In addition, the recycling of building wastes are becoming an impediment to the process of construction, and new regulations and energy assessments forced by governments also increase complexity, time and cost of construction (Manseau and Shields, 2005).

Climate change calls for change in the traditional ways of construction and introduces new ways, new materials and new processes to achieve greater sustainability. A transition to a more green economy is foreseen at all levels and the construction industry is driven to respond to those challenges.

Globalisation and the climate changes that call for continuous change and innovations are not the only drivers in the macro level environment. The global economy can seriously affect the prosperity of the construction industry as it is very closely interrelated to the funding of the public sector.

2.3.2.3 Credit Crunch

The UK construction industry is currently facing many serious challenges. The 2008 credit crunch started in the US sub-prime mortgage market triggered a catastrophic crash in the US banking sector, which in turn created problems in UK financial markets. Some UK banks now have a significant degree of government control and credit is very difficult to obtain, for either domestic or business purposes (Research and Markets, 2009). In the construction industry market review it is noted that in the house building sector, although the government is planning to build more homes, buyers are lacking the ability to afford mortgages, which remain expensive despite the falling of prices in homes. Cost effective house building is not bringing the desired results in terms of the affordability of mortgages.

Commercial construction is also facing a downturn due to the banking problems and the reduced spending of consumers. The building materials sector, is also facing a downturn because of the reduction in construction activity (Research and Markets, 2009). However, significant investments in energy and communications in the transport and airports sectors, is the area that the UK is focused on making investment in the decades ahead. Based on the New Innovation Procurement Plans requested by the government to be published by all departments in 2009 (HM Governement, 2009), the construction industry should prepare to face new challenges that could transform the orientation of delivering projects. Construction project portfolios are pushed to change and now privately financed concession projects are often bundled as multi-projects as they are more financially attractive (Aritua, Smith and Bower, 2009) The industry needs to be more re-oriented to the range of project delivery and seek skilled personnel for big infrastructure projects such as airports, transport and energy efficient projects. Construction companies need to be able to respond to the requirements of new public procurement rules. This process of the transformation of the market is urging for organisational and process innovations in the construction industry.

It is argued that the global economy that emerges from this downturn is hiding both significant challenges for Europe and considerable opportunities. New trends in technology, the need to move to a low carbon and resource-efficient economy and the continuing rapid development of the emerging economies will challenge European industries and production patterns. These new challenges however, offers valuable opportunities for Europe's innovative businesses and their skilled workforces (Department for Business Innovation & Skills, 2009).

The economic downturn brought structural changes in the global economies that are radically transforming the world in which business and people compete. The UK government policy for reforming the economy after the economic downturn is to invest in infrastructure. This leads the industry towards preparation to be able to respond to the challenge of changing the 'product' from house building, to huge and massive construction projects such as airports, transport and energy efficient projects. This reforming of the final delivery of the 'product' requires a reform in practices and processes that used to be made in different ways.

2.4 Summary

This chapter has described the nature of the construction industry, identifying the types of products the industry delivers, the nature of the delivery, the products life cycle and the actors involved in the delivery of a construction project. The above revealed the special characteristics of the construction industry. The general concept of innovation has been analysed offering general definitions of innovation, the context of innovation at the organisational level and the scope of innovation in the construction industry. A review of the reports and the initiatives generated, as well as the macro-level environment challenges, revealed the call for major reforms and innovations in the construction industry. The above shows that the industry challenges that foster innovation are driven by the evolution in science and technology, the evolution in governance and regulation, the increasing need to demonstrate 'value' and control cost, the changing customers expectations, the increasing demand for customisation, the increased competition at a global environment, the need to commit to sustainability, and the global economic environment. These challenges that drive innovation inform the research problem of this research as described in Chapter 1.

The next chapter, Chapter 3, presents the philosophical context of this research and demonstrates the research methods used in order to address each one of the objectives of this research as described in Chapter 1.

CHAPTER 3: RESEARCH PHILOSOPHY AND METHODS

The purpose of this chapter is to review the philosophical approaches to research and link them with the context of this research. It also aims to explain the methodologies adopted to address each research objective.

Specifically this chapter:

- reviews the research philosophical approaches and demonstrates the philosophical context of this research;
- describes the development of the conceptual model; and
- discusses the considerations of the research methods employed in order to address each research objective described in section 1.5.2.

3.1 Philosophical approaches to research

Philosophical perspectives of research begin with the so called 'standard view' of science, known as *positivism*, which is used to describe natural phenomena and is linked to quantitative research. The aim of positivism is to explain phenomena in a strict manner by creating fundamental laws that describe and explain the cause and effect of the observed phenomena. Positivism study the sequence of occurrence of the phenomena and looks for constant relationships between events in order to predict (Robson, 2002; Payne and Payne, 2004). Positivism in management research is regarded as applying scientific research methods and deriving laws to explain social phenomena (Riley, 2000). Positivism has been criticised in social research thus: observations of reality cannot be entirely objective as human subjectivity in the process of research plays an important role (Muijs, 2004).

Positivism was followed by *post-positivism*. *Post-positivism* recognised the above criticism of positivism that the phenomena studied and the findings derived are influenced by the people doing the research and the political and cultural environmental conditions. However objectivity is still crucial in post-positivism but with a recognition of the impact of possible biases (Robson, 2002). In the post-positivism approach, reality can be explained probabilistically and not universally because of the limitations revealed by subjectivity.

Subjectivity is linked to qualitative research, whose findings rely on the researcher's instruments and observations. In this manner the truth observed can only be relative and never absolute (Muijs, 2004). The notion of relativism leads to *constructivism*. In constructivism, the reality can be constructed through interaction and the findings include multiple context approaches. Constructivism is again criticised due to the limitations on what can be known about reality, which leads to doubts about absolute relativism approaches and calls for the exercise of caution about its scientific credibility.

A framework that satisfies the approaches of both post-positivists and the constructivists is experiential realism. Experiential realism admits that what is measured is influenced by the researcher's perceptions. However, it claims that subjectivity can be limited because of the interaction of the researcher with the world which eventually formulates the views for research. The most important dimension of realism which differentiates it from positivism is the assumption that reality exists independently from our awareness of it. Contrary to positivism, realism is not supporting claims about the derivation of fundamental, universal laws but derives theories to contribute to the knowledge of the world relating to the time being studied and the current cultural characteristics. The outcome therefore is subject to reinterpretation if further knowledge supports it (Robson, 2002).

Philosophical approaches to research provide an overview of the philosophical context of this study. Realism in social research assumes that social structures pre-exist and are transformed by action. Action in realism is meaningful and intentional - at the same time it limits the possible ways that action can derive desirable results. In this perspective organisations can be transformed by fostering appropriate actions or employing practices that can lead to innovation.

The philosophical context adopted for this research is experiential realism as this study seeks to contribute to the knowledge by encapsulating factors identified in the literature capturing current practices within different contexts and using a holistic approach to contribute to the area of innovation management. However, it is recognised that observations are related to the specific time and to the environmental characteristics of when the study is conducted. As such, the outcome can be revisited in case the study is conducted in different circumstances.

The following section explains the development of the conceptual model of this research providing the basis for addressing the first objective of the research which is to provide a holistic model of innovation in the construction industry.

3.2 The conceptual model

The conceptual model was derived from the knowledge gap and the grand theories explored, which provided the theoretical background to this research, as seen in Chapter 1. It was also developed standing on the principles of experiential realism as shown in the section above. The conceptual model was developed to help with the clarification of concepts for realising the aim and for delivering the objectives of this research (Babbie, 2007).

In order to illustrate the principles of the realist explanation (see Section 3.1) the example of gunpowder is often used. Gunpowder blows when flame is applied but only if the conditions are right. It would not blow for example if the gunpowder is dump, or in the absence of oxygen, or if heat is not applied for adequate time. The realist approach in simple terms is described thus: 'the outcome (explosion) of an action (applying the flame) follows from the mechanisms (the chemical composition of the gunpowder, meaning the properties of the mixture) acting in particular contexts (the particular conditions that the reaction takes place)' (Robson, 2002, p. 31). The approach is illustrated in Figure 3.1. The figure is based on the representation of the realists' explanation proposed by Robson (Robson, 2002) and adapted for the concept of innovation employed in this research.

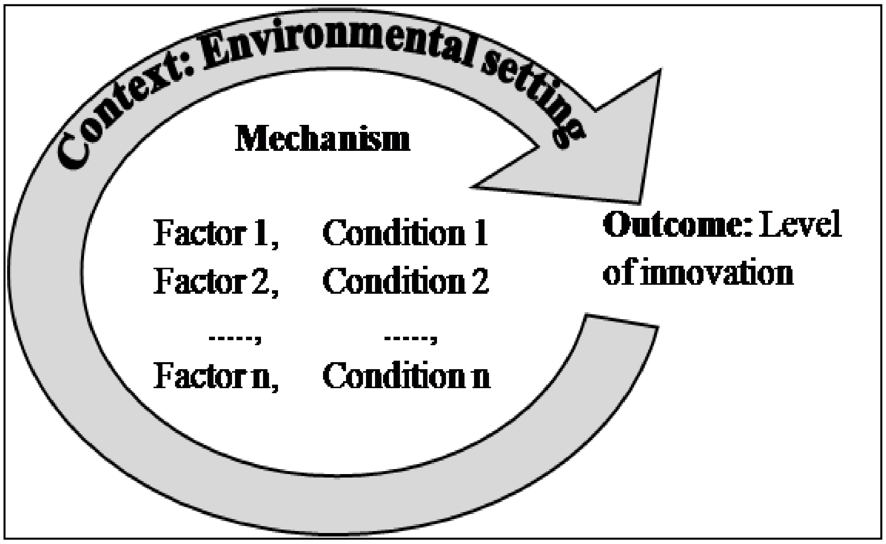

Figure 3.1 The concept of innovation in a relativist's context

On the basis of the realist approach, innovation can be seen as resulting from a mechanism that is powered by factors playing a key role in innovation and the particular conditions that pertain to each factor, acting into a specific context (Gkiourka, Tutesigensi and Moodley, 2009). The mechanism is composed of all of the factors that facilitate innovation and the particular conditions that apply to each factor explaining the causality of innovation. Conditions reflect the current practices of the organisation with respect to each factor or the specific features of contextually-dependent factors. The context involves the different environmental settings (e.g. country or sector) within which different innovation levels can be observed. The composition of different factors and the variability of the respective conditions explain why more than one mechanism can create a causal change on the outcome. The realist approach looks for possible mechanisms at the different levels of the complex social system (micro, macro, organisational). In different contexts, it is expected that the allowing or hindering of innovation mechanisms could not be applied universally. Innovation is likely to occur differently in organisations where change is already an attained capability, rather than in organisations that are more reluctant to it. The way forward is then to explain how and for whom it works best, and under what circumstances.

Realising what the factors and the relevant conditions are that have an effect on innovation can increase the understanding on how innovation can emerge and be managed. This understanding can be used to manipulate the mechanism and optimise the outcome by applying changes to the factors and/or conditions depending on the context.

3.3 A review on the research methods employed

The discussion on the principles of research philosophy and the development of the conceptual model led to the research strategies developed for acquiring new knowledge in order to achieve the aim of this research. This section provides an overview on the methods of inquiry and discusses the research methods and strategies employed in this research.

Social science is about knowing what is, in the world, and why (Babbie, 2007). Social research aims to find patterns of regularity in social life. ‘Social research can be applied in educational settings, environmental settings, health settings, business settings and so forth’ (Bickman and Rog, 1997, p.iv). This research is business research - studying business organisations - and because an organisation’s attributes are derived from the actions of people and groups of people (society), the research employs methods applied in social research.

Methods of inquiry are addressed in the context of building theory and building from theory. Scientists, in their pursuit of explanations for natural phenomena, form ideas into hypotheses about the qualities or behaviour of a phenomenon. The hypothesis is then tested to establish the support or refusal of the initial idea following verification or falsification methods. The terms ‘deduction’ and ‘induction’ play an important role in understanding theory construction’ (Riley, 2000, p.12). The main expression of positivism is the hypothetico - deductive method (Riley, 2000). According to Riley, deduction is the process that begins with the theory and continues by forming a hypothesis to explain a phenomenon. This hypothesis is then tested using data collection and analysis methods to derive conclusions on whether or not to support the hypothesis. Induction is the process of exploring and analysing an observation that leads to the construction of theory which would systematically link with the observation in a meaningful manner (Riley, 2000).

The major methods of inquiry developed and employed in social research can be categorised as quantitative, qualitative and mixed methods approaches. Quantitative research carries the notion of post-positivistic thinking and explain the phenomena by collecting numerical data and by using mathematical methods (statistics) for analysis (Muijs, 2004). Qualitative research carries the notion of constructivism, collecting usually non-numerical data and subjecting it to non-statistical processes of analysis. A mixed method of research implies that the research strategy used for collecting the information is a mixture of both qualitative and quantitative research approaches. However, there is a debate on the status of the distinction between qualitative and quantitative research. The debate is based on the fact that in practice the distinction between qualitative and quantitative is not absolute (Gilbert, 2008). For instance, it is often the case that in qualitative research the quantification of data after a coding process is required. The same can be observed in quantitative research for instance, employing surveys where qualitative data is collected using open questions (Gilbert, 2008). Despite the debate on the distinction between qualitative and quantitative research there is little evidence to suggest that the distinction is abating (Bryman and Bell, 2007). Thus, the distinction between qualitative and quantitative research was used to classify different methods of research but along with the following admissions (Bryman and Bell, 2007):

- Quantitative research can be designed as a research strategy that emphasises quantification on collection and analysis of the data; emphasises a deductive approach to testing theories based on the positivism approach and embodies a view of social reality as an external, objective reality.
- Qualitative research can be designed as a research strategy that emphasises words rather than quantification in the collection of data and analysis; emphasises an inductive approach where importance is given to the generation of theories using the individualistic approach to interpret the world and

embodies a view of social reality as an emergent property of an individual's creation similar to the experiential realism approach.

As such, it can be said that strategies of inquiry that emphasise quantitative techniques include experiments and surveys:

- 'experiments include random assignments of subjects to treatment conditions as well as non randomized designs which are known as quasi experiments' (Creswell, 2003, p. 14) - experiments in social research are imitating experiments of natural science in that they are conducted in 'controlled conditions to demonstrate a known truth or examine the validity of hypothesis' (Muijs, 2004, p.13) - experiments are usually conducted in laboratories where environmental influences are eliminated and predictor variables are manipulated; and
- surveys include longitudinal or cross-sectional studies using instruments administered by mail, face to face, telephone or the internet - the intention of surveys is to generalise the results from the sample of the population (Babbie as cited in Creswell, 2003) using quantitative or numerical descriptions about the attributes of research questions by employing statistical analysis.

It can also be said that strategies of inquiry that emphasise qualitative techniques include: ethnographies, grounded theory, case studies, phenomenological research and narrative research (Creswell, 2003):

- ethnographies aim to study the nature of cultural groups for long periods of time by selecting data from observations - the context of the research is subject to evolution depending upon the lived realities encountered during the research (Creswell, 2003) - practices for collecting empirical data in ethnography includes observation and interviewing (Travers, 2001);
- grounded theory aims to derive a theoretical approach of processes - it studies action or interactions based on observations- it uses intensive interviewing or textual analysis - data collection is a multistage process and follows the coding

and analysing of observational data and the refining of information - this process involves comparing the data with categories that emerge and maximising similarities and differences from information (Creswell, 2003);

- case studies examine individuals, processes or events by collecting information using multiple methods for a limited time period - phenomena in case studies are examined in context and are studied intensively and in detail (Ritchie, 2006);
- phenomenological research aims to study the phenomena by understanding the living experiences of participants in the study - a few subjects are studied for long periods of time to develop meaningful relationships – the researcher's experience should be isolated to study only the experiences of the participants – data collection includes interviewing and participants observation (Creswell, 2003); and
- narrative research aims to study individual lives in the context of selecting information by telling stories about the participant's life, the story is then reproduced by the researcher into a narrative chronology - the story is reviewed, combining views from both the researcher and the participant in a collaborative narrative way (Creswell, 2003).

Both quantitative and qualitative methods of inquiry have strengths and weaknesses. In typical terms qualitative observation examines the presence or absence of an event, while quantitative methods observes the presence or absence of an event by measuring the extent to which it is present (Kirk & Miller as cited in Tashakkori and Teddlie, 2003). Qualitative data provides greater in-depth detail about the subject investigated because qualitative techniques in business and organisation research (e.g. observations or interviews) involve physical interaction with the participant creating a higher level of understanding of the subject. However it is argued that personal interaction may introduce bias in the respondent's answers (Sapsford, 2007). Furthermore, the knowledge on the history and norms of an organisation provides insight into the context of the observations which are interpreting the specific actions. However, there are also methodological disadvantages of qualitative approaches. In qualitative approaches there is a danger of not recording some of the behaviours of participants due to the information processing limitations of the observer (Tashakkori and Teddlie, 2003).

Although there may be explicit information on the recording data techniques it is not obvious for other researchers to identify the nature of the derivation of interpretations (Tashakkori and Teddlie, 2003). Moreover, there is a limitation on the explanation of qualitative data as it cannot always be used for statistical inference techniques. Although qualitative techniques provide a more in-depth insight of the subject of investigation there are limitations to the generalisation of the findings.

Quantitative research is widely used in management and business research in order to describe the strength and the relationships of the variables relating to an organisation. Quantitative approaches can be considered to allow more for employing inferential statistics (which include correlations, regression analysis etc.) and can be used to compare results with other studies in the same field. Quantitative data can be subjected to probability tests by examining whether an incident occurs by chance, and allows for deriving cumulative results based on standardised statistical indexes (Tashakkori and Teddlie, 2003). Quantitative answers can be used to derive a mathematical model for evaluating the framework and allows generalisation as it can involve a large number of participants (Muijs, 2004). However, there are certain disadvantages in quantitative approaches. Correlations may provide only limited insight on the causality of events investigated. In addition, experimental designs in laboratories control the environmental characteristics to such an extent that the outcome deviates substantially from the reality losing the perspective of realism. Overall quantitative approaches and the data collection techniques employed (surveys, interviews, laboratory experiments), although they allow for increased level of analysis and explanation through statistical inference they are often criticised for falsely representing the phenomena studied (Tashakkori and Teddlie, 2003).

Mixed methods are commonly used by some researchers in interrelated multi project programs for an overall research problem (Tashakkori and Teddlie, 2003). Other researchers include multiple approaches of data collection for triangulation purposes in order to minimise the limitations of each research strategy (Creswell, 2003). Mixed methods approaches allow for a more comprehensive design as it limits the constraints of a single design. However mixed methods is criticised for introducing thin supplements to an overall design and thus attention should be drawn to carefully describe the methods and techniques of all the information and interpretations (Tashakkori and Teddlie, 2003). Studies in the service sector innovation management tend to use both qualitative and quantitative research (Oke, 2007).

It is recognised that both quantitative and qualitative approaches are used by social researchers (Muijs, 2004). All methods have strengths and weaknesses. However, the discussion above forms the reason for applying a mixed method approach for the purpose of this study. A mixed methods approach is employed in this research in order to ensure greater reliance on the information exploited by limiting the constraints of applying a single method approach. Qualitative research is used to facilitate the quantitative research (Bryman and Bell, 2007). The in-depth knowledge in the area of managing innovation is acquired using grounded theory techniques. This knowledge is then used to inform the design of survey questions. Cycles between inductive and deductive methods are employed allowing for both the expansion and the refinement of the theory (Tashakkori and Teddlie, 2003). According to Tashakkori and Teddlie 'cycling emphasizes the dynamic characteristic of social systems central to social-physiological theory' (Tashakkori and Teddlie, 2003, p. 561).

The research methods employed to address each objective of this research in order to accomplish the research aim are analysed in the following sections.

3.3.1 Developing a generic holistic model of innovation

In order to address the first objective of this research which was the development of a generic holistic model of innovation, an in-depth knowledge in the area of managing innovation was required. This knowledge of gathering the existing theory in order to refine it for developing a more advanced theory of a holistic model for managing innovation was acquired by employing grounded theory techniques. An alternative to employing grounded theory techniques for acquiring in-depth knowledge in the area of managing innovation would be to employ case studies of organisations analysing their methods of managing innovation. However, this approach would limit the generalisation of the results as the findings would rely very much on the specific characteristics of the organisations being studied. This would oppose the overall purposes of this research that is to describe the mechanism of innovation using a holistic approach as the holism could be case study specific.

The notion of grounded theory refers to theoretical explanations of the social world that are the product of empirical data (Gilbert, 2008). However, often grounded theory has been used, and criticised for it, in the verification of existing theory using deductive and quantitative methodologies. Glaser and Strauss have outlined a series of procedures to carry out inductive and theory generating research (Glaser and Strauss, 1967). This section describes the grounded theory techniques used and discusses the elaborations on Glaser and Strauss' model.

One of the most influential features of the grounded theory approach is based on the methodological framework of deriving categories from data in social research (Bryant and Charmaz, 2007). An important aspect in this process is letting the categories emerge from research material rather than concentrating effort on preconceived concepts and terms, which poses the danger of forcing the exception of important theoretical knowledge (Bryant and Charmaz, 2007). The technique of grounded theory employed was textual analysis (Charmaz, 2007) of the relevant literature. Textual analysis includes elicited texts and extant texts. Elicited texts involve production of data to respond to the researcher's request by engaging research participants. Extant texts involve data that the researcher could not have affected their production. These include public records, government reports, organisational documents, mass media, literature, correspondence (Charmaz, 2007). The approach of extant text analysis was used in order to avoid general interests or motivation for studying the issue of managing innovation within a specific theoretical framework (Gilbert, 2008).

Initially, an examination of the extant texts identified in the literature relating to innovation, innovation theories, organisational innovation practices and the construction industry as a preliminary source of data, was conducted in a relatively open and non prescriptive way. The texts in the literature were used as objects of analytic scrutiny and not as evidence (Charmaz, 2007). This preliminary exploration of the data revealed that other researchers' work related to innovation can be classified in three key areas:

- research of innovation focused into the internal environment of organisations (Pavitt, 1976; Porter, 1985; Senge, 1991; Gilbert and Birnbaum-More, 1996; Manseau and Seaden, 2001; Kash and Rycroft, 2002; Landry, Amara and Lamari, 2002; Rahman and Kumaraswamy, 2002; Kash, Auger and Li, 2004; Krause, 2004; Lau and Ngo, 2004; Lemon and Sahota, 2004; Miozzo and Dewick, 2004a; Sexton and Barrett, 2004; Aragon-Correa, Garcia-Morales and Cordon-Pozo, 2005; Storey and Salaman, 2005; Hartmann, 2006; Oshagbemi and Ocholi, 2006; Dainty, Green and Bagilhole, 2007; Jong and Hartog, 2007; Carneiro, 2008; Toor and Ofori, 2008);
- research of innovation related to the external environment in which organisations operate (Garavan, 1997; Tang, 1998; Marceau *et al.*, 1999; Gann and Salter, 2000; Manseau and Seaden, 2001; Seaden and Manseau, 2001; Sanghoon, 2002; Trott, 2002; Fagerberg, Mowery and Nelson, 2005); and
- research on strategic resources that facilitate innovation to occur (Cohen and Levinthal, 1990; Manu, 1996; Tang, 1998; Hendriks and Vriens, 1999; Levy, 2000; Manseau and Seaden, 2001; Seaden and Manseau, 2001; Yankov and Kleiner, 2001; Carrillo and Anumba, 2002; Trott, 2002; Kotler, 2003; Vinding, 2006).

The identification of these three areas shifted the process of the preliminary examination of the literature to the deliberate investigation of emerging theoretical concepts or possibilities (Glaser and Strauss, 1967).

Coding was used to create the 'bones' of the analysis, which integrated with the theoretical constructs to form the 'skeleton' of the research (Charmaz, 2007). Coding included naming segments of data in the extant texts followed by focusing on the most significant and frequent concepts of innovation, so as to sort and synthesise them into theoretical categories emerging from the data. Although Glaser and Strauss suggest that there should be coding of every single line of data, codes emerged as a result of an ongoing and flexible synthesis of research data and the unit of analysis was paragraphs of journal articles and books relating to the theme of innovation, innovation management, innovation theories and construction industry (Gilbert, 2008). During the coding process, each paragraph was given a code that referred to a certain variable. During the preliminary literature search, codes were detailed, specific and numerous but during the process of analysis of the extant texts, the initial codes were combined into larger more generalised categories whose properties provided the base for the theoretical explanation of the data. Through the process of constantly comparing each new instance within a category with all previous instances, it was revealed that there were texts describing the same variable (e.g. culture of organisations) within different perspectives. The ongoing writing of memos about the properties of the categories that emerged helped in understanding the haunches for each category and in splitting the initial category-variable into subcategories comprising of factors representing dimensions of the same category (i.e. factors such as technology, leadership, ownership, collaborations represented the category 'culture in organisations') as shown in Figure 3.2. The analysis of the literature has reached a point of saturation meaning that the research on the different instances within a category stopped at the point where the instances that were revealed started to repeat and further extant texts examined did not contribute with any new information or revealing categories.

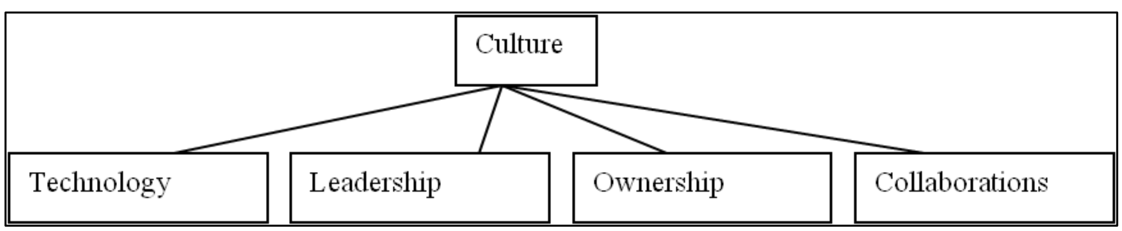

Figure 3.2 Hierarchical structure of subcategories

Another challenge was to ensure the grounding of the categories applying theoretical sensitivity by linking relevant data with empirical evidence in the light of theoretical terms. Theoretical sensitivity as a prerequisite to the category building has been explained by Strauss and Glasier, who developed two different methodological tools for clarifying the concept of theoretical sensitivity in grounded theory research (Bryant and Charmaz, 2007). Berney Glasier in his explanation of theoretical sensitivity introduced the terms 'theoretical codes', 'theoretical coding' and 'coding families' to describe a process where analysts have a wide variety of theoretical concepts to develop the categories for the emerging theory. Strauss introduced the notion of developing of an axis or a skeleton of the most important categories as the so called ‘paradigm model’ based on human action and interaction rooted in a pragmatist social theory which could provide the key areas for further categorisation. However, both methods are criticised for their reflection on the original intention of grounded theory. Bryant and Charmaz, (Bryant and Charmaz, 2007) argue that Glasier’s explanation is subject to the researcher’s approach on theoretical sensitivity, entailing the researcher’s ability to grasp empirical phenomena in theoretical terms. This competence demands a broad background in sociological theory and extended training. Strauss and Corbin paradigm is a more straightforward concept in terms of the construction of a theoretical framework for the development of empirically grounded theories in an explicit manner (Bryant and Charmaz, 2007, p. 203).

The theoretical notions, definitions and categories from the grand theories such as systems theory (Askarany and Smith, 2008), resource based theory (Kristandl and Bontis, 2007) and diffusion theory (Rogers, 2003; Askarany, 2005; Askarany and Smith, 2008) provided the theoretical concepts that constituted the basis for comparison. The grand theories were used to sensitise and compare the emerging categories with the identification of theoretical related phenomena in the field. Those heuristic categories formed the theoretical axis to which empirical information in the research area was added. Therefore, the development of the categories for innovation management-related areas and the propositions with growing empirical content from innovation practices in the construction industry was supported by the heuristic concepts from the grand theories.

The grounded theory approach increased the theoretical understanding of the factors playing a key role within the studied area and informed the development of the next steps of the research process. The next step was to develop a system in order to identify the condition of each factor identified, as explained in the conceptual model in section 3.2.

3.3.2 Developing a generic system for depicting innovation practice

The conceptual model developed in Section 3.2 describes the mechanism of innovation as being empowered by the composition of the factors that facilitate the innovation process and the condition of each factor in reflecting the current practices or the specific features of the organisation within a context. The combination of the factors and the identification of the practices employed or the specific features referred as 'the condition of the factors' can be used to determine the performance of the organisation towards innovation.

In social research the combination of answers with several indicators or factors each of which being a scale, is used to measure attitude. In not just social science but also physics, attitude, as a theoretical construct, is difficult to be measured and therefore its existence and properties must be inferred indirectly (Gilbert, 2008). However, it is argued that an underlying attitude is not solely determined by the verbal or non verbal behaviour but it can be the result of relationships with other factors that can have an influence effect of the final behaviour. The verbal or non verbal statement is the behavioural component of an attitude (Gilbert, 2008). Other components of an attitude can be the cognitive (i.e. thinking mentally, organising); and the affective (i.e. emotional and feeling) (Whyte, 2000).

Linking the components of attitude to an organisation's attitude it can be said that the behavioural component of the organisation's attitude can help to realise what the organisation does well or what the organisation does poorly regarding innovation. This can be achieved by determining the current condition of the factors playing a key role to innovation or, in other words, depicting the current practices that are employed towards innovation. As such, the behavioural component can be used to explain how innovation occurs in some organisation and not in others. The cognitive component of organisational behaviour can be realised by measuring the extent to which each factor is considered by organisations to be contributing to innovation. This, in effect, can be used to explain why innovation occurs as it can be said that innovation is more likely to occur in organisations where factors that are playing a key role to innovation are valued.

Finally, the affective component could also be studied by examining the feelings of managers, directors and employees towards innovation. Although, the affective component was outside the focus of this research, it can be said that the behavioural and the cognitive components can indirectly represent the psychology of the organisations towards innovation by eliciting their tactical actions.

It is helpful and often essential to have multiple indicators or factors relevant to the concept that is measured. In this sense, the categories that emerged from the grounded theory technique and the factors describing different dimensions of each category were used as the construct to identify the organisation's behavioural and cognitive components of attitude. Based on the above, the strategy developed to address the second objective of the research which was to develop a generic system that can identify the condition of each factor playing a key role in innovation reflecting the behavioural component of organisations, was addressed using attitude scale methods as described below.

There are many methods for constructing attitude scales. The most common ones are: paired comparisons, the rank order method, direct magnitude estimation, and rating scales (Jupp, 2006). Every scaling procedure has two components – stimuli and a response method. The paired comparison method uses a pair for stimuli and a response dimension is defined. Respondents are asked to indicate which stimulus in each pair is higher or lower in the dimension of interest. The rank order method offers multiple stimuli. The respondents are asked to place the stimuli in order along the defined dimension. Direct magnitude estimation asks respondents to provide a score on a dimension for each stimulus. Rating scales asks respondents to select one response choice from several that are in order along a dimension. Each choice is defined by an anchor point that describes its position in the dimension being measured (Jupp, 2006).

In order to project the position of an organisation along a dimension and identify the anchor point that best describes the condition of the organisation, for each factor, relative to other conditions (representing different anchor points), the logic of the rating scales was used. A scale was constructed for each factor. Each scale had as stimuli each factor and respondents were asked to select one response along the dimension that best described each factor. The measurement embodied an assessment of the practices employed by the organisation for each factor. The scales for each factor had two extreme anchor points and intermediary points that demonstrated progression of the underlying dimension. The left anchor point represented the absence of the underlying dimension and the right anchor point represented a maximum position in terms of the underlying dimension.

Defining the construct of the scale carefully and completely was a vital step in the process of constructing the scales. This process was a conceptual/theoretical task of describing the nature of the construct for each factor. A definition for each factor was written, in order to describe what is intended to be measured. Definitions of each of the factors identified are provided in Chapter 4. Anchor points and intermediary points were informed from the grounded theory stage and during extensive literature research, based on qualitative information identified in the literature. The findings of the literature research were then operationalised on a scale denoting progression from the left anchor point to the right anchor point. The response categories were exhaustive, covering all possibilities by making fairly broad suggestions that satisfy the objectives of this project. One extreme denotes a low likelihood of being innovative and the other extreme denotes a high likelihood of being innovative. The scales constructed were used to assign scores to the organisation according to the underlying dimension based on the organisation's position on the scale. (*Herein after, the scales constructed to identify the condition of the organisation for each factor will be called in future reference 'Part B' of the questionnaire*) (see questionnaire in Appendix A).

Taking as an example the different dimensions of the category 'culture' represented by the factors: 'technology', 'leadership', 'ownership' and 'collaborations' as illustrated in Figure 3.2 above, the response categories identified for each factor are illustrated in Figure 3.3.

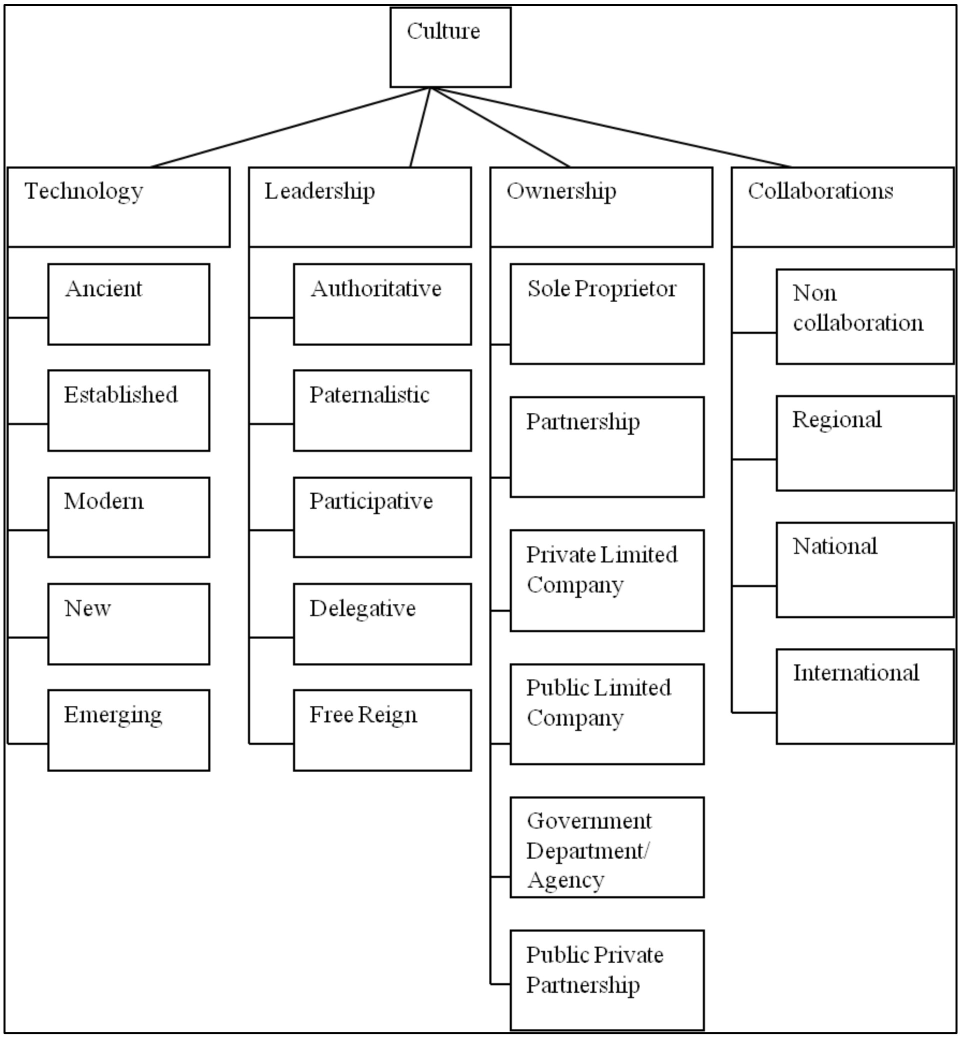

Figure 3.3 Response categories of factors

In the examples shown in Figure 3.3 the underlying dimensions for constructing the scales and identify the condition for each factor were: for the factor 'technology' the underlying dimension is 'newness'; for the factor 'leadership style' the dimension is 'freedom'; for the factor 'ownership' the underlying dimension is 'capacity to overcome bureaucracies and flexibility to work with others'; for the factor 'collaboration' the underlying dimension is 'geographical dispersion'. The underlying dimension of each scale constructed for each factor is analysed in Chapter 5.

The scales constructed for each factor were used to develop a survey instrument for identifying the behavioural component of organisational attitude towards innovation and depict the current practices employed within the construction industry. The content validity of the constructs that were developed is addressed in the following section, within the overall examination of content validity of the survey instrument developed. The practices employed by the construction organisations represent the condition of each factor, as referred within the explanation of the conceptual model, and was captured during the survey employed.

3.3.3 Exploring innovation practice in the construction industry in the UK

The initial application of the grounded theory techniques and the development of a system that could identify the condition of each factor playing a key role to innovation provided the basis for determining innovation practice in the construction industry. The strategy adopted to address the third objective of the research and to determine the innovation practice in the construction industry in the UK was a survey using a postal administered questionnaire.

3.3.3.1 Research design

As suggested in section 3.3 there are different types of survey. Both interviews and questionnaires have strengths and weaknesses. Interviews are good for measuring attitudes and most other content of interest and they allow for follow up questions by the interviewer to provide more in-depth information. They have moderately high measurement validity, they can be used in probability samples and they often have high response rates. However, interviews are expensive and time consuming. Moreover, the reactive effects of presenting desirable information may insert biases as anonymity cannot be ensured and needs validation (Sapsford, 2007). Questionnaires are good for measuring attitudes and are often inexpensive compared to interviews. They can be administered in probability samples and they can have a quick turnaround. They can ensure anonymity of the respondents and can have high measurement validity for well constructed questionnaires. However, some of the disadvantages are that questionnaires should be kept short, and the people filling out questionnaires may not recall certain information due to lacking self awareness (Tashakkori and Teddlie, 2003). Furthermore, in questionnaires, there is no explanation of the meaning of the question and therefore careful treatment should be given on the design of brief and clear questions. Response rates in postal surveys may be low and data analysis may be time consuming for open-ended questions. Measurement of questionnaires also needs validation (Tashakkori and Teddlie, 2003).

A survey method using postal questionnaires was opted for, for the purpose of allowing a large probabilistic sample that could be used for generalised purposes and to allow for the interpretation of the mechanism of innovation in different contexts. The questionnaire was developed through the following stages: determining the questions to be asked, constructing the response scales and deciding on the overall layout of the questionnaire.

The extensive literature review that was undertaken was coupled with the grounded theory techniques that were employed to address the first objective of the research and helped to identify all the factors that play a key role in innovation (see chapter 4). Then, the system developed for indentifying the condition of these factors, involved constructing ranking scales as explained in Section 3.3.2 and presented in Chapter 5. This system that involves the rating of potential practices that can be employed by organisations according to the degree they favour innovation, was designed to help the identification of the behavioural component of the organisation's attitude towards innovation. The importance that was attributed to each factor by the professionals in the industry was also important to understand the cognitive component of the organisations' attitude towards innovation. At this stage, a key link was established between the research aim and the individual questions via the research issues. The processes of defining the appropriate questions to derive answers that contribute to the accomplishment of the specific objective and as such the research overall aim are illustrated in the 'Question Focus' in the Figure 3.4 below.

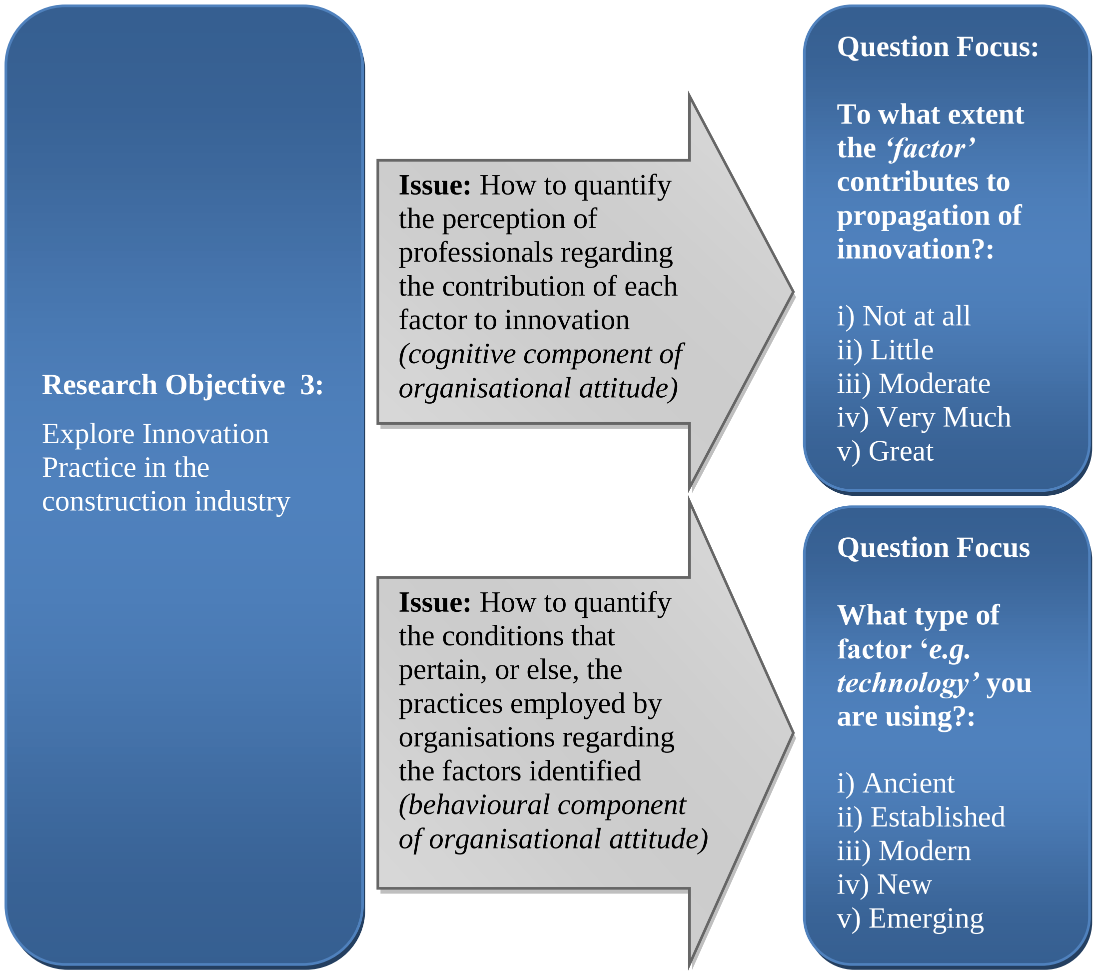

Figure 3.4 The process of determining the appropriate questions

The above process generated the focus on a two measure approach. The first measure was to identify to what extent each factor identified, contribute to propagation of innovation according to professionals in the industry representing the cognitive component of the organisation's attitude towards innovation. The second measure was to identify the condition of each factor describing the current practices employed representing the behavioural component of the organisation's attitude towards innovation. These two types of questions were used to depict the innovation mechanism. The first measure was recorded using a five point Likert scale (0-4) with 'Not at all' coded as '0' and proceeding gradually to 'Little' coded as '1', 'Moderate' coded as '2', 'Very' coded as '3' and 'Great' coded as '4'. The second measure was recorded using the system developed to identify the condition of each factor (see Table 3.1).

The questions of the instrument were designed to be brief and clear in order to achieve maximum understanding of their meaning for all the respondents. The questions and the answer choices were attractively and neatly presented. The questions were standardised by using only two types of questions for the two measures approach. The two types of questions are shown in Table 3.1.

Table 3.1 Types of questions in the research instrument

Organisational attitude components	**Question**
1. Cognitive component (reflects the value attributed to each factor showing whether it is considered important to the innovation process)	1. To what extent does the *'factor'* contribute to propagation of innovation?
2. Behaviour component (reflects the condition of each factor)	2. Which of the following best describes the *'factor'* in your organisation?

All questions were closed type except for two open type questions used to identify the proportions of revenue and expenditure associated with innovation. Closed type questions were preferred because they lend themselves easily to summarising replies and producing a picture of the population. Closed questions describing the population were also included to allow the comparison of the different categories of respondents based on their characteristics in terms of area of operations and type of organisation (see questionnaire in Appendix A).

3.3.3.2 Questionnaire validity and reliability

There are two major measures for evaluating measurements: validity and reliability (Zikmund, 2003).

Validity refers to whether the instrument gives accurate measures of what it is supposed to measure (Gomn, 2008). The basic approaches to evaluate the validity are to test for: content validity, construct validity and criterion validity.

Content validity refers to the subjective agreement among professionals that a scale of an instrument logically appears to reflect accurately what it is supposed to measure (Zikmund, 2003). Content validity is dealing with the content of the questions in the questionnaire. Content validity was ensured through a three stage process. The first stage included an extensive search on the literature and the concepts of innovation, innovation terminology, and innovation practices using grounded theory techniques. The grounded theory approach developed understanding on the related disciplines for identifying the categories and the factors describing the different dimensions of the categories. The factors included in the research were based on the theoretical framework of the resource based theory, diffusion theory, and systems theory that lent the heuristic categories to compare the findings from the grounded theory techniques employed. The second stage included the analysis of the extant texts. The analysis stopped when a point of saturation was reached indicating that the categories and factors revealed within these categories started to repeat and further extant texts examined did not contribute with any new information or categories. Finally, the third stage included the examination of the questionnaire by an expert. The expert was a member of the university staff who had prior experience on surveys and commented on the content, wording of questions, and the overall layout. The key consideration was whether the factors used to describe the mechanism were the right factors; and if the conditions of the factors identified and the scale constructs developed for both the behavioural and the cognitive component of determining the attitude of the organisation were the right ones. Useful comments by the expert contributed to the development of the final wording and the overall layout of the questionnaire.

Construct validity 'refers to the ability of a measure to confirm a network of related hypotheses generated from a theory based on the concepts' (Zikmund, 2003, p. 303). There are no specific tests for testing construct validity but in effect, all tests during the statistical analysis of the data imply that the empirical evidence generated by the measures behave the way it is supposed to, in patterns of intercorrelations with other variables. Construct validity could be best demonstrated by the accumulation of correlations from many different studies using the same instrument although that was not possible in this research as the instrument has never been applied before.

Criterion validity refers to the 'ability of a measure to correlate with other measures of the same construct' (Zikmund, 2003, p. 302). Although a strong proof of criterion validity would be to conduct statistical tests of co-variation and correlation measuring the extent of agreement between the results of using this instrument and the results of using another instrument, this was not possible due to the lack of a similar instrument. However, in such cases a weaker proof of criterion validity can be the judging of the results against expert opinion. The results were audited by a member of the research community and there was agreement that criterion validity was satisfied (Gomn, 2008).

Reliability refers to 'the degree to which measures are free from error and therefore yield consistent results' (Zikmund, 2003, p. 300). The basic approach to evaluate the reliability of a multiple-item measure is to check for internal consistency of the constructs in the questionnaire. Internal consistency is tested by using the statistical test for calculating Cronbach's alpha (Gomn, 2008). Cronbach's alpha was calculated to check the consistency of the constructs measured and the results are demonstrated in Chapter 6. Generally internal consistency was achieved as the Cronbach's *a* for the first type of measurement was above the 0.7 threshold (Gomn, 2008).

3.3.3.3 Measurement level

The level of measurement of the factors refers to how the different responses or attributes relate to one another. There are three levels of measurement: interval (or continuous), ordinal and nominal (or categorical or qualitative) (de Vaus, 2002).

Interval variables can be ranked from low to high in a meaningful way. It is also possible to specify the amount of difference between the attributes (Alreck and Settle, 2004). Interval level variables is the highest level of measurement as it contains three types of information: occurrence, order of occurrence and quantity of occurrence (de Vaus, 2002). The difference between ratio and interval level variables is that ratio variables have an absolute zero (Neuendorf, 2002; Alreck and Settle, 2004) which implies the absence of a characteristic.

Ordinal level variables can be ranked from low to high, however the exact difference between the attributes cannot be specified in numeric terms (Alreck and Settle, 2004). Ordinal level variables contain two types of information (de Vaus, 2002). They indicate the occurrence and the order of the occurrence of an event (Field, 2005).

Nominal level variables have no set rank order and cannot be classified from low to high in any sense. Nominal level variables contain one type of information (de Vaus, 2002) and that is the name of the category (Field, 2005).

The closed questions in Part A and Part B of the questionnaire are technically designed to be ordinal variables. This is because the actual distance between the responses is qualitative and therefore cannot be defined in absolute terms. However ordinal types of measurement used in Likert scales are often treated by researchers as interval scale measurements for allowing more sophisticated statistical analysis (Gomn, 2008). Questions from part A of the questionnaire were designed to include an absolute 0 (absence of the characteristic defined in the category 'Not at all') and as such they were treated as ratio variables. The descriptive variables questions included in the Section A of the questionnaire (see questionnaire in Appendix A) were nominal level variables. High levels of measurement were used so as to derive results that are more accurate, use more powerful statistical tests, and apply discriminations between cases in order to increase research power.

3.3.3.4 Questionnaire layout

The final questionnaire was summarised in four and a half pages. The first section (Section A) of the questionnaire included the descriptive questions and the open questions concerning proportions of revenue and expenditure associated with innovation. On Section A of the questionnaire, respondents were allowed to complete their contact details in case they wished to be sent the results of the survey. Sections B, C and D included the questions as stated in section 3.3.3.1. The sections were organised in terms of the key areas identified: the internal environment, the strategic resources, and external environment, and by grouping together all the questions that relate to similar categories of factors that impact in innovation according to the holistic conceptual model of innovation, illustrated in Chapter 4.

A cover letter accompanied the questionnaire for explaining the purposes of the research, the importance of the contribution of the respondents and the amount of time allowance offered for completing and returning it to the researcher. The questionnaire layout and the cover letter are provided in appendix A.

3.3.3.5 Survey sample

The sample of the survey was designed by considering the following factors: specification of the sample unit, specification of the sample frame, specification of the population, random sampling, sample size, response rate and non response bias.

The survey's sample unit was construction organisations. An exhaustive list of construction organisations was provided by the Registrar of Companies in England and Wales on a DVD. The DVD directory contained basic company details of over 2 million live companies registered in England, Scotland and Wales. The DVD provided a built in search facility that allowed up to 6 combinations of searches to be made. The search options were company name, company number, registered office address lines, postcode, date of incorporation or range of dates, SIC codes or description, company type, company status or accounts type. The term 'construction companies' was used as a search term within the CD and it resulted in generating a list of 59,544 construction organisations.

The list of 59,544 organisations provided names and addresses of the construction organisations for the mail survey constituting the sample frame. The sample frame was all-inclusive - it included every member of the population to be surveyed and exclusive to the population being studied (Alreck and Settle, 2004). The units identified in the sample frame were defined exactly the same way as the sampling units.

The population surveyed were the managing directors of each organisation who were considered to posses the information sought by the survey. A question of how long has the respondent been working for the organisation helped to assess whether the information came from the people who had the required knowledge.

Random sampling provides a sample that is representative of the entire population and it is least likely to result in bias. Randomness defined by Neuendorf (2002) means that every element (unit) in the population has an equal chance of being selected. Random sampling is the most appropriate kind of sampling as it is important to the reliability and validity of the data. The statistical properties of the random sampling used allowed the researcher to make inferences about the population based on the results obtained from the sample, allowed for the computation of confidence intervals indicating the probability, allowed for calculating the population average and other parameters necessary to generate statistics (Alreck and Settle, 2004) (see Chapter 6). Random sampling allowed for calculating and reporting the statistical significance of relationships between survey items, based on the probability that such relationships would result only from sampling error (Alreck and Settle, 2004). Random selection allowed these statistical coefficients to be more accurate and legitimate compared to any other kind of sampling methods.

The random selection method used, was a computer-generated list of random numbers. The list was provided from the DVD ROM and it was exported into an excel file. Excel was then instructed to select a random sample of 1,000 numbers between 1 and 59,544. The random numbers were sorted in sequence and the duplicate numbers were discarded. The units to be included in the sample were then picked from the sampling frame according to the sample list.

Although there are statistical formulas for the calculation of a specific sample size to yield a given level of confidence for single variable these formulas require accurate estimates of population variance and that was not known in advance (Neuendorf, 2002; Alreck and Settle, 2004). Therefore, judgement on these factors is necessary. The decisions based on this survey would influence the final framework and this would result in costly consequences if the framework would be used in practice. Another concern was that it was likely to have a high level of variance among the units in the population to be sampled and that would result in greater sampling error. A pilot study was conducted to reveal deficiencies in the design of the proposed instrument and address issues such as the establishment that replies can be interpreted in terms of the information that is required, before time and resources were expended on the main study. The pilot survey was conducted to address a sample of 100 organisations selected with the same way as described above. The response rate of pilot survey was 8%. The analysis of the pilot study indicated that changes needed to be made in the response scale of a few items and provided insight on the sample size which should be big enough to provide adequate data. Those considerations led to the decision that a large sample was required and the maximum practical size which was the size of the sample for this survey was 1,000 respondents (Alreck and Settle, 2004).

In order to maximise response rate, respondents were provided with a prepaid envelope, they were assured of anonymity and were offered a report on the results. At the end of the mail-out, a total of 55 completed questionnaires were received, giving a net response rate of 10.4%. The response rate was calculated according to de Vaus (de Vaus, 2002) by using the formula below:

$$\text{Response Rate} = \frac{Number\,\mathrm{Re}turned}{NinSample - (ineligible + unreachable)} \text{ x } 100$$

$$\text{Response Rate} = \frac{97}{1000 - (42 + 20)} \text{ x } 100 = 10.4\%$$

The relatively low response rate did not come as a surprise given that postal surveys have often been plagued by low response rates (Church, 1993). According to Alreck and Settle (Alreck and Settle, 2004) non response may be independent of the survey content or it may interact with it. If people decide to respond to the survey or not to respond, purely on a random basis, then the non response will be independent of the survey content and there won't be non response bias. In the case of this survey the response rate was estimated according to the indications of the pilot study so the data collection yielded an adequate number of respondents to satisfy the sample size requirements.

However, non response is never entirely independent (Alreck and Settle, 2004). There is a need to clarify what sort of interaction exists between the survey and non response. A direct interaction might be that the respondents do not consider innovation as an important factor to enhance their organisations' performance and in that case, they may be not interested in the survey at all. An indirect relationship is that although respondents might be interested in the survey, they didn't have sufficient time to complete the questionnaire or their corporate policy does not allow them to participate in the survey. Finally, answers that indicated that the company has ceased trading and therefore could not answer the questionnaire, was also another form of an indirect relationship. Adding to the reasons above, non-delivered questionnaires might also contribute to the low response rate. However, non response did not affect the results of this survey as the final sample was considered adequate for analysis.

The analysis of the exploration of the data collected from the survey and the association between the items measured are presented in Chapter 6.

3.3.4 The modelling of the generic mechanism of innovation

The survey results, along with the identification of the factors and the system for identifying the practices of innovation in the construction industry, helped to address the fourth objective of the research and model the generic mechanism of innovation. The fundamentals of modelling are presented below along with an explanation of the approach of mathematical modelling employed in this research.

According to a dictionary definition, a model is: *a miniature representation of something; a pattern of something to be made; an example for imitation or emulation; a* *description or analogy used to help visualize something (e.g. an atom) that cannot be directly observed; a system of postulates, data and inferences presented as a mathematical description of an entity or state of affairs* (Dym, 2004). A model is used to represent something in a comprehensive way (Meyer, 2004). It is a formal description of the essential elements of a problem (Grant, Pedersen and Marín, 1997). Modelling the mechanism of innovation is required in order to describe how the innovation mechanism works in different contexts and in different organisation as proposed by the conceptual model developed.

There are different kinds of model that can be used to describe behaviours or mechanisms. The different kinds of models can be classified in various ways (Grant, Pedersen and Marín, 1997). The main dichotomy for the purposes of this research is physical versus abstract. Physical models are miniatures of real objects. Physical models are used to test, study, display and experiment a real situation using simulation. The globe is an example of a physical model representing the earth. Abstract models use symbols instead of physical devices to represent the system being studied. The symbolism can include written language, a verbal description, or a thorough process. A mathematical model is a special type of an abstract model using the language of mathematics. Mathematical models are fundamentally the same as the other types of abstract models but because they are using mathematical notation they are more specific than verbal description. Mathematical models are less ambiguous than most word models.

In organisational studies mathematical theory building can add structure to the description and analysis of the research question by "facilitating the articulation of model assumptions, relationships among variables and testable implications" (Lιvesque, 2004). Mathematical models are built on existing theories that form the basis for model assumptions (Lιvesque, 2004). Modelling a mechanism of facilitating innovation in the construction industry is a complex process that involves collection, presentation and utilisation of the data analysis results, and operationalisation of the derived relationships into a language that can represent the situation under study. In order to offer greater specificity to the modelling of the mechanism of innovation mathematical modelling has been applied.

The large number of factors (forty one factors measured with two different types of measurement-cognitive component and behavioural component) indicated the need to reflect on how those factors can be included in a mathematical model. The results of the data analysis presented in Chapter 6, show that all forty one factors are important to increasing revenues. Furthermore, the principles of the systems theory indicate that a small change of a system's property may lead to significant changes to other system properties. There are two types of strategies for dealing with large number of factors. The first strategy is to reduce the factors by discarding the less important ones or group them in higher level factors (Tutesigensi, 1999). The second strategy is to keep all the factors but ensure that they are treated without compromising validity of the results (Tutesigensi, 1999). Reduction of the observed factors or grouping them to higher level factors would contradict the notions of the system theory. The obtained results would be of reduced sensitivity and also important information would be lost considering the fact that all the factors were found to be important in generating revenues (see Chapter 6). Furthermore, according to the conceptual model the mechanism of innovation is dependent on the context being studied. Based on the realism approach adopted for this research, the results are subject to the time and the current conditions that the survey has been carried out. For the reason explained above, the second strategy was found to be less compromising than the first one and as such, all the factors were kept in the model.

It is taken that the combination of the factors and the conditions of those factors represented by the practices an organisation employs can form the innovation potential of an organisation. It is also taken that ideally there would be a position in which an organisation would account for all of the factors identified as being important to innovation and then employ all of those practices that facilitate the innovation process. However, this ideal situation which could be compared to a state of innovating in 'perfection' could be rarely found. The mathematical formula developed determines the organisation's current potential towards innovation and its ideal potential, and provide alternative scenarios for increasing the organisation's potential towards innovation.

Initial shortcomings within the modelling process that were due to mistakes in the manipulation or the design of the mathematical formulas were redesigned (Meyer, 2004). New formulations followed the mathematical manipulation and new evaluations were conducted until the formulas agreed well with the observations of the collected data. The steps included in the mathematical modelling process were formulation, mathematical manipulation and evaluation and are presented in Chapter 7.

3.3.5 Systematising the generic mechanism of innovation

In order to manipulate the large number of factors and effectively operationalise the mathematical model developed, the generic mechanism of innovation was systematised within a software program developed, named **InnoAct**. **InnoAct** increased the usability of the mathematical model and offered a systematic procedure for managing the generic mechanism of innovation. The software programming approach employed, addressed the fifth objective of the research and allowed for systemising the management of innovation.

The computer application, **InnoAct** was designed with two main features: ability to evaluate organisational performance towards innovation and ability to produce 'what if scenarios' and alternative Action Plans for increasing innovation potential using an optimisation routine.

The programming language used to develop the computer application and the optimisation routine incorporated for developing the Action Plans are discussed in sections 3.3.5.1 and 3.3.5.2 respectively. The methods of Validation and Verification for testing the software are discussed in 3.3.5.3.

3.3.5.1 The computer application programming language

Programming languages can be categorised into two main categories: the low-level programming languages and the high level programming languages. Low-level programming languages are characterised by their ability to control a computer's operating system and the hardware, something that is often more difficult to perform with a high-level programming language. Low-level languages can perform tasks more quickly than high-level languages, but they tend to be more cryptic and are therefore harder to learn, remember and use. High-level languages and application-level languages tend to be more user friendly as they use a more ordinary to spoken language, however, they run slower (Roman, 2002).

High-level languages are designed for specific purposes, such as designing specific types of applications. Visual Basic and Visual C++ are primarily used to write stand alone Windows applications. FORTRAN is also used to write scientific and computational applications for various operating systems, including Windows. COBOL is used to write business-related applications. On the highest level of the programming-level hierarchy, there are languages such as Visual Basic for Applications (VBA). The purpose of VBA is not to control hardware or write stand alone Windows applications, but to manipulate high-level software applications (Roman, 2002).

The object oriented programming language that was used for realising the required application was Excel Visual Basic for Applications. Excel is a highly programmable product and offers more than 200 classes of objects and over 5000 properties and methods that can be controlled with VBA. Using Excel meant that designing objects and transforming objects that had already been developed, so as to achieve the most operable solution, could be performed.

The features provided from Excel include (Walkenbach, 2007):

- *File Structure:* Easy organisation of application elements; multiple worksheets and chartsheets are stored in one workbook. The workbooks also contain VBA modules that can be hidden from the user.
- *Visual Basic for Applications:* The macro language is powerful and allows for the design and implementation of powerful programs.
- *Easy Access to controls:* Controls such as buttons, list boxes and option buttons can be added to excel worksheets and can offer user interaction.

- *Custom dialog boxes:* Creating user forms and dialogue boxes is easy.
- *Custom worksheet functions:* Worksheets function can be programmed with VBA to simplify formulas and calculations.
- *Customisable User Interface:* User interface can be customised creating new toolbars and menus.
- *Customisable shortcut menus:* The right click shortcuts menus can be customised with excel.
- *Powerful data analysis options:* Excel Pivot tables can help summarize large amounts of data.
- *Microsoft Query:* Important data sources such as text files, web pages and standard database file format can be accessed directly from the worksheets.
- *Extensive protection options:* Information and data can be confidential and protected from data users.
- *Ability to create "compiled add-inns":* New add-inns can be created to add new features to Excel.
- *Support for automation:* VBA supports automation that controls other applications such as generate reports as a Word document.

Although Fortran, C++ were available for use upon request from the IT services at the University of Leeds, the software programming was incorporated using Excel Visual Basic for Applications (VBA), which provided an easy to use tool for programming the application, it was available free with Excel and combined the rich object library of the Excel that could be used for manipulation.

3.3.5.2 The optimisation routine

In order to provide the users with the option to produce alternative 'what if scenarios' and Action Plans that could improve the innovation potential of the organisation according to the user specific requirements, an optimisation routine was incorporated into the computer application, **InnoAct.**

Optimisation deals with the analysis and solutions of problems for finding the best item in a set. The way that the term 'best' is defined, and the structure of the set, determines the different fields of optimisation theory: linear, integer, stochastic, nonsmooth optimisation, optimal control, semi-infinite programming, etc (Ruszczynski, 2006). The most common areas in which optimisation theory is applied include: engineering, statistics, economics, management sciences, computer science and mathematics. It is beyond the scope of this research to analyse the different fields of optimisation theory. For full details on optimisation theories see Ruszczynski (Ruszczynski, 2006).

The objective function that would be used by the optimisation algorithm (see Chapter 8) was a non-linear function. There are a variety of methods for solving optimisation Non Linear Programming (NLP) problems, and no single method is best for all problems. The most widely used methods are the Generalized Reduced Gradient (GRG) and the Sequential Quadratic Programming (SQP), both of which are called active-set methods, the Interior Point or Barrier method and the genetic algorithms. It is beyond the scope of this research to analyse the different methods. However, the discrete nature of the factors included in the function required a suitable optimisation technique of which the genetic algorithm (GA) is currently the most popular choice and as such the method incorporated within the optimisation routine (Toropov, Alvarez and Querin, 2010).

An optimisation process using the Genetic Algorithm that could be incorporated as an AddIn for Excel was available for purchase from the Frontline Systems Inc. However, an optimisation routine that could be used as an AddIn for the Excel using also the GA was developed within the School of Engineering, at the University of Leeds by Professor Toropov and Dr. Querin. The decision to develop the Add Inn for Excel within the University of Leeds was based on minimising the cost required for obtaining the Front Line Systems Add Inn. The AddInn that was developed within the University of Leeds was incorporated into the software application, **InnoAct**, and allowed for the calculation of alternative scenarios of Action Plans for a user defined innovation potential. The optimisation routine is demonstrated in Chapter 8.

3.3.5.3 Validation and verification methods

The software evaluation was conducted using software verification and validation (V & V) techniques. Verification ensured that the product was built right and involved checking software specifications. Validation dealt with whether the product to be built was the right product and involved ensuring that the software met the needs or expectations of the users (Sommerville, 2001). V&V involved checking processes such as inspections and reviews during all stages of the design, implementation and testing (Sommerville, 2007).

The computer application V&V was planned in the early stages of the development process. V&V involved checking processes such as inspections and reviews during all the stages of component testing, system testing and acceptance testing (Sommerville, 2007). The results of the V&V process are discussed in Chapter 8.

3.3.6 Developing a generic systematic procedure for managing innovation

The previous accomplishments: the generic holistic model of innovation that included the identification of all the factors playing a key role to innovation; the generic system developed to identify the condition of each factor; the mathematical model developed to describe the innovation mechanism; and the computer application developed to increase the usability of the mathematical model; were all integrated to define a generic proposed procedure for managing innovation using a holistic approach. This proposed procedure was designed for two main purposes: for facilitating the management of innovation indicating the necessary steps in improving innovation performance; and for providing a standardised procedure that could be offered for repeating the process followed within this research for the sake of evolving the generic mechanism of innovation.

The different methods for designing the process are analysed in section 3.3.6.1 by examining the outputs of modelling processes. A justification of the method used for modelling the proposed process is also provided within section 3.3.6.2.

3.3.6.1 Methods of modelling processes

The products of the modelling process are models. Some of the most common models used to identify processes and components, that lead to the expected program outcomes, are the causal loop diagrams (Ford, 2009), the logical frameworks (NORAD, 1999; World Bank, n.d.), and the logic models (Wyatt Knowlton and Phillips, 2009). Those models have been used for similar purposes; however, they are fundamentally different, yet complementary tools.

Causal loop diagrams are used to represent the cause and effect relationships of a complex system. The emphasis is placed on the role of the information feedback (Ford, 2009). Causal loop diagrams are mainly used for behaviour analysis, however, they cannot explicitly represent a decision-making process, and therefore lack the organising power (Ford, 2009).

Logical frameworks have been used widely by large organisations to design, implement and to evaluate large international projects. Despite the wide use of logical frameworks, they have been criticised because of the limited emphasis they give to the logic behind what the framework is attempting to achieve. Logical frameworks tend to use a rigid, fixed format, and their focus is more on auditing and less on learning (Gasper, 2000).

A single and coherent form of logic is critical input for the planning, execution and evaluation of programs (Wyatt Knowlton and Phillips, 2009). Logic models are offered to provide for the deeper understanding of the logic that follows the appropriate actions and the links to expected results. Logic models place more emphasis upon the increasing of knowledge and learning, and on whether the actions that are applied really help to achieve the desired results (Royse, Thyer and Padgett, 2010). Logic models entail this notion of a coherent logic, and have been widely used to support the design, planning, communication and evaluation of programs (Millar, Simeone and Carnevale, 2001; Stufflebeam and Shinkfield, 2007; Royse, Thyer and Padgett, 2010).

Based upon the previous discussion, a logic model was used to communicate the proposed process the aim of this process, and how the process can affect those who use it.

3.3.6.2 Logic Models

Logic models are visual approaches that depict planned activities and expected results, providing a roadmap to a specific end. There are two types of logic models: the theory of change model and the program model. The two types of models differ in the level of detail, but do represent the same logic. A theory of change model is simply a general conceptual model on how a change can occur. A Program Logic Model (PLM) includes a detailed description of resources, planned activities, outputs, outcomes and intended results (Wyatt Knowlton and Phillips, 2009).

The modelling exercise of the logic model undertaken resulted in the development of both types of models. The conceptual model that was developed (see Chapter 3) represents the theory of change model, and was used as a basis to inform the development of a programme logic model. The program logic model (PLM) was developed to describe with detail the resources needed and the activities that should be planned in order to facilitate innovation. If the activities planned in the PLM are implemented then the short and long term outputs, the outcomes and impacts, could be accomplished (Wyatt Knowlton and Phillips, 2009). The development stages of the program logic model are analysed in Chapter 9.

3.3.7 Evaluation of the proposed systematic procedure

Evaluation refers to the systematic process of delineating, obtaining, reporting and applying descriptive and judgemental information about an object’s merit, worth, need, need assessment, feasibility, and significance (Stufflebeam and Shinkfield, 2007). An explanation of the meaning of these terms, included in the definition above, is provided below.

Delineating involves focusing the evaluation on key questions, key audiences, clarification of the pertinent values and criteria, and interacting with the stakeholders of a program. Obtaining encompasses the work involved in collecting, organising, analysing and synthesising information. Reporting involves providing feedback of the evaluation process. The application step involves the application of the findings to improve the program. Descriptive and judgemental information refers to the description of the program's goals and operations, and the assessment and judgement of the program (Stufflebeam and Shinkfield, 2007).

Evaluation is used for three main reasons: improvement, accountability, and enlightenment. The first main use of evaluation is to provide information for developing a program, ensuring its quality or improving it. The evaluation process that serves the above purposes is called verification. The second main use of evaluation is to produce accountability or retrospective assessment of a completed program. The evaluation process that serves the above purposes is called validation. The third main use of evaluation is to help the dissemination of proven practices and help potential recipients to decide upon adoption of those practices (Stufflebeam and Shinkfield, 2007).

In using the PLM for evaluation purposes, the process of designing and conducting the evaluation focused on both verification and validation. Verification helped to improve the program's quality and effectiveness by logically connecting the resources, activities and outcomes. Validation helped to collect information on whether the program can achieve its intended results. Although, it is not possible to prove that the intended result, which is the growth of the organisation as a result of increasing the proportion of its revenues associated to innovation, the evaluation can establish the logical links between the activities and intended short-term, intermediate and long-term outcomes. Testing the success of the intended long-term outcome and impact would require a longitudinal research study, and measurements of an individual organisation's planned interventions, both of which are outside the scope and the timeframe of this research.

The evaluation processes incorporated the use of the software application and thus conclusions were also derived concerning the validity of the software application that has been developed. The results of the evaluation procedure are demonstrated in Chapter 10.

3.4 Summary

This chapter has reviewed the philosophical approaches to research and demonstrated the linkage between the context of this research and the philosophical context of experiential realism. This chapter has also explained issues on research methods in general and specifically for the methods adopted for this research. The methodology issues and the techniques adopted were explained objective by objective.

The implementation of the methodologies described in this chapter generated data that had to be analysed in order to understand better the innovation management practices and describe the innovation mechanism. The next chapter, Chapter 4, describes all the factors that were found to play a key role to innovation and were obtained during the development of the holistic model of innovation addressing the first objective of this research. The results of the elaboration of the techniques explained for each of the seven objectives are demonstrated in Chapters 4, 5, 6, 7, 8, 9, and 10 respectively.

CHAPTER 4: A GENERIC HOLISTIC MODEL OF INNOVATION

This chapter presents the output of the grounded theory techniques employed for developing a holistic model of innovation as explained in section 3.3.1.

Specifically this chapter's focus is on:

- presenting the three key areas of innovation management research and the main categories emerged from the grounded theory techniques employed;
- discussing the emergent categories and describing the factors related to the different dimensions of each category;
- illustrating the holistic model of innovation in the construction industry by capturing all the factors identified within each emergent category.

4.1 The key areas of innovation research and the main emergent categories

The exploration of the literature revealed that other research in the field can be classified into three key areas: research on innovation relating to the internal environment of organisations; research on the strategic resources that cause innovation to occur; and research on innovation relating to the external environment in which organisations operate (also refer to table 4.1.p.128).

Within the key area of the internal environment the main categories that emerged were:

- the organisational culture (Landry, Amara and Lamari, 2002; Lemon and Sahota, 2004; Uher and Loosemore, 2004; Aragón-Correa, García-Morales and Cordón-Pozo, 2005; Carbonell and Rodrvguez-Escudero, 2009);
- the organisational structure (Kash and Rycroft, 2002; Simmie *et al.*, 2002; Buchanan and Huczynski, 2004; Kash, Auger and Li, 2004; Shefer and Frenkel, 2005);
- the organisational strategy (Porter, 1985; Gilbert and Birnbaum-More, 1996; De Wit and Meyer, 2004; Harvard Business School, 2005);
- the organisational policy (Pavitt, 1976; Faulkner and Campbell, 2006); and

- the organisational learning systems (Koontz and O'Donnell, 1968; Senge, 1991; Worthington and Britton, 2000; Thompson, 2003; Fox and Waldt, 2007).

Within the key area of strategic resources, the main categories that emerged were:

- the marketing strategy (Kotler, 2003; Lau and Ngo, 2004; Greco, 2008);
- the finance (Mintzberg, 1979; O' Sullivan, 2005; Medina, 2006);
- the operations management (Manu, 1996; Hendriks and Vriens, 1999; Brown *et al.*, 2000; Lowson, 2002; Bettley, Mayle and Tantoush, 2005); and
- the human resources management(Bratton and Gold, 1999; Hendriks and Vriens, 1999; Lau and Ngo, 2004).

Within the key area of external environment the main categories that emerged were:

- the political–legal framework (Manseau and Seaden, 2001; Gillespie, 2007; Rhodes, Binder and Rockman, 2008);
- the economic environment (European Commission, 2005; European Commission, 2006; Katz, 2006); and
- the infrastructures (Tang, 1998; Klein Woolthuis, Lankhuizen and Gilsing, 2005; OECD, 2006; HM Government, 2009).

The following sections present the findings of the grounded theory techniques that were applied and discuss the main categories identified in each key area and the factors reflecting the different dimensions of these categories as explained in Section 3.3.2.

4.2 Internal Environment

The internal environment capacity for managing innovation is alternatively called within the literature ‘organisational innovation’. The literature provides diverse approaches to depicting the internal characteristics of an organisation in order to explain the complex phenomenon of organisational innovation. A part of literature focuses on the identification of the ‘structural characteristics of an innovative organisation and its effects on product and technical process innovations’ (Mintzeberg, Teece as cited in

Armbruster *et al.*, 2008, p.645). Another part of literature focuses on 'theories of organisational change and development', 'how changes occur' (Hannan and Freeman, 1984; Armbruster *et al.*, 2008) and 'how organisational innovation emerges (Armbruster *et al.*, 2008). A third part deals with how innovation emerges, using theories of organisational creativity and organisational learning systems (Storey and Salaman, 2005). However the term "organisational innovation" remains ambiguous (Lam, 2005). The underlying issue is that innovation is the key to an organisation being able to successfully exploit new ideas, implement new practices and procedures and turn them into economic benefit. It is not enough to address innovation by partly focusing on what tends to be of significant importance at the specific time that innovation in organisations is studied. Therefore, all potential factors that can influence innovation within the organisational context should be studied.

The organisational context is found to play a key role in shaping innovation performance. This section analyses the key elements in which the innovation process can be improved within the organisational context, by examining the factors of an organisation's internal environment that are found to contribute to innovation. Overall, sustaining the capability for innovation drives the focus on the organisation's cultural, structural, strategic and policy characteristics.

4.2.1 Organisational culture

Culture refers to the cumulative deposit of knowledge, experience, beliefs, values, attitudes, meanings, hierarchies, religion, notions of time, roles, spatial relations, concepts of the universe, and material objects and possessions acquired by a group of people in the course of generations through individual and group striving, and is passed along by communication and imitation from one generation to the next (Hoftede, 1997). Different layers of culture can be found within the same culture. The different layers exists at the following levels: the nation's culture at the national level; the ethnic, linguistics, or religious differences that exist within a nation; the gender level; the generation level associated with the differences between generations; the social class level associated with education and occupation; the corporate level associated with an organisation's culture.

The concept of organisational culture is particularly important in managing the change within an organisation, but at the same time it is a very challenging concept because of its intangible nature (Uher and Loosemore, 2004). Cultural characteristics underpin actions and in that sense culture is important to support the strategy of an organisation. Therefore, strategies that bring change can be successful not only by changing structures and processes but also by changing culture. As such, organisational culture has a crucial role in fostering innovative behaviour (European Foundation for the Improvement of Living and Working Conditions, 1997). For example organisations with highly capable and motivated people can support innovation if "they have the culture of sharing the same values and a common commitment, among organisation members, in accepting innovation-related norms and beliefs prevalent within the organisation" (Hartmann, 2006, p. 159). Carneiro (Carneiro, 2008, p.177) further notes:

> "An environment that nurtures motivation to adopt innovative effort can be cultivated in the functional area, in the contacts with customers, or throughout an entire organisational culture".

One way of understanding culture is to analyse an organisation's symbols, rituals, and ideologies (Uher and Loosemore, 2004). However within the context of studying the cultural characteristics that encourage innovative behaviour, culture can also be studied by looking at attributes such as: technology used, leadership style, ownership type and types of collaborations (Carbonell and Rodrvguez-Escudero, 2009).

4.2.1.1 Technology

Taking a broad view, technology is defined as being the state of the art of the know-how, and the tools used (Sclove, 1995). Often, technologies are characterised by their intended function (Sclove, 1995). In the construction industry, the adoption of advanced technology resulted in productivity gains and innovation due to automation and improvement of production processes and better product quality.

Although the above definition is quite straightforward there is another notion relating to technology. Sclove (Sclove, 1995) argues that technology can be recognised as an aspect of social structure. Social structure refers to 'the background features that help define or regulate patterns of human interaction' (Sclove, 1995, p. 11). In that sense, technology can often embody and express political value choices that in their operation and effects are binding to individuals and groups. The way in which technology is used for coordination between individuals and groups determines the appropriate form of organisation, which significantly affects culture (Hartmann, 2006). The more complex the technical system is, the more elaborate and professional the supporting staff. Technology is an integral part of contemporary culture and innovation and its role is important in shaping the culture of innovation in the next century (Irish Council, 1998). In that sense, the technology used by construction organisations can have a profound effect on culture and thus on work patterns.

The role of technology in forming social behaviour reveals that it impacts on organisational dimensions such as structure, size, centralisation/ decentralisation, leadership, communication effectiveness and productivity (Orlikowski, 1992). The important role of technology is both recognised in forming social behaviour as seen in the paragraph above and in increasing performance. This leads the focus on the role of technology towards increasing innovation performance. Overall, the literature shows that technology is an essential component for an organisation to reconstruct, transform, communicate, evolve and remain competitive in order to respond to the market challenges (Sexton and Barrett, 2004; Hargadon, 2005; Guan *et al.*, 2006a). New technologies and technology transfer can be a potentially powerful source of innovation, as they can appropriately transform and complement current technologies, so as to create and sustain better levels of performance in construction firms (Irish Council, 1998). Analysis on the notions of technology used by organisations for increasing performance and achieving innovation is provided later in Section 5.2.1.1.

4.2.1.2 Leadership

Leadership is referred to as the ability to inspire confidence and support among the people who are needed to achieve organisational goals (DuBrin, 2010). Leadership and power in an organisation can influence organisational culture (Finlay, 2000). Leaders who wish to encourage an environment of motivated employees should facilitate 'task involvement' rather than 'ego involvement' (Day, 2001). Contrary to what leadership behaviours used to represent in the past, innovation and organisational development can only be supported by a philosophy of leadership that is diametrically different than in the past. Innovative activities should be fostered by developing a spirit of teamwork and by encouraging higher employee motivation, both are characteristics that are found to have a positive impact on performance levels (Carneiro, 2008, p. 178). Many studies focus mainly on the creative or idea generation stage of innovation (Carneiro, 2008). However, innovation also includes the implementation of ideas that can be facilitated with an appropriate leadership style (Mumford, 2000; McAdam, 2002).

4.2.1.3 Ownership

Ownership is a very important relationship, as it carries rich semantics with respect to the owner and the property that is owned (Halper *et al.*, 2007). According to Webster's dictionary, ownership is defined as: the state or fact of being an owner; proprietorship; legal right to own. The construction sector in the UK consists mainly of private organisations which in conjunction with sole proprietors account for a 66.1 per cent of private sector turnover. The industry's characteristic is that it has the highest percentage of enterprises with no employees, constituting 88.6 per cent of the total enterprises, while sole proprietors in the construction industry in the UK account for 23.8 per cent of the private sector turnover (Dainty, Green and Bagilhole, 2007). It is recognised that the different types of ownership may contribute differently in allowing or supporting innovation in organisations.

4.2.1.4 Collaborations

Collaboration is defined as the act of working together not only to solve problems, but also to learn, to share, or just be together (Beyerlein, Beyrlein and Kennedy, 2006). The culture of collaborations in the construction industry relies heavily on cooperation, which is found to generate a reflective and mutual learning environment, encouraging the effective transfer of knowledge - internally among employees, and externally among members of their network. Collaborations act as a mechanism for stimulating mutual satisfaction as well as improving the competitive advantage of partners regarding quality, safety performance, sustainability, dispute resolution, human resource management, open innovation, and also time and cost reductions (Finlay, 2000; Love *et al.*, 2002). Long-term alliances aim to incorporate a learning environment that encourages mutual understanding and benefits from the relationships created among the different parties, as shown by various authors such as Barlow, Cohen, Jashapara & Simpson (Barlow *et al.*, 1997), Chan, Chan & Ho, (Chan, Chan and Ho, 2003), Egan (Egan, 1998), and Dahlander and Gann (Dahlander and Gann, 2010).

In construction the increased need for cooperation also stems from the increased complexity of the sector, and also the uncertainty and time pressure that characterise construction projects (Hyland and Beckett, 2005). These characteristics require relation-specific investments, knowledge sharing, flexibility and integration, which are facilitated in long-term cooperative relationships (Gidado, 1996; Pietroforte, 1997; Eriksson and Pesämaa, 2007). Collaborations initially occurred among organisations that were geographically co-located, forming sectoral clusters. Co-located collaborations in the form of sectoral clusters represent the territorial agglomeration that provides the best context for an innovation-based globalising economy. There are various studies emphasising the need for understanding the innovation observed within clusters (Asheim and Coenen, 2005; Engel and del-Palacio, 2009).

4.2.2 Organisational structure

Organisational structure is the formal system of task and reporting relationships that controls, coordinates and motivates employees so that they work together to achieve organisational goals (Simmie *et al.*, 2002) The structural composition of an organisation could not foster innovation unless it supports the free flow of information. It is important for the functionality of organisations that the decision-making authority is based upon expertise rather than positional authority, and intense communication within the functional groups within the project context (Buchanan and Huczynski, 2004). Organisational structure can be explored by examining the organisational hierarchy, the number of people that report to a manager, the organisational relationships, and the organisational size.

4.2.2.1 Hierarchy

Hierarchy is defined as a rank of ordered groups of people or things within a system (Walker, 2007). Although hierarchies in an organisation tend to be considered as rigid and lacking in flexibility and adaptability, they still continue to exist within organisations. A reason for the existence of hierarchies is that they prove to be great devices to cope with complexity, especially in large growing organisations. Systems theory recognises the existence of hierarchies and as organisations can be seen to be a system, their processes consist of a number of integrated subsystems where existence of a hierarchy is needed (Walker, 2007). Moreover, it is recognised that hierarchical organisations are different from each other implying that they can adapt to their different environments. This can be linked to the fact that organisations can be seen as being open systems, with hierarchies being a part of that system.

Hierarchies are important in performing large, complicated, enduring tasks. However complicated hierarchies tend to have flattened, teamed and networked to achieve greater flexibility, performance and to create a climate of innovation (Finlay, 2000). There are different types of hierarchies, which facilitate innovation to a lesser or greater extent.

4.2.2.2 Number of people reporting to a manager

Linked to the spatial dispersion is the s*pan of control,* which refers to the number of subordinates who report to a single supervisor or manager, and for whose work that person is responsible. In an organisation with flat hierarchy, it can be seen that there are many employees reporting to each supervisor, hence that person has a broad span of control. In a tall organisational structure, fewer employees report to each manager and hence the span of control of the managers is narrow. Effectiveness and innovation within organisations can result from the better coordination and management of teams, which is affected by the span of control (Langford and Male, 2001).

4.2.2.3 Organisational relationships

Linked to the number of hierarchical layers and span of control are organisational relationships and communication. Ideally, employees from different parts of the business and at different levels of the hierarchy will feel willing and able to talk openly with each other, sharing problems, ideas, learning, and forming relationships. In that respect, employees should be trusted and empowered to an appropriate degree to communicate with one another, as this is important in the diffusion of information, knowledge and experience that can allow innovation to grow (Sir Ian Hamiliton as cited in Buchanan and Huczynski, 2004).

4.2.2.4 Organisational size

According to the European Commission's definition, micro, small and medium-sized enterprises are categorised according to their staff headcount and turnover, or annual balance-sheet total (European Commission, 2003). A microenterprise is defined as an enterprise which employs fewer than 10 persons and whose annual turnover and/or annual balance sheet total does not exceed EUR 2 million. A small enterprise is defined as an enterprise which employs fewer than 50 persons and whose annual turnover and/or annual balance sheet total does not exceed EUR 10 million. A medium-sized enterprise is defined as an enterprise which employs fewer than 250 persons and whose annual turnover does not exceed EUR 50 million or whose annual balance-sheet total does not exceed EUR 43 million. A large enterprise is defined as an enterprise which employees more than 250 persons and whose annual turnover exceeds 50 million

The size of an organisation has been considered to be an important factor in determining their ability to adopt innovations. Old and large organisations tend to be bureaucratic and have more formalised behaviours. Empirical evidence supports the hypothesis that R&D expenditures are a precondition for determining an organisation's level of innovation activities (Finlay, 2000). Many previous studies have focused on the positive effect that an organisation's size has on its level of R&D expenditure. An organisation's propensity to invest in R&D is positively associated with its size (Shefer and Frenkel, 1998; Frenkel *et al.*, 2001; Shefer and Frenkel, 2005). It is widely believed that a major proportion of industrial R&D is undertaken by large firms. However, Fisher & Temin (as cited in Shefer and Frenkel, 2005) in their study of a high-tech group of organisations found that there is a statistically significant negative relationship between the rate of investment in R&D and an organisation's size. Such arguments by researchers are based on the findings that larger firms increase bureaucratic control, which hinders R&D activity. Furthermore, when organisations grow, incentives for individual scientists and entrepreneurs to innovate might weaken, due to the diminishing opportunities for an individual to benefit by contributing in innovation (Shefer and Frenkel, 2005). In many cases, hierarchically-established conservatism in larger organisations contributes towards the obstruction of such incentives. Evidence shows that small organisations tend to achieve high innovation rates in relation to their size, whilst R&D productivity (innovations per R&D unit) tends to decrease along with firm size (Arias-Aranda, Minguela-Rata and Rodríguez-Duarte, 2001).

4.2.3 Organisational strategy, policy and learning systems

The following sections discuss the impact of the organisational strategy, policy and the organisational learning systems towards innovation.

4.2.3.1 Organisational strategy

A strategy is what an organisation does, what is the vision and the goal to achieve and how, to focus on the plan to reach this goal (European Commission, 2003). 'Strategies are all the things that businesses do, the ways they choose to do those things, and the decisions they take, in order to obtain success' (Harvard Business School, 2005p. xiv). Concerning a strategy towards innovation, Thompson (2003) argues that organisations gain competitive advantage by developing a set of activities that distinguishes them from their competitors. Mintzberg (as cited in Porter, 1985) also argues that strategy is based on firms' existing culture, rules, and assumptions.

4.2.3.2 Organisational policy

Policies are related to stated objectives and strategies and assist in their implementation. At the same time, they should not restrict managers to the extent that they are unable to make incremental and adaptive changes when these are appropriate or necessary. Policies need not be written down or even formulated consciously. They may emerge as certain behaviour patterns, become established in the organisation and should be regarded as a facet of values and culture (Faulkner and Campbell, 2006). Studies of innovation policies have emphasized that innovation is the result of complex and intensive interactions between various actors, knowledge spillovers are crucial to a successful innovation process and collaborations and networking can facilitate innovation. Organisations policies that share the above propositions can foster innovation in organisations while other types of policies might be less encouraging or hindering.

4.2.3.3 Organisational learning systems

Organisational learning systems can be regarded as being the capacity or processes within an organisation to maintain or improve performance based upon experience (Fox and Waldt, 2007). An organisation may be compared to a human body. Organisations interact with the environment in which they operate and convert inputs into outputs

(Koontz and O'Donnell, 1968). Inputs, in organisational terms can be considered to be the people working to achieve the organisation's goals, the physical and financial resources available to the organisation, and the availability and exploitation of information, provided by the environment. Outputs comprise of the goods and services developed, information and knowledge, and ideas and waste, all of which are 'discharged into the environment for consumption by "end" or "intermediate" users, in some cases representing inputs that are used by other organisations' (Thompson, 2003). According to Thompson the form of organisations that develop valuable outcomes such as sustainable competitive advantage, innovations and organisation efficiency and increased performance are the learning organisations (Worthington and Britton, 2000). In a knowledge-based economy the dynamic systems of learning is important in building the capacity to respond to new market opportunities (Thompson, 2003).

4.3 Strategic resources

'Strategic resources' refers to all of the physical, financial, human and organisational capital capabilities and competences that can be used to enable organisations to conceive and implement value-creating strategies (Barney and Clark, 2007). Strategic resources can facilitate change and innovation in organisations. Innovative organisations are ready for change, and looking to make positive changes, in order to get ahead and stay ahead of competition using their strategic resources (Kotler, 2003). The strategic issues that are relevant to the resources used to create and sustain competitive advantage and innovation focus on: marketing; systems/processes and knowledge management; finance; and human resources.

4.3.1 Marketing

Marketing is the managing of activities that comprise marketing function, such as product design and pricing, advertising, selling and distribution (Lau and Ngo, 2004). The marketing strategy of an organisation is important in orchestrating all the activities necessary in executing the organisation's plan to sell and market products or services to the customer (Kotler, 2003). The rationale of the marketing strategy is to analyse and conduct an appraisal of the brand, the category of the products and/or services, the competitive pricing strategy, the marketing and promotional spending strategy, and any R&D and market research expenditure (Greco, 2008). Marketing strategies are successful when they are aligned with the needs of the customers.

The construction industry in the past has not been very active in the marketing of their services (Smyth, 2000). They limited their marketing practices to the extent that they needed to show their ability to correspond positively to the situation requirements of a project and manage it successfully in high inflation environments. The situation has now long changed, the competition has increased enormously at a global level, meaning that effective marketing and sales are required to serve clients more efficiently in productivity and value (Smyth, 2000). The focus on marketing has evolved from being a one discipline issue to a multi-discipline issue involving integration and interaction with processes from other organisational disciplines. Marketing and sales are now merging and being used in harmony for several reasons. For instance, for the creation of flatter management structures, due to faster changing markets, and for the internationalisation of markets due to working over larger geographical markets. The marketing discipline in an organisation can have an effect on its innovation effort and can be analysed by looking at: the promotion of products and services, intellectual property rights, sales management, and the market information availability.

4.3.1.1 Promotion of products and services

Promotion refers to the strategy adopted for communicating the availability of products or services to the target market (Pezzullo, 1998). Promotion of products and services is often used as a complementary tool, alongside the sales effort. In organisations when promotions are not used, sales management needs to start from a very low base without being able to use the profile, image and credibility that is established through promotional efforts. Although promotions seem to be underused by contractors and consultants, there are some examples of promotion that are common. Sometimes contractors offer construction finance to developers as an incentive. Generally, there are desired valuable outcomes to be derived from promotion campaigns, outcomes such as: bringing innovation to the client, increasing volume of products or services, increasing repeat business, creating interest, increasing loyalty, widening usage, etc. Bringing innovation to the client implies that the organisation should always try to create value which provides the incentives to innovate. This value can then be offered to the client through employing professional techniques to promote the services (Smyth, 2000).

4.3.1.2 Intellectual property rights

"Intellectual Property Rights" means patents, registered and unregistered designs, copyright, and all other intellectual property protection (other than trademarks) wherever in the world enforceable (Christou, 2005). Patenting records have steadily increased in all broad technological sectors showing that there is an increasing incentive to patent and privatise knowledge based assets (Andersen, 2005). There is a well documented relationship between Research and Development and patenting (Andersen, 2005). It is apparent that R&D intensive industries such as, pharmaceuticals and computers tend to patent a lot more than industries with smaller technological and R&D activities, such as the textiles industry (OECD, 2009a). Patent statistics have been used to measure the dynamics of the innovation process. Although, it is argued that patent application is an indicator of the successful exploitation of research – an invention covered by a patent need not be industrially applied, and therefore patents are considered to be as an intermediate step between R&D and innovation. In that sense patents can be classified as being an output of R&D and as an input for innovation (OECD, 2009a).

4.3.1.3 Sales management

Sales management refers to the systematic process of formulating a sales strategy and implementing it through selecting, training, motivating, and supporting the sales force, through setting sale revenues targets, and monitoring the sales performance by analysing the associated behavioural patterns and costs (Business Dictionary, 2010b). Innovation is defined as being the successful exploitation of ideas, or the implementation and commercialisation of inventions (Gaynor, 2002). Therefore for innovation to occur some action must take place (Gaynor, 2002). The results of innovation must be sold and it is often that new products or services initiate a sales call (Gaynor, 2002). Selling is the attempt to persuade a customer of the value of products or services (Smyth, 2000). Traditionally, selling has relied upon techniques such as powerful openings, distinguishing between features and benefits, spotting buying signals, and overcoming objections. Although these techniques have a proven success rate, a professional sales management approach needs to create the image of a credible, professional organisation, that builds productive and long term relationships with customers (Gillen, 2005). Without an established, knowledgeable and well motivated sales team, a good product development could lead to failure (Gaynor, 2002).

4.3.1.4 Market information availability

Market research information is important, helping to create both the marketing strategy and the R&D activities of an organisation. Most innovations are driven by the customer needs, therefore keeping updated information on customers is a cognitive and dynamic process that provides feedback and ensures that the marketing and sales plan is evolving in relation to changes in the market and the organisation (Smyth, 2000). Organisations are then able to respond quickly to opportunities based upon good market information. Furthermore, information from the market might imply a change in R&D plans that can lead to a revision of the R&D strategy and recalibration to meet the needs of the market. The rate of the ability to find opportunities is defined by the organisation's ability to locate and manage the appropriate information (Mintzberg, 1979). Recognition of the valuable information made available through environmental scanning is, according to Cohen & Levinthal (1990), the organisations absorptive capacity. This capacity is essential to the organisation's innovative capability.

4.3.2 Operations management

Every organisation that offers goods or services has an operations activity (Lowson, 2002). Operations management can be defined as being the design, operation and improvement of the internal and external systems, resources, and technologies that create and deliver an organisation's primary products and services (Lowson, 2002) Operations management has been conceived as being the vehicle by which business strategy is delivered. This conception has changed somewhat, as operations require not only to improve functional performance but also to ensure that processes are designed and executed in the best possible way, so as to maximise effectiveness and efficiency and deliver high value to all stakeholders (Bettley, Mayle and Tantoush, 2005) and to customers (Brown *et al.*, 2000). Innovation can also be viewed as a process, as it requires a sequence of activities that can successfully lead to an outcome (Brown *et al.*, 2000). Within an organisation innovation is a core process that requires the capability of renewing and translating ideas and resources into new products and processes. Innovation therefore must be applied along with operations management, if it is to contribute to development. The dimensions of operations management that have been found to have a strong relation to innovation are: process integration, quality management and control, and knowledge management systems (Hendriks and Vriens, 1999; Perdomo-Ortiz, Gonzαlez-Benito and Galende, 2006; Prajogo and Sohal, 2006).

4.3.2.1 Process integration

Business processes integration describes the improvement of processes and the connection or synchronisation of two or more organisational processes (Berente, Vandenbosch and Aubert, 2009). It also describes the communication links used in exchanging information during all stages of the process, by engaging with all of the contributing factors (Valle and Vαzquez-Bustelo, 2009). The aim of integration is to enhance decision support, reduce asset bases and costs, receive more accurate and timely information, higher flexibility or increased customer satisfaction (Bernroider and Bernroider, 2005).

Traditional approaches for developing new products usually result in a lack of integration of activities, and also a lack of coordination between the functional areas and the contributors that are involved in the process (Valle and Vαzquez-Bustelo, 2009). These approaches focused on carrying work on separate tasks and in isolation resulting 'in lack of communication, between product design and production and consumer needs' (Valle and Vαzquez-Bustelo, 2009). Business process integration is often a key goal associated with the implementation of information technologies, such as Enterprise Resource Planning (Rajagopal, 2002). The scope of it, is to minimise the effort needed to facilitate the flow of information across an organisation's different disciplines and functions with the overall aim to better serve the customer (Berente, Vandenbosch and Aubert, 2009). Innovation can be seen as a process facilitated by incremental or radical changes in different organisational disciplines. As such, the concept of business process integration is vital in achieving greater communication and information exchange, so as to power the innovation process more effectively.

4.3.2.2 Quality control

Quality is the result of a sequence of activities embodied within the processes of an organisation. Quality is a measure that can identify relevant information for improving processes (Brown *et al.*, 2000) by measuring critical aspects such as reliability and durability (Prajogo and Sohal, 2006). Therefore, quality is assimilated into the management practices of an organisation, becoming an integral management priority in the continuous improvement of processes and products. Quality control is regulated by the concept of Total Quality Management (TQM) (Perdomo-Ortiz, Gonzαlez-Benito and Galende, 2006). TQM is viewed as an organisational behavioural model that reflects the evaluations of all business practices and has to be managed effectively. Innovation can sometimes occur out of a desire to increase both the quality of production and the management of operations. The relationship between innovation and quality is that TQM creates a favourable and fertile climate for developing innovation (Perdomo-Ortiz, Gonzαlez-Benito and Galende, 2006).

4.3.2.3 Knowledge Management

Knowledge Management (KM) is defined as being the systematic activity of an organisation when capturing and sharing knowledge (OECD, 2003b). Improving the conditions within an organisation for creating and transforming knowledge assets increases its capability for innovation (National Statistics, 2007). The creation and management of knowledge leads to the development of the organisational learning system. Creation and management of knowledge are interrelated and interdependent into the organisational learning system. This interrelation helps to transform the static nature of knowledge into a more dynamic form, and also contributes to the creation of new knowledge and innovation (Hendriks and Vriens, 1999). Organisational knowledge and exploitation is also related to other characteristics of an organisation such as culture, structure, available resources (IT skills), and processes (Chang and Lee, 2008).

4.3.3 Finance

Finance concerns the provision of money and the effective use of funds (Medina, 2006). The process of innovation is often expensive and time consuming, requiring that the resources allocated for innovation purposes are committed to the process until it is complete. At the same time the results and the returns from these investments are not always guaranteed (O' Sullivan, 2005). The characteristics of the organisations capital structure, financial management; the financiers’ attitude towards organisations and the R&D expenditures are likely to differ significantly and can result in different speeds of innovation.

4.3.3.1 Capital structure

Capital structure is defined as the framework of different types of financing employed by a firm to acquire resources necessary for its operations and growth. Commonly it comprises of stakeholders investments (equity capital) and long term loans (loan capital) (Business Dictionary, 2010a). The capital structure of an organisation can be researched by measuring the debt to equity ratio (Acs, 2002). O'Brien (O'Brien, 2003), studied the implications of the capital structure in adopting an innovative strategy and argues that there is substantial variability in capital structures across organisations of the same sector that serve different competitive strategies. O'Brien (O'Brien, 2003), advocates that capital structure cannot be treated as exogenous to the organisation or irrelevant to its strategy. Therefore, it has been concluded that capital structure should be treated as a function for regulating an organisation's strategy and its basis for competition within an industry. An inappropriate capital structure can hamper the strategy of an organisation and hinder its ability to compete, resulting in significant negative performance consequences. Empirical findings indicate that organisations that are attempting to compete on the basis of innovation will make financial slack a strategic priority and keep financial leverage at lower level than organisations that are not pursuing a strategy of innovation (O'Brien, 2003).

4.3.3.2 Financial management

Financial management refers to the acquisition, financing, and management of assets (Van Horne and Wachowicz, 2009). The financial management approach, as opposed to traditional financial assessments is valued as being a systematic way of assessing the feasibility of innovation before time, money and resources are put into an innovation project (Silverstein, Samuel and DeCarlo, 2009). Innovation is usually risky, therefore the enforcement of methods of articulating and verifying relevant information and knowledge at all times of a project's development, can reduce this risk. Most innovations are driven by customers, and so when there is lack of the right tools to: understand the markets, create brands, define the target market, select the appropriate team of employees and to exercise an appropriate strategy, then they create situations in which innovations fail (Silverstein, Samuel and DeCarlo, 2009). Financial management is an alternative to traditional financial analysis tools such as discounted cash flow and net present value, which tend to distort the possibilities of success of an innovation project. An advanced way of financially managing innovations was introduced with innovation financial management, which is seen as being a more adequate procedure. Innovation financial management can help to identify, track and update key assumptions, and relate and verify them so as to evaluate the innovation before putting too much time, money and resources (Silverstein, Samuel and DeCarlo, 2009).

4.3.3.3 Financiers' attitude

A financier is someone who provides venture capital or other forms of investment to a company, and in return receives the invested money back with interest, or receives a percentage of the company's profits (Business Dictionary, 2010b). The results from a Deutche Bank study suggest that the increase in venture capital investments supports the translation of ideas into innovations (Meyer, 2008). The study shows that early stages (i.e. seed stage) types of financing like venture capital are playing a greater role in the commercialisation of ideas than later stages of financing (i.e. start ups, expansions, buyouts). However, empirical evidence shows the increased importance of the internal financiers of the organisation as opposed to the external financiers (Berger and Udell, 1998). Financing R&D investment has greater implications than financing any other forms of investment (O' Sullivan, 2005), and as such financial constraints may hold back innovation and growth (Hyytinen and Toivanen, 2005) Regardless of the fact that the financing of R&D may be acquired from the inside or outside of an organisation, the ability to innovate is directly influenced by the attitude of the financiers.

4.3.3.4 R&D spending

R&D is defined as the process that is undertaken so as to introduce innovation to an industry and it is found to have a positive effect on innovations (Vinding, 2006). The level of spending in R&D can provide insight on an organisation's intention to innovate. Innovations are the product of R&D. The construction sector is not very active in investing in R&D projects. According to DTI, the UK construction spends 0.1% on R&D as a proportion of output, which is comparable to France but lower than other competitors such as USA (0.2%), Japan (0.3%), Denmark (0.7%) and Finland (2.5%). When compared to other sectors the level of research intensity is low, but does have a significant scope for improvement (Department for Business Innovation & Skills, 2009). However, R&D is prerequisite for the development of new knowledge and technologies constituting innovations.

4.3.4 Human Resources Management

Financial management provide differentiation and competitive advantage including control of costs, so that profit is achieved and value is added to products and services, primarily in areas that matter to consumers (Trott, 2002). In human resources management, values are communicated and spread throughout the organisation.

Human Resource Management is the management of people in work organisations. Human resource management theory emphasizes that employees are critical in achieving sustainable competitive advantage, and therefore human resources practices have to be integrated with the corporate strategy. This, helps the organisation managers to meet efficiency and equity objectives (Bratton and Gold, 1999) Human Resources Management (HRM) practices are found as having a positive impact on a firm's ability to innovate (Hendriks and Vriens, 1999; Carrillo and Anumba, 2002). In innovation oriented organisations, human resources management is being practised along with innovation enhancing HR policies, which differ from traditional HR approaches (Lau and Ngo, 2004). An innovative oriented HR system can improve the organisational capabilities and become a source for creating competitive advantage. However, the literature (Guest *et al.*, 2003) does not provide evidence for a causal effect between an organisation's performance and HRM, and only an association can be established. Lau and Ngo approaches (Lau and Ngo, 2004) in their study show that Human Resources (HR) practices can be an important factor within the overall organisational context that can contribute to increasing innovative performance.

Human resources management in the construction industry is an issue of great importance. It is found that in the recent decades, there is a growing shortage of skilled labour and qualified and experienced managers (Vinding, 2006). Increased quality and quantity of training is needed in order to increase the efficiency and performance of the construction sector (Yankov and Kleiner, 2001; CIOB, 2008). Human resources management can contribute to increasing innovation performance by addressing issues like: number of R&D staff, competence skills of R&D staff, performance of R&D staff, age profile of R&D staff, retention of R&D staff and staff development.

4.3.4.1 Number of R&D staff

R&D staff refers to the human resources that are systematically involved with R&D activities. R&D staff plays a key role in an organisations ability to innovate. According to the Frascati manual for surveys in research and experimental development (OECD, 2002), R&D staff refers to: researchers who are professionals occupied for the development of new products, processes, methods and systems that contribute to the creation of new knowledge; R&D personnel that includes both skilled and unskilled supporting personnel e.g. technicians (carrying out bibliographic searches, experiments, tests analyses, preparing computer programmes etc.); and other supporting staff (such as secretaries or craftsmen), that participate and support the R&D projects (OECD, 2002). As such, it is contended that the percentage of R&D staff in an organisation provides insight on the intention of an organisation to innovate.

4.3.4.2 Competence skills of R&D staff

R&D activities requires high skilled staff based on the assumption that high skilled employees are considered to be more able to cooperate with research institutions due to lesser cognitive distance (Nooteboom *et al.*, 2007). High skilled personnel is considered to increase the level of innovation activities in organisations (Schmiedeberg, 2008).

4.3.4.3 Performance of R&D staff

Performance of staff can be viewed not only as a human resource management issue but also as a business process, which can be aligned with meeting the strategic goals of the organisation (Gupta, 2004). Staff performance is often associated with encouragement to innovate and perform tasks in a profitable and creative way. Personal creativity from thinking employees is creating a climate of innovation that can be easier converted to economic gains (Nijhof, Krabbendam and Looise, 2002).

4.3.4.4 Age profile of R&D staff

The rapidly changing technology has made young people an important source of new skills bringing energy and new ideas into an organisation. Young people can be an invaluable resource that no nation can underestimate (Reid and Barrington, 1999). Quality education and training is critical, and ensures that skills and international competitiveness is improving. Fortunately, the proportion of young people participating in education beyond the statutory school leaving age has been increasing (Reid and Barrington, 1999). Vinding (Leonard, 1998) stresses that young people are educated with the 'most recent knowledge about technology and management practices' contrary to elder people that may have difficulty in applying new technologies. As such the value of new ideas and practices brought from young people can have an impact to the overall performance of an organisation towards innovation.

4.3.4.5 Retention of R&D staff

Retention of R&D staff refers to the staff turnover for a period of time (Kearns, 2003). Kearns (Kearns, 2003), stresses that organisational effectiveness is highly dependent on the retention of the organisation's employees. Employee retention is a core design requirement in human resources strategies. In staff turnover terms employee retention rate of 100 percent means that all staff is replaced. This creates a non ideal environment for increasing efficiency of human resources due to the very large inconsistencies and extra cost this incurs. It is also obvious that staff turnover rate of zero could not be feasible or desirable in most of the cases (Kearns, 2003). The lack of fresh ideas and new employees is likely to breed 'a culture of complacency and lead to organisational atrophy'(Kearns, 2003, p.192). The right level of retention needs to be agreed by the organisation human resources strategists. Even small improvement retention rates would release substantial resources for other purposes (Reed, 2001).

Human resources can respond to the challenge of innovation by attracting, recruiting and retaining the key employees (Reed, 2001).

4.3.4.6 Staff development

Human Resource Development (HRD) refers to the 'process of developing and unleashing expertise for the purpose of improving individuals, teams, work processes, and organisational system performance' (Swanson and Holton, 2009, p. 4). One of the first elements on an innovation oriented HRD policy is training and development (Lau and Ngo, 2004). Training plays a key role in increasing employee knowledge, competences and capabilities that can be critical to the innovation process. Training also facilitates organisational learning and supports the knowledge management systems of organisations. Organisational effectiveness and high performance of firms can be achieved if training is supported by the organisational strategy. Leede et al.(2002) stress that organisations that spend more time and resources on education and training can perform better. At a strategic level, commitment to the development of staff using training can achieve a competitive advantage and can be linked to the innovation performance of an organisation (Leede, de Looise and Alders, 2002; Swanson and Holton, 2009).

4.4 External environment forces

The extent of the innovation capacity of an organisation is dependent on the challenges posed by the external environment in which it operates. "Construction activities are booming when the overall economy is going well" (Garavan, 1997; Egbu, 2004). The characteristic of the external environment in which organisations operate 'is likely to produce more innovative and entrepreneurial organisations' (as cited in Manseau and Shields, 2005, p. 38). The performance of organisations is interrelated with internal factors as well as with the interactions of the external environment. The external factors that nurture innovation can be identified through scanning the external environment's major disciplines, which can impact organisations directly or indirectly. Innovation according to Tang (Tang, 1998) 'thrives on challenge'. Therefore, an innovative organisation would respond to a challenging external environment in which it operates according to its vision, mission and strategy. The political and legal regulations, the economic rules and the technological competences form a larger system in which, organisations' innovation capability is influenced (Tang, 1998).

4.4.1 Political and legal framework

The political and legal framework refers to the structure of society, a legal or a political system. A political system can reflect 'the rules that determine opportunities and incentives for behaviour, inclusion and exclusion of potential players, and structure the relative ease or difficulty of inducing change and the mechanisms through which change may be facilitated or denied' (Rhodes, Binder and Rockman, 2008, p. iiix). The legal system is defined as the set of laws and the concept of how law is administered i.e. common law and civil law (Gillespie, 2007). The political and legal framework can encourage or discourage innovation activity of a country (European Commission, 2005; European Commission, 2006). The construction industry sector is assumed to be the growth engine and an asset base of every country and regulations have a vital role to play in ensuring the market is functioning effectively, consumers are protected, and employees are treated fairly. The political and legal regulations can describe the levels of political freedom in a country and provide the framework to encourage innovation by promoting incentives such as favourable taxation laws, competition and employment laws, and health and safety regulations (Manseau and Seaden, 2001).

4.4.1.1 Political freedom

Political freedom is a form of empowerment. That empowerment can be expressed in three forms: entitlement, involvement, and enablement (Brenkert, 1991). Political freedom is entitlement, because 'not only individuals and their actions should not be restrained by others (including institutions or governments), individuals have the right to demand protection from these forms of inference' (Brenkert, 1991, p. 139). Political freedom is involvement, as individuals can participate in the formation of policies and activities that affect the major features of their lives (Brenkert, 1991). Political freedom is enablement, as individuals have various opportunities available and the means required to carry out activities essential to their lives as political beings (Brenkert, 1991, p. 140) Farr et al. study on providing evidence of causality between measures of economic freedom, political freedom and economic growth suggested that economic well being enhances both political freedom and economic growth. The findings of this study do not support the reverse for political freedom, however the evidence implies that there is an indirect relationship through the level of real per capita GDP. The findings suggest that economic wellbeing and political freedom are related through the impact of economic freedom on the level of economic wellbeing and the subsequent impact of economic wellbeing on political freedom (Farr, Lord and Wolfenbarger, 1998). Other empirical studies on the relationship between civil and political rights with economic development conclude that freedom in all civil, political and economic dimensions tends to favour economic growth and stability that is related to innovation (Chauffour, 2009; Department for Business Innovation & Skills, 2009).

4.4.1.2 Incentives to foreign investors

Incentives to foreign investors is defined as being ‘the measures designed to influence the size, location or industry of a foreign direct investment project by affecting its relative cost or by altering the risks attached to it through inducements that are not available to comparable domestic investors’ (OECD, 2003a, p. 103). Host countries can obtain maximum benefits from foreign investment innovation when affiliates import foreign technology, purchase their inputs in the host country and have technological autonomy (Rama, 2008). The interaction of foreign investors with the governments is dependent upon various interest-group pressures. Although there is a potential for mutual gains, there are complex preferences throughout the investment cycle. Governments offer various fiscal incentives such as physical assets, tax reliefs, and grants or loans to attract foreign investors (Herrmann and Lipsey, 2003).

4.4.1.3 Competition framework

Competition framework is defined as being the set of policies and laws that ensure that competition in the marketplace is not restricted in such way as to reduce economic welfare' (Motta, 2004, p. 30). There is a positive impact on competition-enhancing policies that can have long lasting effects on economic performance. Competition can affect actors in the market structure by providing incentives and encouraging innovative activities (Ahn, 2002). Policy changes like regulatory reforms in different sectors, increased global competition and competition in not-for-profit sectors also confirm that competition brings the market changes that lead to innovation and growth (Ahn, 2002). Schumpeterian theory of market power and innovation supports the idea that competition is detrimental to innovation (Schumpeter, 1942). However, recent empirical studies have shown that competition is forcing firms to innovate in order to survive (Motta, 2004).

4.4.1.4 Employment framework

The employment framework is referred to being the legislation that regulates the contractual agreements between the employee and the employer (Chandler, 2003). Employment protection legislation is playing a key role in the employer's decision to invest in equipment, in education and in R&D in order to grow and expand (Pierre and Scarpetta, 2004). Employers in countries that have tight labour regulations tend to believe that those regulations are restrictive to their plans for growth. However, organisations are affected by employment regulation according to their size. The research of Pierre and Scarpetta (Pierre and Scarpetta, 2004) clearly shows that larger organisations are not affected so much by employment regulations as small organisations are. Small organisations cannot use internal mobility as an alternative to hiring and firing or obtain special arrangements with the regional authorities to dilute associated costs in a way that large organisations do. There is also evidence supporting the view that innovative firms, those that are upgrading their production processes or their products, are more likely to be constrained by strict employment regulations (Pierre and Scarpetta, 2004).

4.4.1.5 Health and Safety regulations

Health and safety regulations form the legislation that applies and controls health and safety issues (Hughes and Ferret, 2009). The term ‘health’ refers to ‘the protection of the body and mind of people from any illness that results from the materials, processes and procedures used in the workplace’ (Hughes and Ferret, 2009, p. 2). The term ‘safety refers to the protection of people from physical injury’ (Hughes and Ferret, 2009, p. 2). The distinction of the two terms is ill defined and ‘they are used together to indicate concern for the physical and mental wellbeing of the individual at the place of work’ (Hughes and Ferret, 2009, p. 2).

Changes to the regulations concerning health and safety and issues, are found to impact positively upon the birth of innovations. Manseau and Shields stress that certain innovations have been born due to new regulations (Manseau and Shields, 2005). Construction organisations need to comply with new regulations, which often stimulate innovation. Health and safety regulations seem to play an important role in innovation as they can foster or hinder it, impacting upon an organisation’s capacity to adapt to new standards (Katz, 2006).

4.4.2 Economic environment

The success of innovation depends greatly on the economic environment of the country. A nation’s competitiveness towards innovation can be analysed by looking at economic factors, such as the level of economic activity, trends in GDP, rate of inflation, currency strength, tax policy and government spending in R&D (Katz, 2006).

4.4.2.1 Economic activity

Economic activity refers to ‘the production and distribution of goods and services at all levels’ (Scott, 2010). ‘Economic activity and expected future levels of it have an important influence on corporate profits, inflation, interest rates, and other variables’ (Scott, 2010). Economic activity is associated with economic growth and innovation activity (Feldman and Audretsch, 1999). The growth of economic activity, innovation and technological change have all been aligned with growth of knowledge and knowledge spill-over (Audretsch and Feldman, 1996). Investment in R&D by private corporations and universities can create knowledge spill-over that can be exploited by third parties. In cases when economies of scale do not play an important role, proximity to the source of new knowledge, such as universities and research institutions, is likely to create innovative activity.

4.4.2.2 GDP trend

Gross Domestic Product (GDP) 'is a measure of the value of all the goods and services newly produced in a country during some period of time' (Taylor, 2007). Studies of national innovation systems show that there is a predictable correlation of GDP and the Gross Domestic Expenditure for Research and Development (GERD), showing that both GDP and GERD exhibit a perfect exponential growth (Katz, 2006; Gao and Guan, 2009). According to Katz (2006), the scale of independent indicators for the European Innovation system show that the GERD for the UK during the period 1981-2000 did not grow as fast as its GDP, while in the Canadian provinces with which the European system was compared, GERD grew faster than the GDP. The realisation of the trend in GDP and GERD relation led the European Commission to publish a press release concerning the R&D intensity as a measure of R&D expenditure as a percentage of GDP. The press release highlights the fact that Europe is on track to miss the objective it set itself, which was to increase its innovative activities, by increasing spending on R&D from 1.9 to 3% by 2010 (European Commission Directorate-General for Research, 2005).

4.4.2.3 Rate of inflation

Inflation is 'a situation where there is a persistent and appreciable increase in the level of prices' (Dwivedi, 2005, p. 389). Inflation rate is the percentage rate of change of a measure of inflation in a preceding year (Dwivedi, 2005). Most commonly, the inflation rate is measured with the annual percentage rate of the Consumer Price Index.

Funk and Kromen (Funk and Kromen, 2005) examined the influence of price rigidities and inflation on growth. Their study focused on the effects of monetary policy on the incentives to innovate and engage in R&D activity, which can lead to an increase in productivity and therefore in economic growth. Their main findings on the impact of inflation to growth are countervailing. Past price rigidity causes the use of large quantities of cheap intermediate goods which can prove to be inefficient, and which at the same time reduces the demand for new goods, and also therefore reduces the incentives to innovate and achieve economic growth. Future price rigidity implies that the relative price of a firm's new goods will reduce with inflation, which can lead to a growing demand for the good and therefore to an increase of the incentives to innovate. Funk and Kromen continue and state that after calibration the former effect dominates, such that money growth, that determines the growth rate of prices, reduces economic growth (Funk and Kromen, 2005). They conclude that moderate inflation rates cause a sizeable reduction in economic growth. Their view is supported by a variety of frameworks by Gillman, Harris et al. (Gillman, Harris and Mátyás, 2004), Gillman and Kejak (Gillman and Kejak, 2005), Itaya and Mino (Itaya and Mino, 2003) who analyse the effects of inflation on economic growth, concluding that inflation has a negative effect on growth.

4.4.2.4 Currency strength

By definition the strength of a currency is relative to the values of other currencies. The fall or rise of currency's strength has both advantages and disadvantages. A falling currency can increase exports of goods as they will be less expensive overseas. It can also increase prices of foreign goods (Papier, 2010). This can result in higher sales for organisations and more expensive foreign labour, which leads to the creation of more jobs for the citizens of the country. Higher sales also mean higher tax revenue for the government, which can positively affect budget deficits. However, a long term drop in the value of a currency can have negative effects for the economy. Inflation can be pressured for various reasons. Commodities that are priced in the global markets are more expensive and the raw materials for the production of goods are more expensive causing an increase in the sale of local goods (Papier, 2010). At the same time, a falling currency means that investing in the country's bonds is discouraged unless interest rates increase, and force the government to pay more on borrowed money. There are also higher interest rates on other items, such as home loans and credit bills, which creates less competition. Situations such as these have often created other effects, like less innovation, slower reaction to customers' needs and higher prices.

4.4.2.5 Tax policy

Tax policy is defined as being the program decided by a government to allocate private income to public assets by means of taxes (Dwivedi, 2005). Tax concessions in Research and Development (R&D) are extensively used by OECD countries as an indirect way of encouraging business R&D expenditures and promote innovation (OECD, 2007). Special tax treatment for R&D expenditures includes write-off of current R&D expenditures and various types of tax relief, such as tax credits or allowances against taxable income (OECD Science Technology and Industry Scoreboard, 2009). In 2008, more than two thirds of the OECD countries had R&D tax credits. R&D tax concessions are a popular measure among OECD and non-OECD governments with France and Spain providing the largest subsidies and making no distinction between large and small firms. Canada and the Netherlands provide more generous tax subsidies to small firms than to large ones. Emerging economies are also implementing these policy instruments to encourage R&D investments. Brazil, India, South Africa and China provide a generous and competitive tax environment for investment in R&D. According to the OECD the United Kingdom increased the rate of tax subsidies by 10 percent in 2008 aligning it with the OECD average, whilst the support for small enterprises in the UK is higher than that of the OECD average (OECD Science Technology and Industry Scoreboard, 2009).

4.4.2.6 Government spending in R&D

The role of government policies in encouraging economic growth involves the government spending in R&D which is measured as a percentage of the Gross Domestic Product. Government support for R&D in the UK accounted for £20.8 billion in 2003

(National Statistics, 2005). However, both UK-based businesses and the Government itself continue to invest less in R&D as a percentage of GDP than other comparator economies. Total R&D intensity is 1.8% of the UK GDP in 2007 that is below the 1.9 OECD average and the government funded R&D in business is 2.2% below the OECD average (OECD Science Technology and Industry Scoreboard, 2009).

4.4.3 Infrastructural provision

Good communication with the technological community and knowledge of the latest technological achievements enables a firm to track technological trends. In addition the technological environment in respect of the government's R&D spending, energy and transportation provision create a prosperous ground towards innovation (HM Government, 2009). Infrastructural provisions in terms of energy availability and transport can therefore be regarded as helping to encourage innovation.

4.4.3.1 Transport provision

Infrastructural issues and their relation to innovation have not been given a great deal of attention by innovation researchers (Klein Woolthuis, Lankhuizen and Gilsing, 2005). However, investment in transportation infrastructure is important for the transformation of a region, and greatly contributes to the economic growth of a country. Transportation infrastructure, such as road and rail networks, reduces the cost of transport between regions. It also plays an important role in reducing regional disparities and in improving the competitiveness of a region, it also helps: to facilitate trade, the movement of labour and economies of scale. The improvement of the competitiveness of a region creates a prosperous ground for new investments (OECD, 2006).

4.4.3.2 Energy provision

Energy supply is essential for carrying out basic operations, and when considered in combination with communication infrastructure, can enable firms to grow more quickly and become more competitive in the global arena (Edquist *et al.*, 1998). Energy infrastructure contributes to the creation of the external environment that fosters innovation.

4.5 The generic holistic model of innovation

Research on the evolution of research in innovation management and innovation models revealed that there is an opportunity to encapsulate what other models in the literature suggest into one single model (Gkiourka, Tutesigensi and Moodley, 2009). This model can combine the dynamics of the external ecosystem of an organisation with the organisational internal strategic competences. The exploration of the extant literature in the field of innovation management (as explained in section 3.3.1) revealed that the body of knowledge in the field of innovation management has accumulated from research in three key areas: research on innovation related to the internal environment of organisations; research on strategic resources that facilitate innovation to occur; and research on innovation related to the external environment in which organisations operate. For each key area, the body of knowledge was organised in categories. Furthermore, each category was represented by factors that describe different dimensions of each category. This effort led to a clear picture of the factors that play a key role in innovation shown in Table 4.1.

Table 4.1 Categories and factors emerged in the key areas of research on innovation

Key Area	**Categories**	**Factors**	**Source**
Internal environment of organisations	***Culture***	• Technology	(Orlikowski, 1992; Sclove, 1995; Irish Council, 1998; Sexton and Barrett, 2004; Hargadon, 2005; Guan *et al.*, 2006b; Hartmann, 2006)
		• Leadership style	(Finlay, 2000; Mumford, 2000; Day, 2001; McAdam, 2002; Oshagbemi and Ocholi, 2006; Carneiro, 2008; Hannah *et al.*, 2008; DuBrin, 2010)
		• Ownership type	(Dainty, Green and Bagilhole, 2007; Halper *et al.*, 2007)
		• Collaborations	(Finlay, 2000; Love *et al.*, 2002; Miozzo and Dewick, 2002;

			Chan, Chan and Ho, 2003; Asheim and Coenen, 2005; Hyland and Beckett, 2005; Eriksson and Pesämaa, 2007; Engel and del-Palacio, 2009)
	Structural Constructs	• Hierarchy	(Finlay, 2000; Langford and Male, 2001; Keegan and Turner, 2002; Walker, 2007)
		• Number of people reporting to a manager	(Finlay, 2000; Langford and Male, 2001)
		• Organisational relationships	(Thompson, 2003; Buchanan and Huczynski, 2004; Egbu, 2004)
		• Organisational size	(Shefer and Frenkel, 1998; Finlay, 2000; Arias-Aranda, Minguela-Rata and Rodríguez-Duarte, 2001; Frenkel *et al.*, 2001; European Commission, 2003; Shefer and Frenkel, 2005)
	Strategy- Policy	• Strategy	(Porter, 1980; Porter, 1985; Gelderen, Frese and Thurik, 2000; Faulkner, 2002; European Commission, 2003; Thompson, 2003; Harvard Business School, 2005)
		• Policy	(Koontz and O'Donnell, 1968; Faulkner and Campbell, 2006)
		• Organisational learning systems	(Koontz and O'Donnell, 1968; Worthington and Britton, 2000; Thompson, 2003; Ortenblad, 2004; Fox and Waldt, 2007)
Strategic resources of organisations	***Marketing strategy***	• Promotion of products/services	(Pezzullo, 1998; Smyth, 2000; Kotler, 2003)
		• Intellectual property rights	(Andersen, 2005; Christou, 2005; OECD, 2009a)
		• Sales management	(Smyth, 2000; Gaynor, 2002; Gillen, 2005; Business Dictionary, 2010b)
		• Market information availability	(Mintzberg, 1979; Cohen and Levinthal, 1990; Tang, 1998; Smyth, 2000)
	Finance	• Capital structure	(Acs, 2002; O'Brien, 2003; Business Dictionary, 2010a)
		• Financial management	(Silverstein, Samuel and DeCarlo, 2009; Van Horne and Wachowicz, 2009)
		• R&D spending	(Vinding, 2006; Dale, 2007; Department for Business Innovation & Skills, 2009)

		• Financiers attitude	(Berger and Udell, 1998; Kumaraswamy *et al.*, 2004; Hyytinen and Toivanen, 2005; O' Sullivan, 2005; Meyer, 2008; Business Dictionary, 2010a)
	Systems-Processes-Knowledge management	• Process integration	(Rajagopal, 2002; Bernroider and Bernroider, 2005; Berente, Vandenbosch and Aubert, 2009; Valle and Vαzquez-Bustelo, 2009)
		• Quality control	(Brown *et al.*, 2000; Perdomo-Ortiz, Gonzαlez-Benito and Galende, 2006; Prajogo and Sohal, 2006)
		• Knowledge management	(Hendriks and Vriens, 1999; OECD, 2003b; Egbu, 2004; Egbu, 2005; National Statistics, 2007; Chang and Lee, 2008)
	Human resources management	• Number of R&D staff	(OECD, 2002)
		• Competence skills of R&D staff	(Nooteboom *et al.*, 2007; Schmiedeberg, 2008)
		• Performance of R&D staff	(Nijhof, Krabbendam and Looise, 2002; Gupta, 2004)
		• Age profile of R&D staff	(Reid and Barrington, 1999; Vinding, 2006)
		• Retention of R&D staff	(Reed, 2001; Kearns, 2003)
		• Staff development	(Leede, de Looise and Alders, 2002; Lau and Ngo, 2004; Swanson and Holton, 2009)
External environment of organisations	***Political and legal framework***	• Political freedom	(Brenkert, 1991; Farr, Lord and Wolfenbarger, 1998; Chauffour, 2009; Department for Business Innovation & Skills, 2009)
		• Incentives to foreign investors	(Herrmann and Lipsey, 2003; OECD, 2003a; Rama, 2008)
		• Competition framework	(Schumpeter, 1942; Manseau and Seaden, 2001; Ahn, 2002; Motta, 2004)
		• Employment framework	(Chandler, 2003; Pierre and Scarpetta, 2004)
		• Health and safety regulations	(Ahn, 2002; Manseau and Shields, 2005; Katz, 2006; Hughes and Ferret, 2009)
	Economic environment	• Economic activity	(Gittleman and Wolff, 1995; Audretsch and Feldman, 1996; Feldman and Audretsch, 1999; Scott, 2010)

		• GDP trend	(European Commission Directorate-General for Research, 2005; Katz, 2006; Taylor, 2007; Gao and Guan, 2009)
		• Rate of inflation	(Itaya and Mino, 2003; Gillman, Harris and Mátyás, 2004; Dwivedi, 2005; Funk and Kromen, 2005; Gillman and Kejak, 2005)
		• Currency strength	(Oppenheimer, 2010; Papier, 2010)
		• Tax policy	(Dwivedi, 2005; OECD, 2007; OECD, 2009b)
		• Government spending in R&D	(National Statistics, 2005; National Statistics, 2007; OECD, 2009b)
	Infrastructures	• Transport provision	(Edquist *et al.*, 1998; Klein Woolthuis, Lankhuizen and Gilsing, 2005; OECD, 2006)
		• Energy provision	(Edquist *et al.*, 1998; Klein Woolthuis, Lankhuizen and Gilsing, 2005; OECD, 2006)

The holistic model of innovation is developed integrating Table 4.1into the conceptual model (see Figure 2.1) as shown in Figure 4.1

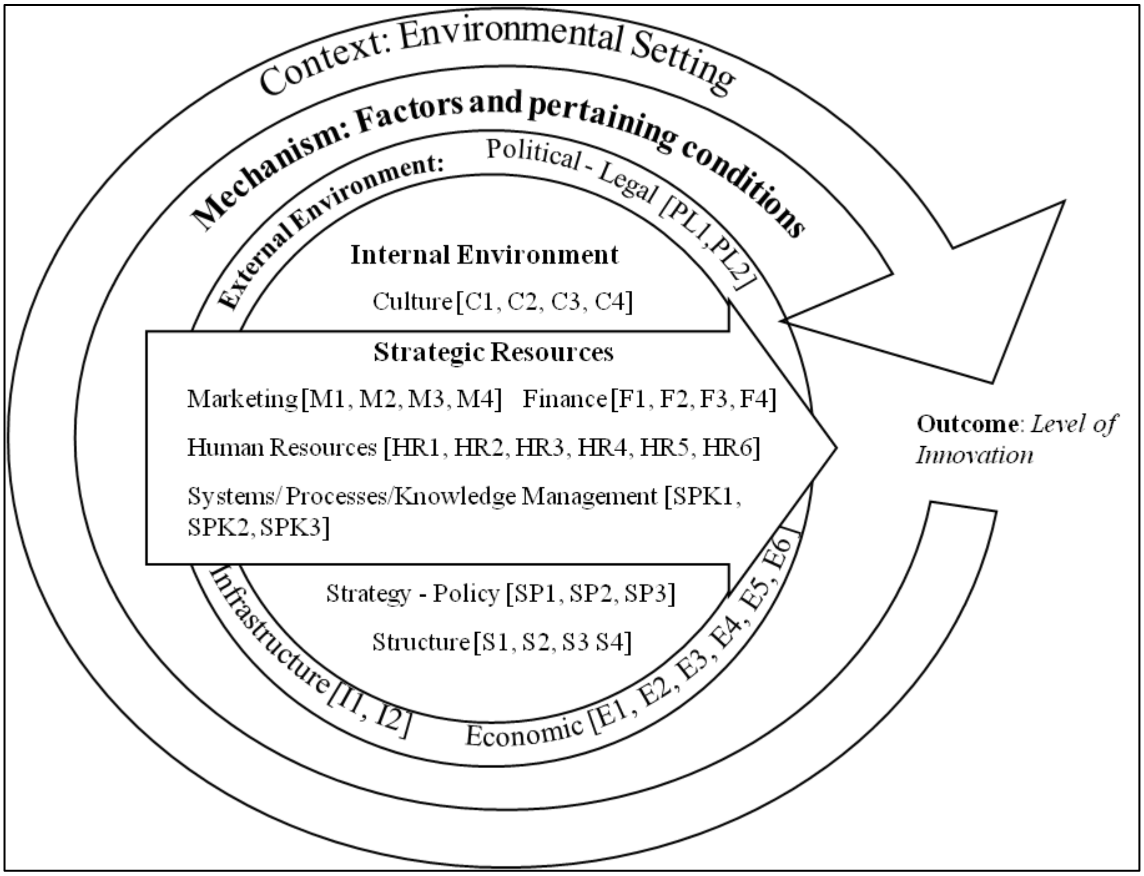

Figure 4.1The holistic model of innovation

Every category identified in each key area: internal environment, strategic resources, and external environment was described by the different factors within the category. The factors shown in each category in Figure 4.1 are explained in Table 4.2.

Table 4.2 Categories and factors of the Holistic Model of Innovation

Factors within each Category	
Culture	I2: Energy provision
C1: Technology	***Marketing***
C2: Leadership style	M1: Promotion of products/services
C3: Ownership type	M2: Intellectual property rights
C4: Collaborations	M3: Sales management
Economic Environment	M4: Market information availability
E1: Economic activity	***Political-Legal***
E2: GDP trend	PL1: Political freedom

E3: Rate of inflation	PL2: Incentives to foreign investors
E4: Currency strength	PL3: Competition framework
E5: Tax policy	PL4: Employment framework
E6: Government spending in R&D	PL5: Health and safety regulations
Finance	***Structure***
F1: Capital structure	S1: Hierarchy
F2: Financial management	S2: Number of people reporting to a manager
F3: R&D spending	S3: Organisational relationships
F4: Financiers attitude	S4: Organisational size
Human Resources	***Strategy Policy***
HR1: Number of R&D staff	SP1: Strategy
HR2: Competence skills of R&D staff	SP2: Policy
HR3: Age profile of R&D staff	SP3: Organisational learning systems
HR4: Performance of R&D staff	***Systems-Process-Knowledge Management***
HR5: Retention of R&D staff	SPK1: Process integration
HR6: Staff development	SPK2:Quality control
Infrastructures	SPK3:Knowledge management
I1: Transport provision	

The holistic model of innovation illustrates the main categories within the three key areas identified, and also illustrates the factors that can impact innovation in an organisation (Gkiourka, Tutesigensi and Moodley, 2009). However Figure 4.1, is still a partial depiction of the mechanism described in the conceptual model (see Section 3.2), as it does not provide the specific conditions that act upon each factor. The mechanism of innovation can only be fully described once measurements have been obtained on each of the factors within a given context. The conditions of each factor and the full description of the mechanism of innovation in the construction industry are presented in Chapter 5.

4.6 Summary

This chapter has demonstrated that there is theoretical and empirical evidence to support that the categories emerged within the key areas of the internal environment, the strategic resources; and the external environment of an organisation can have significant importance in enabling innovation to emerge. All of the factors identified within each category describe a different dimension of the same category. The discussion in this chapter reveals that an isolated change in one element is not sufficient enough to create innovation. The approach used to develop the holistic model of innovation included a thorough and up-to-date understanding of the background knowledge, focusing on how the factors identified can support the process of innovation. Innovation is seen as a distributed process that can be influenced by various disciplines inside of an organisation. It can also be influenced by other organisations and also the environmental conditions in which it emerges. Innovation is now looked at within the framework of the context in which it occurs, which includes a multidisciplinary spread of factors, leading to the importance of recognising an organisation's unique strengths and weaknesses, and also market signals and social concerns.

The next chapter, Chapter 5 presents the system developed for identifying the condition of each factor presented in this chapter. The 'condition of the factors' as explained in section 3.3.2 reflects the actual practices adopted by the organisations which are relevant to each factor identified.

CHAPTER 5: A GENERIC SYSTEM FOR DEPICTING INNOVATION PRACTICE IN THE CONSTRUCTION INDUSTRY IN THE UK

This chapter presents the results of the methods employed to address the second objective of this research that was to develop a generic system that can be used to identify the condition of the factors in the construction industry in the UK. The factors identified in the previous chapter and the system developed in this chapter for identifying the condition of the factors which, refers to the innovation practices employed, were combined and integrated to describe the mechanism of innovation.

More specifically this chapter focuses on:

- constructing the scales for depicting the condition of the factors identified in the previous chapter and identifying innovative practices which, can be ordered on a continuum denoting an underlying dimension that favours innovation;
- presenting and explaining the scales constructed and discussing the underlying dimension for each scale; and
- integrating the system developed for depicting the condition of the factors into the holistic model of innovation for the construction industry and describe the mechanism of innovation.

5.1 The scales describing the condition of factors

The scales constructed to describe the condition of each factor included different response choices representing different anchor points. Each response choice represented an innovation practice. These innovation practices were ordered along an underlying dimension identified for each factor as explained in Section 3.3.2. The position of an organisation on one of the anchor points, on the scale, can explain part of an organisation's potential to innovate. The scales constructed for each of the factors within the key areas of the internal environment, the strategic resources, and the external environment, are discussed in the following sections.

5.2 Internal environment

Innovation management research, within the key area of the internal environment of organisations, has been found to focus into the following categories: organisational culture, structure, strategy, policy and learning systems. The factors that were identified, as seen in Chapter 4, within each category were used to describe different underlying dimensions of each category.

5.2.1 Organisational culture

The category 'organisational culture' is described by the factors: technology, leadership, ownership type and collaborations. The scales constructed for each factor are discussed in the following sections.

5.2.1.1 Technology

Although the use of advanced technology in industries such as the automobile or the manufacturing has had significant impact on improving productivity, the results are less significant for the construction industry due to the project-based nature of the work. However, the use of automation systems, programmable machines, better quality, more physically durable materials and new fixing technologies have all increased not only the accuracy of construction, but also the speed, the productivity and the aesthetics of the final product (OECD, 1998).

Overall the implementation of new technology is essential for the reformation of the internal functions throughout the different departments of a construction organisation (Sexton and Barrett, 2004). The extent to which new technology can be effectively used by a construction organisation is substantially influenced by other organisational characteristics of the adopting organisation.

In summary, the literature stresses the important role of new technology usage in developing innovations successfully and offers insightful guidance on how to manage the process of technology transfer (Wilson, and Hickson et al., as cited in Sexton and Barrett, 2004, p. 342). Building on the term 'new' used by Sexton and Barrett (Sexton and Barrett, 2004), the author contends that the age of the technology used by organisations can partly explain the innovation capacity of organisations. It is also the author's contention that the age of technology can be described on a scale of (in order of increasing newness) *ancient*/*established*/*new*/*emerging*.

5.2.1.2 Leadership

Basadur (as cited in Jong and Hartog, 2007) stresses that innovative behaviour is closely related to employee creativity, leading to a focus on the kinds of leadership style that can be adopted to stimulate and increase employee creativity. A short analysis of the critiques of different leadership styles and how they contribute to organisational innovation provides a list of attributes that can be used to gauge leadership-related innovation practices. Oshagbemi and Ocholi's research on grouping managers in the UK, according to their behaviours on the basis of leadership styles, define authoritative, delegate, participative, and laissez faire leadership styles (Oshagbemi and Ocholi, 2006).

A paternalistic leadership style is defined as being strongly hierarchical (Antonakis, Cianciolo and Sternberg, 2004). The superior assumes having the role of the father towards the subordinates, whilst the subordinates are showing loyalty. The superiors are assumed to know 'what is best' for the subordinates. Such a leadership style is concerned about the well-being of the subordinates as well as their families (Antonakis, Cianciolo and Sternberg, 2004). Although such a leadership style cares for the needs of subordinates, it does not exploit them accordingly to achieve high performance (Nagendra and Manjunath, 2008).

Authoritative or directive leadership is defined as being the "extent to which a boss attains desired objectives by telling subordinates or others what to do and how to do it"

(Oshagbemi and Ocholi, 2006, p.755). This style can be considered to be an old style of management, one of ‘command and control’. However, it appears that this style is now giving way to ‘one demanding real leadership and creativity’, supported by good systems management and in-depth administration (Adair, 2007).

Delegate leadership refers to the “extent to which a manager attains desired objectives by leaving subordinates or others free to make their own decisions” (Oshagbemi and Ocholi, 2006, p. 756) . Empirical research indicates that there is a positive relationship between delegation-style leadership and idea generation, which is the very first stage to innovation (Bass and Avolio, 1994, p.13). Krause (Krause, 2004), studied German middle managers, and investigated whether the provision of freedom and autonomy to employees can influence the innovation process. Krause found that granting freedom and autonomy was positively related to various types of innovative behaviour, including the generation, testing, and implementation of ideas, all of which increase innovation performance. Jong and Hartog (Jong and Hartog, 2007) refer to other studies that have similar results. These studies include work by West and Wallace (West and Wallace, 1992) in primary care teams, by Frischer (Frischer, 2006) in product development departments, by Frischer (Frischer, 1993) in a transport firm, and by Judge et al. (Judge, Gryxell and Dooley, 1997) in the biotechnology sector.

Participative or democratic leadership is defined as being “the extent of sharing in a consensual decision-making process with others, i.e. joint decisions” (Oshagbemi and Ocholi, 2006, p. 762). Participative leadership style encourages the active participation of subordinates in the decision making process , to an extent in which they can influence decisions on a consultative basis (Oshagbemi and Ocholi, 2006, p. 762). Such leadership has been identified as an antecedent of individual innovation (Yukl, 2002).

Laissez-faire or free reign leadership, according to Judge et al. (Judge, Gryxell and Dooley, 1997), is when the manager provides little or no direction and gives employees as much freedom as possible. This leadership style gives authority and power to the employees to determine goals, make decisions, and to resolve problems on their own.

From the above discussion, the author contends that leadership style can explain, at least in part, any organisation's potential to innovate. The author also contends that the leadership style can be described on a scale of (in order of increasing freedom available to employees) *authoritative/paternalistic/participative/delegation/free reign.*

5.2.1.3 Types of ownership

The construction industry is mainly dominated by small and medium sized enterprises. This fact, along with the very nature of construction projects leads the construction industry to rely to a large extent on subcontracting. Large organisations often transfer the risks to smaller companies, which may not be in position to handle them. However, the forming of partnerships between large and small firms provides a more secure future for the small organisation, increasing the possibilities for it to perform at a high standard (Dainty, Green and Bagilhole, 2007). Partnerships assume a win-win scenario for all parties, with the basic benefits, as determined by Turner and Simister (Turner and Simister, 2000) being: low risk of time and cost overruns, reduced exposure to litigation, creation of a mutual trust environment ensuring for less confrontation and early resolution of problems encountered, improved performance and project quality, increased innovation through open communication and trust, improved safety and buildable designs.

Public organisations are the largest organisations in the construction industry often formed by groups of companies. They tend to include not only building and civil engineering companies but also plant hire, services work and specialist work, component and material manufacture. They are mostly large in size and thus they have more funds to undertake research and development work, innovations and training schemes (Fellows *et al.*, 2002). However, disadvantages of public companies include: separate management from ownership, increased bureaucracy and reduced efficiency, and increased fragmentation between departments –thus reducing cooperation (Fellows *et al.*, 2002).

The construction industry is seeking rapid change through governmental agencies such as Constructing Excellence in the UK. However, there are multiple agencies dealing with various different areas, such as: acquisition of public works, technology development, safety, consumer protection, or losses due to natural disasters. All of these agencies lack a national point of convergence, resulting in no unified industrial representation within the government (Manseau and Shields, 2005, p. 129). Therefore, although different agencies drive innovation at various areas, those agencies do not converge to foster national policies.

Public Private Partnership (PPP) introduced a new way of funding, building and managing public buildings and infrastructure (Carassus, 2005). The PPP processes oblige the client and the users, the funding body, the designer, the construction firm and the facilities manager to work together, which brought about a cultural revolution. For the first time, the architects needed to work closely with the end users and the facilities manager, bringing new insight to the design process. All of the competences of the actors involved are combined and integrated with the competences of the client and the facilities manager, while many aspects of the project such as ventilation, heating, lighting etc. are designed in a more sophisticated manner (Carassus, 2005).

The author suggests that the prevalent types of organisation ownership have different capacities to overcome bureaucracy and facilitate working with others. As less bureaucracy and working with others can facilitate innovation (Turner and Simister, 2000; Fellows *et al.*, 2002; Carassus, 2005; Manseau and Shields, 2005; Dainty, Green and Bagilhole, 2007), the type of ownership can, at least in part, explain any organisation’s potential to innovate. Furthermore, the author contends that type of ownership can be described on a scale (in order of increasing capacity to overcome bureaucracy and flexibility to work with others) of *sole proprietor/partnership/private limited company/public limited company/government department/agency/public private partnership.*

5.2.1.4 Collaborations

According to various authors like Pietroforte (Pietroforte, 1997), Rahman & Kumaraswamy (Rahman and Kumaraswamy, 2002), Miozzo and Dewick (Miozzo and Dewick, 2004b), Abudayyeh (Miozzo and Dewick, 2004b) and Eriksson & Pesämaa (Eriksson and Pesämaa, 2007) the strength of inter-organisational collaborations and the proper use of innovation through open communication, is responsible for the enhanced performance of the construction industry in many countries.

Empirical studies show that innovation is more common in collaborative companies than in non-collaborative companies (Fiedler and Deegan, 2007). The spatial nature of collaboration encompasses collaborations at three levels: local, regional and international (Wilhelmsson, 2007; Engel and del-Palacio, 2009). Simmie et al.(Simmie *et al.*, 2002) suggest that factors such as proximity, suppliers and local academic institutions play a key role in the innovation system of regions. The author contends that collaboration in any organisation can be described on a scale (in order of increasing commitment to collaboration) of *none/regional/national/international*.

5.2.2 Organisational structure

The category 'organisational structure' is described by the factors: hierarchy, number of people reporting to a manager, organisational relationships, and organisational size. The scales constructed for each factor for the category 'organisational structure' are presented in the following sections.

5.2.2.1 Hierarchy

Organisational structures may not truly represent the way people work in an organisation, but they can reflect hierarchical thinking. There are three types of dispersion in hierarchy structures, the horizontal, the vertical and the spatial dispersion. Construction organisations tend to have spatial dispersion, due to construction projects often being delivered in different geographical areas from the main offices through geographically dispersed regional operating units (subsidiaries), which have construction sites that report to a region's operating unit. Construction organisations also tend to have estimating, buying, surveying and contract management departments, differentiating the structure horizontally. Construction organisations are by their very nature more complex, as they cannot avoid horizontal and spatial dispersion (Langford and Male, 2001). However, vertical dispersion can have a significant effect in innovation, as high numbers of organisational levels imply an extensive hierarchy that distorts the efficiency of communication (Keegan and Turner, 2002). The flow of information in an organisation where extensive hierarchy levels exist may not be the same as in organisations with a more flat structure. Organisational hierarchies that are flat and flexible are more likely to provide a supportive setting for innovation. Organisational hierarchy can be measured in terms of the extent of the dispersion of vertical management in structural layers and described on a scale (in order of increasing flexibility) of *more than 10 layers/8-10 layers/5-7 layers/2-4 layers*.

5.2.2.2 Span of control

The management and coordination of a team is related to the effectiveness of an organisation. As shown in Section 4.3.2.2, the larger the number of subordinates reporting to one manager, the greater the difficulty in effectively supervising and coordinating the subordinates (Finlay, 2000). The authors contend that effective supervision and control of control can, at least in part, explain the organisation's potential to deliver organisational results including innovation. According to Langford & Male (Langford and Male, 2001, p.63) "No one brain can effectively control more than six or seven brains". From the above, the author therefore contend that the number of people reporting to a manager can be described on a scale (in order of increasing effectiveness) of *'more than 24 people'/'19-24 people'/'13-18 people'/'7-12 people'/'1-6 people.*

5.2.2.3 Organisational relationships

An organisation might have two possible structures for communication. A formal structure, where change and decisions are difficult to make and take time, and where rules, procedures, guidelines, and records control an individual's behaviour. Or an informal continually changing structure, which may be unstable and ambiguous. Relationships in informal structures provide flexibility and create stronger bonds between the employees of an organisation (Thompson, 2003). Furthermore, Egbu (2004), in researching the development of a prototype-training simulator for providing the experiential learning of the cultural aspects of the innovation process, stresses that flexibility in the lines of communication, in the allowing of top-down, bottom up and lateral communications within a construction firm is an attribute favourable to innovation. From this perspective, organisational relationships focus on identifying the types of relationship that exist in construction organisations in terms of: formal - informal and vertical – lateral, as well as the integration of vertical and lateral relationships. Therefore, organisational relationships can be described on a scale (in order of increasing flexibility of interaction) of *formal lateral relationships/formal vertical relationships/formal diagonal relationships/informal lateral relationships/informal vertical relationships/informal diagonal relationships.*

5.2.2.4 Organisational size

The three most reliable empirical frameworks relating to innovation and firm size are the following, as described in Arias-Aranda et al. (Arias-Aranda, Minguela-Rata and Rodríguez-Duarte, 2001, p.134):

1. R&D activity increases – usually in a proportional way – with firm size.
2. Innovations tend to increase – less than proportionally – with firm size.
3. R&D productivity tends to decrease with firm size.

Despite the contradictory evidence regarding the relationship between organisation size and innovation, it is contended that larger organisations have a higher capacity to innovate, as they are more likely to invest more in R&D than smaller organisations.

Therefore, the author contends that organisational size can be described on a scale (in order of increasing capacity to invest in R&D) of *micro, small and medium organisations ('1-250 employees')/large organisations ('250< Employees')*.

5.2.3 Organisational strategy, policy and learning systems

The category 'organisational strategy, policy and learning systems' is described by the factors: strategy, policy, and organisational learning systems. The scales constructed for each factor within the category 'organisational strategy, policy and learning systems' are presented in the following sections.

5.2.3.1 Organisational strategy

The types of strategies identified as having an impact on the innovation process to a lesser or greater extent are: environmental/opportunistic strategies, entrepreneurial/visionary strategies, learning and capabilities based strategies and competitive positioning strategies.

Environmental/opportunistic strategies involve initial fundamental planning and continuous scanning of the business and market environment for opportunities (Mintzberg, 1979). Organisations that use opportunistic strategies are flexible, and have the advantage of quickly adjusting to attractive new opportunities (Gelderen, Frese and Thurik, 2000). This type of organisation is referred to in the literature by a typology defined by Miles & Snow (as cited in Morden, 2007) as being 'prospectors' and 'creators' of change. These types of organisations respond to emerging trends by carrying out research and development on new products.

As stressed by Johnston Jr. & Bate (Johnston Jr. and Bate, 2003, p. 141), on one side of the spectrum (Figure 5.1) lies the 'visible' opportunities, which are usually lower risk and shorter term, they are the 'low hanging fruits that are easy to harvest', which require only small changes to the business model. On the other side lies the 'visionary' opportunities, which are longer term, requiring the development of new technologies and infrastructure, and the development of a market that does not already exist. Increasing its value is the ultimate goal of an organisation that has entrepreneurial/visionary strategies, with the potential rewards being higher for it than those available for 'visible' opportunists.

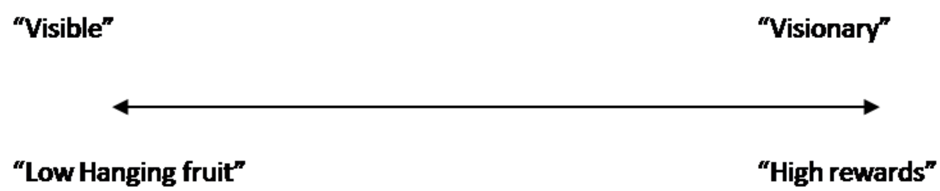

Figure 5.1 Strategic opportunity spectrum adopted by Johnston Jr. & Bate (1978)

To be able to implement a visionary strategy an organisation should not only imagine what the needs of the market are, but it must also know what its own specific strengths and weaknesses are in relation to that particular target set. Thus, 'what a firm can do is not just a function of the opportunities it confronts; it also depends on what resources the organisation can master' (Johnston Jr. and Bate, 2003, p. 141). Learning and Capabilities-based models of strategy are known from the resource-based theories for organisations. According to the resource-based theories, the specific assets that are unique to the firm can provide value (low prices, better quality, new technology etc.) and turn it into economic benefit. The most sustainable competitive advantage are capabilities and competences from tacit, knowledge-based resources (Faulkner, 2002; Faulkner and Campbell, 2006). However, the resource-based approach can only provide a short term competitive advantage, as it will be imitated if it is successful.

Competences or capabilities of a firm do not, however, grant competitive advantage. Capabilities need to fit the market demand in order to deliver competitive advantage, otherwise they cannot bring any revenues (Faulkner and Campbell, 2006). As Porter (Porter, 1985) stresses, resources are valuable because they allow a firm to perform activities that create an advantage in particular markets. In addition, sustainable competitive advantage is developed from the continuous evolution of a firm's capabilities. It is the dynamic nature of these competences that evolve through an ever changing market which build up the capacity to innovate from a competitive position (Faulkner and Campbell, 2006), otherwise called a competitive/ positioning strategy. Organisations that do not base their strategic orientation for increasing growth on the exploitation of well known capabilities, but instead continue to explore new business opportunities based upon newly developed capabilities will, through time, be able to survive and profit.

Building on the model of Johnston Jr. & Bate (as cited in Porter, 1985) the subcategories reflecting 'organisational strategy' can be based upon the underlying characteristic of 'orientation for continuous growth', as shown in Figure 5.2.

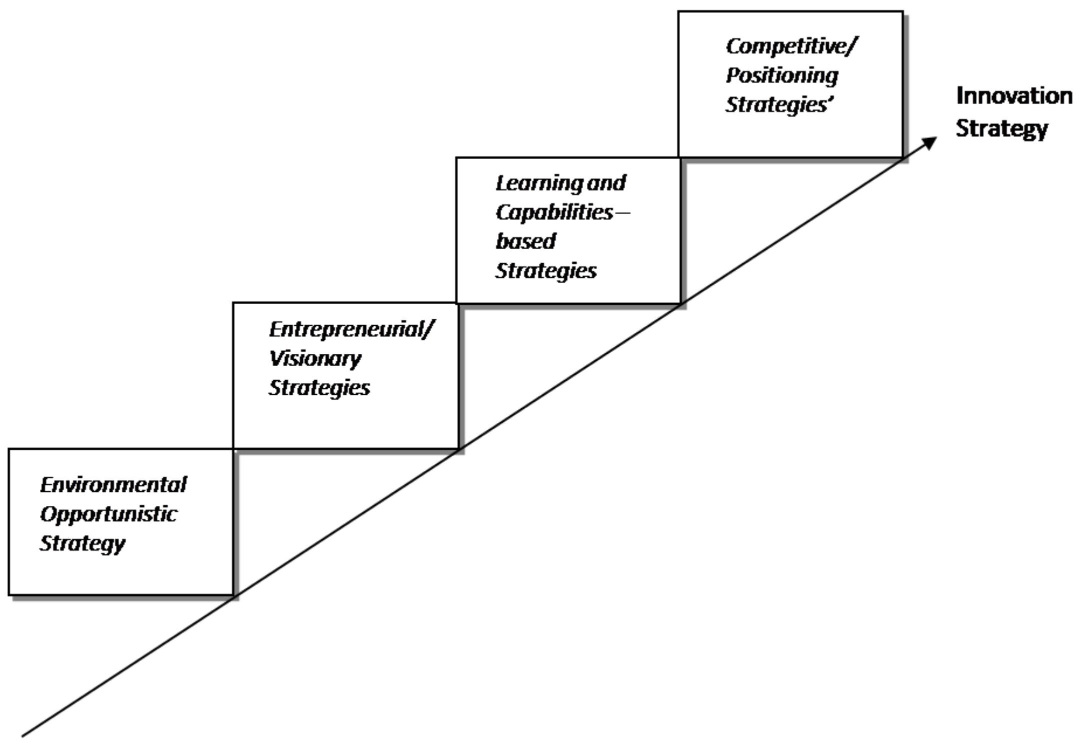

Figure 5.2 Towards a strategy for innovation

Orientation for continuous growth, according to Faulkner and Campbell (Faulkner and Campbell, 2006), is the process of business model renewal. This renewal is not only the improvement of products or services, but also the renewal of an organisation's competences and evolving capabilities. The author contends that organisational strategy can, at least partly, explain any organisation's potential to innovate. The author also contends that the organisational strategy can be described of (in order of organisations' orientation for continuous growth) *environmental, opportunistic strategy/visionary strategy/learning and capabilities learning strategies/competitive positioning strategies.*

5.2.3.2 Organisational policy

Policies can be either advisory, leaving decision makers with some flexibility, or mandatory, whereby managers have no discretion. Koontz and O'Donnell (as cited in Thompson, 2003) suggest that mandatory policies should be regarded as 'rules' rather than policies. Koontz and O'Donnell (Koontz and O'Donnell, 1968) further argue that mandatory policies tend to stop managers and other employees from thinking about the most efficient and effective ways in which to carry out tasks and searching for improvements. Policies should guide rather than remove discretion. Advisory policies should normally be used because it is essential that managers are allowed some flexibility to respond and adapt to changes in both the organisation and the environment. Moreover, mandatory policies are unlikely to motivate managers, while advisory guides can prompt innovation (Koontz and O'Donnell, 1968).

Certain key policies are established by the overall strategic leader and are filtered down through the organisation. Consistency between the policies created by general managers for their divisions and functional managers for their departments is important. Policies can exist for any functional task undertaken by the organisation. Policies may be forced on the company by external stakeholders. Government legislation regarding contracts of employment, redundancy terms and health and safety at work can all affect organisational policies. In some cases, financial policies can be dictated by powerful shareholders or bankers (Thompson, 2003). It is shown that different types of policies can explain the motivation of organisations to innovate. Based on the above discussion organisational policies can be described on a scale (in order of increasing potential to facilitate innovation) of *always mandatory/mainly mandatory /mainly advisory/always advisory*.

5.2.3.3 Organisational learning systems

According to Cross & Israelit (Cross and Israelit, 2000) the key element of the organisational learning process is the absorptive capacity and the role of 'prior knowledge in assimilating and exploiting new knowledge'. The first stage of organisational learning, defined as 'l*earning facts, knowledge, processes and procedures'* (Cross and Israelit, 2000) is the ability to recognise, capture and store what an organisation's current knowledge on processes and procedures is, which constitutes an organisations' 'memory' (David Skyrme & Associates, 2002).

'Learning new job skills that are transferable to other situations' (Peters, 1996) can be defined as acquiring new knowledge 'to be added to memory' (David Skyrme & Associates, 2002). Robey & Sales (as cited in Garavan, 1997) argue that knowledge may be acquired from internal or external experience, or from organisational memory. There is no distinguishing between the internal and external knowledge of an organisation. However, organisations are not built instantly and contain knowledge gained during their existence.

In order to create a competitive advantage from the knowledge that an organisation has acquired through its existence, it should be able to 'retain, disseminate and integrate' it into other situations (Garavan, 1997). This skill leads to the next stage of learning that is the '*learning to adapt'* stage (Prieto and Revilla, 2006). The adaptation stage 'implies that an organisation experiences a continuous changing process while enabling individuals to learn' (Ortenblad, 2004). 'Adaptive' learning coincides with Senge work (as cited in Garavan, 1997) and Argyris & Schön's (as cited in Senge, 1991) notion of 'single-loop' learning. Single-loop learning simply involves 'corrective actions of errors through a feedback loop' while Senge's concept of adaptive learning 'centres on evolutionary changes in response to developments in the business environment and which are necessary for the survival of an organisation'(Senge, 1991).

Learning to learn is the next stage of learning and it is about innovation and creativity; designing the future rather than merely adapting to it. This is where assumptions are challenged and knowledge is reframed. However, Batestone (Batestone, 1972) suggests deutro-learning or second-order learning. He draws a distinction between the process of learning and the process of learning to learn. Individuals have the capacity to learn how to learn, in that they can reflect and enquire into previous contexts of learning or failure, so as to learn, question and evaluate the appropriateness of their actions.

From the above discussion, the author contends that the nature of organisational learning within an organisation may explain, at least in part, the organisation's potential to innovate. Furthermore, the organisaltional learning systems can be described on a scale (in order of increasing ability to learn) of *learning facts, knowledge, processes and procedures*/*Learning new job skills that are transferable to other situations/Learning to adapt*/*Learning to learn*.

5.3 Strategic resources

The main categories emerged within the key area 'strategic resources' were: marketing, operations management, finance and human resources. Each category is described by different factors, which represent a different dimension of the same category.

5.3.1 Marketing

The category 'marketing' is described by the factors: promotion of products and services, intellectual property rights, sales management and market information availability. The scales that have been constructed for each factor within the category 'marketing' are presented in the following sections.

5.3.1.1 Promotion of products and services

Although promotion of products and services has been underused in the construction industry, construction organisations that hav some experience with it have been rewarded. It has been argued that creativity can be applied so as to improve matters relating to the identification of promotions relevant to an organisation, and the decision to use them in tandem with personal selling (Smyth, 2000). Organisations can view promotions as a technique to assist sales, and as a new approach for examining these techniques in a professional way. The systematic use of promotion techniques in a professional manner can support innovation and create more incentives to increase the value of products or services offered to the clients (Greco, 2008) and therefore explain, at least in part, the organisation's potential to innovate. The practice of promoting products and services can be described on a scale (in order of increasing professionalism) of *amateur/Semi-Professional/Professional*.

5.3.1.2 Intellectual property rights

Although patenting is related to R&D and therefore innovation, there is a debate on whether patents are the result of well organised and implemented R&D plans, whether they act as stimulators of incentives to perform R&D, or both. The rationale of using Intellectual Property Rights (IPR) to protect knowledge-based ideas was initially designed to create 'economic incentives' for inventors. The efficiency of the incentive system is based upon driving people to invent things they would otherwise not invent, for the purposes of benefiting the society as a whole. It is also argued that even if IPR is not the most essential ingredient for innovation, it at least motivates people towards invention and innovation. Patent motives aren't directly related to profits, but they create good opportunities for joint ventures or alliances with other firms, for instance with those that have production and marketing capabilities (Andersen, 2005).

Conversely, there are arguments that advocate that, although intellectual property rights are necessary because of the high risk of creating a market around a novel idea, investment in research is often underinvested. In the manufacturing industry, patents and copyrights are usually found to be sold by the original inventor to the employers at a low price and are therefore under rewarded.

The above discussion shows that IPR can either hinder or enable innovation. Ascertaining what the role of IPR is in creating innovation, the main characteristic that emerges is that IPR motivates organisations, by offering an added incentive to invent and to innovate. The role of IPR can therefore be described on a scale (in order of increasing desirable motivation) of *restrictive/ facilitating/supportive.*

5.3.1.3 Sales management

Selling has been perceived to be an individual activity outside of the mainstream operations of an organisation, which can result in lack of integrity and can be considered unprofessional (Smyth, 2000). A professional approach to sales management can give members of an organisation the opportunity to understand marketing and sales functions by building enhanced communication. Enhanced communication can establish a flow of ideas and innovations, which can create competitive advantages that can be communicated to the customer, so as to increase efficiency and persuasion. The level of professionalism in sales management can provide insight on the flow of information within an organisation and towards a customer. The practice of sales management can be described on a scale (in order of increasing professionalism) of *amateur/semi-professional/professional.*

5.3.1.4 Market information availability

The absorptive capacity of an organisation to identify and manage appropriate information is strengthened through close communications and collaborations, creating information channels. Collaborations with educational institutions can feed the rate of opportunity findings, but does also require a higher absorptive capacity due to the sophistication of the information (Tang, 1998; Vinding, 2006). Information availability therefore plays a key role in increasing innovation within an organisation. It is contended that the underlying characteristic required to recognise market opportunities is the availability of market information. Availability of information can be described on a scale (in order of increasing availability) of *never available/sometimes available/always available'.*

5.3.2 Operations management

The category 'operations management' is defined by the factors: process integration, quality control, and knowledge management. The scales constructed for each factor within the category 'operations management are presented in the following sections.

5.3.2.1 Process integration

Process integration has been facilitated by Enterprise Resource Planning (ERP) systems which have been introduced to make corporate use of information technology in the 1990s, in order to enhance organisational cross-functional efficiency and effectiveness by increasing connectivity and bringing together various and diverse functions for better coordination of performance (Davenport, 1998; Rajagopal, 2002). The ERP systems implementation phase can be used to describe the levels of process integration. The author contends that the implementation of integration processes can explain, at least in part, an organisation's potential to innovate. Therefore, the levels of process integration as described in Rajagopal (Rajagopal, 2002) six stage model can be used on a scale of (in order of increasing potential to innovate):
Initiation/Adoption/Adaption/Acceptance/Routinisation/Infusion.

5.3.2.2 Quality control

Prajogo & Sohal (Prajogo and Sohal, 2006) provide evidence that Total Quality Management (TQM) is strongly correlated with technology and R&D, and that these are the key factors for increasing innovation performance. Prajogo & Sohal (Prajogo and Sohal, 2006) in their study demonstrate that organisations must be capable of managing quality before they develop the capabilities to manage innovation. In other words advanced quality control measures create a fertile ground for managing innovation. The attributes used to depict an organisation's quality management system can be judged by the level of excellence relating to quality control, and can be described on a scale (in order of increasing excellence) of *not advanced/semi-advanced/very advanced*.

5.3.2.3 Knowledge management

Managing knowledge is critical to making knowledge productive, to knowledge development and to the exploitation of knowledge in increasing innovative performance (Egbu, 2005). An appropriate context for knowledge management is crucial to get the added value of knowledge that exists within an organisation (i.e. in the processes, in systems, in humans) (Egbu, 2005). The key issues in readiness for knowledge management can be recognised as: *obtaining/capturing knowledge, locating and accessing knowledge, propagating knowledge, transferring knowledge, modifying knowledge, maintaining knowledge* (Egbu, 2005). The capabilities of an organisation in effectively managing knowledge in the key issues mentioned above increases as the ability to manage knowledge more effectively increases. The author contends that the level of readiness in knowledge management may explain, at least in part, an organisation's potential to innovate. Therefore, the practice of knowledge of management can be described on a scale (in order of increasing potential to innovate) of *obtaining or capturing knowledge/locating and accessing knowledge/ propagating knowledge/ transferring knowledge/modifying knowledge/maintaining knowledge.*

5.3.3 Finance

The category 'finance' is described by the factors: capital structure, financial management, financiers' attitude, and R&D spending. The scales constructed for each factor within the category 'finance' are presented in the following sections.

5.3.3.1 Capital structure

There are performance consequences for organisations that have an inappropriate capital structure. It is shown that R&D expenditure is not important in determining capital structure, but it does highlight the strategic importance that an organisation gives to innovation in order to compete. O'Brien, has used as leverage Equation 1, that describes leverage as the ratio of the book value of debt to the total market value of the firm (O'Brien, 2003). The results were identical if total value of assets was used in the denominator:

$$\frac{Debt}{Assets} = \frac{Debt}{Debt + Equity} = \frac{\frac{Debt}{Equity}}{1 + \frac{Debt}{Equity}} \qquad \text{(Equation 1)}$$

If an organisation has a debt to equity ratio greater than 1, this means that the majority of its assets are financed from debt. If the debt to equity ratio is smaller than 1, assets are primarily financed through equity. Although, different levels of debt are acceptable in different industries and there is no conventional rule, a debt/equity ratio of 2:1 is generally considered to be satisfactory (Krantz, 2008). The logic that underlies this general rule is that even with a drop out of 50 percent of the value of current assets, an organisation can still meet their obligations, meaning that there is a 50 per cent margin of safety which is assumed to be sufficient to deal with the worst possible situation (Khan, 2004; OECD, 2004).

Based on O'Brien's study financial slack i.e. low leverage, should be a strategic priority for firms that are competing on the basis of innovation. The position of an organisation on the scale whose underlying dimension can be described as the 'financial slack' can explain part of an organisation's ability to innovate. This study uses as a leverage measure the debt over equity ratio (Li and Simerly, 2002) and the measures for an organisation's capital structure can be described on a scale (in order of increasing capacity to innovate) of *'Higher than 10'/2 to 10/0 to 2.*

5.3.3.2 Financial management

Innovation-related financial management is a more professional way of dealing with the decision process of innovations (Silverstein, Samuel and DeCarlo, 2009) as it reduces the risks by increasing the ratio of verified knowledge to unverified assumptions as the projects develops. This process allows for more accurate information and feedback, which enables an organisation to proceed or abandon an innovation project at any point (Silverstein, Samuel and DeCarlo, 2009). Financial management, according to the level of professionalism applied to it can be described on a scale (in order of increasing professionalism) of *amateur/semi-professional/'professional.*

5.3.3.3 Financier's attitude

The complexity of infrastructural projects in construction arise from the growing demands of the stakeholder's, including financiers (Kumaraswamy *et al.*, 2004). The financier's prospect to positively see the investment of R&D projects can be reflected by their willingness to invest in an organisation's R&D project. The attitude of financier's attitude towards R&D and innovation in an organisation can be defined as being: '*highly supportive', 'supportive', 'undecided', and 'not supportive'.* The attitude of financier's towards R&D and innovation in an organisation can be described on a scale (in order of increasing support) of *not supportive/highly supportive/ supportive/undecided.*

5.3.3.4 R&D spending

The construction industry's investment in R&D and innovation is very low compared with other industries, such as the pharmaceutical industry. It could be argued that the pharmaceutical industry is very research intensive regarding product innovation, which explains why it has a total spending of £3308m, compared with just £33m for the construction industry. However the UK construction sector accounts for 8% of the UK's GDP, compared to the pharmaceutical industry's contribution of just 0.6% to the UK's GDP (National Statistics, 2007). At industry level it seems therefore that the more innovative an industry is, the more it spends on R&D – this argument can be extended to industry to explain the relationship between innovation and expenditure on R&D. Therefore, the level of investment in the UK construction industry can explain its overall intentions regarding innovation. Levels of investment in R&D can be described on a scale (in order of increasing expenditure on R&D) of *no R&D investment/under £1m'£1m to 10m/£10m to £100m/over £100m.*

5.3.4 Human Resources Management

The category 'human resource management' is described by the factors: number of R&D staff, competence of R&D staff, performance of R&D staff, age profile of R&D staff, retention of R&D staff, and staff development. The scales constructed for each factor within the category 'human resources management' are presented in the following sections.

5.3.4.1 Number of R&D staff

A measure of an organisation's intention to innovate is shown by the percentage of staff that are specifically employed for R&D activities (OECD, 2002). This percentage can be described on a scale (in order of increasing R&D personnel) of *0%-20%/20%-40%/40%-60%/60%-80%/80%-100 %*.

5.3.4.2 Competence skills of R&D staff

The level of competence of R&D staff can explain the dynamic capacity an organisation has towards innovation. Competence can be measured in many ways. A convenient way of measuring competence is to use academic qualifications. Therefore competence of R&D staff cane described on a scale (in order of increasing competence) of *non - degree holder/Bachelor's degree holders/Master's degree holder/PhD degree holders (OECD, 2002).*

5.3.4.3 Performance of R&D staff

The performance of R&D staff can be increased in an environment where there is freedom to develop and to implement new ideas (Nijhof, Krabbendam and Looise, 2002). The level of R&D staff performance can explain an organisation's encouragement to employees' creativity and innovation. The level of staff performance can be described on a scale (in order of increasing encouragement for creativity) of *very low/low/medium/high/very high.*

5.3.4.4 Age Profile of R&D staff

According to Levy (Levy, 2000) the age of the construction industry's workforce in getting older. It is therefore of increasing importance that more young people are employed and that continuous training is given to employees, so as to build up innovation capability (Vinding, 2006). The 'age profile' of R&D staff can be described on a scale (in order of increasing innovation capability) of *Older than 55 years old/45-55 years old/34-44 years old/23-33 years old*.

5.3.4.5 Retention of R&D staff

Within the process of innovation, the key workers are R&D staff, and their retention can be linked to an organisation's efficiency. Retention of R&D staff can therefore reflect the strategy that is adopted by an organisation with regards to increasing innovative potential by saving resources and maximising efficiency. A short length of stay would indicate a poor retention rate of R&D staff. Practically, this means that if the length of service of R&D staff is overall less than one year then the organisation's retention rate is considered to be poor (Reuters, 2000). Retention can be described on a scale (in order of increasing efficiency) of *tend to stay for 1-6 months/tend to stay for 1 year/tend to stay for 2 years/tend to stay for more than 2 years*.

5.3.4.6 Staff development

The training of employees is linked with organisational efficiency and innovative performance (Leede, de Looise and Alders, 2002; Lau and Ngo, 2004; Swanson and Holton, 2009). Staff training practices can be defined by the number of hours that are devoted to staff development. The levels of annual staff development can be described in terms of hours of training per year on a scale (in order of increasing competences) of *0-20hrs/20-40hrs40-60hrs/60-80hrs/80-100hrs.*

5.4 External environment forces

In the external environment key area the following categories have emerged: political and legal framework, economic environment, and infrastructural provision. Each category is described by different factors, representing a different dimension of the same category.

5.4.1 Political and legal framework

The category 'political and legal framework' is described by the factors: political freedom, incentives to foreign investors, competition framework, employment framework, and health and safety regulations. The scales constructed for each factor within the category 'political and legal framework' are presented in the following sections.

5.4.1.1 Political freedom

There are two basic types of political structures that may impact national construction issues as presented in Farr, Lord and Wolfenbarger (1998):

- Centralised governmental systems (Japan, France, United Kingdom, Netherlands, Denmark, Finland) that have a ministry of 'construction', which promotes all of the relevant innovation-enhancement policies for construction.

- Federal types of constitution and decentralised governmental structures (USA, Germany, Canada, Australia), which distribute the responsibility of construction at a regional or a state level.

In centralised governmental systems, 'research funding is being redirected from products to processes, government acquisition practices are being modified to stress a value over price, industrial collaboration is being promoted and technology/knowledge brokers are introduced' (Manseau and Seaden, 2001). With federal types of constitution no centralised body deals with construction issues, which results in a non-unique representation at the governmental level. Instead, many agencies deal with various issues, such as public works, safety, technology development etc. There seems to be no significant public policy interest regarding construction innovation.

Another approach is the 'social systems of innovation' proposed by Amable et al. (Amable, Barré and Boyer, 1997) and presented in Manseau & Seaden (Manseau and Seaden, 2001). Amable et al. (1997) identify four innovation systems, each with different characteristics:

- The market driven system (e.g. in USA, UK, Canada, and Australia) assumes 'that the market allocates resources and exploits opportunities, in the most efficient way through bidding processes'. The public sector is considered to be rather conservative, hindering innovation and thus is just another key client in the market. In such a system the public sector should only intervene in periods of market crisis, and that their role is to keep regulation at a minimum, whilst dealing with issues of safety and consumer protection. Labour arrangements are flexible, and innovations are assumed to be fostered by the increased competition and market opportunities that arise.

- The government-led system (e.g. in France, Germany, Italy, and Netherlands) considers the government to be the basic player in the construction market. Innovations, such as new technology, are mainly introduced through public-financed projects and then disseminated to the rest of the practitioners. In this system there are significant regulations that cover every aspect of construction. Labour arrangements are also inflexible. Innovation is only fostered through public instruments.

- The Social-democratic system (e.g. in Scandinavian countries) has a lot of similarities with the government-led system. This system puts emphasis on industry/labour/government relations. Labour arrangements are more flexible and support competitive forces. Innovation in this system is supported to a great extent by the government, which fosters to balance socioeconomic and environmental issues.

- The Meso-corporatist system (e.g. in Japan) is designed around the concept of very large corporations. This system contains a high amount of competition within the construction sector, but with a wide market share, allowing for high margins. An excess of profit is expected to be reinvested due to innovation being considered to be an important asset, not just for the company but for the nation. Public policy is completely focused on supporting a company's efforts at innovation. Consensus between the industry's key players and those of the government is achieved on issues such as regulation, training and innovation. Labour arrangements are flexible and tend to have long employee retention, often featuring lifetime employment.

The systems described above provide an overview of the policy context that may foster or hinder innovation. They reflect the concept/factor of political freedom. Political freedom can be described on a scale (in order of increasing potential to facilitate innovation) of fully r*estrictive/partially restrictive/non restrictive.*.

5.4.1.2 Incentives for foreign investors

Incentives for foreign investors include both financial and non-financial measures. Non-financial measures include the provision of infrastructure, such as prepared industrial sites (Herrmann and Lipsey, 2003). In order to encourage investment, governments also offer low tax rates to investors. However, such motives are not always credible, as governments tend to redistribute investor returns when capital is formed (Rama, 2008). Other financial incentives include expenditures on grants, subsidies and loan guarantees (Herrmann and Lipsey, 2003). The role of investment in promoting foreign direct investment has been the subject of many studies, but the advantages and disadvantages concerning each measure have never been clearly established (United Nations, 2000; Herrmann and Lipsey, 2003). Incentives can be discretionary according to the type of investment. It is recognised that financial incentives such as grants and loans are a direct drain on the government budget. These incentives are generally offered by developed countries, whilst developing countries often prefer to offer fiscal incentives that do not directly drain government funds (United Nations, 2000). There is an increased trend towards offering tax rate reductions or tax holidays for specific activities. Almost 85 percent of the countries surveyed by the United Nations (2000) offer these incentives. The other trend (almost 60 percent of the countries reviewed) is to offer allowances for investment in machineries or industrial buildings, or a combination of allowances for training, research and development or similar activities (United Nations, 2000).

Based on the discussion above, the type of incentives given to foreign investors indicates the level of economic development of a country, and also its ability to provide direct or indirect resources as incentives to investment. According to Fan et al. the economic development of a country is directly linked to innovative performance (Fan *et al.*, 2009). Combining this finding with the types of incentives given by governments to attract investments, it is contended that a country that is providing grants as an investment incentive is much more economically developed than a country that provides tax incentives. Similarly, a country that is providing tax incentives as an investment incentive is much more economically developed than a country that provides physical assets. As such the type of incentives offered can also reflect a country's innovative performance. Based on the above arguments the types of incentives provided by governments can be described on a scale (in order of increasing potential to innovate according to the level of economic development of the country) of *none/physical assets/tax relief/grants.*

5.4.1.3 Competition framework

The competition framework, under a government-political context, is identified as playing an important role in increasing the competitiveness and economic growth of a country by encouraging innovative activities (Manseau and Seaden, 2001). The competition framework of a country can be described on a scale (in order of increasing support for innovation) of *restrictive/facilitating/supportive*.

5.4.1.4 Employment framework

The employment framework is linked with the intention of an organisation to invest and expand. The response of an organisation concerning strict regulations is to invest more on training and make more use of temporary employment. Innovative organisations tend to allocate more resources to training their employees and upgrading their skills (Pierre and Scarpetta, 2004). The employment framework can thus be described on a scale (in order of increasing support for innovation) of r*estrictive/facilitating/supportive*.

5.4.1.5 Health and Safety regulations

Health and safety regulations are an important, intriguing source of innovation in some areas, but at the same time they may hinder it in other areas. This directly affects construction processes and the capacity to adapt to new standards (Gann and Salter, 2000; Katz, 2006). The role of health and safety regulations can be described on a scale (in order of increasing support for innovation) of r*estrictive/facilitating/supportive*.

5.4.2 Economic Environment

The category 'economic environment' is described by the factors: economic activity, GDP trend, rate of inflation, currency strength, tax policy, and government spending in R&D. The scales constructed for each factor within the category 'economic environment' are presented in the following sections.

5.4.2.1 Economic activity

The levels of economic activity of a region or a country are linked to innovation activity and knowledge spill-over (Audretsch and Feldman, 1996; Feldman and Audretsch, 1999). Level of economic activity is linked to innovation activity and knowledge spill-overs and explains, at least in part, an organisation's ability to innovate. The level economic activity can be described on a scale (in order of increasing contribution to innovation) of *very low/low/medium/high/very high*.

5.4.2.2 GDP trend

The relationship between GDP trends and gross domestic expenditure for research and development (GERD) shows that the innovative performance of a country is associated with investment in R&D, which is directly linked to GDP trends. The status of GDP can thus indicate GERD, which provides useful insight into GDP's impact on innovation (European Commission Directorate-General for Research, 2005; Taylor, 2007). The GDP trend can be described on a scale (in order of increasing public investment in R&D) of *falling/steady/rising*.

5.4.2.3 Rate of inflation

Monetary policies are conducted by governments to fight inflation and to keep inflation rates at low levels. This is done by applying inflation targeting, in order to encourage savings and investments and increase economic growth (Debelle *et al.*, 1998). Developed countries have adopted inflation targeting from a low starting point (less that 10 percent of inflation rate). Based on literature (Debelle *et al.*, 1998; Funk and Kromen, 2005) the effect of inflation rates can be described on a scale (in order of increasing incentive to innovate) *very low/low/medium/high/very high*.

5.4.2.4 Currency strength

The literature shows that a strong currency is the sign of a healthy economy (Oppenheimer, 2010). Despite the fact that a strong currency makes a country less competitive, it promotes innovation. This is because the reduced competitiveness that results from a country's strong currency forces it to focus in exporting more sophisticated goods and services (Oppenheimer, 2010). The effect of currency strength can be described on a scale (in order of increasing incentive to innovate) of *very low/low/medium/high/very high*.

5.4.2.5 Tax policy

Tax policies and tax incentives to organisations can provide incentives to invest in R&D and innovations (OECD, 2007). The effect of the tax policy can be described on a scale (in order of increasing incentive to innovate) of *very low/low/medium/high/very high*.

5.4.2.6 Government spending in R&D

Government spending on R&D is important for fostering innovation and increasing growth (OECD Science Technology and Industry Scoreboard, 2009). The level of government spending on schemes that support R&D can be described on a scale (in order of increasing incentive to innovate) of *very low/low/medium/high/very high.*.

5.4.3 Infrastructures provision

The category 'infrastructural provision' is described by the factors: transport provision and energy provision. The scales constructed for each factor within the category 'infrastructure provision' are presented in the following sections.

5.4.3.1 Transport provision

Transportation infrastructure is an important element in contributing to the successful facilitation of an organisation's daily operations and long term development. Increasing the competitiveness of a region by ensuring transportation infrastructure can stimulate innovation. The level of government provision for transportation infrastructure reflects a factor that influences innovation. A government's provision of infrastructure can be described on a scale (in order of increasing competitiveness) of *very low/low/medium/high/very high.*

5.4.3.2 Energy provision

Energy infrastructure is an important element in providing an external environment for increasing economic growth. The level of government provision for energy infrastructure reflects a factor that can influence the occurrence of innovation. A government's provision for infrastructure can be described on a scale (in order of increasing competitiveness) of *very low/low/medium/high/very high.*.

5.5 The generic system for identifying the condition of factors in the construction industry in the UK

The discussion in the sections above assisted in the description of the system for identifying the condition of each factor in influencing innovation. As explained in section 3.3.2 the system is designed based on the scales that have been constructed for each factor from the discussion in the sections above. The system is illustrated in Table 5.1.

Table 5.1 System for identifying the condition of factors

Internal Environment				
Factors	**Continuum**			
	Left Anchor			**Right Anchor**
Technology	Ancient	Established	New	Emerging

	(in order of increasing newness)					
Leadership	Authoritative	Paternalistic	Participative	Delegative	Free Reign	
	(in order of increasing freedom available to employees)					
Ownership	Sole proprietor	Private limited Co	Partnership	Public limited Co	Government Dpt/agency	Public Private Partnership
	(in order of increasing capacity to overcome bureaucracy and flexibility to work with others)					
Collaborations	Non collaborating	Regional	National	International		
	(in order of increasing commitment to collaboration)					
Hierarchy layers	More than 10 layers	8-10 layers	5-7 layers	2-4 layers		
	(in order of increasing flexibility)					
People reporting to a manager	>24 people	19-24 people	13-18 people	7-12 people	1-6 people	
	(in order of increasing effectiveness)					
Organisational relationships	Formal lateral relationships	Formal vertical relationships	Formal diagonal relationships	Informal lateral relationships	Informal vertical relationships	Informal diagonal relationships
	(in order of increasing flexibility of interaction)					
Organisational size	Micro & Small Medium Organisations					Large organisations
	(in order of increasing capacity to invest in R&D)					
Organisational strategy	Environmental/ opportunistic strategy	Entrepreneurial/ visionary strategies	Learning and capabilities - based strategies	Competitive / positioning strategy		
	(in order of organisations' orientation for continuous growth)					
Organisational policy	Always mandatory	Mainly mandatory	Mainly advisory	Always advisory		
	(in order of increasing potential to facilitate innovation)					
Organisational systems	Learning facts, knowledge, processes and procedures	Learning new job skills that are transferable to other situations	Learning to adapt	Learning to learn		
	(in order of increasing ability to learn)					
Strategic Resources						
Factors	**Continuum**					
	Left Anchor		**Right Anchor**			
Promotion of products and services	Amateur	Semi Professional	Professional			
	(in order of increasing professionalism)					
IPR	Restrictive	Facilitating	Supportive			

		(in order of increasing desirable motivation)
Sales manageme nt	Amateur; Semi Professional; Professional	***(in order of increasing professionalism)***
Market informatio n availability	Never available; Sometimes available; Always available	***(in order of increasing availability)***
Process integration	Initiation; Adoption; Adaption; Acceptance; Routinisation; Infusion	***(in order of increasing potential to innovate)***
Quality control	Non Advanced; Semi Advanced; Very Advanced	***(in order of increasing excellence)***
Knowledge manageme nt	Obtaining/ capturing knowledge; Locating and accessing knowledge; Propagating knowledge; Transferring knowledge; Modifying knowledge; Maintaining knowledge	***(in order of increasing potential to innovate)***
Capital Structure	Higher than 10; 2 to 10; 0 to 2	***(in order of increasing capacity to innovate)***
Financial manageme nt	Amateur; Semi Professional; Professional	***(in order of increasing professionalism)***
Financier attitude	Not Supportive; Undecided; Supportive; Highly Supportive	***(in order of increasing support)***
R&D spending	Non R&D Performers; Under £1m; £1m to 10m; £10m to £100m; Over £100m	***(in order of increasing expenditure on R&D)***
Number of R&D staff	0%-20%; 20%-40%; 40%-60%; 60%-80%; 80%-100 %	***(in order of increasing R&D personnel)***
Skills of R&D staff	Non -degree holders; Bachelor's degree holders; Master's degree holders; Phd degree holders	***(in order of increasing competences)***
Performan ce of R&D staff	Very Low; Low; Medium; High; Very High	***(in order of increasing encouragement for creativity)***
Age profile of R&D staff	Older than 55 years old; 45-55 years old; 34-44 years old; 23-33 years old	***(in order of increasing innovation capability)***
Retention of R&D staff	Tend to stay for 1-6 months; Tend to stay for 1 year; Tend to stay for 2 years; Tend to stay for more than 2 years’	

	(in order of increasing efficiency)				
Staff development	0-20hrs	20-40hrs	40-60hrs	60-80hrs	80-100hrs
	(in order of increasing competences)				
External Environment					
Factors	**Continuum**				
	Left Anchor				**Right Anchor**
Political Freedom	Fully restrictive		Partially restrictive		Non restrictive
	(in order of increasing potential to facilitate innovation)				
Incentives to foreign investors	Physical assets		Tax relief'		Grants
	(in order of increasing potential to innovate according to the level of economic development of the country)				
Competition framework	Restrictive		Facilitating		Supportive
	(in order of increasing support for innovation)				
Employment framework	Restrictive		Facilitating		Supportive
	(in order of increasing support for innovation)				
Health and Safety Regulations	Restrictive		Facilitating		Supportive
	(in order of increasing support for innovation)				
Economic Activity	Very Low	Low	Medium	High	Very High
	(in order of increasing contribution to innovation)				
GDP Trend	Falling		Steady		Rising
	(in order of increasing public investment in R&D)				
Rate of inflation	Very Low	Low	Medium	High	Very High
	(in order of increasing incentive to innovate)				
Currency strength	Very Low	Low	Medium	High	Very High
	(in order of increasing incentive to innovate)				
Tax Policy	Very Low	Low	Medium	High	Very High
	(in order of increasing incentive to innovate)				
Governement spending in R&D	Very Low	Low	Medium	High	Very High
	(in order of increasing incentive to innovate)				

Energy Provision	Very Low	Low	Medium	High	Very High
	(in order of increasing competitiveness)				
Transport Provision	Very Low	Low	Medium	High	Very High
	(in order of increasing competitiveness)				

The system developed in order to identify the condition of the factors in the construction industry was used during the survey conducted within organisations of the construction industry in the UK. The system helped to describe the behavioural component of organisations by depicting the practices organisations are employing to facilitate innovation. The results of the survey that included both the identification of the behavioural and the cognitive component of organisations' attitude towards innovation can be seen later in Chapter 6.

5.6 The generic mechanism of innovation for the construction industry in the UK

The mechanism of innovation is described as being the combination of all the factors identified and the conditions of the factors. The conceptual model (see Section 3.2) is adapted to integrate all the factors identified to play a key role to innovation, as presented in Chapter 4, and also the system developed to identify the condition of the factors in order to depict innovation practices. Figure 5.2 illustrates this adaptation and presents the mechanism of innovation. In Figure 5.2 each main category identified (e.g culture, structure, etc) is described by the different factors and the condition for each factor. For example, the category *Culture*, is described by the factors technology (C1), leadership style (C2), ownership style (C3), and collaborations (C4) and the conditions that pertain for each factor or else the practices that are employed by organisations i.e. C_{C1}, C_{C2}, C_{C3}, C_{C4} respectively (see Table 5.2).

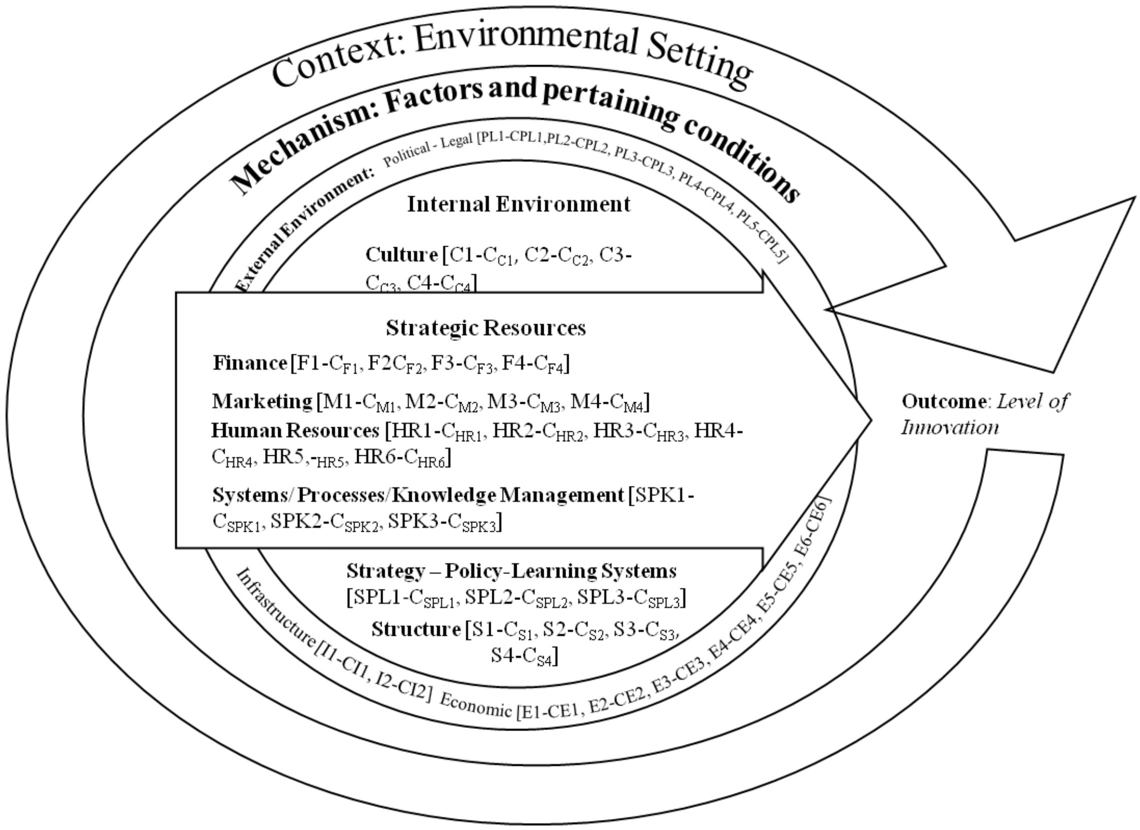

Figure 5.2 The mechanism of innovation

In the Mechanism of Innovation every category identified in each of the three key areas: internal environment; strategic resources; and external environment; was described by the different factors and the condition of the factors. These factors and their conditions, shown in Figure 5.2, are explained in Table 5.2.

Table 5.2 Categories and factors of the Mechanism of Innovation

Factors and condition of factors within each Category	
Culture	I2-C $_{I2}$: Energy provision
C1-C $_{C1}$: Technology	***Marketing***
C2 -C $_{C2}$: Leadership style	M1-C $_{M1}$: Promotion of products/services
C3-C $_{C3}$: Ownership type	M2-C $_{M2}$: Intellectual property rights
C4 -C $_{C4}$: Collaborations	M3-C $_{M3}$: Sales management
Economic Environment	M4-C $_{M4}$: Market information availability

E1-C $_{E1}$: Economic activity	***Political-Legal***
E2-C $_{E2}$: GDP trend	PL1-C $_{PL1}$: Political freedom
E3-C $_{E3}$: Rate of inflation	PL2-C $_{PL2}$: Incentives to foreign investors
E4-C $_{E4}$: Currency strength	PL3-C $_{PL3}$: Competition framework
E5-C $_{E5}$: Tax policy	PL4-C $_{PL4}$: Employment framework
E6-C $_{E6}$: Government spending in R&D	PL5-C $_{PL5}$: Health and safety regulations
Finance	***Structure***
F1-C $_{F1}$: Capital structure	S1-C $_{S1}$: Hierarchy
F2-C $_{F2}$: Financial management	S2-C $_{S2}$: Number of people reporting to a manager
F3-C $_{F3}$: R&D spending	S3-C $_{S3}$: Organisational relationships
F4-C $_{F4}$: Financiers attitude	S4-C $_{S4}$: Organisational size
Human Resources	***Strategy Policy***
HR1-C $_{HR1}$: Number of R&D staff	SP1-C $_{SP1}$: Strategy
HR2-C $_{HR2}$: Competence skills of R&D staff	SP2-C $_{SP2}$: Policy
HR3-C $_{HR3}$: Age profile of R&D staff	SP3-C $_{SP3}$: Organisational learning systems
HR4-C $_{HR4}$: Performance of R&D staff	***Systems-Process-Knowledge Management***
HR5-C $_{HR5}$: Retention of R&D staff	SPK1-C $_{SPK1}$: Process integration
HR6-C $_{HR6}$: Staff development	SPK2-C $_{SPK2}$:Quality control
Infrastructures	SPK3-C $_{SPK3}$:Knowledge management
I1-C $_{I1}$: Transport provision	

5.7 Summary

The mechanism formed by the factors and the condition of the factors, can explain the emergence of innovation. There is theoretical and experimental evidence to support the theory that the different practices employed by organisations regarding all of the factors previously identified, have an impact in innovation to some degree. All of these factors, and the condition of these factors, should therefore be examined using an integrated approach, within a supportive organisational context, so as to exploit new opportunities for the benefit of the organisation (Lundvall and Nielsen, 2007, p. 207). A central finding in innovation literature is that 'a firm does not innovate in isolation, but depends on extensive interaction with its environment' (Vinding, 2006). It is thus expected that the ability of the construction industry to innovate is profoundly shaped by the long-established characteristics of the industry, whilst also being affected by both internal and external environmental factors and the condition of these factors (Fagerberg, Mowery and Nelson, 2005). The next chapter explores the practices of innovation that are employed by the construction industry in the UK and using the mechanism of innovation developed it presents the mechanism of innovation in the construction industry in the UK.

CHAPTER 6: EXPLORING PRACTICES OF INNOVATION IN THE CONSTRUCTION INDUSTRY IN THE UK

The identification of the factors playing a key role to innovation as demonstrated in Chapter 4 and the system for depicting the condition of the factors as demonstrated in Chapter 5 provided the basis for exploring the practices of innovation in the construction industry. The purpose of this chapter is to present the analysis of the data generated in the application of the data acquisition methods employed to address the third objective of this research, as explained in Section 3.3.3. Specifically, this chapter presents the results of the data analysis in four stages:

- stage 1: includes the results of the pre-analysis data preparation and data examination;
- stage 2: includes the univariate analysis which was undertaken to explore and describe the data;
- stage 3: includes the bivariate analysis which was undertaken to explain the relationships within the data; and
- stage 4: includes the demonstration of the innovation mechanism within the context of the construction industry in the UK.

6.1 Pre-analysis data preparation and data examination

The data preparation phase included naming and coding the factors, and entering the data into SPSS. The data examination phase included judging the completeness of the questionnaires; reviewing missing value analysis mechanisms; identifying any missing mechanism in the data; reviewing the methods of handling missing data; and handling the missing data.

6.1.1 Naming the factors and coding the responses

The research instrument used for the data acquisition stage was described in Chapter 3 (see Section 3.3.3) and can be seen in Appendix A. The items that were measured can be categorised into three main groups:

- Group 1: included two items, proportion of revenues and proportion of expenditures associated with innovation;
- Group 2: included items of demographics; and
- Group 3: included two types of measurements for the 41 factors that constitute the mechanism of innovation (see Section 3.3.3).

A total of two items were measured in Group 1: the proportion of annual revenues (PROPREV) and the proportion of annual expenditures (PROPEXP) that were associated with innovation. A total of four demographic items were measured for the Group 2: an item depicting the geographical coverage of an organisation, an item depicting the professional background of the respondent, an item depicting the position the respondent held within the organisation and an item depicting the professional discipline of the organisation. The items measured in Groups 1 and 2 were complementary, so as to support any ensuing arguments.

A total of 82 items were measured in Group 3: two types of measurements that were obtained for the 41 factors, which were identified to play a key role in innovation, as can be seen in section 3.3.3. The first measurement depicted the extent to which each factor contributes to the propagation of innovation (cognitive question), and the second measurement depicted the condition for each factor (behavioural question). The categories for the 82 items included: eight measures for organisational culture, eight measures for organisational structure, six measures for organisational strategy, policy and learning systems, eight measures for marketing, eight measures of finance, twelve measures for human resources, six measures of operations management, ten measures for political and legal environment, twelve measures for economic environment and four measures for infrastructural provision.

Initially, all of the items measured were named using a short abbreviation, which represented the description of each factor. For example, the extent to which technology contributes to the propagation of innovation is named ‘techcont’. The names of all the variables can be seen in Appendix B.

The responses for each factor for Groups 1 and 2 were coded as natural numbers representing each of the responses. The responses for each factor in the third group were coded with numbers, which represented different levels on the scales that were constructed, as explained in Section 3.3.3. For example in the question 'to what extent does the technology that is used contribute to the propagation of innovation' the response, 'Not at all' was given a code of '0', the response 'Little' was given a code of '1', the response 'Moderate' was given a code of '2', the response 'Very much' was given a code of '3', and the response 'Great' was given a code of '4'.

All of the questionnaires were assigned with a unique number after the data collection stage. Afterwards, this case number was keyed to the data file that represented each completed questionnaire. This offered the capability to return to a specific questionnaire and retrieve any necessary information in case of a problem or an error ever occurring after the data was transferred into SPSS.

6.1.2 Entering data into SPSS

The selection of the statistical software was based mainly upon which of the statistical processing applications were supported by the IT services of the University of Leeds. SPSS is one of the statistical software programmes supported by the IT services in the University of Leeds and can be used for the statistical analysis of the data. Other software such as SAS and Matlab were also available within the School of Civil Engineering, but SPSS was preferable due to the prior knowledge of the author in using it. The data from the questionnaires was transferred to SPSS using the names that were created as shown in the Section 6.1.1 above. The types of measurement, the labels and the value labels were specified according to the requirements of SPSS.

Respondents were allowed to give more than one answer to questions that measured the condition of each factor. For analytical purposes, the code attributed to the questions that were given more than one answer was the code of the response that represented a better position on the dimension it was measuring. For example if an organisation responded that it was using both 'New' and 'Emerging' technology then the code used in the data set was the one that corresponded to ‘Emerging’ technology. This decision was based upon the logic that innovation in the organisation has already benefited from using ‘emerging’ technology and as such the organisation is in a more advantageous position that it would be if it only used ‘new’ technology.

During the process of entering the data, missing values were identified. In order to handle the missing values a numeric value with the label ‘999’ was created to represent the missing data point for the numeric variables and the value NR to represent non-response for the string variables. The chosen code did not correspond to any naturally occurring data value but it denoted that a value was missing for a particular person.

6.1.3 Judging the completeness of questionnaires

Initially, in order to check the completeness of questionnaires each section of the questionnaire was checked thoroughly to make sure that the respondent followed the instructions and recorded answers in the proper spaces provided (Alreck and Settle, 2004). Then, the missing value analysis (MVA) provided in SPSS was used to analyse the completeness of the questionnaires. The analysis showed that 29 cases had no missing values (52.72%) and 26 cases had at least one missing value (47.27%). Two groups of questionnaires were formed in terms of completeness: (1) the ‘*yes’* pile, included the questionnaires that were acceptable, and (2) the ‘*no’* pile, included the questionnaires that were obviously rejected. The ‘yes’ pile included 51 questionnaires with less than 10% of their values missing, with only 5 cases having a percentage of missing values between 10% and 15%, which is generally accepted for imputation methods (McDermeit, Funk and Dennis, 1999; Van Riel, 2005). The ‘no’ pile included 4 cases with 29.2%, 38.2%, 55.1% and 67.4% of their values missing, being excluded from further analysis due to the high percent of the missing values (Alreck and Settle, 2004). The final number of questionnaires that were used for data analysis was reduced to 51.

6.1.4 Missing value analysis mechanisms

To address the issue of the missing values that were encountered in this survey, an analysis of the literature revealed that there are a variety of methods for dealing with missing data. The most appropriate way of handling missing or incomplete data depends upon how the data points become missing (Houcka *et al.*, 2004). Howell (2007) identified three unique types of missing data mechanisms, Missing Completely At Random (MCAR), Missing At Random (MAR), and Missing Non At Random (MNAR).

When data are missing completely at random (MCAR), the probability that an observation (X_i) is missing is unrelated to the value of X_i or to the value of any other variables (Howel, 2007). A missing completely at random (MCAR) situation exists when missing values are randomly distributed across all observations (Garson, 2007).

Often data are not missing completely at random, but they may be classifiable as missing at random (MAR). The data are missing at random if the missing pattern does not depend on the value of X_i after controlling for another variable (Howel, 2007). Missing at random (MAR) is a condition which exists when missing values are not randomly distributed across all observations but are randomly distributed within one or more subsamples. MAR is much more common than MCAR (Garson, 2007).

If data are not MCAR or MAR then it is classified as missing not at random (MNAR) (Howel, 2007). This form exists when missing values are not randomly distributed across observations, but the probability of missingness cannot be predicted from the variables in the model.

Recognition of the underlying missing-data mechanism is important in selecting an appropriate statistical technique for analysis, since methods that disregard the missing data process often lead to biased and inefficient estimates (Houcka *et al.*, 2004).

6.1.5 Identify missing mechanism for survey data

There are statistical methods available for analysing data under the assumption of MAR or NMAR, but no statistical test is currently available to test those two missingness mechanisms. Generally, MAR is assumed when it is believed that subjects drop out because of the observed history of their response values. In order to test if the missing data mechanism is systematic Little's test (Little, 1988) can be applied,. The test is a chi-square test for missing completely at random (MCAR). It divides the samples into groups based upon the patterns of missingness. Test statistics are based on the pattern-specific means and the pooled estimates of the population mean and covariance. The results from the Little's MCAR test suggest that data is missing completely at random ($\chi2$ = 710.09, N=51, p = 0.956) (Longino, 2007).

Analysis with a complete sample (usually referred to as a complete analysis or complete-case analysis) only includes the cases that have all of their items answered. It can result in a loss of information by excluding the cases that do not have all of the items completed. The complete analysis uses a chosen set and the modelling does not depend on the missing data. This method is not desirable due to attrition (Liu and Gould, 2002). Recent methods, such as ignorable maximum likelihood (IML) and multiple imputation MI, which require less stringent assumption, such as MAR, are more robust and favoured by the statistical community (Collins, Schafer and Kam, 2001; Schafer and Graham, 2002). The different methods for handling missing data are analysed in the following section.

6.1.6 Methods of handling missing data

Some of the more popular methods for handling missing data appear below. This list is not exhaustive, but it covers some of the more widely recognised approaches for the handling of databases with incomplete cases.

6.1.6.1 Listwise or casewise data deletion

If a record has missing data for any one of the variables used in a particular analysis, the entire record can be omitted from the analysis. This approach is implemented as the default method of handling incomplete data by many statistical procedures in commonly-used statistical software packages such as SAS and SPSS (Enders, 2010). Listwise or casewise deletion methods assume MCAR and can produce distorted parameter estimates when this assumption is not valid. However, even if MCAR assumption is valid, the deletion approach leads to eliminating data and reducing power (Enders, 2010).

6.1.6.2 Pairwise data deletion

Pairwise data deletion is available in a number of SAS and SPSS statistical procedures (2004). Pairwise deletion omits cases which do not have data on a variable used in the current calculation only. This means that different calculations (e.g. different correlation coefficients) will utilise different cases and will have different sample sizes (different n's). This effect is undesirable (and in some procedures, like structural equation modelling, may prevent a solution altogether), but pairwise deletion may be necessary when overall the sample size is small or the number of cases with missing data is large. However, misinterpretation may well result unless missing data are missing completely at random (MCAR) (Garson, 2007; Enders, 2010).

6.1.6.3 Mean substitution

Mean substitution is a single imputation method that replaces missing values with a variable's mean value computed from available cases (Enders, 2010). Substitution of the simple (grand) mean reduces the variance of the variable. Reduced variance can bias correlation downward (attenuation) or, if the same cases are missing for two variables and the means are substituted, correlation can be inflated. This method then creates a spiked distribution at the mean in frequency distributions and causes attenuation in correlation of the item with others, and underestimates variance (Enders, 2010). These effects on correlation carry over in a regression context to lack of reliability of the beta weights and of the related estimates of the relative importance of independent variables. Mean substitution in the case of one variable can lead to bias in estimates of the effects of other or all variables in the regression analysis, because bias in one correlation can affect the beta weights of all variables. Somewhat better is the substitution of the group mean for a categorical (grouping) variable that is known to correlate highly with the variable which has missing values. Mean substitution assumes data are MCAR and was once the most common method of imputation of missing values. It is however, no longer preferred (Garson, 2007).

6.1.6.4 Regression methods

Regression imputation replaces missing values with predicted scores from a regression equation (Enders, 2004). The regression equation is based on a complete case of data for a given variable, treating it as the outcome and using all other relevant variables as predictors. Then, for cases where Y is missing, the available data is plugged into the regression equation as a predictor and then substituted in the equation's predicted Y value in the database. The fact that the imputed values fall directly on a straight line implies that the filled-in data may lack variability. An improvement on this method involves adding uncertainty to the imputation of Y, so that the mean response value is not always imputed (Enders, 2004). The regression method assumes missing values are MAR (as opposed to MCAR), however, under the MCAR mechanism the improvements of the method yield consistent estimates, which are closer to the population (Enders, 2004).

6.1.6.5 Hot Deck imputation

The hot deck imputation method identifies the most similar case to the case with a missing value and substitutes the most similar case's Y value for the missing case's Y value. Among hot deck's advantages are its conceptual simplicity, its maintenance of the proper measurement level of variables (categorical variables remain categorical and continuous variables remain continuous), and the availability of a complete data matrix at the end of the imputation process that can be analysed like any complete data matrix. Generally, the hot deck imputation preserves the distributions of the data without attenuating the variability (Enders, 2004; Enders, 2010). One of hot deck's disadvantages comes from the difficulty in defining "similarity"; there may be any number of ways to define what similarity is in this context. Thus, the hot deck procedure requires the development of custom software syntax to perform the selection of donor cases and the subsequent imputation of missing values in the database. More sophisticated hot deck algorithms would identify more than one similar record and then randomly select one of those available donor records to impute the missing value or use an average value if that was appropriate (2004; Enders, 2004).

6.1.6.6 Expectation Maximization method

The Expectation Maximisation (EM) method of handling missing data is an iterative procedure that proceeds in two discrete steps. First, in the expectation (E) step, the expected value of the complete data log likelihood is computed. In the maximisation (M) step, the expected values for the missing data obtained from the 'E' step is substituted. Then the likelihood function, which assumes that no data were missing, so as to obtain new parameter estimates, is maximised. The procedure iterates through these two steps until convergence is obtained. The strength of the approach is that it has well-known statistical properties and it generally outperforms popular ad hoc methods of incomplete data handling, such as listwise data deletion, pairwise data deletion and mean substitution. It outperforms them because it assumes incomplete cases have data missing at random (MAR) rather than missing completely at random (MCAR). The primary disadvantage of the EM approach is that it adds no uncertainty component to the estimated data. This means that while parameter estimates based upon the EM approach are reliable, standard errors and associated test statistics (e.g., t-tests) are not. This shortcoming led statisticians to develop a multiple imputation method for handling missing data.

6.1.6.7 Multiple Imputation

The multiple imputation method is similar to the maximum likelihood method, except that multiple imputation generates actual raw data values which are suitable for filling in the gaps in an existing database. Typically, five to ten databases are created in this fashion. The investigator then analyses these data matrices using an appropriate statistical analysis method, treating these databases as if they were based on complete case data. The results from these analyses are then combined into a single summary finding. Multiple imputations combine the well-known statistical advantages of EM and raw maximum likelihood with the ability of hot deck imputation so as to provide a raw data matrix to analyse. Multiple imputation works by generating a maximum likelihood-based covariance matrix and vector of means, like EM. Multiple imputations takes the process one step further by introducing statistical uncertainty into the model and using that uncertainty to emulate the natural variability among cases one encounters in a complete database. Multiple imputation then imputes actual data values to fill in the incomplete data points in the data matrix, just as hot deck imputation does (Enders, 2004). The primary difference between multiple imputation and hot deck imputation from a practical or procedural standpoint is that multiple imputations require that the data analyst generate five to ten databases with imputed values. The data analyst then analyses each database, collects the results from the analyses, and summarises them into one summary set of findings. Multiple imputation has several advantages. It is fairly well-understood and robust to violations of non-normality of the variables used in the analysis. Like hot deck imputation, it outputs complete raw data matrices. It is clearly superior to listwise, pairwise, and mean substitution methods of handling missing data in most cases. Disadvantages include the time intensiveness requiredto imput five to ten databases, testing models for each database separately, and recombining the model results into one summary. Furthermore, summary methods have been worked out for linear and logistic regression models, but work is still in progress to provide statistically appropriate summarisation methods for other models such as factor analysis, structural equation models, and multinomial logit regression models.

6.1.7 Selection of a missing data handling method

All methods for handling missing data as analysed above have strengths and weaknesses. Mean substitution is generally only advisable when the missing values are less than 5% which was not the case (Enders, 2004). Furthermore the MCAR assumption can be wrong, but it would by definition be impossible to know on the basis of the data alone, and so all existing general purpose imputation models assume it (Honaker and King, 2006). Thus, MAR assumptions for handling missing data are much safer than the more restrictive missing completely at random (MCAR) assumptions which are required for listwise deletion, where missingness patterns must be unrelated to observed or missing values. Although the assumption of MCAR was satisfied for the data set (see Little's MCAR test in Section 6.1.5) listwise or pairwise deletion was not used as this would cause an unacceptable loss of data. Regression models would result in standard errors (and hence confidence intervals and probability values) being smaller than they should be had no imputation been necessary (Enders, 2010). Although multiple imputation is a more advanced method, the combination of the large number of factors in the data set with the required five to ten databases, which would need to be tested separately, would make the analysis incredibly time intensive. Thus, the method used for handling the missing data in the data set was the estimation maximisation algorithm (EM). Clearly, EM maximum likelihood estimation has stronger theoretical advantages over the other missing data techniques and is preferred by researchers (Longino, 2007; Enders, 2010). Data imputation was employed and the EM algorithm was incorporated with the Missing Value Analysis commands in SPSS. The remaining analysis was conducted on the imputed data set after applying EM and rounding of the imputed values to represent integer values.

6.2 Univariate analysis

In order to explore the items measured within each group univariate analysis was undertaken. Descriptive statistics for the individual items were provided for all the three groups and included graphing and screening the data and data normality tests to inform the appropriateness of the subsequent use of statistical tests.

6.2.1 Descriptive statistics for the individual items

The profile of an organisation relating to the proportion of revenues and expenditures associated with innovation, representing the items of the first group, is summarised in Figures 6.1 and 6.2 below. 51% of organisations generated between 1-10% of their revenues from innovation. Another 10% of organisations generated between 11-20% of revenues from innovation (see Figure 6.1). It is worth noting that there were 31% of organisations that were not investing in innovation, or were investing very little in it (see Figure 6.2). However, 59% of organisations were investing between 1-10% in innovation and another 10% were investing more than 10% in innovation. In total, it is seen that the majority of organisations were investing in innovation and in having revenues associated with it.

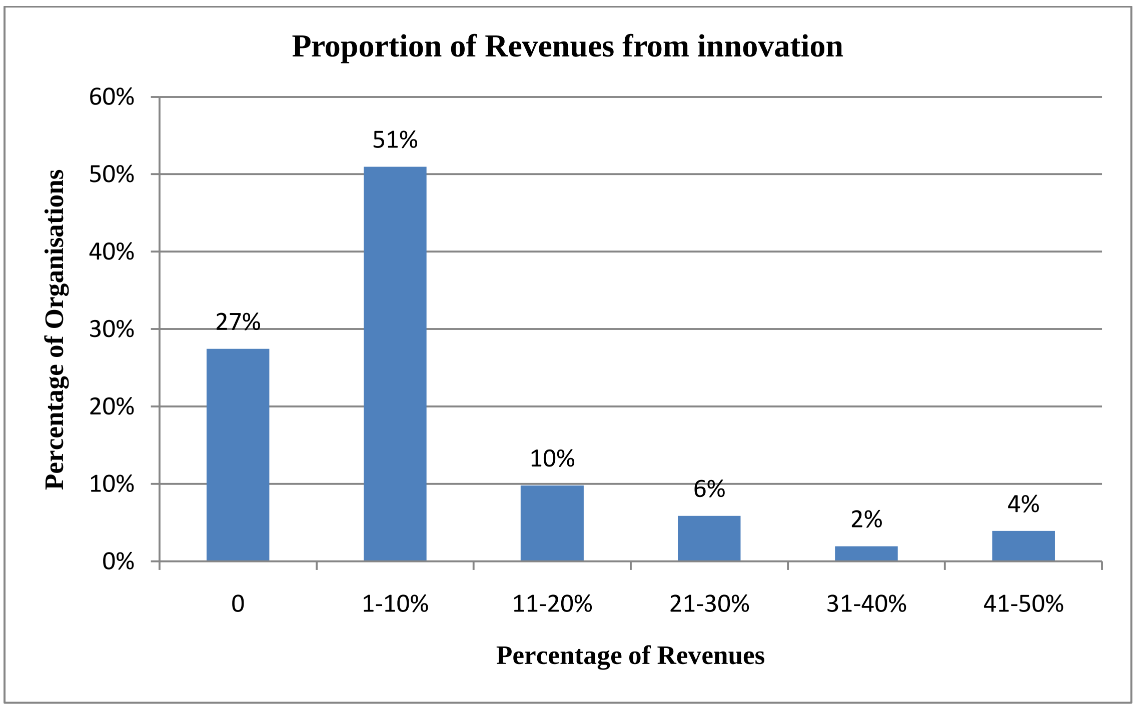

Figure 6.1 Proportion of revenues associated with innovation

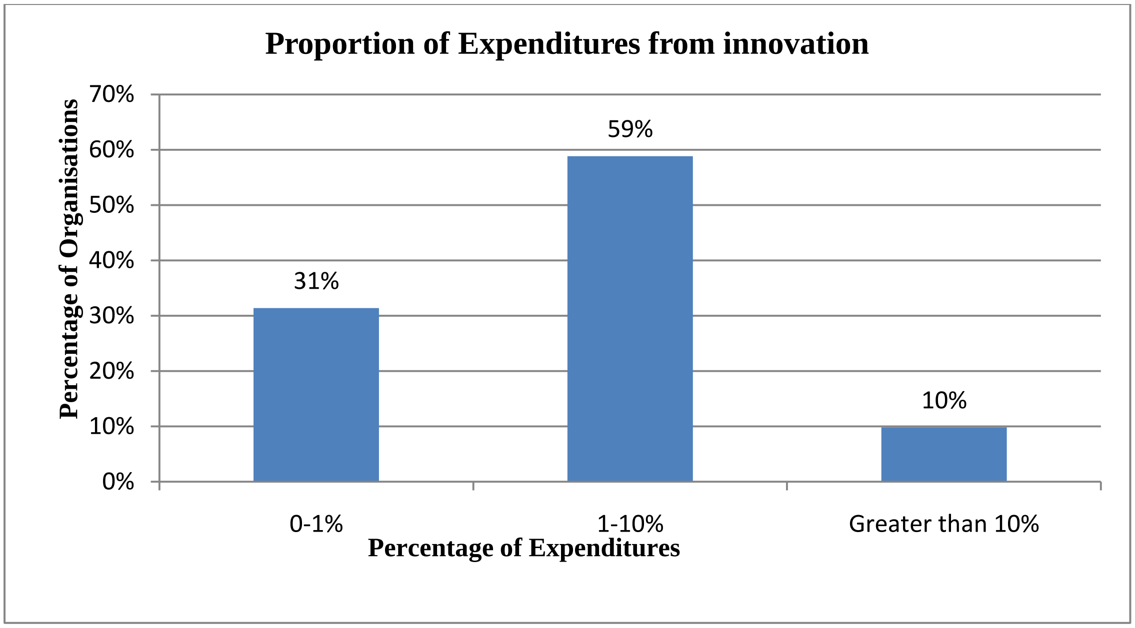

Figure 6.2 Proportion of expenditures associated with innovation

A summary of organisations' profiles on the demographic items measured for the second group is summarised in Table 6.1. Although organisational size was not one of the items measured for the demographics it is included in Table 6.1 as it demonstrates the size of the organisations participating in the survey. The sample consisted of 86.2% of micro and small and medium enterprises employing 1 to 250 while the remaining 13.7% included large organisations with more than 250 employees (Table 6.1). The majority of the organisations (70.6%) operated locally and regionally, while only 11.8% operated internationally. The majority of the respondents (84.3%) held a management position and were in the organisation for more than five years (84.3%). More than half of the companies surveyed were building (49%) or civil engineering contractors (17.6%). The table also includes the size of the organisations that participated in the research.

Table 6.1 Organisations' profile

Demographics		**n**	**%**
Organisation size by no. of employees			
	1-250 employees	44	86,2
	250<employees	7	13,7

	Total	51	100,0
Geographical coverage of the organisation			
	Local	23	45,1
	Regional	13	25,5
	National	9	17,6
	International	6	11,8
	Total	**51**	**100,0**
Professional background of the respondents			
	Architect	1	2,0
	Architectural Tech/Asst	1	2,0
	Builder/Contractor	18	35,3
	Chartered Surveyor	1	2,0
	Cost Consultant	1	2,0
	Engineer	16	31,4
	Quantity Surveyor	4	7,8
	Project Manager/Director	3	5,9
	Other	6	11,8
	Total	**51**	**100,0**
Post of the respondent in the organisation			
	Senior Management	29	56,9
	Management	14	27,5
	Self-employed/no staff	8	15,7
	Total	**51**	**100,0**
Describe organisation			
	Architectural Practise	1	2,0
	Building Contractor	25	49,0
	Building Surveying Practise	1	2,0
	Civil Engineering Contractor	9	17,6
	Civil Engineering Consultancy	4	7,8
	House Builder	2	3,9
	Multidisciplinary Practise	3	5,9
	Property Developer	4	7,8
	Specialist Sub-Contractor	1	2,0

	Other	1	2,0
	Total	**51**	**100,0**
Years in the organisation			
	1 to 4 years	8	15,7
	5 to 9 years	12	23,5
	>10 years	31	60,8
	Total	**51**	**100,0**

Descriptive statistics for all the items in the third group were generated with SPSS. The output of the analysis provided central tendency measures such as the medians and standard deviations (SD) as shown in Table 6.2 below. Medians are provided instead of the means as the items in this third group were designed as ordinal variables. Other measures of the items in the third group, such as skewness and kurtosis values are provided in Appendix B. There were positive values of skewness that indicated a pile-up of scores on the left of the distributions, as well as negative values that indicated a pile-up on the right. The positive values of kurtosis indicate a pointy distribution while the negative values indicated a flat distribution. The descriptive statistics provided a first view concerning the normality of the data. The values of skewness and kurtosis should be zero in a normal distribution (Field, 2005). However, the majority of the items had values of skewness and kurtosis far from zero, indicating that the data was not normally distributed. Normality of the data was further examined and the results are presented in the following section.

Table 6.2 Descriptive statistics for the individual items in Group 3

Key Areas, Categories Construct and Factors	**Median**	**SD**
Key Area 1: Internal Environment		
Construct 1: Culture		
1) The extent to which technology contributes to propagation of innovation (techcont; 5-point scale measure)	2.00	1.06
2) The type of technology used by the organisation (techtype, 5-point scale measure)	2.00	1.05
3) The extent to which the leadership style contributes to propagation of innovation (leadcont, 5-point scale measure)	2.00	1.14

4)	The leadership style employed by the organisation (leadstyl, 5-point scale measure)	2.00	0.96
5)	The extent to which the ownership type contributes to propagation of innovation (owncont,5-point scale measure)	2.00	1.26
6)	The ownership type of the organisation (owntype, 6-point scale measure)	2.00	0.56
7)	The extent to which the collaborations contributes to propagation of innovation (collcont, 5-point scale measure)	2.00	1.18
8)	The collaboration type of the organisation (colltype, 4-point scale measure)	1.00	1.02
Construct 2: Structure			
1)	The extent to which the hierarchy contributes to propagation of innovation (hiercont, 5-point scale measure)	1.00	1.10
2)	The number of hierarchy layers of the organisation (hiercont, 4-point scale measure)	3.00	0.46
3)	The extent to which the span of control contributes to propagation of innovation (layernum, 5-point scale measure)	2.00	1.05
4)	The typical number of people reporting to one manager of the organisation (spancont, 5-point scale measure)	4.00	1.05
5)	The extent to which organisational relationships contribute to propagation of innovation (relacont, 5-point scale measure)	2.00	1.29
6)	The organisational relationships of the organisation (relatype, 6-point scale measure)	2.00	1.70
7)	The extent to which organisational size contributes to propagation of innovation (sizecont, 5-point scale measure)	1.00	1.14
8)	The organisational size of the organisation (orgasize, 3-point scale measure)	0.00	0.73
Construct 3: Strategy-Policy-Organisational Learning Systems			
1)	The extent to which the organisational strategy contributes to propagation of innovation (stracont, 5-point scale measure)	2.00	1.18
2)	The strategy of the organisation (stratype, 4-point scale measure)	1.00	1.04
3)	The extent to which the policy contributes to propagation of innovation (policont, 5-point scale measure)	2.00	1.27
4)	The policy type of the organisation (politype, 4-point scale measure)	2.00	0.75
5)	The extent to which organisational learning systems contributing to propagation of innovation (learcont, 5-point scale measure)	1.00	1.08
6)	The organisational learning systems of the organisation (learsyst, 4-point scale measure)	1.00	0.85
Key Area 2: Strategic Resources			

Construct 4: Marketing		
1) The extent to which the promotion of products/services contribute to propagation of innovation (promcont, 5-point scale measure)	2.00	1.09
2) The promotion of products/services of the organisation (promprod, 4-point scale measure)	2.00	1.16
3) The extent to which the intellectual property rights contribute to propagation of innovation (propcont, 5-point scale measure)	1.00	1.13
4) The intellectual property rights of the organisation (intelrig, 3-point scale measure)	1.00	0.65
5) The extent to which sales management contribute to propagation of innovation (salecont, 5-point scale measure)	1.00	1.07
6) The sales management of the organisation (salemana, 4-point scale measure)	2.00	1.21
7) The extent to which market information availability contribute to propagation of innovation (infocont, 5-point scale measure)	2.00	1.04
8) The market information availability of the organisation (infoavai, 3-point scale measure)	1.00	0.58
Construct 5: Operations management: Systems-Process-Knowledge Management		
1) The extent to which process integration contribute to propagation of innovation (proccont, 5-point scale measure)	1.00	0.99
2) The process integration of the organisation (procinte, 6-point scale measure)	2.00	1.17
3) The extent to which quality control contribute to propagation of innovation (qualcont, 5-point scale measure)	2.00	1.10
4) The quality control of the organisation (qualdesc, 4-point scale measure)	2.00	0.82
5) The extent to which knowledge management processes contribute to propagation of innovation (knowcont, 5-point scale measure)	1.00	1.26
6) The knowledge management processes of the organisation (knowmana, 6-point scale measure)	0.00	1.53
Construct 6: Finance		
1) The extent to which the capital structure contribute to propagation of innovation (capicont, 5-point scale measure)	1.00	1.21
2) The capital structure of the organisation (debtrati, 3-point scale measure)	2.00	0.67
3) The extent to which the financial management contribute to propagation of innovation (finacont, 5-point scale measure)	2.00	1.20
4) The financial management of the organisation (finamana, 3-point scale measure)	1.00	0.69

5) The extent to which the financiers attitude contribute to propagation of innovation (fiatcont, 5-point scale measure)	1.00	1.28
6) The financiers attitude of the organisation (finatit, 4-point scale measure)	2.00	0.59
7) The extent to which R&D expenditure contribute to propagation of innovation (rdexcont, 5-point scale measure)	2.00	1.10
8) The R&D expenditure of the organisation (rdexpend, 5-point scale measure)	2.00	0.81
Construct 7: Human Resources		
1) The extent to which the number of R&D staff contribute to propagation of innovation (rdnucont, 5-point scale measure)	1.00	1.15
2) The number of R&D staff of the organisation (rdstaffn, 6-point scale measure)	0.00	0.67
3) The extent to which the competence skills of R&D staff contribute to propagation of innovation (skilcont, 5-point scale measure)	0.00	1.20
4) The competence skills of R&D staff of the organisation (rdskills, 5-point scale measure)	0.00	1.05
5) The extent to which the performance of R&D staff contribute to propagation of innovation (perfcont, 5-point scale measure)	0.00	1.15
6) The performance of R&D staff of the organisation (rdperfor, 6-point scale measure)	0.00	1.57
7) The extent to which the age profile of R&D staff contribute to propagation of innovation (profcont, 5-point scale measure)	0.00	1.01
8) The age profile of R&D staff of the organisation (ageprofi, 5-point scale measure)	0.00	1.61
9) The extent to which retention of R&D staff contribute to propagation of innovation (retecont, 5-point scale measure)	0.00	1.04
10) The retention of R&D staff within an organisation (retedesc, 5-point scale measure)	0.00	1.59
11) The extent to which staff development processes contribute to propagation of innovation (stafcont, 5-point scale measure)	2.00	1.22
12) The staff development of the organisation (stafdeve, 6-point scale measure)	1.00	1.27
Key Area 3: External Environment		
Construct 8: Political-Legal Framework		
1) The extent to which the political freedom contributes to propagation of innovation (pofrcont, 5-point scale measure)	1.00	1.24
2) The political freedom on the organisation (polifree, 3-point scale measure)	2.00	0.49
3) The extent to which do incentives to foreign investors contribute to propagation of innovation (invecont, 5-point scale measure)	0.00	0.63

4) The incentives to foreign investors (inveince, 4-point scale measure)	0.00	0.31
5) The extent to which does competition law and policy contribute to propagation of innovation (compcont, 5-point scale measure)	0.00	0.79
6) The competition law and policy (compelaw, 3-point scale measure)	1.00	0.81
7) The extent to which does employment law and policy contribute to propagation of innovation (emplcont, 5-point scale measure)	1.00	1.06
8) The employment law and policy (emplolaw, 3-point scale measure)	1.00	0.76
9) The extent to which does health and safety regulations contribute to propagation of innovation (regucont, 5-point scale measure)	3.00	1.32
10) The health and safety regulations (hsregula, 3-point scale measure)	1.00	0.86
Construct 9: Economic		
1) The extent to which the level of economic activity contribute to propagation of innovation (econcont, 5-point scale measure)	2.00	1.17
2) The level of economic activity (econacti, 5-point scale measure)	2.00	0.91
3) The extent to which the trend in Gross Domestic Product contribute to propagation of innovation (gdpcont, 5-point scale measure)	1.00	1.00
4) The trend in Gross Domestic Product (gdptrend, 3-point scale measure)	1.00	0.40
5) The extent to which the rate of inflation contribute to propagation of innovation (inflcont, 5-point scale measure)	1.00	1.08
6) Describes the rate of inflation (inflrate, 5-point scale measure)	2.00	0.94
7) Assesses the extent to which the strength of the currency contribute to propagation of innovation (currcont, 5-point scale measure)	1.00	1.05
8) The strength of the currency (currstre, 5-point scale measure)	1.00	0.95
9) The extent to which the rates of taxation contribute to propagation of innovation (taxacont, 5-point scale measure)	2.00	1.29
10) The rates of taxation (taxarate, 5-point scale measure)	2.00	1.00
11) The extent to which the level of government spending in R&D contribute to propagation of innovation (gordcont, 5-point scale measure)	1.00	1.10
12) The level of government spending in R&D (gordspen, 5-point scale measure)	1.00	0.83
Construct 10: Infrastructure Provision		

1)	The extent to which the energy provision contribute to propagation of innovation (enercont, 5-point scale measure)	1.00	0.97
2)	The energy provision (enerprov, 5-point scale measure)	1.00	0.87
3)	The extent to which the transport provision contribute to propagation of innovation (trancont, 5-point scale measure)	1.00	1.13
4)	The transport provision (tranprov, 5-point scale measure)	2.00	1.02

Figures 6.3, 6.4 and 6.5 below, show the variation of the responses for each item measuring the extent to which each factor contributes to the propagation of innovation in percentage terms. Frequency tables were also generated for looking at the cumulative percent of each response in measuring the extent to which each factor contributes to propagation of innovation and are provided in Appendix B. The figures below and the tables in Appendix B show that all factors were at a greater or lesser extent important to propagation of innovation according to the professionals participated in the survey.

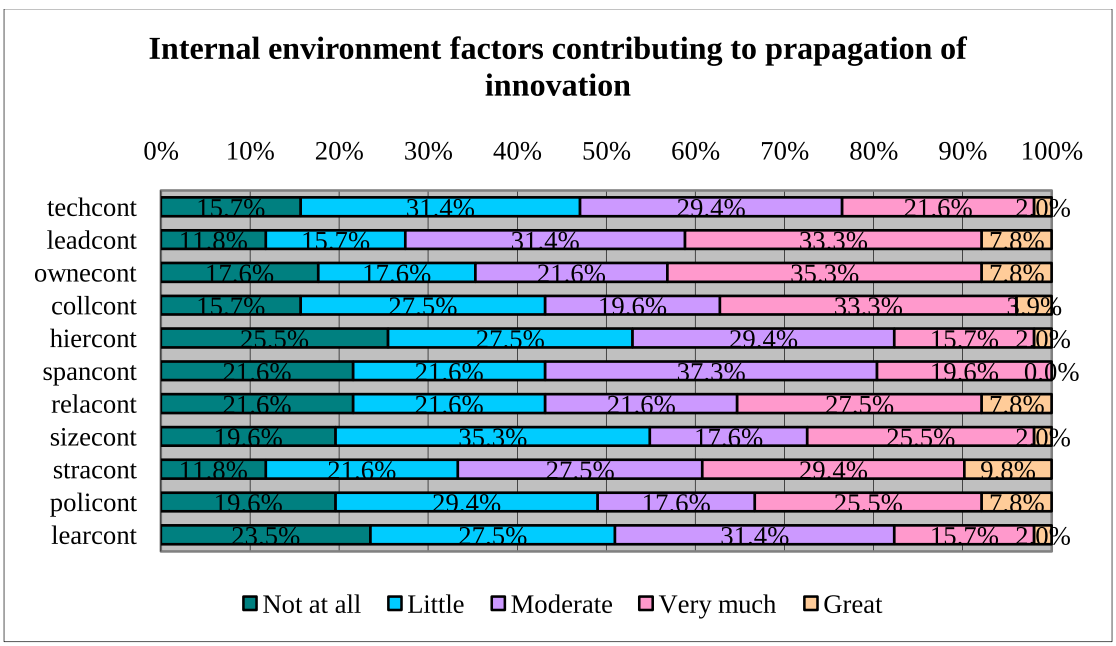

Figure 6.3 The extent to which each factor contributes to propagation of innovation (Key area 1: internal environment)

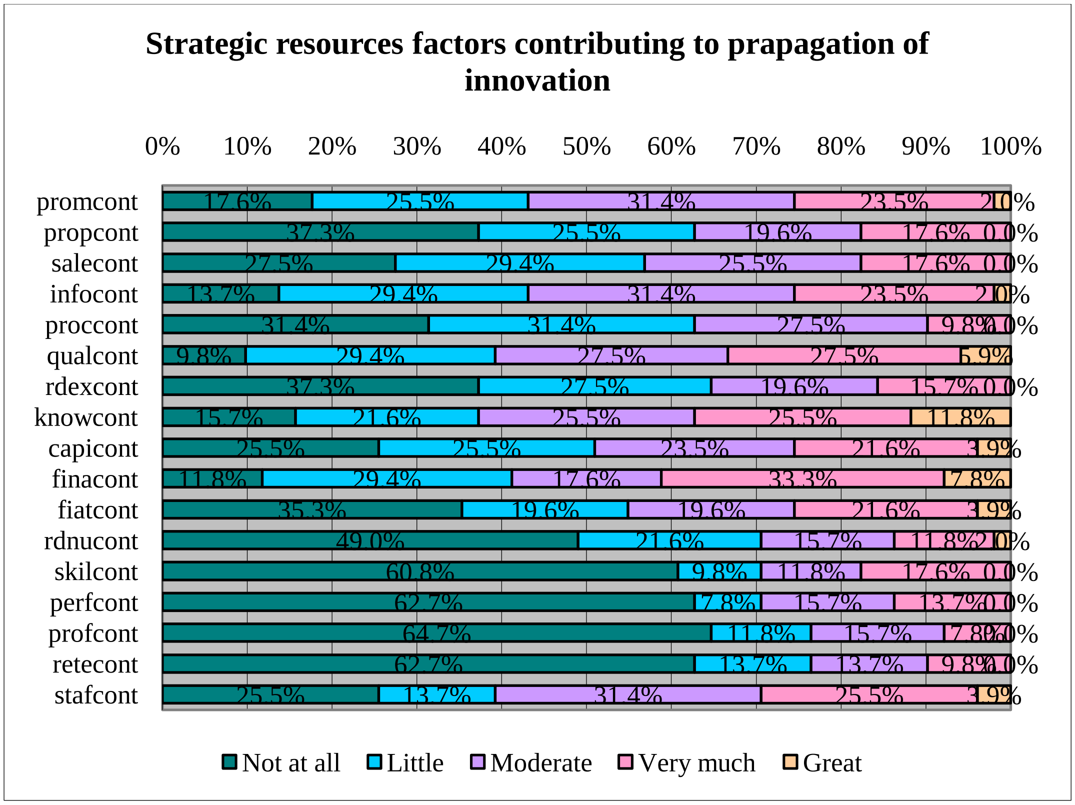

Figure 6.4 The extent to which each factor contributes to propagation of innovation (Key area 2: strategic resources)

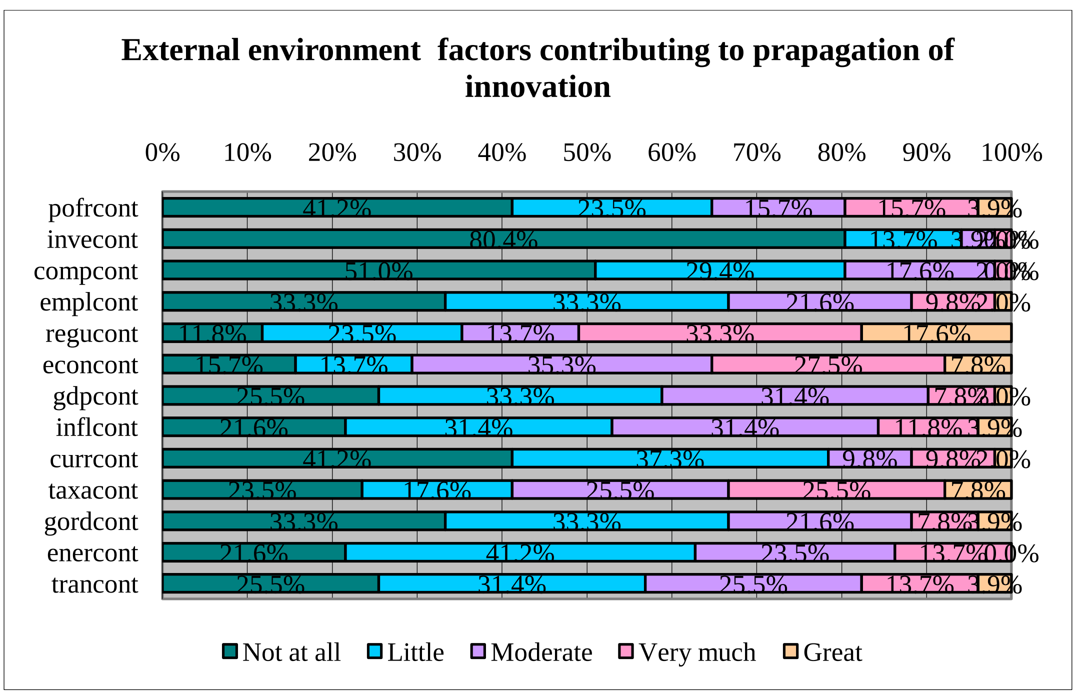

Figure 6.5 The extent to which each factor contributes to propagation of innovation (Key area 3: external environment)

Figure 6.6 shows in percentage terms the variation of the responses for the items measuring the condition of the factor 'technology'. Figure 6.6 shows that almost half of the respondents, 45.1% are using established technology and a 25.5% are using modern technology. All of the figures and the tables generated for each factor that illustrate the variation of the current practices are provided in Appendix B. Tables were also generated for looking the cumulative percent of each response in measuring the condition of the factors and are provided in Appendix B.

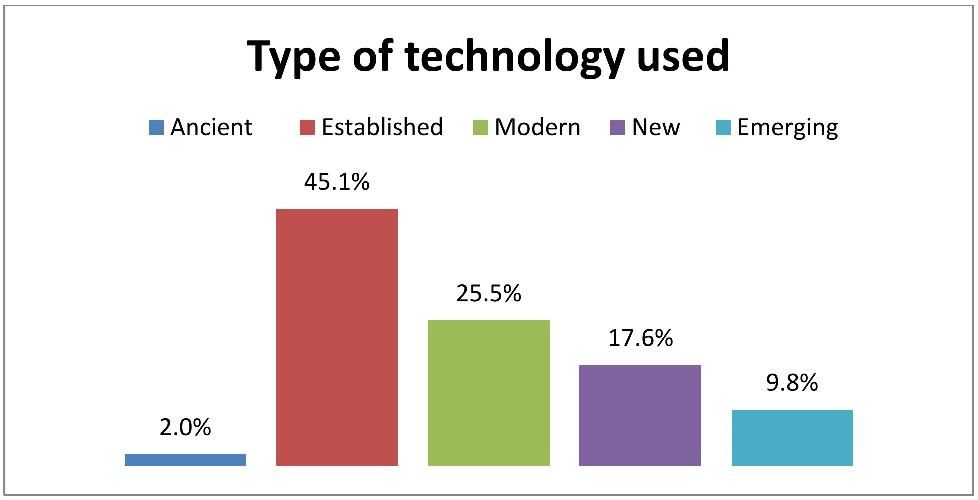

Figure 6.6 Type of technology used

Descriptive statistics provided the initial view of the data gathered, with the next step being to check for the normality of the data, in order to decide on the appropriate steps for further analysis.

6.2.2 Check for normality of the data

The actual values of skewness and kurtosis generated for each factor and presented in Appendix B are not in themselves decisive regarding the normality of the data (Field, 2005). There was a need to take a further step, in order to check for normality in a more objective way, by applying the Kolmogorov-Smirnov test (K-S). The Kolmogorov-Smirnov test compares the scores in the sample to a normally distributed set of scores with the same mean and standard deviation. The K-S test, performed using SPSS, included the test statistic itself, the degrees of freedom (which was equal to the sample size), and the significance value of the test. All of the measurements were highly significant ($p<0.05$) indicating deviation from normality. In addition, a visual screening of the normal probability Q-Q chart plots, generated using SPSS for each item, showed that the observed values deviate from the straight line of the expected values. This was another indication confirming the initial suggestions that there were significant deviations from normality within the data. The deviation from normality indicated that parametric tests could not be used for further analysis of the data because the assumption of normality was not tenable. In these circumstances, non parametric tests were used for the rest of the analysis. The table presenting the results of the K-S test can be seen in Appendix B.

6.3 Bivariate analysis

Bivariate analysis was undertaken to examine and explain any relationships in the data. Correlation analysis and reliability analysis was undertaken and the results are presented in the following sections.

6.3.1 Correlation analysis

The correlation analysis between pairs of variables was obtained by using Spearman's correlation coefficient r_s. Spearman's r_s correlation coefficient is a non-parametric statistic and is used when the data has violated parametric assumptions, such as non-normally distribution of the data, like that found in this research set. A two tailed test was used, because the nature of the relationships was not predicted. The SPSS output provided a matrix for the correlation coefficients for all the factors. Underneath each correlation coefficient both the significance value of the correlation and the sample size (N) on which the correlation is based were displayed. Correlation coefficient values can lie between -1 and +1. A coefficient of +1 indicates that the two variables are perfectly positively correlated, meaning that when one variable increases, the other increases by a proportionate amount. Conversely, a coefficient of -1 indicates a perfect negative relationship: if one variable increases the other decreases by a proportionate amount. A coefficient of 0 indicates no linear relationship and so if one variable changes the other variables remains the same. Correlations, however, do not necessarily indicate causality; because between two variables there may be a third unseen variable that affects the results. Furthermore, correlations do not indicate the direction of causality. Even if the third variable was ignored the correlation coefficient would not indicate the direction in which causality operates (Field, 2005).

Correlation analysis was undertaken in two parts. In the first part of the correlation analysis the relationships examined were between the measurements depicting the extent to which, professionals in the construction industry valued each factor for its contribution to innovation (Part A of the questionnaire- cognitive questions) and the measurements depicting the proportions of revenues. For the first part of the correlation analysis it was expected that the more, professionals valued the factors identified as contributing to innovation, the higher the proportion of revenues associated with innovation.

Table 6.3 presents the results for the first part of the correlation analysis. Significant correlations were found for 39 out of the 41 variables ($p<0.01$) indicating that the proportion of revenues associated with innovation was positively related with the extent to which, professionals in the construction industry valued each factor for its contribution to innovation. The two factors that were found not to have a significant correlation coefficient with the proportion of revenues were: a) health and safety laws and b) employment laws and policies.

Table 6.3 Correlation coefficients for proportion of revenues and extend to which variables contribute to propagation of innovation

	Spearman's rho Proportion of Revenues			Spearman's rho Proportion of Revenues	
	Corr. Coef.	Sig. (2-tailed)		Corr. Coef.	Sig. (2-tailed)
technology	,354(**)	0,005	level of government spending in R&D	,264(*)	0,031
leadership	,381(**)	0,003	energy provision	,500(**)	0,000
ownership	,328(**)	0,009	transport provision	,383(**)	0,003
collaboration	,405(**)	0,002	promotion of products/services	,444(**)	0,001
hierarchy	,338(**)	0,008	intellectual property rights	,520(**)	0,000
span of control	,430(**)	0,001	sales management	,377(**)	0,003
organisational relationships	,445(**)	0,001	market information availability	,438(**)	0,001
size of organisation	,364(**)	0,004	process integration	,501(**)	0,000
strategy	,599(**)	0,000	quality control	,342(**)	0,007
policies	,559(**)	0,000	R&D expenditure	,518(**)	0,000
organisational learning systems	,572(**)	0,000	knowledge management processes	,468(**)	0,000
political freedom	,618(**)	0,000	capital structure	,410(**)	0,001
incentives to foreign investors	,428(**)	0,001	financial management	,549(**)	0,000
competition law and policy	,297(*)	0,017	financiers attitude	,422(**)	0,001
employment law and policy	0,182	0,101	number of R&D staff	,437(**)	0,001
health and safety regulations	0,222	0,058	competence skills of R&D staff	,503(**)	0,000
level of economic activity	,373(**)	0,004	performance of R&D staff	,538(**)	0,000

GDP	,351(**)	0,006	age profile of R&D staff	,523(**)	0,000
rate of inflation	,355(**)	0,005	retention of R&D staff	,469(**)	0,000
strength of currency	,388(**)	0,002	staff development	,568(**)	0,000
rates of taxation	,403(**)	0,002	proportion of revenue	1,000	.

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Listwise N = 51

In the second part of the correlation analysis the relationships examined were between the measurements depicting the condition of the factors- the current practices employed (Part B of the questionnaire – behavioural questions) and the measurements depicting the proportions of revenues. For the second part of the correlation analysis it was expected that the higher the score on the scales measuring the condition of the factors (the scales were ranked on order from a poor condition favouring innovation to a rich condition favouring innovation), the higher the proportion of revenues associated with innovation.

Table 6.4 presents the results for the second part of the correlation analysis. Significant correlations were found for 18 out of 41 variables ($p<0.01$) indicating that the proportion of revenues associated with innovation was positively related with the condition of the factors or else described as the current practices employed. The factors that were not found to have a significant correlation with the proportion of revenues were: technology type, leadership style, ownership type, organisational relationships, strategy, policy, organisation learning systems, political freedom, incentives to foreign investors, competition law and policy, employment law and policy, health and safety regulations, economic activity, trend in GDP, rate of inflation, strength of currency, rates of taxation, transport provision, intellectual property rights, quality control, knowledge management, capital structure, financial management, and financiers' attitude.

Table 6.4 Correlation coefficients for proportion of revenues and condition of current practices

	Spearman's rho Proportion of Revenues Corr. Coef.	Sig. (1-tailed)		Spearman's rho Proportion of Revenues Corr. Coef.	Sig. (1-tailed)
proportion of revenue	1,000	.	describe rates of taxation	0,223	0,058
technology description	0,226	0,055	government spending in R&D	,269(*)	0,028
leadership style	0,091	0,263	describe energy provision	,307(*)	0,014
ownership type	-0,106	0,230	describe transport provision	0,160	0,132
collaboration type	,487(**)	0,000	describe the promotion of products/services	,381(**)	0,003
number of hierarchy layers	,352(**)	0,006	describe intellectual property rights	0,190	0,090
number of people reporting to a manager	,306(*)	0,014	describe sales management	,415(**)	0,001
organisational relationships	0,166	0,122	describe market information availability	,358(**)	0,005
organisation size	,240(*)	0,045	level of process integration	,361(**)	0,005
strategy type	-0,079	0,292	describe quality control	0,094	0,255
policies type	0,078	0,293	describe R&D expenditure	,512(**)	0,000
organisational learning systems	0,177	0,107	describe knowledge management processes	-0,156	0,137
political freedom	-0,140	0,163	describe capital structure	0,134	0,174
incentives to foreign	0,127	0,187	describe financial	0,171	0,115

investors			management		
describe competition law and policy	-0,055	0,352	describe financiers attitude	0,023	0,435
describe employment law and policy	0,044	0,379	describe percentage of R&D staff	,503(**)	0,000
describe health and safety regulations	-0,105	0,232	describe competence skills of R&D staff	,520(**)	0,000
describe economic activity	0,058	0,343	describe performance of R&D staff	,479(**)	0,000
trend in GDP	0,052	0,360	describe age profile of R&D staff	,503(**)	0,000
describe rate of inflation	-2.223	0,115	describe retention of R&D staff	,417(**)	0,001
strength of currency	,275(*)	0,025	hours of typical staff development	,526(**)	0,000

**. Correlation is significant at the 0.01 level.

*. Correlation is significant at the 0.05 level .

a. Listwise N = 51

Further correlation analysis between the items: proportion of revenues (proprev) and proportion of expenditures (propexp) associated with innovation showed a direct positive proportional relation (r=0.713, N=51, p<0.001). This means that the higher the expenditures for employing practices that favour innovation, the higher the revenues associated with innovation for the organisation. Further data analysis was preceded with the item 'proportion of revenues' that demonstrated higher percentages of associations within the correlation analysis and not the item 'proportion of expenditures associated with innovation' which showed lower percentages of association.

6.3.2 Reliability analysis

In order to check for the consistency of the measures, reliability analysis was performed. Reliability analysis examines how well the items, measured the constructs of the questionnaire. The reliability of the scales was initially calculated using Cronbach's alpha coefficient. The results (see Table 6.5) showed that the Cronbach's alpha measured for the items in Part A of the questionnaire exceed the 0.7 threshold point suggested by Nunnaly (1978).

Table 6.5 Descriptive Statistics & Reliability Analysis (Part A of the questionnaire)

	Factor	Item	Min	Max	Mean	Std.dev.	Cronbach's Alpha
Internal Environment							
	Culture		0	3.5	1.88	0.99	0.879
		Technology					
		Leadership					
		Ownersip					
		Collaborations					
	Organisational Structure		0	3,25	1,57	0,96	0.859
		Hierarchy					
		Span of control					
		Organisational relationships					
		Organisational size					
	Strategy-Policy		0	3,67	1,74	1,09	0.914
		Strategy					
		Policy					
		Organisational learning systems					
External Environment							
	Political-legal Environment		*0*	2,60	1,10	0,70	0.693
		Political freedom					
		Incentives to foreign investors					

		Competition law Employment law Health and safety regulations					
	Economy		0	3,67	1,43	0,92	0.9
		Economic activity GDP trend Inflation rate Currency strength Rates of taxation Government spending in R&D					
	Infrastructure		0	3,50	1,34	0,98	0.84
		Energy provision Transport provision					
Strategic Resources							
	Marketing		0	3,00	1,47	0,89	0.839
		Promotion of products and services Intellectual property rights Sales management Information availability					
	Systems-Processes-Knowledge Management		0	3,33	1,67	0,89	0.701

	Process integration					
	Quality control					
	Knowledge management					
Economic Resources		0	3,75	1,50	0,96	0.816
	R&D expenditure					
	Capital structure					
	Financial management					
	Financiers attitude					
Human Resources		0	3,17	0,95	0,97	0.928
	Number of R&D staff					
	Skills of R&D staff					
	Performance of R&D staff					
	Age profile of R&D staff					
	Retention of R&D staff					
	Staff development					

The reliability analysis also showed that the constructs measured were consistent and therefore the instrument used was reliable.

The results of the univariate and the bivariate analysis helped to describe the Mechanism of Innovation in the Construction Industry in the UK.

6.4 The mechanism of innovation in the construction industry in the UK

According to the univariate and bivariate statistical analysis demonstrated in the previous section, the items that were found to significantly correlate with the proportion of revenues were used to describe the mechanism of innovation for the construction industry. The mechanism of innovation for the construction industry in the UK is illustrated in Figure 6.7. The mechanism of innovation in the construction industry in the UK is described using the mechanism of innovation developed in Section 5.6, but now the items that were found to be non significant to the proportion of revenues for the construction industry in the UK are included within a parenthesis. These items can be seen in Table 6.6.

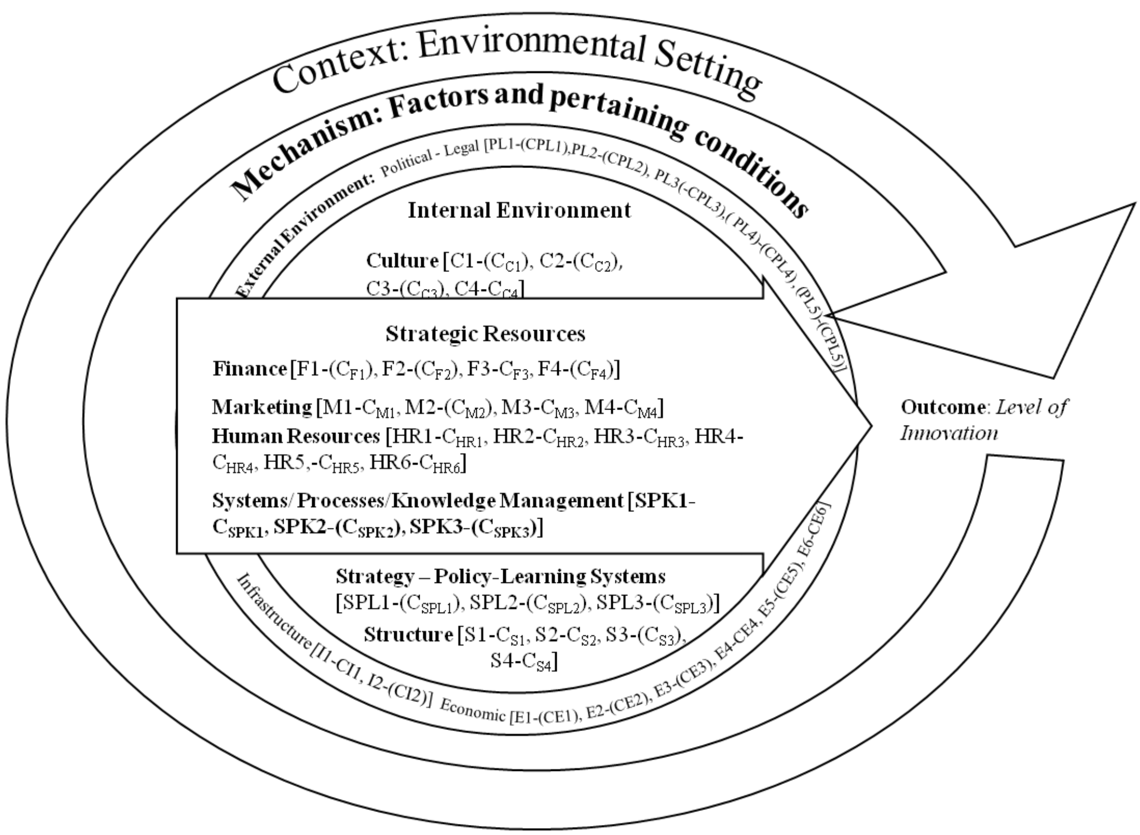

Figure 6.7 The mechanism of innovation in the construction industry in the UK

The items that were found to have non significant correlations with the proportion of revenues for the construction industry in the UK can be seen in Table 6.6.

Table 6.6 The Categories and factors within each category

Factors and condition of factors within each Category	
Culture	I2-(C_{I2}): Energy provision
C1-(C_{C1}): Technology	***Marketing***
C2 –(C_{C2}): Leadership style	M1-C_{M1}: Promotion of products/services
C3-(C_{C3}): Ownership type	M2-(C_{M2}): Intellectual property rights
C4 -C_{C4}: Collaborations	M3-C_{M3}: Sales management
Economic Environment	M4-C_{M4}: Market information availability
E1-(C_{E1}): Economic activity	***Political-Legal***
E2-(C_{E2}): GDP trend	PL1-(C_{PL1}): Political freedom
E3-(C_{E3}): Rate of inflation	PL2-(C_{PL2}): Incentives to foreign investors
E4-C_{E4}: Currency strength	PL3-(C_{PL3}): Competition framework
E5-(C_{E5}): Tax policy	(PL4)-(C_{PL4}): Employment framework
E6-C_{E6}: Government spending in R&D	(PL5)-(C_{PL5}): Health and safety regulations
Finance	***Structure***
F1-(C_{F1}): Capital structure	S1-C_{S1}: Hierarchy
F2-(C_{F2}): Financial management	S2-C_{S2}: Number of people reporting to a manager
F3-C_{F3}: R&D spending	S3-(C_{S3}): Organisational relationships
F4-(C_{F4}): Financiers attitude	S4-C_{S4}: Organisational size
Human Resources	***Strategy Policy***
HR1-C_{HR1}: Number of R&D staff	SP1-(C_{SP1}): Strategy
HR2-C_{HR2}: Competence skills of R&D staff	SP2-(C_{SP2}): Policy
HR3-C_{HR3}: Age profile of R&D staff	SP3-(C_{SP3}): Organisational learning systems
HR4-C_{HR4}: Performance of R&D staff	***Systems-Process-Knowledge Management***
HR5-C_{HR5}: Retention of R&D staff	SPK1-C_{SPK1}: Process integration
HR6-C_{HR6}: Staff development	SPK2-(C_{SPK2}):Quality control
Infrastructures	SPK3-(C_{SPK3}):Knowledge management
I1-C_{I1}: Transport provision	

Although the statistical analysis suggested that some factors were not as important as other factors, it is argued that those non-important factors should not be eliminated from further analysis and data manipulation. This position is in line with the context of the conceptual model developed in Chapter 3, which particularly explains that a mechanism of innovation applies within a specific context. As such the mechanism of innovation is adapted for the specific context of the construction industry in the UK. The holistic model of innovation (developed in Chapter 4) has provided the general context to understand the mechanism of innovation (developed in Chapter 5). Using this mechanism of innovation to design a survey to be applied in the construction industry in the UK has facilitated in describing the innovation mechanism in the construction industry in the UK. The following table, Table 6.7, presents the median, min, max and standard deviation for the variables forming the mechanism of innovation in the construction industry in the UK. Further descriptive statistics are provided in Appendix B.

Table 6.7 Descriptive Statistics for the variables forming the mechanism of innovation

Variable	**N**	**Median**	**Min**	**Max**	**Std. Deviation**
technology contribution	51	2	Not at all	Great	1.06
leadership contribution	51	2	Not at all	Great	1.14
ownership contribution	51	2	Not at all	Great	1.26
collaboration contribution	51	2	Not at all	Great	1.18
collaboration type	51	1	None	International	1.02
hierarchy contribution	51	1	Not at all	Great	1.10
number of hirerarchy layers	51	3	8-10 layers	2-4 layers	0.46
span of control	51	2	Not at all	Very Much	1.05
number of people reporting to a manager	51	4	more than 24 people	1-6 people	1.05

organisational relationships contribution	51	2	Not at all	Great	1.29
size of organisation contribution	51	1	Not at all	Great	1.14
organisation size	51	0	Employess<250	250<employee s	0.73
strategy contribution	51	2	Not at all	Great	1.18
policies contribution	51	2	Not at all	Great	1.27
organisational learning systems contribution	51	1	Not at all	Great	1.08
political freedom contribution	51	1	Not at all	Great	1.24
incentives to foreign investors contribution	51	0	Not at all	Very Much	0.63
competition law and policy contribution	51	0	Not at all	Moderate	0.79
level of economic activity contribution	51	2	Not at all	Great	1.17
GDP conntribution	51	1	Not at all	Great	1.00
rate of inflation contribution	51	1	Not at all	Great	1.08
strength of currency contribution	51	1	Not at all	Great	1.05
strenth of currency	51	1	Very Low	High	0.95
rates of taxation contribution	51	2	Not at all	Great	1.29
level of government spending in R&D contribution	51	1	Not at all	Great	1.10
government spending in R&D	51	1	Very Low	High	0.83
energy provision contribution	51	1	Not at all	Very Much	0.97

transport provision contribution	51	1	Not at all	Great	1.13
describe transport provision	51	1	Very Low	High	1.02
promotion of products/services contribution	51	2	Not at all	Great	1.09
describe the promotion of products/services	51	2	Not Applicable	Professional	1.16
intellectual property rights contribution	51	1	Not at all	Very Much	1.13
sales management contribution	51	1	Not at all	Very Much	1.07
describe sales management	51	2	Not Applicable	Professional	1.21
market information availability contribution	51	2	Not at all	Great	1.04
describe market information availability	51	1	Never Available	Always Available	0.58
process integration contribution	51	1	Not at all	Very Much	0.99
level of process integration	51	2	Initiation	Routinization	1.17
quality control contribution	51	2	Not at all	Great	1.10
R&D expenditure contribution	51	1	Not at all	Very Much	1.10
describe R&D expinditure	51	0	Non R&D Performers	£10m to £100m	0.81
knowledge management processes contribution	51	2	Not at all	Great	1.26
capital structure contribution	51	1	Not at all	Great	1.21
financial management contribution	51	2	Not at all	Great	1.20

financiers attitude contribution	51	1	Not at all	Great	1.28
number of R&D staff contribution	51	0.969544	Not at all	Great	1.15
describe percentage of R&D staff	51	0	Not applicable	20%-40%	0.67
competence skills of R&D staff contribution	51	0	Not at all	Very Much	1.20
describe competence skills of R&D staff	51	0	Not Applicable	Phd degree holders	1.05
performance of R&D staff contribution	51	0	Not at all	Very Much	1.15
describe performance of R&D staff	51	0	Not Applicable	Very High	1.57
age profile of R&D staff contribution	51	0	Not at all	Very Much	1.01
describe age profile of R&D staff	51	0	Not Applicable	23-33 years old	1.61
retention of R&D staff contribution	51	0	Not at all	Very Much	1.04
describe retention of R&D staff	51	0	Not Applicable	Tend to stay for more than 2 years	1.59
staff development contribution	51	2	Not at all	Great	1.22
hours of typical staff development	51	1	Not Applicable	80-100 hours	1.27

6.5 Summary

This chapter has presented the techniques employed for the pre-analysis data preparation and data examination and demonstrated the method used to address the missing data issues. The data exploration performed, provided frequency statistics and results for the normality of the data. The bivariate analysis that was undertaken demonstrated correlations and established two key relationships. The extent to which, professionals in the construction industry valued each factor for its contribution to innovation (Part A of the questionnaire- cognitive questions), and the condition of the factors (Part B of the questionnaire- behavioural questions) were both found to be positively correlated with the proportion of revenues associated with innovation. Reliability analysis demonstrated the consistency of the constructs measured. The mechanism of innovation for the construction industry in the UK was illustrated according to the results of the statistical analysis. The factors for which correlation with the proportion of revenues was not established were excluded from the description of the mechanism of innovation for the construction industry in the UK.

The next chapter is presenting the results of the modelling techniques employed incorporating the key outputs of the data analysis presented in this chapter.

CHAPTER 7: MODELLING THE MECHANISM OF INNOVATION

As seen in Chapter 3, mathematical modelling was employed in order to manipulate the findings of the exploration of innovation practices within the construction industry and address the fourth objective of this research which was to explicitly describe the mechanism of innovation and demonstrate the 'what if scenarios' for increasing innovation potential. This chapter illustrates the three steps that were followed during the process of mathematical modelling, and presents the outputs of this process.

The three steps included:

- formulation of the mathematical model in order to explicitly describe the mechanism of innovation;
- manipulation of the formulas developed in order to illustrate the application of the mathematical model; and
- evaluation of the mathematical model in order to test its usability.

7.1. Formulation of the mathematical model

Formulation of a mathematical model involves three stages: i) stating the question; ii) identifying relevant factors; and iii) mathematical description (Meyer, 2004).

7.1.1 Stating the question

Stating the question is the process of defining the original problem, taken from the real world. Although it is well established that innovation is connected to an organisation's proliferation and growth, research in this area revealed that the problem of defining how and why innovation occurs in some organisations and not in others remains fragmented. The conceptual model that was developed (see Chapter 3), explains all the factors that impact innovation in organisations, and provides the basic platform that was used to state the question and formulate the mathematical model. The statement of the question for formulating the mathematical model was led by the business organisations' real concern to innovate and convert inputs into outputs. Using the conceptual model that was developed, which explains that innovation is the outcome of a mechanism that is comprised of factors and the conditions pertaining to each of these factors, the question arised was: *'what formula can describe the mechanism of innovation that an organisation can use to positively impact the proportion of revenues associated with innovation'?* This question led to the second stage of the modelling process, which was to identify the relevant factors that could be used within the mathematical model.

7.1.2 Relevant factors

The second stage of formulation was to identify the relevant factors of the mathematical model. This identification of the relevant factors included two stages: the development of an axiom system that describes the logic of the mathematical model; and the development of the measuring system of the relevant quantities.

7.1.2.1 The axiom system of the mathematical model

Abstract mathematics uses logical models, such as definitions, axioms and rules of inference to deduce theorems (Maki and Thompson, 2006). The system of definitions, axioms and theorems forms a mathematical theory. The logical model of an axiom system is useful in determining the characteristics of the system (Maki and Thompson, 2006).

To assist the identification of the relevant quantities an axiom system of the mathematical model was developed. According to the etymology of the Greek word *αξίωμα* (axioma), an axiom is a claim for which the truth can be logically derived and therefore does not need proof (Maki and Thompson, 2006). The purpose of defining the axiom system was to provide the starting point for mathematical theory. "*A mathematical model is an axiom system consisting of undefined terms and axioms that are obtained by abstracting and making precise the essential ideas of a real model*" (Maki and Thompson, 2006, p19). The axioms represent the logical flow of the understanding that underlies the relevant factors inserted into the mathematical model.

To illustrate the approach of defining the logical assumptions of the mathematical model, a list of common notions was described. Let S_a be the axiom system whose terms are: a) *efficiency of innovation*; b) *effectiveness of innovation*; c) *mechanism;* d) the *potential to innovate*; and d) *growth* whose axioms are described in Table 7.1.

Table 7.1 The axiom system S_a of the mathematical model

Axiom systems terms	**Axioms**
1. Efficiency for innovation	• Every organisation has a level of efficiency as it deploys available resources for achieving innovation. This efficiency derives from the importance given by managers, owners, directors in making best use of what is available to the organisation, which in turn can result in increasing the organisation's revenues.
2. Effectiveness for innovation	• Every organisation has a certain level of effectiveness as it deploys certain practices for achieving innovation. This effectiveness for innovation derives from how favourable the organisation's practices are towards innovation which in turn can result in increasing the organisation's revenues.
3. Mechanism	• The factors playing a key role to innovation and the condition of the factors as expressed by the practices employed, constitute a unique mechanism of innovation for each organisation.
4. The potential to innovate	• The potential to innovate can be explained by the mechanism of innovation. • Different mechanisms are comprised of different factors and different pertaining conditions. As such, the potential to innovate for each organisation can be unique and depends upon its efficiency and effectiveness towards innovation.
5. Growth	• Increase in efficiency and effectiveness can overall increase performance and explain organisational growth.

The relevant quantities needed to build relationships that were important to answering the question raised in Section 7.1.1, were the terms of the axiom system S_a. The relevant quantities are described below.

The contribution of each factor towards organisational efficiency is the quantity representing the first axiom term. Efficiency is seen as making the best use of the resources available. The extent to which managers value the factors impacting innovation can have an effect on the organisations efficiency towards innovation. Factors valued less tend to be given less consideration that can lead to not making the best possible use of the resources available. During the process of innovation, efficiency facilitates the refinement of, and incremental improvements to proven practices, through the increased utilisation of an organisation's resources. Efficiency has been connected to innovation in a way that firms can create competitive advantages. It is observed that it is usually rare to have both efficiency and innovation in an organisation (Sarkees and Hulland, 2009). However, a recent study of efficiency and innovation has showed that there are ambidextrous strategies for balancing efficiency and innovation, so as to create competitive advantage. A firm which employs an ambidextrous strategy simultaneously engages in a high degree of both efficiency and innovation, relative to its competitors. According to Sarkees and Huland (Sarkees and Hulland, 2009) 'ambidextrous firms utilize their resources in such a way that they efficiently deliver products and services to their current customer base while also innovating to serve the future needs of their existing and potential customers'. The study showed that when ambidextrous firms compete with non-ambidextrous firms, they gain performance advantages and their strategy has a positive effect on revenues, profits, customer satisfaction and new product introductions.

The contribution of each factor towards effectiveness is the quantity representing the second axiom term. Effectiveness is seen as experimenting, changing and employing practices which favour innovation, and allowing for new methods, and new products or services to be created. This is supported by different researchers, who have looked at how for example new technology can contribute to progress towards innovation

(Sexton and Barrett, 2004), or how the leadership style applied can have an effect on the creativity of employees (Oshagbemi and Ocholi, 2006). See Chapter 5 for more examples on how different condition of the different factors can increase effectiveness towards innovation.

The combination of effectiveness and efficiency can otherwise be explained by the mechanism of innovation within the context explained in the paragraphs above and represent the quantity for the third axiom term. The mechanism is seen as the importance attributed on the variety of factors and the orchestration of practices employed explaining efficiency and effectiveness respectively.

A maximum of efficiency and effectiveness can be seen as an ideal mechanism for innovation. The distance between a poor innovation mechanism and an ideal innovation mechanism can be seen as the innovation potential representing the quantity for the fourth axiom term.

Increase in the potential for innovation increases growth. The proportion of revenues associated with innovation is a measure of growth representing the quantity for the fifth axiom term.

Figure 7.1 illustrates the relevant quantities identified from the axiom system and presents their association.

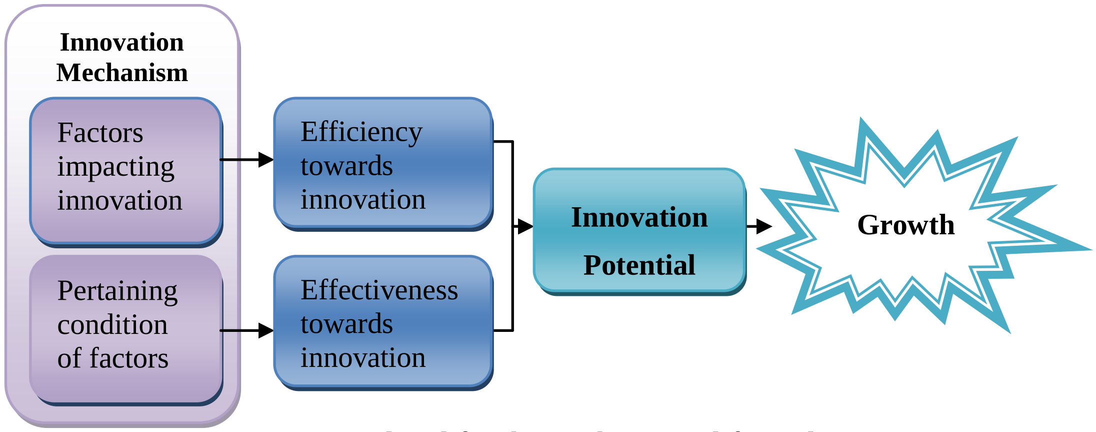

Figure 7.1 Quantities considered for the mathematical formula

7.1.2.2 The measuring system of the relevant factors

In Chapter 4, the factors that play a key role in innovation were identified. These factors were measured by capturing the extent to which managers thought of each factor to contribute to propagation of innovation. In Chapter 5, a system was developed to describe the condition of these factors. The rationale of this system sees the different conditions ranked on order, from a less favourable condition to innovation, to a more favourable condition to innovation. A more favourable condition to innovation is regarded as being one that increases the potential of an organisation to innovate. As such, the two types of measurement used to describe efficiency and effectiveness were: a) the extent to which each factor contributes to the propagation of innovation; and b) the condition of each factor.

Increasing innovation within an organisation can be a complex problem, involving 'qualitative based' or 'intangible' measures of relative efficiency and effectiveness contributions towards the goal. This can be achieved using multi-criteria decision making models. Multi-criteria decision making models integrate qualitative and quantitative criteria, so as to produce an aggregate performance measure, using a 'compromise' technique which scores each option on the basis of a trade-off of its performances relative to the other options on each of the decision criteria (Rogers, 2001).

In mathematical modelling all of the terms used in the mathematical formulas should be dimensionally consistent. That is, each term in an equation must have the same net physical conditions (Dym, 2004). In order to convert the multi-criteria problem to a single dimension problem and use the two types of measurements (as they had the same net physical conditions) the principles of the Simple Additive Weighting (SAW) method (Rogers, 2001) were used. The SAW method is the most commonly used methods for Multiple Attribute Decision Making (MADM) problems and has its basis on the Multi-Attribute Utility Theory (MAUT). A utility function is expressed as an ordered metric scale. The numbers on the metric scale have no absolute physical meaning. The scale is constructed by assigning numbers to the two extremes of an underlying measured dimension (Rogers, 2001). Usually the two extremes denote the best possible condition and the worst possible condition for the attribute question. In Utility Theory, a function U is maximised, aggregating many different attributes. Often, the different attributes are expressed in various units of measurements. Then they are converted to a common scale. A common procedure employed is to convert all factor scores to a normalised linear scale going from 0 (worst) to 10 (best) (Rogers, 2001). This conversion allows for the derivation of a single score on a standard scale, based on its raw score, reflecting its importance relative to the others (Rogers, 2001)

This research depicts the diverse origins of the various underlying dimensions that favour innovation for the different factors (i.e. economic, technical, organisational, etc.) using different scales (see Chapter 5). According to the SWM method, the scales for both types of measurements have to be converted onto a common scale before an additive model can be utilised. For the first type of measurement (a), the different factors were assessed to determine the extent to which each factor contributed to innovation (see Chapter 3). They were assessed using the 5-point Likert scale ascending from 'Not at all' to 'Great' as seen in Chapter 3. For the second type of measurement (b), the condition of the factors was assessed using rating scales (see Chapter 3) so as to depict the condition of practices that were employed, using the system for identifying the condition of factors as seen in Chapter 5.

The initial scales were transformed by assigning the best raw score a 10-rating and the worse raw score a 1-rating. All of the other raw scores were assigned scores between these two boundary points by means of linear interpolation (Rogers, 2001). A zero to ten rating scale was not used in this case, as the value of zero would indicate an absolute absence of the underlying dimensions of effectiveness and efficiency, which would consist an arbitrary conclusion.

The scores for all of the factors that represented the first type of measurement were converted into dimensionless numbers, by calculating the ratio of each factor score relative to the best overall score over all of the available options. The new normalised scale that was constructed denoted efficiency. Efficiency is defined as being '*a* *dimension of organisational performance involving the ability to make the best use of available resources in the process of achieving goals'* (Institute of Industrial Engineering, 2009). Thus, the relative scores derived from the conversion to dimensionless units represented the contribution of each factor to efficiency.

In the same way, the scores for all of the factors that represented the second type of measurement were converted into dimensionless numbers, by calculating the ratio of each factor score relative to the best overall score over all of the available options. This new normalised scale denoted effectiveness. Effectiveness is defined as being '*a dimension of organisational performance involving the ability to choose and achieve appropriate goals'* (Institute of Industrial Engineering, 2009). Thus, the relative scores derived from the conversion to dimensionless units represented the contribution of each factor to effectiveness. Table 7.2 indicates the raw scores and the dimensionless scores on each factor scale.

Table 7.2 Raw scores and converted dimensionless scores

Raw factor scores for scales with three responses	**Dimensionless relative scores by linear interpolation** ($y= yo+(x-x_0)*(y_1-y_0)/(x_1-x_0)$)
x_0: 0	y_0: 1
x: 1	y: 6
x_1: 2	y_1:10
Raw factor scores for scales with four responses	**Dimensionless relative scores by linear interpolation** ($y= yo+(x-x_0)*(y_1-y_0)/(x_1-x_0)$)
x_0: 0	y_0: 1
x: 1	y: 4
x: 2	y: 7
x_1: 3	y_1:10
Raw factor scores for scales with five responses	**Dimensionless relative scores by linear interpolation** ($y= yo+(x-x_0)*(y_1-y_0)/(x_1-x_0)$)
x_0: 0	y_0: 1
x: 1	y: 3

x: 2	y: 6
x: 3	y: 8
x_1: 4	y_1:10
Raw factor scores for scales with six responses	**Dimensionless relative scores by linear interpolation** ($y= yo+(x-x_0)*(y_1-y_0)/(x_1-x_0)$)
x_0: 0	y_0: 1
x: 1	y: 3
x: 2	y: 5
x: 3	y: 6
x: 4	y: 8
x_1: 5	y_1:10

After developing the measuring system of the relevant factors the next stage was to determine the mathematical description.

7.1.3 Mathematical description

The third stage of the formulation involved the mathematical description. A general mathematical description for initialising the process of developing the mathematical formula derived from an assumption that was articulated on the relations of the quantities identified within the Axiom System in Section 7.1.2.1. The assumption was articulated as follows: the higher the efficiency and effectiveness (as the extent to which factors contribute to innovation and the more favourable to innovation are the current practices employed), the higher the potential of innovation towards innovation, and the higher the growth (proportion of revenues). It can be said that this assumption has already been proven by the results and the key outputs of the data analysis as presented in Chapter 6. As seen in Chapter 6 the two key outputs of the data analysis were that the extent to which, professionals in the construction industry valued each factor for its contribution to innovation (Part A of the questionnaire- cognitive questions), and the condition of the factors (Part B of the questionnaire – behavioural questions) were both found to be positively correlated with the proportion of revenues associated with innovation and as such to the growth of the organisation. As such let 'r' denote the proportion of revenues associated to innovation as a measure of growth, 'C_k' denote the condition of the factor x representing the current practice employed to facilitate innovation and 'k' denote the extent to which the factor x is contributing to innovation, 'R' is a function of the combination of efficiency and effectiveness, and 'P' is the potential to innovate. The above assumption was algebraically written as follows:

Assumption 1: $\sum R(k, C_k) \propto P \propto (r)$,

The aggregation of the relative scores for all items representing efficiency and for all items representing effectiveness for all factors k identified could be written:

Innovation Efficiency = $\Sigma_{\text{relative score}}$ ($k_{\textit{technology}} + k_{\textit{leadership style}} + k_{\textit{ownership}} + k_{\textit{collaborations}} + k_{\textit{hierarchy}} + k_{\textit{span of control}} + k_{\textit{organisational relationships}} + k_{\textit{organisational size}} + k_{\textit{organisational strategy}} + k_{\textit{policy}} + k_{\textit{organisational learning systems}} + k_{\textit{political freedom}} + k_{\textit{incentives to foreign investors}} + k_{\textit{competition law and policy}} + k_{\textit{employment law and policy}} + k_{\textit{health and safety regulations}} + k_{\textit{economic activity}} + k_{\textit{trend in Gross Domestic Product}} + k_{\textit{rate of inflation}} + k_{\textit{strength of the currency}} + k_{\textit{rates of taxation}} + k_{\textit{level of government spending in R\&D}} + k_{\textit{energy provision}} + k_{\textit{transport provision}} + k_{\textit{promotion of products/services}} + k_{\textit{intellectual property rights}} + k_{\textit{sales management}} + k_{\textit{market information availability}} + k_{\textit{process integration}} + k_{\textit{quality control}} + k_{\textit{R\&D expenditure}} + k_{\textit{knowledge management processes}} + k_{\textit{capital structure contribute}} + k_{\textit{financial management}} + k_{\textit{financiers attitude}} + k_{\textit{number of R\&D staff}} + k_{\textit{competence skills of R\&D}} + k_{\textit{performance of R\&D staff}} + k_{\textit{age profile of R\&D staff}} + k_{\textit{retention of R\&D staff}} + k_{\textit{staff development processes}}$), and

Effectiveness for innovation = $\Sigma_{\text{relative score}}$ ($C_{\textit{technology used}} + C_{\textit{leadership style used}} + C_{\textit{ownership type}} + C_{\textit{collaboration types}} + C_{\textit{hierarchy layers}} + C_{\textit{typical number of people reporting to a manager}} + C_{\textit{organisational relationships}} + C_{\textit{organisational size}} + C_{\textit{strategy}} + C_{\textit{policy type}} + C_{\textit{organisational learning systems}} + C_{\textit{political freedom}} + C_{\textit{incentives to foreign investors}} + C_{\textit{competition law and policy}} + C_{\textit{employment law and policy}} + C_{\textit{health and safety regulations}} + C_{\textit{level of economic activity}} + C_{\textit{trend in Gross Domestic Product}} + C_{\textit{rate of inflation}} + C_{\textit{strength of the currency}} + C_{\textit{rates of taxation}} + C_{\textit{government spending in R\&D}} + C_{\textit{energy provision}} + C_{\textit{transport provision}} + C_{\textit{promotion of products/services}} + C_{\textit{intellectual property rights}} + C_{\textit{sales management}} + C_{\textit{market information availability}} + C_{\textit{process integration}} + C_{\textit{quality control}} + C_{\textit{R\&D expenditure}} + C_{\textit{knowledge management processes}} + C_{\textit{capital structure}} + C_{\textit{financial management}} + C_{\textit{financiers attitude}} + C_{\textit{number of R\&D staff}} + C_{\textit{competence skills of R\&D staff}} + C_{\textit{performance of R\&D staff}} + C_{\textit{age profile of R\&D staff}} + C_{\textit{retention of R\&D staff}} + C_{\textit{staff development processes}}$)

Mathematical description involved the representation of each quantity using a suitable mathematical entity. In order to incorporate together the two types of measurements, efficiency and effectiveness, an object that could be described by two properties needed to be identified. The first property would contain information on the relative score of each factor representing its contribution to efficiency and the second property would contain information on the relative score of each factor representing its contribution to effectiveness.

A search of different mathematical theories, so as to identify an object that could be represented using two measures, revealed that Euclidean vectors could meet this prerequisite. In mathematics, physics and engineering a vector is a geometric object that has two critical measurements, a magnitude (length) and a direction. In mathematics, vectors' operations are differentiated from scalar quantities. The component method is used to add or subtract vectors, as component vectors lie along a co-ordinate axis direction and are numbers and not vectors. However, the magnitude of a vector is only scalar and can only be positive. In physics, vectors are used to describe quantities such as: displacement which is *the distance* that something moves *in a certain direction.* Forces are also described as vectors, as they contain both a magnitude and a direction (Sumi and Itoh, 2009). In engineering, vectors are used in: the dynamic analysis of landscapes (Wang and Pullar, 2005), the dynamic analyses and stability of systems in power systems analysis (Jia *et al.*, 2008), and in flight control (Shin *et al.*, 2009).

In the Cartesian coordinate system, a vector can be represented by identifying the coordinates of the initial and terminal point. In Cartesian Coordinates, bound vectors are usually considered. A bound vector is determined by the coordinates of the terminal point and the initial point, which is always the origin O = (0, 0). Each factor has two measured items: an item representing efficiency and an item representing effectiveness.

Building on the existing theory of vectors, the x-axis was assigned a scale from 1-10, representing the relative scores of the items contributing to effectiveness. In the same way the y-axis was assigned a scale from 1-10, which represented the relative scores of the items that contribute to efficiency. The different scores on the x and y axis for each factor were represented by one vector. These vectors for all the factors, which could have different magnitudes and directions, measured the potential of an organisation to innovate.

The components of any two dimensional vectors are illustrated in Figure 7.2. For the vector $\vec{A}$ the components A_x and A_y can be written as multiples of the unit vectors $\hat{x}$ and $\hat{y}$ which has a value of one on the x-axis and a value of three on the y-axis.

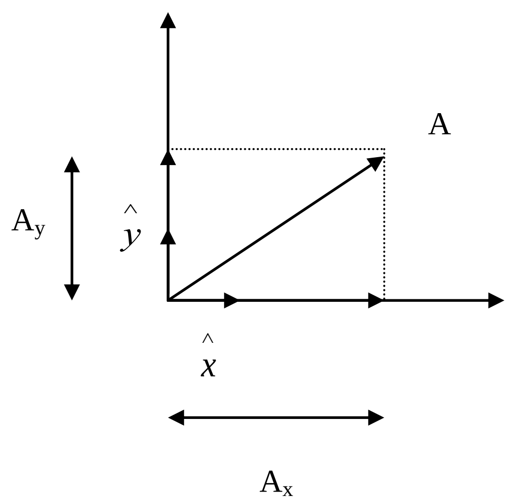

Figure 7.2 Components of unit vectors

The Cartesian product of two sets, X (the points on the x-axis) and Y (the points on the y-axis), $X \times Y$ is the set of all possible ordered pairs whose first component is a member of X and whose second component is a member of Y so that the whole of the x-y plane is: $X \times Y = \{(x, y) | x \in X, y \in Y\}$. The corresponding product then has $100 = 10 \times 10$ elements.

In the Cartesian space, a vector can be represented by identifying the coordinates of the terminal point. For instance, the points A (1, 3) determine vector $\vec{A}$. The algebraic representation of the vector, $\vec{A}_k$ for each factor k on the coordinate system can be written as follows:

$$\overrightarrow{A_{k,Actual}} = A_{kx}\hat{x} + A_{ky}\hat{y} \qquad \text{(eq.1)}$$

Where:

$\overrightarrow{A_k}$ =is the vector representing a factor k as identified in the literature

A_{kx} =is the score for factor *k* on the *x* axis,

A_{ky} =is the score for factor *k* on the *y* axis, and

$\hat{x}$ = is the unit vectors in the x- direction

$\hat{y}$ = is the unit vectors in the y- direction

All the 41 vectors for the 41 factors may have different magnitudes and directions. The sum of the x and y components of the vectors of all the factors is represented by the resultant vector $\overrightarrow{A_{R,Actual}}$. The vector $\overrightarrow{A_{R,Actual}}$ represents the actual innovation potential of the organisation in the Cartesian space. $\overrightarrow{A_{R,Actual}}$ can be written as follows:

$$\overrightarrow{A_{R,Actual}} = A_x\hat{x} + A_y\hat{y} \qquad \text{(eq.2)}$$

Where:

A_x is calculated from aggregation of all *x* components of all the vectors:

$$A_x = \sum_{k=1}^{k=n} A_{kx} = A_{1x} + A_{2x} + \ldots + A_{nx} \qquad \text{(eq.3)}$$

A_y is calculated from aggregation of all *y* components of all the vectors:

$$A_y = \sum_{k=1}^{k=n} A_{ky} = A_{1y} + A_{2y} + \ldots + A_{ny} \qquad \text{(eq.4)}$$

The magnitude of the resultant vector for the Actual Innovation Potential of the organisation is calculated using the Pythagoras Theorem as follows:

$$\text{AIP}=\left\|\overrightarrow{A_{R,Actual}}\right\| = \sqrt{A_x^2 + A_y^2} = \sqrt{\sum_{k=1}^{k=n}(A_{kx})^2 + \sum_{k=1}^{k=n}(A_{ky})^2} \qquad \text{(eq.5)}$$

In an ideal situation of maximum innovation potential, an organisation would have maximum efficiency and effectiveness. The vector representing the maximum efficiency and maximum effectiveness for each of the factors could be algebraically written as follows:

$$\overrightarrow{I_k} = I_{kx}\hat{x} + I_{ky}\hat{y} \qquad \text{(eq.6)}$$

Where:

$\overrightarrow{I_k}$ =is the vector representing maximum efficiency and maximum effectiveness for a factor k as identified in the literature;

I_{kx} = is the maximum score for factor k on the x axis;

I_{ky} = is the maximum score for factor k on the y axis;

$\hat{x}$ is the unit vectors in the x- direction; and

$\hat{y}$ is the unit vectors in the y- direction

The sum of the max x and y components for the vectors of all the factors provide the resultant vector $\overrightarrow{I_{R,Ideal}}$. The vector $\overrightarrow{I_{R,Ideal}}$ represents the ideal innovation potential of the organisation in the Cartesian space. $\overrightarrow{I_{R,Ideal}}$ could be written as follows:

$$\overrightarrow{I_{R,Ideal}} = \mathrm{I}_x\hat{x} + \mathrm{I}_y\hat{y} \qquad \text{(eq.7)}$$

Where:

I_x is calculated from aggregation of all maximum *x* components of all the vectors:

$$I_x = \sum_{k=1}^{k=n} I_{kx} = I_{1x} + I_{2x} + \ldots + I_{nx} \qquad \text{(eq.8)}$$

I_y is calculated from aggregation of all maximum *y* components of all the vectors:

$$I_y = \sum_{k=1}^{k=n} I_{ky} = I_{1y} + I_{2y} + \ldots + I_{ny} \qquad \text{(eq.9)}$$

The magnitude of the vector for the Ideal Innovation Potential (IIP) of the organisation is calculated using the Pythagoras Theorem as follows:

$$\text{IIP}=\left\|\overrightarrow{I_{R,Ideal}}\right\| = \sqrt{I_x^2 + I_y^2} = \sqrt{\sum_{k=1}^{k=n}(I_{kx})^2 + \sum_{k=1}^{k=n}(I_{ky})^2} \qquad \text{(eq.10)}$$

The distance between the resultant vector of the ideal innovation potential ($\overrightarrow{I_{R,Ideal}}$) and the resultant vector of the actual innovation potential ($\overrightarrow{A_{R,Actual}}$), in the Cartesian space, is described by the vector $\overrightarrow{P_k}$. In order to calculate this distance, the x and y components of equations (1) & (6) were subtracted for each factor *k* as follows:

$$\overrightarrow{P_k} = P_{kx}\hat{x} + P_{ky}\hat{y} = (I_{kx} - A_{kx})\hat{x} + ((I_{ky} - A_{ky})\hat{y} \qquad \text{(eq.11)}$$

Where:

$\overrightarrow{P_k}$ = is the vector representing the distance between an ideal innovation potential and the actual innovation potential for a factor *k*

P_{kx} = is the maximum score for factor *k* on the x axis;

P_{ky} = is the maximum score for factor *k* on the y axis;

$\hat{x}$ is the unit vectors in the x- direction; and

$\hat{x}$ is the unit vectors in the y- direction

The sum of all $\overrightarrow{P_k}$ x and y components provide the resultant vector $\overrightarrow{P_{R,Residual}}$. The vector $\overrightarrow{P_{R,Residual}}$ describes the distance between the actual innovation potential of the organisation and the ideal innovation potential in the Cartesian space. $\overrightarrow{P_{R,Residual}}$ could be written as follows:

$$\overrightarrow{P_{R,Residual}} = \mathrm{P}_x\hat{x} + \mathrm{P}_y\hat{y} \qquad \text{(eq.12)}$$

Where:

P_x is calculated from aggregation of the x components of all $\overrightarrow{P_k}$ vectors as follows:

$$P_x = \sum_{k=1}^{k=n}(I_{kx} - A_{kx}) = (I_{1x} - A_{1x}) + (I_{2x} - A_{2x}) + \ldots + (I_{nx} - A_{nx}) \qquad \text{(eq.13)}$$

P_y is calculated from aggregation of the y components of all $\overrightarrow{P_k}$ vectors as follows:

$$P_y = \sum_{k=1}^{k=n}(I_{ky} - A_{ky}) = (I_{1y} - A_{1y}) + (I_{2y} - A_{2y}) + \ldots + (I_{ny} - A_{ny}) \qquad \text{(eq.14)}$$

The magnitude of the vector $\overrightarrow{P_{R,Residual}}$ is calculated using the Pythagoras Theorem as follows:

$$\text{RIP} = \left\|\overrightarrow{P_{R,Residual}}\right\| = \sqrt{P_x^2 + P_y^2} = \sqrt{\sum_{k=1}^{k=n}(I_{kx} - A_{kx})^2 + \sum_{k=1}^{k=n}(I_{ky} - A_{ky})^2} \qquad \text{(eq.15)}$$

Figure 7.3 below, illustrates the vectors $\overrightarrow{A_{k,Actual}}$, $\overrightarrow{P_{k,Residual}}$, and $\overrightarrow{I_{k,Ideal}}$ and their components for two random factors 1 and 2 in the Cartesian space.

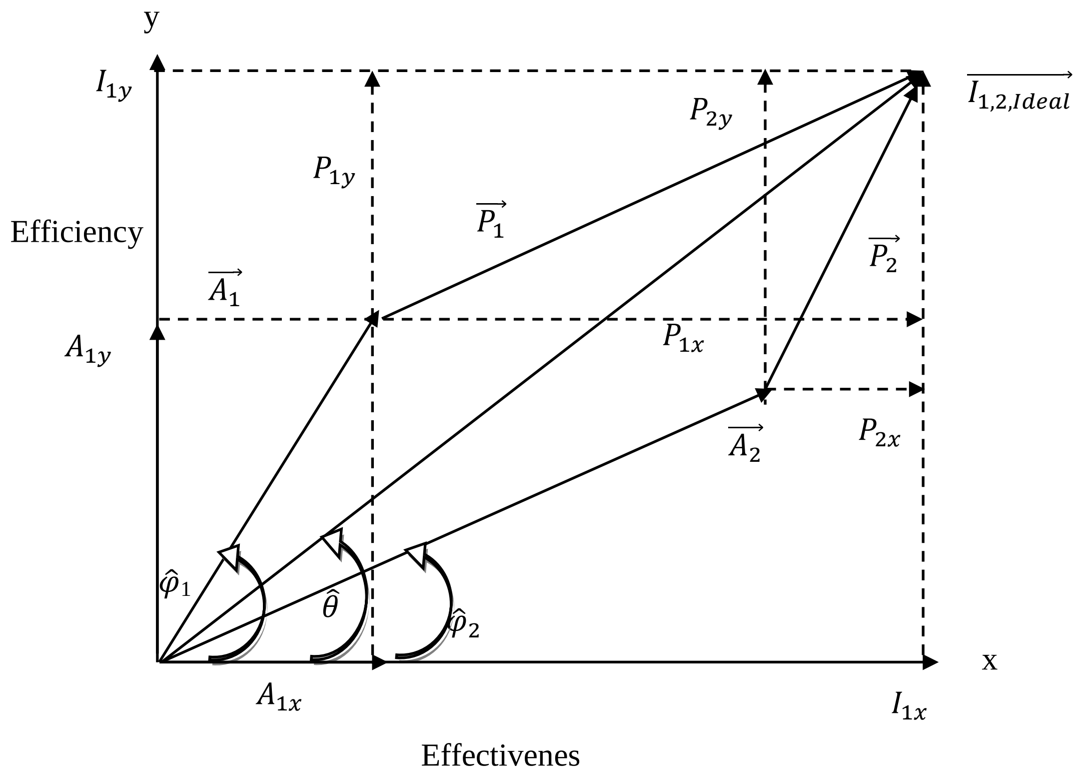

Figure 7.3 Actual Innovation Potential, Residual Innovation Potential and Ideal Innovation Potential for factors 1 and 2.

The two vectors, $\overrightarrow{A_1}$ and $\overrightarrow{A_2}$ represent the quantities of efficiency and effectiveness for an organisation for factors 1 and 2. The vector $\overrightarrow{I_{1,2,Ideal}}$ represents the ideal innovation potential of factors 1 and 2. The A_x, A_y, P_x, P_y, I_x, and I_y are the x and y components of the vectors $\overrightarrow{A_1}$ *and* $\overrightarrow{A_2}$. The vectors $\overrightarrow{A_1}$ and $\overrightarrow{A_2}$ contain information on length and direction. Different vectors could have the same length but they would differ in direction. Then, this difference in direction is meaningful because for any $\hat{\varphi} > \hat{\theta}$, the organisation can be more effective. Effectiveness is explained by the projection of the vector $\overrightarrow{A_1}$ on the x-axis (A_{1x}). The higher an organisation scores on the x-axis the higher its effectiveness is when innovating. For any $\hat{\varphi} < \hat{\theta}$, the organisation can be more efficient. Efficiency is explained by the projection of the vector $\overrightarrow{A_1}$ in the y-axis (A_{1y}). The higher an organisation scores on the y-axis the higher its efficiency towards innovation.

Where:

$$\hat{\varphi} = \tan^{-1} \frac{A_{ky}}{A_{kx}} \qquad \text{(eq.16)}$$

and

$$\hat{\theta} = \tan^{-1} \frac{I_{ky}}{I_{kx}} \qquad \text{(eq.17)}$$

For each factor k there can be possible alternative scenarios/positions on the Cartesian space that an organisation can take in order to reduce the distance from the ideal position. As seen in Chapter 6, correlation coefficients were not significant for some items. It is noted that the components on the x or the y axis, A_{kx} or A_{ky}, for those items that the correlation coefficient was not found significant should remain constant. As such, alternative scenarios can only be provided for the items that significantly correlate with the proportion of revenues. Figure 7.4 illustrates the different scenarios that can be considered for reducing the distance or the Residual Innovation Potential (RIP) between the actual innovation potential and the ideal innovation potential for the vector $\overrightarrow{A_k}$.

In Figure 7.4, the vector $\overrightarrow{A_k}$.is the Actual position of the organisation in terms of efficiency and effectiveness towards innovation. An organisation can increase its potential to innovate by increasing its efficiency and/or its effectiveness towards a more ideal position in terms of innovation. The vector $\overrightarrow{P_k}$ describes the distance which initial point is the end point of the Actual Innovation Potential for a factor *k* with coordinates (A_{kx}, A_{ky}), and its end point is the end point of the vector describing the Ideal Innovation Potential for a factor *k* represented by the vector $\overrightarrow{I_k}$ and its coordinates (I_{kx}, I_{ky}). This distance can be reduced by moving the organisation to any of the highlighted points indicated in Figure 7.4 by increasing its efficiency and/or effectiveness towards innovation. $\overrightarrow{A_k{}'}$

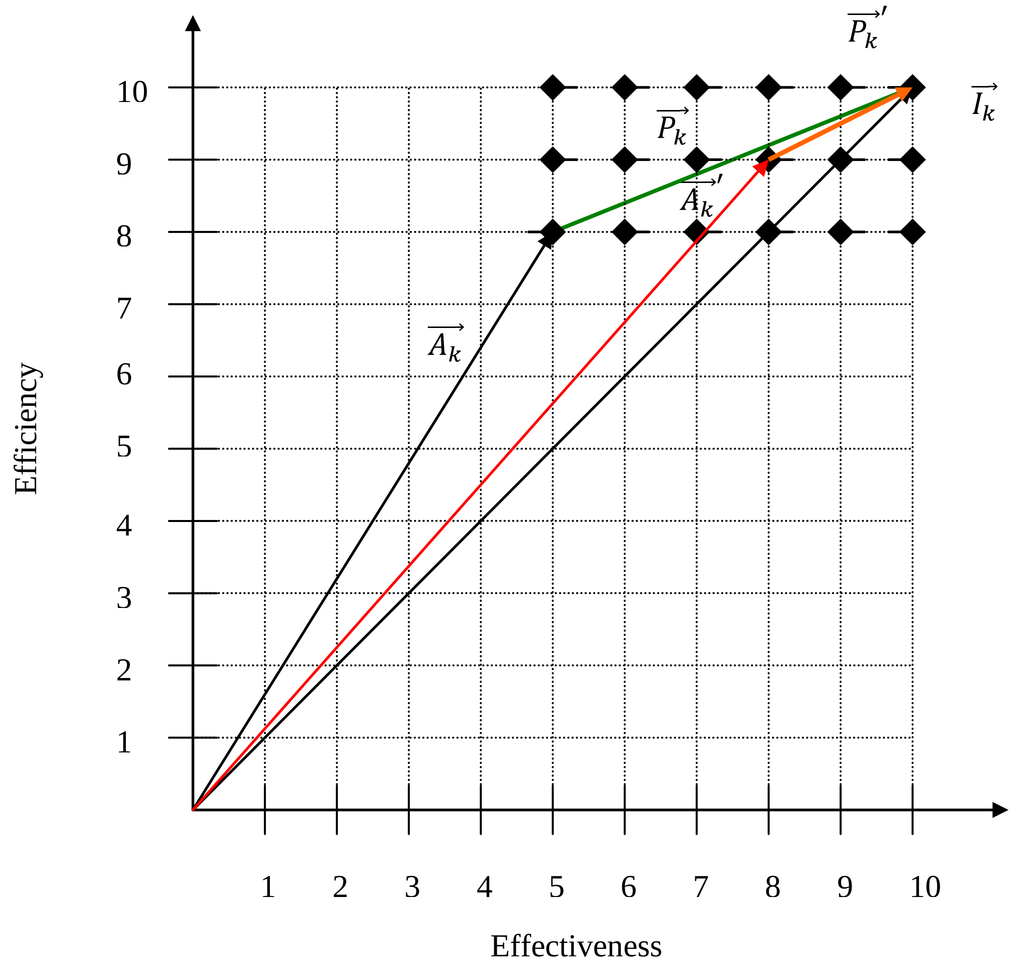

Figure 7.4 Possible alternative scenarios for reducing the distance between the ideal innovation potential and the actual innovation potential.

For each alternative points/scenarios proposed, the length of the vector $\vec{P}_k$ is reduced and therefore the actual innovation potential of the organisation increases. The vector $\vec{P}_k{}'$ describes the new distance between the new Innovation Potential vector $\overrightarrow{A_k}'$, and the Ideal Innovation Potential vector $\overrightarrow{I_k}$, for a factor *k*. The new innovation potential vector has initial point coordinates (A_{kx+v}, A_{ky+v}). Then $\overrightarrow{A_k}'$ can be written as follows:

$$\vec{A}'_k = A'_{kx+v}\hat{x} + A'_{ky+v}\hat{y} \qquad \text{(eq.18)}$$

Where,

$\vec{A}_k{}'$ = the new actual innovation potential;

$\vec{P}_k{}'$ = the new distance between $\overrightarrow{A_k}'$ and $\overrightarrow{I_k}$;

A_{kx+v} = the score for factor *k* on the *x* axis; and

A_{ky+v} = the score for factor *k* on the *y* axis.

ν =1,2,3,4….10 with x< ν <10.

In order to control for items that should be held fixed or those that could be changed depending on their correlation with the organisation's revenues a constant 'a' was introduced. For each factor *k* the vector components, $A'_{kx+\nu}\hat{x}$ and $A'_{ky+\nu}\hat{y}$, could be written as follows:

$$A'_{kx+\nu} = A_{kx} + \alpha(A'_{kx+\nu} - A_{kx}) \quad \text{(eq.19)}$$

$$A'_{ky+\nu} = A_{ky} + \alpha(A'_{ky+\nu} - A_{ky}) \quad \text{(eq.20)}$$

Where a=0,1

Introducing a in the formulas above allows the components to change or to be held fixed. When an item is found to have a non-significant correlation coefficient there is no practical reason to change its position on the axis it refers to. Therefore, if for instance both items of a factor (efficiency and effectiveness) do not significantly correlate with the proportion of revenues then $a=0$ and the score for this factor remains as its initial score-the initial innovation potential.

Then the new vector from equation (18): $\overrightarrow{A_k}' = A'_{kx+\nu}\hat{x} + A'_{ky+\nu}\hat{y}$ and substituting equations 19 and 20 could be written as follows:

$$\vec{A}'_k = (A_{kx} + \alpha(A'_{kx+\nu} - A_{kx}))\hat{x} + (A_{ky} + \alpha(A'_{ky+\nu} - A_{ky}))\hat{y} \quad \text{(eq.21)}$$

The sum of the x and y components of all the vectors provide the new resultant vector for the New Actual Innovation Potential $\overrightarrow{A'_R}$. The vector $\overrightarrow{A'_R}$ could be written as follows:

$$\overrightarrow{A_{R,Actual}}' = A'_x\hat{x} + A'_y\hat{y} \qquad \text{(eq.22)}$$

Where:

A'_x is calculated from aggregation of all x components of all the vectors:

$$A'_x = \sum_{k=1}^{k=n} A_{kx+v} = A'_{1x+v} + A'_{1x+v} + \cdots .. + A'_{nx+v} \qquad \text{(eq.23)}$$

$A_y{}'$ is calculated from aggregation of all y components for all the vectors:

$$A'_y = \sum_{k=1}^{k=n} A_{ky+v} = A'_{1y+v} + A'_{1y+v} + \cdots .. + A'_{ny+v} \qquad \text{(eq.24)}$$

The magnitude of the vector $\overrightarrow{A_R}'$ that describes the New Actual Innovation Potential is calculated using the Pythagoras Theorem as follows:

$$\text{NAIP} = \left\|\vec{A}'_{R,Actual}\right\| = \sqrt{A'_x{}^2 + A'_y{}^2} = \sqrt{\sum_{k=1}^{k=n}\left(A'_{kx+v}\right)^2 + \sum_{k=1}^{k=n}\left(A'_{ky+v}\right)^2} \qquad \text{(eq.25)}$$

The new distance from the ideal position $\vec{P}_k{}'$ could be written as follows:

$$\vec{\mathrm{P}}'_k = P'_{kx+v}\hat{x} + P'_{ky+v}\hat{y} = (I_{kx} - A'_{kx+v})\hat{x} + (I_{ky} - A'_{ky+v})\hat{y} \qquad \text{(eq.26)}$$

Substituting equations 19 and 20 into equation 26 the vector $\overrightarrow{P_k}$ can be written as follows:

$$\vec{\mathrm{P}}'_k = P'_{kx+v}\hat{x} + P'_{ky+v}\hat{y} = (I_{kx} - (A'_{kx+v} + \alpha(A'_{kx+v} - A_{kx}))\hat{x} + (I_{ky} - (A'_{ky+v} + \alpha(A'_{ky+v} - A_{ky}))\hat{y} \qquad \text{(eq.27)}$$

The magnitude of the vector $\vec{P}_k{}'$ using the Pythagoras theorem is written as follows:

$$\left\|\vec{P}'_{R,Residual}\right\| = \sqrt{{P'_x}^2 + {P'_y}^2} =$$

$$\sqrt{\sum_{k=1}^{k=n}(I_{kx} - (A'_{kx+v} + \alpha(A'_{kx+v} - A_{kx}))^2 + \sum_{k=1}^{k=n}(I_{ky} - ({A'}_{ky+v} + \alpha(A'_{ky+v} - A_{ky}))^2}$$

(eq.28)

A complete list of all the formulas developed is provided in Table 7.3

Table 7.3 List of formulas

Eq.	Description and Formulas
1	Actual Innovation Potential for factor *k* on the Cartesian Space (AIP_k) $\overrightarrow{A_k} = A_{kx}\hat{x} + A_{ky}\hat{y}$
2	Actual Innovation Potential of the organisation for all factors *k* on the Cartensian Space (AIP_R) $\overrightarrow{A_{R,Actual}} = A_x\hat{x} + A_y\hat{y}$
3	Component of actual organisational effectiveness $A_x = \sum_{k=1}^{k=n} A_{kx} = A_{1x} + A_{2x} + \ldots + A_{nx}$
4	Component of actual organisational effeciency $A_y = \sum_{k=1}^{k=n} A_{ky} = A_{1y} + A_{2y} + \ldots + A_{ny}$
5	Actual Innovation Potential of an organisation (AIP) $AIP = \left\|\overrightarrow{A_{R,Actual}}\right\| = \sqrt{A_x^2 + A_y^2} = \sqrt{\sum_{k=1}^{k=n}(A_{kx})^2 + \sum_{k=1}^{k=n}(A_{ky})^2}$
6	Ideal Innovation Potential for factor *k* on the Cartesian Space (IIP_k) $\overrightarrow{I_{k,}} = I_{kx}\hat{x} + I_{ky}\hat{y}$
7	Ideal Innovation Potential of the organisation for all factors *k* on the Cartensian Space (IIP_R) $\overrightarrow{I_{R,Ideal}} = I_x\hat{x} + I_y\hat{y}$
8	Component of ideal organisational effectiveness

	$I_x = \sum_{k=1}^{k=n} I_{kx} = I_{1x} + I_{2x} + \ldots.. + I_{nx}$
9	Component of ideal organisational effeciency $I_y = \sum_{k=1}^{k=n} I_{ky} = I_{1y} + I_{2y} + \ldots.. + I_{ny}$
10	Ideal Innovation Potential of the organisation (IIP) IIP=$\left\Vert\overrightarrow{I_{R,Ideal}}\right\Vert = \sqrt{I_x^2 + I_y^2} = \sqrt{\sum_{k=1}^{k=n}(I_{kx})^2 + \sum_{k=1}^{k=n}(I_{ky})^2}$
11	Residual Innovation Potential for a factor *k* in the Cartesian Space (RIP_k) $\overrightarrow{P_k} = P_{kx}\hat{x} + P_{ky}\hat{y} = (I_{kx} - A_{kx})\hat{x} + ((I_{ky} - A_{ky})\hat{y}$
12	Residual Innovation Potential for all factors *k* in the Cartesian Space (RIP_R) $\overrightarrow{P_{R,Residual}} = \mathrm{P}_x\hat{x} + \mathrm{P}_y\hat{y}$
13	Effectiveness Component of residual innovation potential $P_x = \sum_{k=1}^{k=n}(\mathrm{I_{kx}} - \mathrm{A_{kx}}) = (\mathrm{I_{1x}} - \mathrm{A_{1x}}) + (\mathrm{I_{2x}} - \mathrm{A_{2x}}) + \ldots. + (\mathrm{I_{nx}} - \mathrm{A_{nx}})$
14	Effeciency component of residual innovation potential $P_y = \sum_{k=1}^{k=n}(\mathrm{I_{ky}} - \mathrm{A_{ky}}) = (\mathrm{I_{1y}} - \mathrm{A_{1y}}) + (\mathrm{I_{2y}} - \mathrm{A_{2y}}) + \ldots. + (\mathrm{I_{ny}} - \mathrm{A_{ny}})$
15	Residual Innovation Potential (RIP) RIP=$\left\Vert\overrightarrow{P_{R,Residual}}\right\Vert = \sqrt{P_x^2 + P_y^2} = \sqrt{\sum_{k=1}^{k=n}(I_{kx} - A_{kx})^2 + \sum_{k=1}^{k=n}(I_{ky} - A_{ky})^2}$
16	Rate of effectiveness $\hat{\varphi} = \tan^{-1}\frac{A_{ky}}{A_{kx}}$
17	Rate of efficiency $\hat{\theta} = \tan^{-1}\frac{I_{ky}}{I_{kx}}$
18	New Actual Innovation Potential for factor *k* on the Cartesian Space ($NAIP_k$) $\vec{A}'_k = A'_{kx+v}\hat{x} + A'_{ky+v}\hat{y}$
19	Component of effectiveness for factor *k* controlling for correlations with revenues $A'_{kx+v} = A_{kx} + \alpha(A'_{kx+v} - A_{kx})$

20	Component of effectiveness for factor *k* controlling for correlations with revenues $A'_{ky+v} = A_{ky} + \alpha(A'_{ky+v} - A_{ky})$
21	New Actual Innovation Potential for a factor *k* controlling for correlations with revenues $\vec{A}'_k = (A_{kx} + \alpha(A'_{kx+v} - A_{kx}))\hat{x} + (A_{ky} + \alpha(A'_{ky+v} - A_{ky}))\hat{y}$
22	New Actual Innovation Potential of the organisation for all factors *k* on the Cartesian Space ($NAIP_R$) $\overrightarrow{A_{R,Actual}}' = A'_x\hat{x} + A'_y\hat{y}$
23	Component of new actual organisational effectiveness $A'_x = \sum_{k=1}^{k=n} A_{kx+v} = A'_{1x+v} + A'_{1x+v} + \cdots .. + A'_{nx+v}$
24	Component of new actual organisational efficiency $A'_y = \sum_{k=1}^{k=n} A_{ky+v} = A'_{1y+v} + A'_{1y+v} + \cdots + A'_{ny+v}$
25	New Actual Innovation Potential of an organisation (NAIP) $\text{NAIP} = \lVert\vec{A}'_{R,Actual}\rVert = \sqrt{{A'_x}^2 + {A'_y}^2} = \sqrt{\left(\sum_{k=1}^{k=n}(A'_{kx+v})\right)^2 + \left(\sum_{k=1}^{k=n}(A'_{ky+v})\right)^2}$
26	New Residual Innovation Potential for a factor *k* in the Cartesian Space ($NRIP_k$) $\vec{P}'_k = P'_{kx+v}\hat{x} + P'_{ky+v}\hat{y} = (I_{kx} - A'_{kx+v})\hat{x} + (I_{ky} - A'_{ky+v})\hat{y}$
27	New Residual Innovation Potential for a factor *k* in the Cartesian Space ($NIPI_k$) controlling for correlations with revenues $\vec{P}'_k = P'_{kx+v}\hat{x} + P'_{ky+v}\hat{y} = (I_{kx} - (A'_{kx+v} + \alpha(A'_{kx+v} - A_{kx}))\hat{x} +$ $+ (I_{ky} - (A'_{ky+v} + \alpha(A'_{ky+v} - A_{ky}))\hat{y}$
28	New Residual Innovation Potential (NRIP)

$$\left\|\vec{P}'_{R,Residual}\right\| = \sqrt{P'^2_x + P'^2_y} = \sqrt{\begin{array}{l}\sum_{k=1}^{k=n}(I_{kx} - (A'_{kx+v} + \alpha(A'_{kx+v} - A_{kx}))^2 + \\ \sum_{k=1}^{k=n}(I_{ky} - (A'_{ky+v} + \alpha(A'_{ky+v} - A_{ky}))^2\end{array}}$$

7.2 Mathematical manipulation

Mathematical manipulation involved operationalising and solving the equations described during the formulation. To facilitate the manipulation of the model that was developed, one of the survey responses, case 1, was used as an example. Table 7.4 shows the raw score and the dimensionless scores of the factors for Case 1.

Table 7.4 Scores of factors for Case 1

N.	Factor	Raw scores y-axis	Dimensionless scores y-axis	Factor	Raw scores x-axis	Dimensionless scores x-axis
1	techcont	3	8	techtype	4	10
2	leadcont	3	8	leadstyl	2	6
3	ownecont	3	8	ownetype	2	5
4	collcont	3	8	colltype	3	10
5	hiercont	2	6	layernum	1	4
6	spancont	2	6	peoplrep	3	8
7	relacont	3	8	relatype	2	5
8	sizecont	3	8	orgasize	2	10
9	stracont	4	10	stratype	1	4
10	policont	3	8	politype	2	7
11	learcont	2	6	learsyst	1	4
12	pofrcont	2	6	polifree	1	6
13	invecont	0	1	inveince	0	1
14	compcont	0	1	compelaw	2	10
15	emplcont	1	3	emplolaw	2	10
16	regucont	3	8	hsregula	0	1
17	econcont	3	8	econacti	3	8
18	gdpcont	1	3	gdptrend	1	6
19	inflcont	1	3	inflrate	2	6
20	currcont	1	3	currstre	2	6
21	taxacont	1	3	taxarate	2	6
22	gordcont	1	3	gordspen	1	3
23	enercont	3	8	enerprov	3	8

24	trancont	4	10	tranprov	3	8
25	promcont	3	8	promprod	3	10
26	propcont	2	6	intelrig	2	10
27	salecont	3	8	salemana	3	10
28	infocont	2	6	infoavai	1	6
29	proccont	1	3	procinte	2	5
30	qualcont	3	8	qualdesc	3	10
31	rdexcont	2	6	rdexpend	2	6
32	knowcont	3	8	knowmana	2	5
33	capicont	1	3	debtrati	1	6
34	finacont	3	8	finamana	2	10
35	fiatcont	1	3	finattit	2	7
36	rdnucont	2	6	rdstaffn	1	3
37	skilcont	1	3	rdskills	1	4
38	perfcont	1	3	rdperfor	1	3
39	profcont	1	3	ageprofi	1	3
40	retecont	1	3	retedesc	1	3
41	stafcont	2	6	stafdeve	1	3

From equation (1): $\overrightarrow{A_k} = A_{kx}\hat{x} + A_{ky}\hat{y}$ the vectors for all the factors were written as shown in Table 7.5

Table 7.5 Obtained vectors for each factor

Vectors for the scores obtained for the *k* factors			
$\vec{A}_1 = 10\hat{x} + 8\hat{y}$,	$\vec{A}_{11} = 4\hat{x} + 6\hat{y}$	$\vec{A}_{21} = 6\hat{x} + 3\hat{y}$	$\vec{A}_{31} = 6\hat{x} + 6\hat{y}$
$\vec{A}2 = 6\hat{x} + 8\hat{y}$	$\vec{A}_{12} = 6\hat{x} + 6\hat{y}$	$\vec{A}_{22} = 3\hat{x} + 3\hat{y}$	$\vec{A}_{32} = 5\hat{x} + 8\hat{y}$
$\vec{A}_3 = 5\hat{x} + 8\hat{y}$	$\vec{A}_{13} = 1\hat{x} + 1\hat{y}$	$\vec{A}_{23} = 8\hat{x} + 8\hat{y}$	$\vec{A}_{33} = 6\hat{x} + 3\hat{y}$
$\vec{A}_4 = 10\hat{x} + 8\hat{y}$	$\vec{A}_{14} = 10\hat{x} + 1\hat{y}$	$\vec{A}_{24} = 8\hat{x} + 10\hat{y}$	$\vec{A}_{34} = 10\hat{x} + 8\hat{y}$
$\vec{A}_5 = 4\hat{x} + 6\hat{y}$	$\vec{A}_{15} = 10\hat{x} + 3\hat{y}$	$\vec{A}_{25} = 10\hat{x} + 8\hat{y}$	$\vec{A}_{35} = 7\hat{x} + 3\hat{y}$
$\vec{A}_6 = 8\hat{x} + 6\hat{y}$	$\vec{A}_{16} = 1\hat{x} + 8\hat{y}$	$\vec{A}_{26} = 10\hat{x} + 6\hat{y}$	$\vec{A}_{36} = 3\hat{x} + 6\hat{y}$

$\vec{A}_7 = 5\hat{x} + 8\hat{y}$	$\vec{A}_{17} = 8\hat{x} + 8\hat{y}$	$\vec{A}_{27} = 10\hat{x} + 8\hat{y}$	$\vec{A}_{37} = 4\hat{x} + 3\hat{y}$
$\vec{A}_8 = 10\hat{x} + 8\hat{y}$	$\vec{A}_{18} = 6\hat{x} + 3\hat{y}$	$\vec{A}_{28} = 6\hat{x} + 6\hat{y}$	$\vec{A}_{38} = 3\hat{x} + 3\hat{y}$
$\vec{A}_9 = 4\hat{x} + 10\hat{y}$	$\vec{A}_{19} = 6\hat{x} + 3\hat{y}$	$\vec{A}_{29} = 5\hat{x} + 3\hat{y}$	$\vec{A}_{39} = 3\hat{x} + 3\hat{y}$
$\vec{A}_{10} = 7\hat{x} + 8\hat{y}$	$\vec{A}_{20} = 6\hat{x} + 3\hat{y}$	$\vec{A}_{30} = 10\hat{x} + 8\hat{y}$	$\vec{A}_{40} = 3\hat{x} + 3\hat{y}$
			$\vec{A}_{41} = 3\hat{x} + 6\hat{y}$

From equation (2) $\overrightarrow{A_{R,Actual}} = A_x\hat{x} + A_y\hat{y}$ the resultant vector can be written as follows:

A_x was calculated from equation (3): $A_x = \sum_{k=1}^{k=n} A_{kx} = A_{1x} + A_{2x} + ... + A_{nx}$, where all x components of all vectors are aggregated:

$$A_x = \sum_{k=1}^{k=n} A_{k\ x} = 10+6+5+10+4+8+5+10+4+7+4+6+1+10+10+1+8+6+6+6$$
$$+6+3+8+8+10+10+10+6+5+10+6+5+6+10+7+3+4+3+3+3+3=256$$

A_y was calculated from equation (4): $A_y = \sum_{k=1}^{k=n} A_{ky} = A_{1y} + A_{2y} + ... + A_{ny}$, where all y components of all vectors are aggregated:

$$A_y = \sum_{k=1}^{k=n} A_{k\ y} = 8+8+8+8+6+6+8+8+10+8+6+6+1+1+3+8+8+3+3+3+3+3+8$$
$$10+8+6+8+6+3+8+6+8+3+8+3+6+3+3+3+3+6=235$$

Then, the resultant vector from equation (2) was written as follows:

$$\overrightarrow{A_{R,actual}} = 256\hat{x} + 235\hat{y}$$

The magnitude of the vector for the actual position using the Pythagoras Theorem was calculated from equation (5):

AIP=$\|\overrightarrow{A_{R,Actual}}\| = \sqrt{A_x^2 + A_y^2} = \sqrt{\sum_{k=1}^{k=n}(A_{kx})^2 + \sum_{k=1}^{k=n}(A_{ky})^2}$ as follows:

AIP=$\|\overrightarrow{A_{R,Actual}}\| = \sqrt{256^2 + 235^2} = \sqrt{120761} = 347.5$

The angle between $\overrightarrow{A_R}$and the x-axis was calculated from equation (16): $\hat{\varphi} = \tan^{-1}\frac{A_{ky}}{A_{kx}}$ as follows:

$\hat{\varphi} = \tan^{-1}\frac{A_{ky}}{A_{kx}}$ =$tan^{-1}\frac{235}{256} = tan^{-1}(0.916), \hat{\varphi}$ =42.5

The ideal vector for each factor *k* according to equation (6):, is $\forall k \in N : I_x = 10$ and $\forall k \in N : I_y = 10$, thus equation (6) was written as follows:

$\overrightarrow{I_{k,Ideal}} = 10\hat{x} + 10\hat{y}$

For all factors *k* the resultant vector was calculated from equation (7):
$\overrightarrow{I_{k,Ideal}} = I_{kx}\hat{x} + I_{ky}\hat{y}$.

I_x was calculated from equation (8): $I_x = \sum_{k=1}^{k=n} I_{kx} = I_{1x} + I_{2x}$ +.....+$I_{nx}$where all maximum x components of all vectors were aggregated as follows:

$I_x = \sum_{k=1}^{k=n} I_{kx} = I_{1x} + I_{2x}$ +.....+$I_{nx} = 41 * 10 = 410$

I_y was calculated from equation (9): $I_y = \sum_{k=1}^{k=n} I_{ky} = I_{1y} + I_{2y}$ +.....+I_{ny}, where all maximum y components of all vectors are aggregated as follows:

$I_y = \sum_{k=1}^{k=n} I_{ky} = I_{1y} + I_{2y}$ +.....+$I_{ny} = 41 * 10 = 410$

Then, equation (7) for the resultant vector in the ideal position was written as follows:

$\vec{I}_{R,Ideal} = I_x \hat{x} + I_x \hat{y} = 410\hat{x} + 410\hat{y}$

The magnitude of the vector for the actual position using the Pythagoras Theorem was calculated from equation (10):

IIP=$\left\|\overrightarrow{I_{R,Ideal}}\right\| = \sqrt{I_x^2 + I_y^2} = \sqrt{\sum_{k=1}^{k=n}(I_{kx})^2 + \sum_{k=1}^{k=n}(I_{ky})^2}$as follows:

IIP=$\left\|\overrightarrow{I_{R,Ideal}}\right\| = \sqrt{I_x^2 + I_y^2} = \sqrt{410^2 + 410^2} = \sqrt{336200} = 579.8$

The angle between $\overrightarrow{I_{R,Ideal}}$ and the x-axis was calculated from equation (17):

$$\hat{\theta} = \tan^{-1}\frac{I_{ky}}{I_{kx}} = \tan^{-1}\left(\frac{410}{410}\right) = \tan^{-1}(1), \hat{\theta} = 45$$

In order to obtain the distance between $\overrightarrow{A_R}$., which was the actual current position of the organisation and the ideal position $\overrightarrow{I_{R,Ideal}}$ of efficiency and effectiveness towards innovation in the Cartesian space the x and y components of the equations (2) $\overrightarrow{A_k} = A_{kx}\hat{x} + A_{ky}\hat{y}$ and (7) $\overrightarrow{I_{k,Ideal}} = I_{kx}\hat{x} + I_{ky}\hat{y}$ vectors were subtracted for each factor *k* using the equation (11): $\vec{P}_k = P_{kx}\hat{x} + P_{ky}\hat{y} = (I_{kx} - A_{kx})\hat{x} + (I_{ky} - A_{ky})\hat{y}$. The distances obtained for each factor *k* are shown in the Table 7.6

Table 7.6 Distances obtained per factor

N.	Factor	Residual on the y-axis	Factor	Residual on the x-axis
1	techcont	P_{1y} =2	techtype	P_{1x} =0
2	leadcont	P_{2y} =2	leadstyl	P_{2x} =4
3	ownecont	P_{3y} =2	ownetype	P_{3x} =5
4	collcont	P_{4y} =2	colltype	P_{4x} =0
5	hiercont	P_{5y} =4	layernum	P_{5x} =6
6	spancont	P_{6y} =4	peoplrep	P_{6x} =2

7	relacont	P_{7y} =2	relatype	P_{7x} =5
8	sizecont	P_{8y} =2	orgasize	P_{8x} =0
9	stracont	P_{9y} =0	stratype	P_{9x} =6
10	policont	P_{10y} =2	politype	P_{10x} =3
11	learcont	P_{11y} =4	learsyst	P_{11x} =6
12	pofrcont	P_{12y} =4	polifree	P_{12x} =4
13	invecont	P_{13y} =9	inveince	P_{13x} =9
14	compcont	P_{14y} =9	compelaw	P_{14x} =0
15	emplcont	P_{15y} =7	emplolaw	P_{15x} =70
16	regucont	P_{16y} =2	hsregula	P_{16x} =9
17	econcont	P_{17y} =2	econacti	P_{17x} =2
18	gdpcont	P_{18y} =7	gdptrend	P_{18x} =4
19	inflcont	P_{19y} =7	inflrate	P_{19x} =4
20	currcont	P_{20y} =7	currstre	P_{20x} =4
21	taxacont	P_{21y} =7	taxarate	P_{21x} =4
22	gordcont	P_{22y} =7	gordspen	P_{22x} =7
23	enercont	P_{23y} =2	enerprov	P_{23x} =2
24	trancont	P_{24y} =0	tranprov	P_{24x} =2
25	promcont	P_{25y} =2	promprod	P_{25x} =0
26	propcont	P_{26y} =4	intelrig	P_{26x} =0
27	salecont	P_{27y} =2	salemana	P_{27x} =0
28	infocont	P_{28y} =4	infoavai	P_{28x} =4
29	proccont	P_{29y} =7	procinte	P_{29x} =5
30	qualcont	P_{30y} =2	qualdesc	P_{30x} =0
31	rdexcont	P_{31y} =4	rdexpend	P_{31x} =4
32	knowcont	P_{32y} =2	knowmana	P_{32x} =5
33	capicont	P_{33y} =7	debtrati	P_{33x} =4
34	finacont	P_{34y} =2	finamana	P_{34x} =0
35	fiatcont	P_{35y} =7	finattit	P_{35x} =3
36	rdnucont	P_{36y} =4	rdstaffn	P_{36x} =7
37	skilcont	P_{37y} =7	rdskills	P_{37x} =6
38	perfcont	P_{38y} =7	rdperfor	P_{38x} =7

39	profcont	P_{39y} =7	ageprofi	P_{39x} =7
40	retecont	P_{40y} =7	retedesc	P_{40x} =7
41	stafcont	P_{41y} =4	stafdeve	P_{41x} =7

Then from equation (11): $\overrightarrow{P_k} = P_{kx}\hat{x} + P_{ky}\hat{y} = (I_{kx} - A_{kx})\hat{x} + ((I_{ky} - A_{ky})\hat{y}$, the vectors describing the distances for each factor *k* were obtained and are shown in Table 7.7.

Table 7.7 Vectors $\vec{P}_k$ for each factor *k*

Distance vectors for the scores obtained for the *k* factors	
$\vec{P}_1 = P_{1x}\hat{x} + P_{1y}\hat{y} = 0\hat{x} + 2\hat{y}$	$\vec{P}_{22} = P_{22x}\hat{x} + P_{22y}\hat{y} = 7\hat{x} + 7\hat{y}$
$\vec{P}_2 = P_{2x}\hat{x} + P_{2y}\hat{y} = 4\hat{x} + 2\hat{y}$	$\vec{P}_{23} = P_{23x}\hat{x} + P_{23y}\hat{y} = 2\hat{x} + 2\hat{y}$
$\vec{P}_3 = P_{3x}\hat{x} + P_{3y}\hat{y} = 5\hat{x} + 2\hat{y}$	$\vec{P}_{24} = P_{24x}\hat{x} + P_{24y}\hat{y} = 2\hat{x} + 0\hat{y}$
$\vec{P}_4 = P_{4x}\hat{x} + P_{4y}\hat{y} = 0\hat{x} + 2\hat{y}$	$\vec{P}_{25} = P_{25x}\hat{x} + P_{25y}\hat{y} = 0\hat{x} + 2\hat{y}$
$\vec{P}_5 = P_{5x}\hat{x} + P_{5y}\hat{y} = 6\hat{x} + 4\hat{y}$	$\vec{P}_{26} = P_{26x}\hat{x} + P_{26y}\hat{y} = 0\hat{x} + 4\hat{y}$
$\vec{P}_6 = P_{6x}\hat{x} + P_{6y}\hat{y} = 2\hat{x} + 4\hat{y}$	$\vec{P}_{27} = P_{27x}\hat{x} + P_{27y}\hat{y} = 0\hat{x} + 2\hat{y}$
$\vec{P}_7 = P_{7x}\hat{x} + P_{7y}\hat{y} = 5\hat{x} + 2\hat{y}$	$\vec{P}_{28} = P_{28x}\hat{x} + P_{28y}\hat{y} = 4\hat{x} + 4\hat{y}$
$\vec{P}_8 = P_{8x}\hat{x} + P_{8y}\hat{y} = 0\hat{x} + 2\hat{y}$	$\vec{P}_{29} = P_{29x}\hat{x} + P_{29y}\hat{y} = 5\hat{x} + 7\hat{y}$
$\vec{P}_9 = P_{9x}\hat{x} + P_{9y}\hat{y} = 6\hat{x} + 0\hat{y}$	$\vec{P}_{30} = P_{30x}\hat{x} + P_{30y}\hat{y} = 0\hat{x} + 2\hat{y}$
$\vec{P}_{10} = P_{10x}\hat{x} + P_{10y}\hat{y} = 3\hat{x} + 2\hat{y}$	$\vec{P}_{31} = P_{31x}\hat{x} + P_{31y}\hat{y} = 4\hat{x} + 4\hat{y}$
$\vec{P}_{11} = P_{11x}\hat{x} + P_{11y}\hat{y} = 6\hat{x} + 4\hat{y}$	$\vec{P}_{32} = P_{32x}\hat{x} + P_{32y}\hat{y} = 5\hat{x} + 4\hat{y}$
$\vec{P}_{12} = P_{12x}\hat{x} + P_{12y}\hat{y} = 4\hat{x} + 4\hat{y}$	$\vec{P}_{33} = P_{33x}\hat{x} + P_{33y}\hat{y} = 4\hat{x} + 7\hat{y}$
$\vec{P}_{13} = P_{13x}\hat{x} + P_{13y}\hat{y} = 9\hat{x} + 9\hat{y}$	$\vec{P}_{34} = P_{34x}\hat{x} + P_{34y}\hat{y} = 0\hat{x} + 2\hat{y}$

$$\vec{P}_{14} = P_{1x4}\hat{x} + P_{1y4}\hat{y} = 0\hat{x} + 9\hat{y}$$

$$\vec{P}_{15} = P_{1x5}\hat{x} + P_{1y5}\hat{y} = 0\hat{x} + 7\hat{y}$$

$$\vec{P}_{16} = P_{1x6}\hat{x} + P_{1y6}\hat{y} = 9\hat{x} + 2\hat{y}$$

$$\vec{P}_{17} = P_{1x7}\hat{x} + P_{1y7}\hat{y} = 2\hat{x} + 2\hat{y}$$

$$\vec{P}_{18} = P_{1x8}\hat{x} + P_{1y8}\hat{y} = 4\hat{x} + 7\hat{y}$$

$$\vec{P}_{19} = P_{1x9}\hat{x} + P_{1y9}\hat{y} = 4\hat{x} + 7\hat{y}$$

$$\vec{P}_{20} = P_{2x0}\hat{x} + P_{2y0}\hat{y} = 4\hat{x} + 7\hat{y}$$

$$\vec{P}_{21} = P_{2x1}\hat{x} + P_{2y1}\hat{y} = 4\hat{x} + 7\hat{y}$$

$$\vec{P}_{35} = P_{3x5}\hat{x} + P_{3y5}\hat{y} = 3\hat{x} + 7\hat{y}$$

$$\vec{P}_{36} = P_{3x6}\hat{x} + P_{3y6}\hat{y} = 7\hat{x} + 4\hat{y}$$

$$\vec{P}_{37} = P_{3x7}\hat{x} + P_{3y7}\hat{y} = 6\hat{x} + 7\hat{y}$$

$$\vec{P}_{38} = P_{3x8}\hat{x} + P_{3y8}\hat{y} = 7\hat{x} + 7\hat{y}$$

$$\vec{P}_{39} = P_{3x9}\hat{x} + P_{3y9}\hat{y} = 7\hat{x} + 7\hat{y}$$

$$\vec{P}_{40} = P_{4x0}\hat{x} + P_{4y0}\hat{y} = 7\hat{x} + 7\hat{y}$$

$$\vec{P}_{41} = P_{4x1}\hat{x} + P_{4y1}\hat{y} = 7\hat{x} + 4\hat{y}$$

For all factors k the resultant vector representing the distances of an organisation from the ideal innovation potential was calculated from equation (12): $\overrightarrow{P_{R,Residual}} = P_x\hat{x} + P_y\hat{y}$

P_x was calculated from equation (13):

$P_x = \sum_{k=1}^{k=n}(I_{kx} - A_{kx}) = (I_{1x} - A_{1x}) + (I_{2x} - A_{2x}) + \ldots + (I_{nx} - A_{nx})$, where all x components of all vectors were aggregated as follows:

$$P_x = \sum_{k=1}^{k=n}(I_{kx} - A_{kx}) = 0+4+5+0+6+2+5+0+6+3+6+4+9+0+0+9+2+4+4$$
$$+4+4+7+2+2+0+0+0+4+5+0+4+5+4+0+3+7+6+7+7+7+7 = 154$$

P_y was calculated from equation (14):

$P_y = \sum_{k=1}^{k=n}(I_{ky} - A_{ky}) = (I_{1y} - A_{1y}) + (I_{2y} - A_{2y}) + \ldots + (I_{ny} - A_{ny})$, where all y components of all vectors were aggregated as follows:

$$P_y = \sum_{k=1}^{k=n} (a_k I_{yk\ y} - \alpha_k A_{yk\ y}) = 2+2+2+2+4+4+2+2+0+2+4+4+9+9+7+2+2+7$$

$$7+7+7+7+2+0+2+4+2+4+7+2+4+2+7+2+7+4+7+7+7+7+4=175$$

Then, equation (12): $\overrightarrow{P_{R,Resıdual}} = P_x\hat{x} + P_y\hat{y}$ for the resultant was written as follows:

$$\vec{P}_{R,potential} = 154\hat{x} + 175\hat{y}$$

$$\overrightarrow{P_{R,Resıdual}} = 154\hat{x} + 175\hat{y}$$

The magnitude of the vector for the distance between the actual position and the ideal position of innovation potential in the Cartesian space was calculated from equation (15):

RIP=$\left\|\overrightarrow{P_{R,Resıdual}}\right\| = \sqrt{P_x^2 + P_y^2} = \sqrt{\sum_{k=1}^{k=n}(I_{kx} - A_{kx})^2 + \sum_{k=1}^{k=n}(I_{ky} - A_{ky})^2}$as follows:

RIP=$\left\|\overrightarrow{P_{R,Resıdual}}\right\| = \sqrt{P_x^2 + P_y^2} = \sqrt{154^2 + 175^2} = \sqrt{54341} = 233.11$

Figure 7.4 illustrates the vectors $\overrightarrow{A_1}\ \overrightarrow{R_1}\ \overrightarrow{P_1}$ for the factor technology. All the graphs for each factor are provided in the Appendix C.

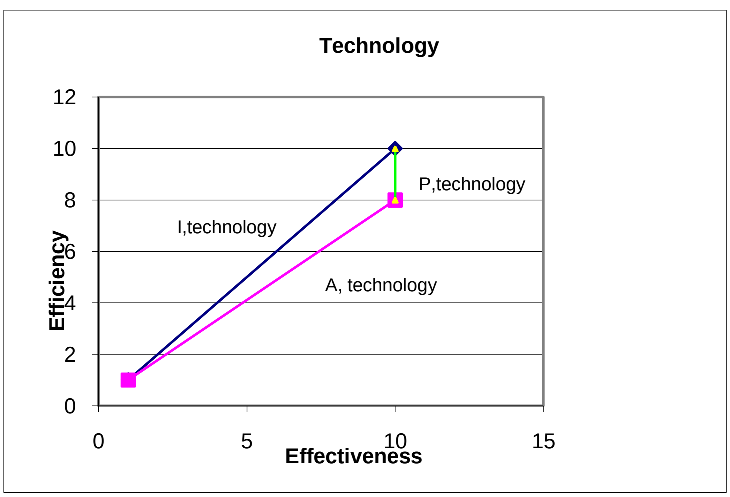

Figure 7.5 Actual position, distance from the ideal (residual) and ideal position for factor technology and case 1.

For each factor, there were possible alternative positions which could be chosen to increase effectiveness and efficiency. For the example of Case 1 explained above, the alternative scenarios that could be obtained for each item are shown in Appendix C assuming that all items correlate with the proportion of revenues.

7.3 Evaluation of the mathematical model

The evaluation of the mathematical model is concerned with examining whether the mathematical formulas developed, give the correct answers or not. The evaluation of the mathematical model was an iterative process that included a formulation stage, an examination stage and a correction stage. The formulation stage included the process of developing the formulas and describing them mathematically in such a way so as to include all the factors identified (see Section 7.1.1). Then, the formulas were being examined by using a real case example to carry out all the calculations and test whether they are producing the right output. When drawbacks in the formulation were identified, the formulas were amended appropriately. This iterative process stopped when the examination of all the formulas showed that they provide the desired measures for the quantities described during the process of formulation and as such further reformulation was not necessary.

7.4 Summary

The mathematical model developed and explained in this chapter illustrates the output of the process for modelling the mechanism of innovation. It explained the steps that were followed for formulating the mathematical model, manipulating the mathematical formulas developed and for evaluating the mathematical model. The mathematical model developed was grounded on the results obtained from the data analysis and incorporated the key outputs of the analysis demonstrated in Chapter 6.

The next Chapter, Chapter 8, presents the results of the operationalisation of the mathematical model using software programming.

CHAPTER 8: SYSTEMATISING THE GENERIC MECHANISM OF INNOVATION

As seen in Section 3.3.5, software programming provided a systematised way of manipulating the generic mechanism of innovation and assisting with the operationalisation of the mathematical formulas that were developed. Software programming offers a more efficient solution to the time and effort intensive exercise of obtaining the results from the formulas, developed in Chapter 7. Specifically, this chapter elaborates on:

- the software process model and the software development process;
- the software specifications which were described for the development of the application;
- the software design and implementation;
- the software validation and verification processes;
- the interface testing; and
- the software evolution and maintenance.

8.1 The Software process models and the software development Process

A software process model is a simplified description of the activities of the software development process. The most common process models are based on the three following process paradigms for software development: the waterfall approach, the evolutionary process model approach, and the component-based software engineering approach.

The waterfall process model is a sequence approach for separately developing the different phases of software, such as the requirements specification, software design, implementation, and testing. The sequence of activities shows that each step of the development process closes before moving onto the next.

The evolutionary process model starts all the phases of the software development having just some abstract requirement specification. Then, an initial system is rapidly developed. This system is then refined using further user input, or reconstructed using more specific requirements.

The component-based process model assumes that components of the system already exist. The focus of this approach is the integration of these components, rather than their development from scratch.

The waterfall process model has been criticised due to its inflexible partitioning of a project into distinct stages (Sommerville, 2007). The component-based process model was deemed not to be appropriate, as it mostly applies to software re-use, assuming that the software or parts of the software pre-existed (Sommerville, 2007). The evolutionary development approach was the preferred approach, being selected over the waterfall approach due to its effectiveness in directly meeting the needs that arise during development (Sommerville, 2007).

All software development processes require an iteration procedure within each phase of implementation, so as to adopt any new or refined requirements. There are two main iteration procedures: incremental delivery and spiral development. During incremental delivery, each phase of the software development is broken down into a series of increments, with each being developed in turn. In the spiral development approach, the process is a sequence of activities backtracking from one activity to another. The process is represented as a spiral where each loop is concerned with a system's feasibility, requirements and design.

The software development process includes a set of activities and results that produce the software product. There are four fundamental software process activities (Sommerville, 2007):

1. *Software specification* is the activity that results in definition of the software that is to be produced and of the constraints on its operations;
2. *Software design and development* are the activities relating to software design and software implementation;

3. *Software validation and verification* is the activity of checking the software to ensure that it is what was initially required; and
4. *Software evolution* is the activity where the software is modified so as to adapt it to changing user and market requirements.

The following sections describe the process activities of software specification, design, development, validation and evolution employed in the development of the software application for the purposes of this research.

8.2 Specification of software application

The software specifications describe the services that are provided by the application and include the scope and the functional and non-functional requirements. The scope of the application, the functional user and system requirements were described to provide insight on the application inputs, outputs and deliverables. The non-functional user requirements specify the system performance, security, availability and the system properties (Sommerville, 2004). The software application was named **InnoAct.** The scope of the application, and the user functional and non-functional requirements are described in Table 8.1.

Table 8.1 User functional and non-functional requirements

Software specifications	**Description**
Scope of the application	The scope of the application is to provide a system that can operationalise and test the mathematical model that was developed for evaluating the innovation potential of an organisation.
User requirements • *Functional*	There were four user functional requirements for the system: 1. The application should calculate the innovation potential of an organisation; 2. The application should provide the option to change manually and/or automatically the initial scores and

recalculate the innovation potential using new user input;

3. The application should use an optimisation routine to produce alternative scenarios assigning improved scores to the factors. These improved scores should be based upon a desired percentage value of innovation potential identified by the user;
4. The application should be able to display initial and subsequent results of innovation potential; and
5. The application should store the records of previous evaluations.

- *Non–functional:* There were two user non functional requirements for the system: product requirements and external requirements.

1. *Product requirements.* Product requirements include efficiency, usability, reliability, and portability requirements. The efficiency of the product could be achieved by increasing performance, whilst also minimising the space requirements for the application. Usability often refers to the interface of the application. Usability requirements can be assessed during validation and verification processes. However, usability of the user interface is an iterative process done through the development of the application. Reliability can be assured by a low rate of failure and availability. Portability ensures that the application is easy to transfer and install.

2. *External requirements.* The system should not disclose any personal information about the system's users unless required by the users. This external requirement was derived from the need for the system to conform to privacy legislation.

The system's functional requirements were used to add detail, and to explain how the user requirements can be provided by the system. The specification of the system requirements are illustrated using a standard form design, detailing the functions that were required, as described by Sommerville (2004). The functions are illustrated in Tables 8.2-8.5.

Table 8.2 Function 1: Calculate Organisational Innovation Potential

Function 1	**Compute Innovation Potential**
Description	Computes innovation potential, in percentage terms, according to the initial scores of factors inserted by users.
Inputs	The raw score describing the extent to which each factor contributes to innovation and the raw score on the condition of each factor describing the organisational practices that are currently employed.
Outputs	The innovation potential, in percentage terms, using the relative scores of effectiveness and efficiency towards innovation. Saving of the results.
Destination	Main control loop
Action	The user inserts the initial raw scores. Interpolation is performed for the user input 'raw scores', in order to transfer it onto the relative scales of efficiency and effectiveness. The magnitude of the resultant vector for the actual innovation potential is divided by the magnitude of the resultant vector for the ideal innovation potential to derive the innovation potential in percentage terms using the equations developed in Chapter 7, as follows: the actual position of efficiency and effectiveness is calculated from equation (2): $$\overrightarrow{A_{\mathrm{R},Actual}} = A_x\hat{x} + A_y\hat{y}$$ The magnitude of the resultant vector for the actual innovation potential is calculated from equation (5): $$\text{AIP}=\left\Vert\overrightarrow{A_{R,Actual}}\right\Vert = \sqrt{A_x^2 + A_y^2} = \sqrt{\sum_{k=1}^{k=n}(A_{kx})^2 + \sum_{k=1}^{k=n}(A_{ky})^2}$$

	The resultant vector $\overrightarrow{I_{R,Ideal}}$. that is sum of the max x and y components for efficiency and effectiveness is calculated from the equation (7): $\overrightarrow{I_{R,Ideal}} = \mathrm{I}_x\hat{x} + \mathrm{I}_y\hat{y}$ The magnitude of the resultant vector for the Ideal Innovation Potential is calculated from equation (10): $\mathrm{IIP} = \left\Vert\overrightarrow{I_{R,Ideal}}\right\Vert = \sqrt{I_x^2 + I_y^2} = \sqrt{\sum_{k=1}^{k=n}(I_{kx})^2 + \sum_{k=1}^{k=n}(I_{ky})^2}$ The percentage of the actual innovation potential compared to the ideal is calculated by dividing the magnitude of the resultant vector for the Actual Innovation Potential with the resultant vector of the Ideal Innovation Potential according to the following equation: $\%\ Innovation\ Potential = \frac{\left\Vert\overrightarrow{A_{\mathrm{R},Actual}}\right\Vert}{\left\Vert\ \overrightarrow{I_{R,Ideal}}\right\Vert}$
Requires	No previous readings

Table 8.3 Function 2: Re-calculate Innovation Potential with new user input

Function 2	**Re-calculate innovation potential with alternative readings.**
Description	Computes innovation potential in percentage terms allowing the user to change the initial input values.
Inputs	The revised readings of the raw score describing the extent to which each factor contributes to innovation and the condition of each factor describing the organisational practices that are currently employed.
Outputs	The percentage of innovation potential using the relative scores of effectiveness and efficiency towards innovation. Saving of the results.
Destination	Main control loop
Action	The user inserts the revised raw scores for each factor. Interpolation is performed in the user input revised ‘raw scores’, in order to transform them into the relative scales of efficiency and effectiveness. The magnitude of the resultant vector for the New Actual Innovation Potential is divided by the magnitude of the

	resultant vector for the Ideal Innovation Potential using the equations developed in Chapter 7 as follows: (22): $\overrightarrow{A_{R,Actual}}' = A'_x\hat{x} + A'_y\hat{y}$ The magnitude of the resultant vector for the New Actual Innovation Potential is calculated from equation (25): $\text{NAIP} = \|\vec{A}'_{R,Actual}\|$ $= \sqrt{{A'_x}^2 + {A'_y}^2} = \sqrt{\left(\sum_{k=1}^{k=n}(A'_{kx+v})\right)^2 + \left(\sum_{k=1}^{k=n}(A'_{ky+v})\right)^2}$ The resultant vector for the Ideal position, $\overrightarrow{I_{R,Ideal}}$,. that is sum of the maximum x and y components for efficiency and effectiveness is calculated from equation (7): $\overrightarrow{I_{R,Ideal}} = \mathrm{I}_x\hat{x} + \mathrm{I}_y\hat{y}$ The magnitude of the resultant vector for the ideal innovation potential is calculated from equation (10): IIP=$\|\overrightarrow{I_{R,Ideal}}\| = \sqrt{I_x^2 + I_y^2} = \sqrt{\sum_{k=1}^{k=n}(I_{kx})^2 + \sum_{k=1}^{k=n}(I_{ky})^2}$ The percentage of the actual innovation potential compared to the ideal is calculated by dividing the magnitude of the resultant vector for the actual innovation potential with the resultant vector of the ideal innovation potential according to the following equation: $\%\ Innovation\ Potential = \frac{\|\vec{A}'_{R,Actual}\|}{\|\overrightarrow{I_{R,Ideal}}\|}$
Requires	One previous reading
Pre-condition	The systems contains at least one initial reading

Table 8.4 Function3: Optimise and Re-calculate Innovation Potential

Function 3	Optimise and re-calculate innovation potential based on user defined percentage value of innovation potential.
Description	The application should optimise the user's raw scores based on a

	user defined percentage of innovation potential. The user should be able to know which items significantly correlate with proportion of revenues. These items could be called ‘default’ items. Then the application should compute innovation potential in percentage terms based on the optimised raw scores that are produced from an optimisation routine.
Inputs	The desired percentage of innovation potential.
Outputs	The percentage of the total innovation potential using the optimised relative scores of effectiveness and efficiency towards innovation. Saving of the results.
Destination	Main control loop.
Action	The optimisation routine produces alternative Action Plans for increasing the innovation potential of organisations. The optimisation is performed using the Genetic Algorithm for optimising nonlinear problems. Then the potential is calculated by the aggregation of the optimised vector components that represent each factor. The magnitude of the Optimised Innovation Potential is divided by the magnitude of the resultant vector for the Ideal Innovation Potential according to the following formula i.e.: $\overrightarrow{A_{R,optimised}} = A_{kx,optimised+v}\hat{x} + A_{ky,optimised+v}\hat{y}$ The resultant vector for the Optimised Innovation Potential is calculated from the following formula: OIP=$\lVert\overrightarrow{A_{R,Optimised}}\rVert = \sqrt{A^2_{x,optimised} + A^2_{y,optimised},} =$ $\sqrt{\sum_{k=1}^{k=n}(A_{kx,optimised})^2 + \sum_{k=1}^{k=n}(A_{ky,optimised})^2}$ The resultant vector for the Ideal position, $\overrightarrow{I_{R,Ideal}}$,. that is sum of the maximum x and y components for efficiency and effectiveness is calculated from equation (7): $\overrightarrow{I_{R,Ideal}} = I_x\hat{x} + I_y\hat{y}$ The magnitude of the resultant vector for the ideal innovation

	potential is calculated from equation (10):
	IIP= $\left\Vert \overrightarrow{I_{R,Ideal}} \right\Vert = \sqrt{I_x^2 + I_y^2} = \sqrt{\sum_{k=1}^{k=n}(I_{kx})^2 + \sum_{k=1}^{k=n}(I_{ky})^2}$
	Then the Percentage of the optimised Potential is calculated as follows:
	$\% \, Optimised\ Innovation\ Potential = \frac{\left\Vert \vec{A}_{R,Optimised} \right\Vert}{\left\Vert \overrightarrow{I_{R,Ideal}} \right\Vert}$
	The optimisation routine can produce numerous different alternative scenarios according to a user defined innovation potential. The solutions offered from the optimisation routine are ranked according to how closely they converge to the required potential defined by the user. Each solution that is obtained can be manually manipulated by the user to incorporate the user's preferences for future course of actions.
Requires	The systems contains at least one initial reading

Table 8.5 Function 5: Insert new factors to the model

Function 4	Insert new factors to the application and customise **InnoAct** according to different contexts.
Description	The application shall provide the option for the users to integrate more factors than those recognised in this research, which may be applicable to different contexts.
Inputs	Measurement scales for the items measuring the condition of the factors. Average values for the two items.
Outputs	Customised set of factors/customised application.
Destination	Main control loop.
Action	The application should integrate new factors into the calculation process.
Requires	Measurements Scales for input factors

Table 8.6 Function 4: Save records of Previous Evaluations

Function 4	Save previous or optimised evaluations of innovation potential.
Description	Save the results
Inputs	Initial or optimised evaluations.
Outputs	New file with a user defined name for saving the results.
Destination	Main control loop.
Action	The application should save any previous and optimised evaluations as a normal excel file.
Requires	One set of initial readings.

The user-functional and non-functional requirements are described as being of assistance to the process of the software design and implementation. The next section describes the activities employed for the **InnoAct** software design and implementation.

8.3 Software design and implementation

The software design is a description of the software that is to be implemented and the data, the interfaces between the system's components and the algorithms. The specific design process activities that were implemented were: architectural design, the design of systems and subsystems, the use case model and the design of the interface. Then, the implementation stage of the software is the process of converting the system specification into an executable system. These design process activities are discussed in the following sections.

8.3.1 Architectural design

The architectural design process focuses on establishing that the organisation of the system satisfies the system's functional and non-functional requirements (Sommerville, 2004). The architectural design describes how the system is structured into subsystems, the approach that was adopted, and how each subsystem was structured into modules. There are three widely used organisational models of systems: the repository model, the client – server model and the layered model.

The basic characteristic of the repository model is that the subsystems make up a system of exchanging information, so that they can work together effectively. This can be achieved by either holding the shared data in a central database, the so called repository model, or by maintaining a database for each subsystem, in which data can be interchanged with other subsystems by passing messages to them. This type of model is suitable for applications where large amounts of data is organised around a shared database or repository and where data is generated by one subsystem and used by another (Sommerville, 2007).

The client server model is a systems model where the system is organised as a set of activities, services and associated servers which clients can access and use. Such a model is often comprised of a set of servers, such as printing or filing servers, a set of clients that call the services provided by the server and often a network that allows the clients to access the services. The client-based model is a distributed architecture that can be used effectively from many distributed processors. However there may be no shared data model across servers and subsystems, meaning that specific data models should be established on each server to allow for optimal performance. XML-based representations of data could be a solution to this problem, however XML is an inefficient way of representing data, and so problems with performance may arise (Sommerville, 2007).

The layered model approach organises the system into layers, each of which provides a set of services. Each layer can be thought of as being an abstract entity whose entity language can be defined by the attributes provided by the layer. This entity 'language' can then be used to describe a next level of this abstract entity. Finally, the abstract entity code is translated into a real entity code. The layered approach supports the incremental development process. When layers are developed some of the services that are provided by that layer can be made available to users. This architectural model makes the application portable and changeable. Finally, layers can be added or replaced easily and new attributes can be integrated easily into existing layers. The absence of the need to maintain a central database, and the lack of a need to exchange data between subsystems, or to use distributed processors, supported the decision to use a layered-approach architecture for the development of **InnoAct** (Sommerville, 2007).

8.3.2 Systems and subsystems

Systems can be broken down into subsystems and modules and can be organised into two main strategies:

1) The object-oriented decomposition, where a system is broken down into a set of communicating objects; and
2) The function-oriented pipelining, where a system is broken down into functional modules. These modules accept input data and transform it into output data.

The object-oriented approach modules are represented as objects with specific state and defined operations on that state. This approach is concerned with object classes, their attributes and their operation. In the implementation phase, the objects are created from the classes and there is a control model that coordinates the object's operation. The advantages of this approach are that the objects are loosely coupled, and so the implementation of an object can be easily modified without affecting other objects. Objects often represent real world entities, thus the structure is easily understandable. Objects can also be reused in different systems, offering a flexibility that requires only a small modification to adjust it for with another system. The main disadvantages of the object-oriented approach is that in order to use the services that are offered, the objects must explicitly reference the name and the interface of other objects. This means that in the event of a change to an object, the effects of that change to all of the users must be evaluated. Another disadvantage is that real world entities can be very complex, increasing thus the difficulty to represent them as objects (Sommerville, 2007).

The function-oriented pipeline approach, or data flow model, is a functional transformation process that produces outputs from inputs. The data transforms as it moves through the sequence. Each processing step is implemented as a transformation. The transformations may be in parallel, or in a sequential order, and they continue until the output is produced. The data can be transformed item by item or in a single batch. This type of system architecture is mainly used in data-processing systems, where reports can be easily produced from computations of a large volume of data inputs. The advantages of this approach are that it supports the transformation; it is intuitive, in that people think of their work in terms of input and output processing; the system can be evolved by adding new transformations; and it can be implemented either as a concurrent or a sequential system. The disadvantages of this approach are that the data has to be in the same format to be recognised by all the transforming factors; and integrating transformations which use incompatible data formats is impossible (Sommerville, 2007).

The advantages of the object-oriented programming approach can be summarised as having simplicity, modularity, modifiability, maintainability, extensibility, and reusability. These qualities support the decision to use an object-oriented design approach in the development of **InnoAct**. An object-oriented strategy was used throughout the development process with iterative development and incremental delivery of the system.

8.3.2.1 Object oriented strategy

Initially, an object-oriented analysis was performed so as to develop the object-oriented model architecture of the application domain. The objects in that model reflected the entities and the operations associated with the problem to be solved. Secondly, the object-oriented design was concerned with developing the software system to implement the identified requirements. The final stage of the strategy was concerned with realising the software design with an object programming language that provides the run-time system and the necessary constructs to define the object classes and create objects from these classes (Sommerville, 2007).

The layered architecture for the **InnoAct** is illustrated in Figure 8.1. The layered architecture is appropriate in this system as each stage relies on the processing of the previous stage for its operation (Sommerville, 2007).

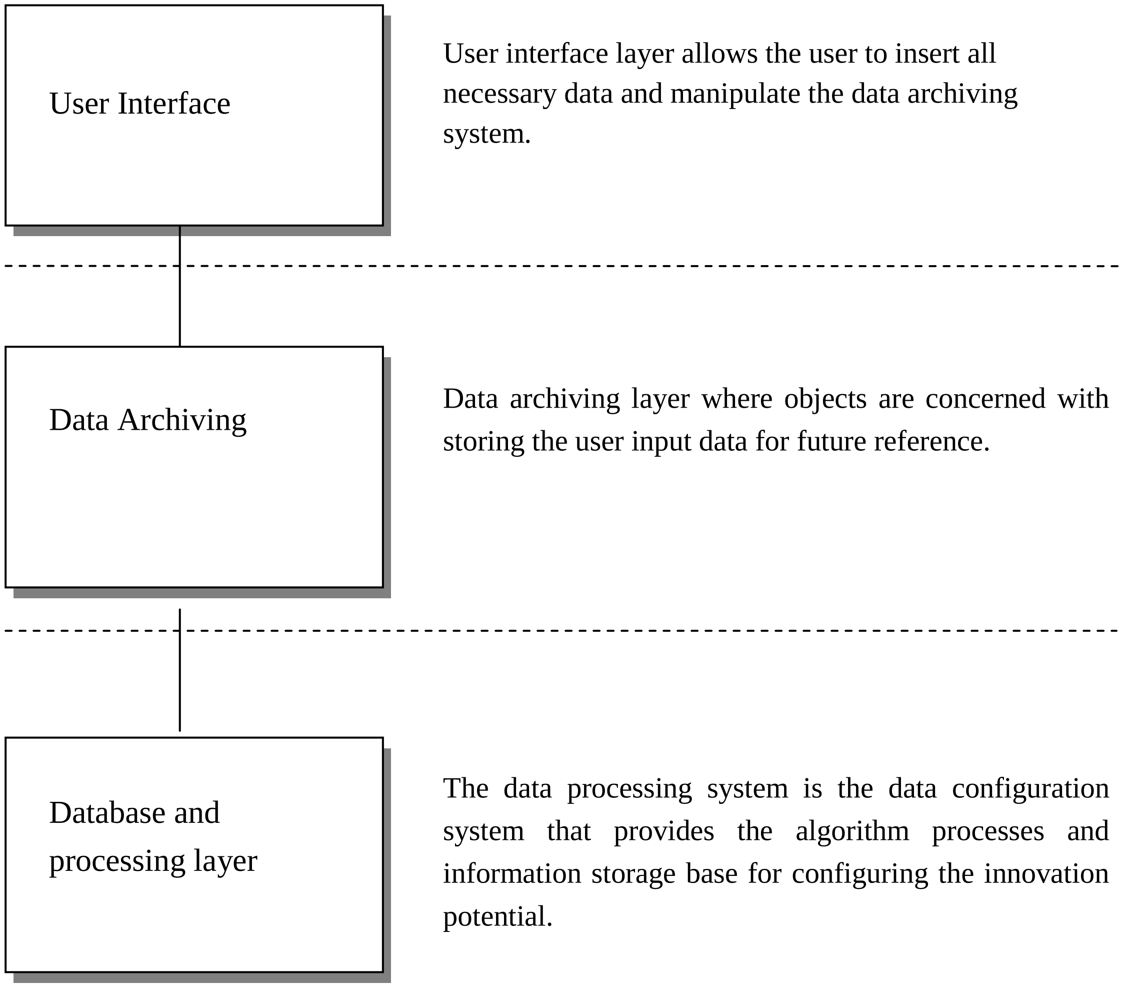

Figure 8.1 Layered architecture for the system of measuring innovation potential

The basic architectural layer in Figure 8.1 can be described by a number of other components or subsystems derived from the initial description and specification of the system. The subsystems are shown in Figure 8.2.

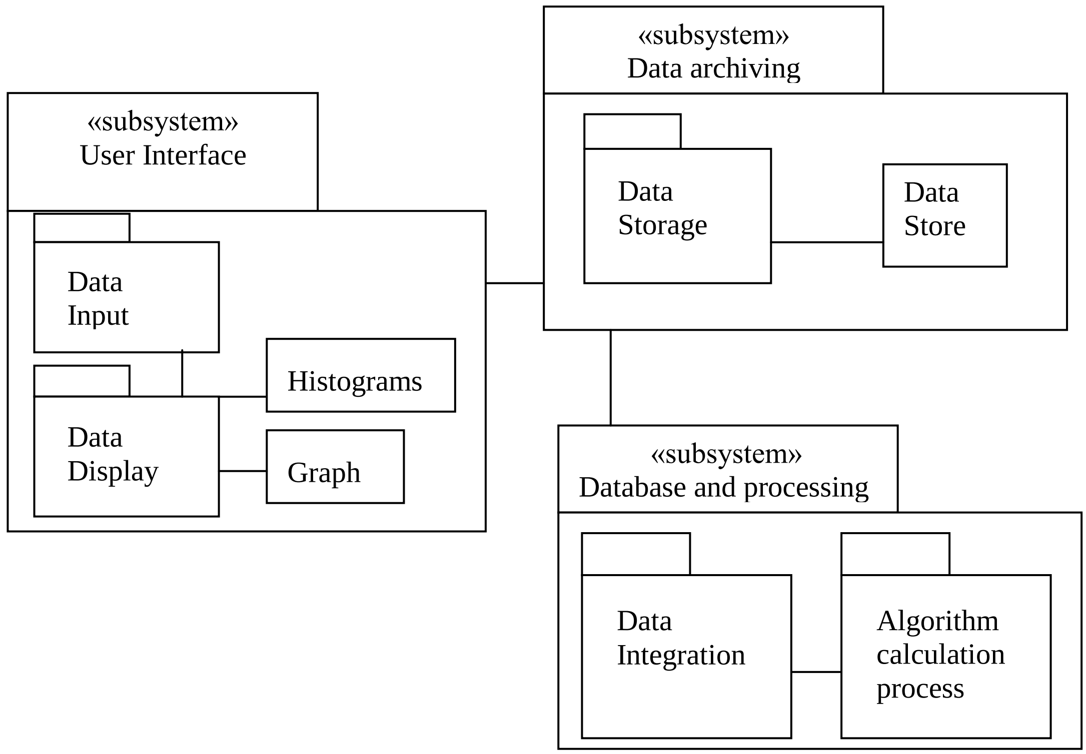

Figure 8.2 Subsystems in the innovation potential system

The subsystem 'User Interface' is the system that the user interacts with, computing the information needed for calculating the innovation potential of an organisation. The subsystem 'Data archiving' is where the inputted data is stored and is used as a reference library to retrieve any information needed for obtaining the results of the computations. The subsystems 'Database and processing' is the system that contains all the formulas as well as the optimisation routine for developing alternative scenarios of action plans.

8.3.2.2 Use case model

A complementary modelling process, the model of use, is able to: ensure functionality; develop an understanding of the relationship between the software being designed and the external environment; and decide on the structure of communication between the system and the environment. The model of the system use or *use case model* is a dynamic model, which describes how the system interacts with its environment. The use case model diagram shows the actions that the system can perform by interacting with the outside actors (see Figure 8.3).

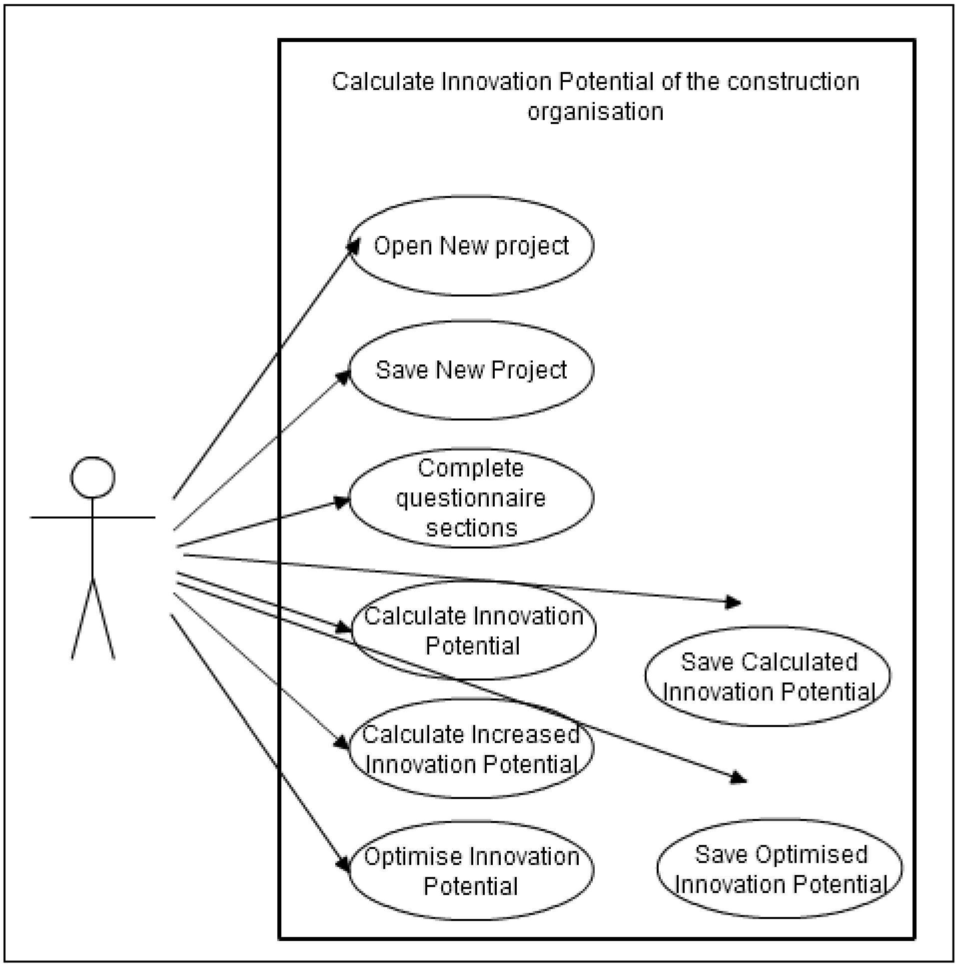

Figure 8.3 Use case model

At this stage, the object-oriented programming languages that are available for realising the system's application were evaluated. There are a variety of object-oriented programming languages available to use for the realisation of the proposed software system. Some of the mostly used ones are: C++, C#, Java, PHP, Python, Visual Basic, Visual Basic for Applications and many more. The choice of the programming language that was used was based on the availability of its use, and the simplicity for employing the programming process. All of the above languages were available for use upon request from the IT services at the University of Leeds. The analysis on the selection of the programming language was seen in section 3.3.5. The programming language that was used was Visual Basic for Applications VBA for Excel as it was an easy to use tool for programming the application required and provided the ability to manipulate the advanced object library of the Excel (see Section 3.3.5).

8.3.3 Interface design considerations

Careful interface design was an essential part of the overall software design process. In order to achieve the system's full potential, it was important that the interface was designed to match the skills, experience and expectations of the users. Human characteristics such as memory, handling of large amounts of information, human capabilities and human interaction preferences form the basis of the design principles for user interfaces. The interface design principles are: user familiarity, consistency, recoverability, and user guidance and diversity (Sommerville, 2007).

The principle of user familiarity suggests that the interface should use terms that are familiar to the user, therefore the user is not forced to adapt to the interface. In this case, the system was designed to depict practices in organisational issues, thus the objects that were manipulated were concerned with the terminology in the business operations area. The associated operation was to calculate the innovation potential of an organisation, with the underlying implementation of the interface in terms of files and data processing being hidden from the user (Sommerville, 2007).

The principle of user interface consistency is concerned with the format of the commands and menus. The commands and menus were designed in a consistent way, with similar command punctuation to reduce user learning and familiarisation time. The user interface was designed with command buttons and option list boxes directly placed on the Excel worksheets (Sommerville, 2007).

The principle of recoverability is concerned with ensuring that the user does not make potentially destructive mistakes. The interface facility of Microsoft Excel is designed to include undo facilities, with multiple levels of undo that restore the system to the desired state before the action occurred. Microsoft Excel is designed with a 'checkpoint' feature, which allows for the regular saving of a system at periodic intervals. Thus the user has the option to go back and restart from the previous checkpoint (Sommerville, 2007).

The principle of user diversity recognises that there may be different users. At this stage of the software development, and because it is in a prototyping phase with the main focus on testing the mathematical model, the conditions for users with disabilities of various types were postponed.

User interaction and the presentation of information to the user were two main issues during the design of the interface. To better achieve coherence, the interface integrated appropriate styles of interaction and presentation of information. There are four main interaction styles that can be used for the user interface design: the direct manipulation, the menu selection, the form fill-in, the command language and the natural language. The application developed supports a mixed design of interaction styles, such as menu-based command selection and form fill-in. The menu-based command selection was used so as to minimise potential user error, by ensuring that only little user typing in required. Then, in order to provide and simplify the entry of the data that was required for the calculation of innovation potential, the users have to fill in a form that is presented to them, and they can initiate actions by pressing a button. There was no direct manipulation, as there was no need for visual representations for tasks and objects (this interaction style is mainly appropriate for video games and CAD systems). Command language or natural language functions were avoided, as they generally take more time to learn, require more typing and have poor error management (Sommerville, 2007).

Presentation of the information comes in two forms: the system can either present the information in the form of text or in the form of graphical representations. The application that was designed used both text and graphical representation to present the data. It used text to present the exact percentage of the potential of the organisation to innovate, and graphs to show the distance from the maximum innovation potential (as shown in Figure 8.4).

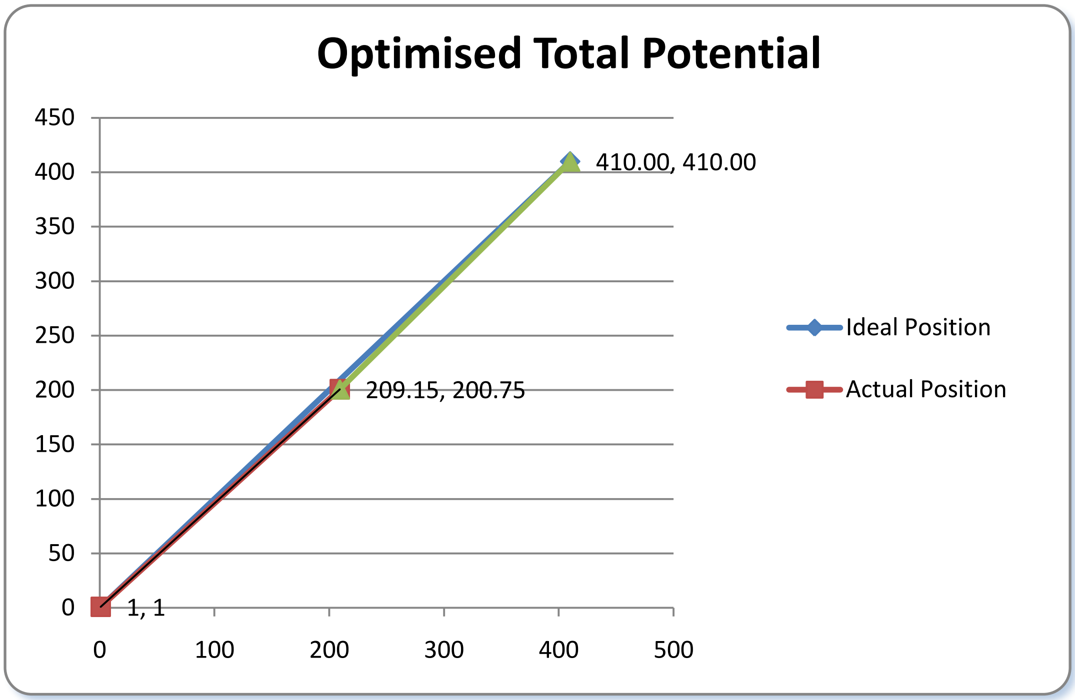

Figure 8.4 Actual innovation potential, Ideal innovation potential, and Residual Innovation Potential.

Special consideration was given to the colours that were used for the interface, so as not to be disruptive, un-attractive or error-prone. The Snneiderman fourteen guidelines were used to effectively select the colours of the interface (Shneiderman, 1998). According to those guidelines, less than seven not very bright colours were used to avoid disturbance and visual tiring. Colour change was only used when indicating the calculation of the New Innovation Potential of the organisation.

The user interface design process was an iterative process and it needed to be evaluated during the software development phases, and often redesigned after exposure to potential users, who guided the evolution of the interface.

8.3.4 The implementation output of the design process

VBA can manipulate the excel object model that can expose numerous powerful data analysis objects such as worksheets, charts, mathematical, financial, engineering and business functions. Thus, the system architecture and the subsystem objects and functions are realised by manipulating and automating the powerful data analysis objects of Microsoft Excel.

The basic excel objects that were used for the realisation of **InnoAct** using VBA were: application, shape, range, worksheet, shaperange, chart, and workbook. Each object has numerous children objects and functions. Informed by the system and subsystems architecture, and by the specification requirements, the application's structure was composed of the following basic worksheets: the '*Main Menu*' worksheet, the S*how Results*' worksheet, the '*Develop Alternative Scenarios*' worksheet, 'C*hange Alternative Scenario Manually'* worksheet, the '*Increase Potential Manually'* worksheet, and the '*Data Analysis*' worksheet. The main functionality and the interconnection of the worksheets are explained below.

The *Main Menu* worksheet provides an interface for data input and data display option, using control forms buttons. The *Main Menu* worksheet (see Figure 8.5) feeds the information inserted by the user to the Data Analysis worksheet object.

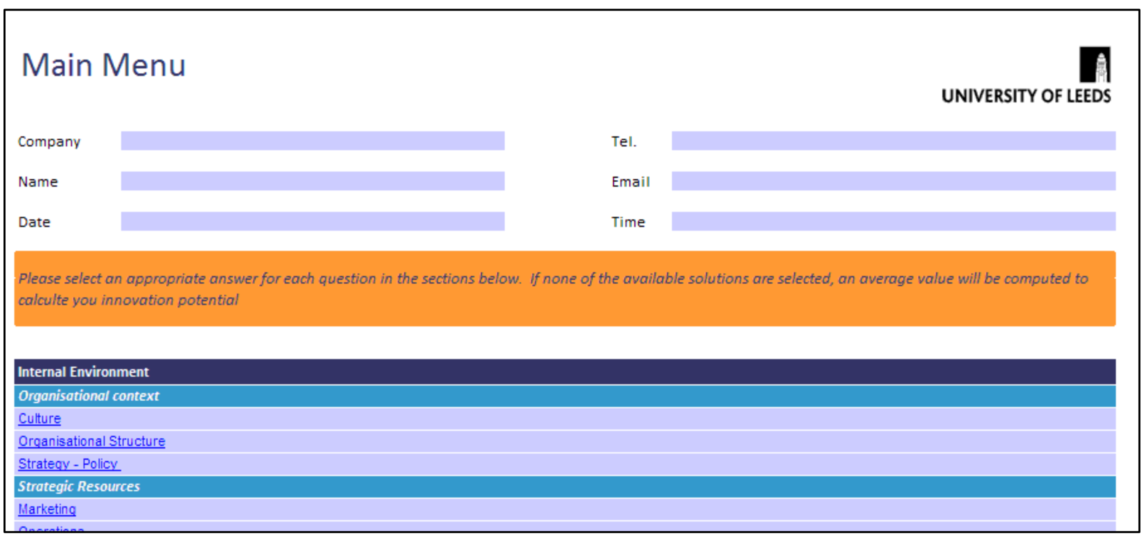

Figure 8.5 The *'Main Menu'* worksheet

The *Show Results* worksheet is the Data Display worksheet providing users with the option to calculate the innovation potential, using either the optimisation routine or the manual controls. The *Show Results* worksheet (see Figure 8.6) presents the results from the calculation of innovation potential, and is taking information from the Data Analysis worksheet.

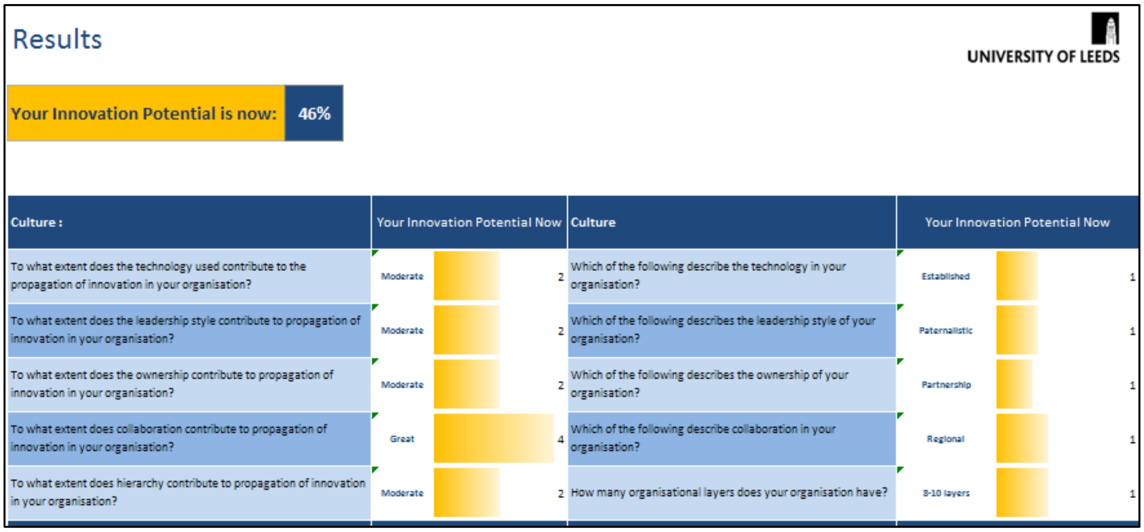

Figure 8.6 The *'Show Results'* worksheet

The *Develop Alternative Scenarios* worksheet (see Figure 8.7) was based on the information sent by the Data Analysis worksheet. It uses an optimisation routine using an Excel AddInn, which was programmed separately (and incorporated into **InnoAct**). The worksheet also includes graphs that present the Actual Innovation Potential compared with the Ideal Innovation Potential. Microsoft Excel provids the utility to save the results produced for each measurement.

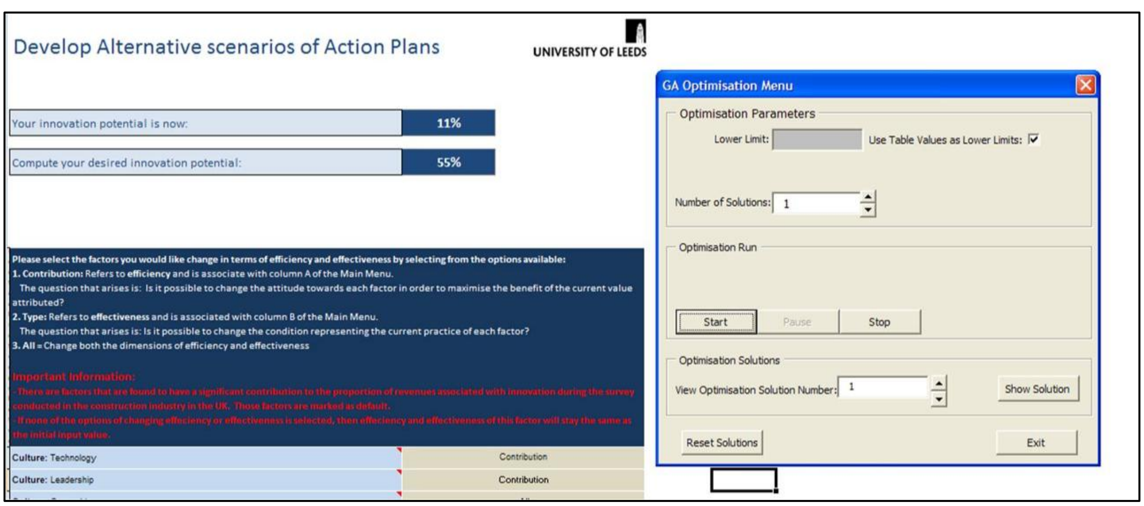

Figure 8.7 The *'Develop alternative scenarios'* worksheet

The *Change Alternative Scenario Manually* worksheet (see Figure 8.8) presents the data that was obtained from the optimisation routine, and allows for the manual changing of the data so as to manipulate the innovation potential.

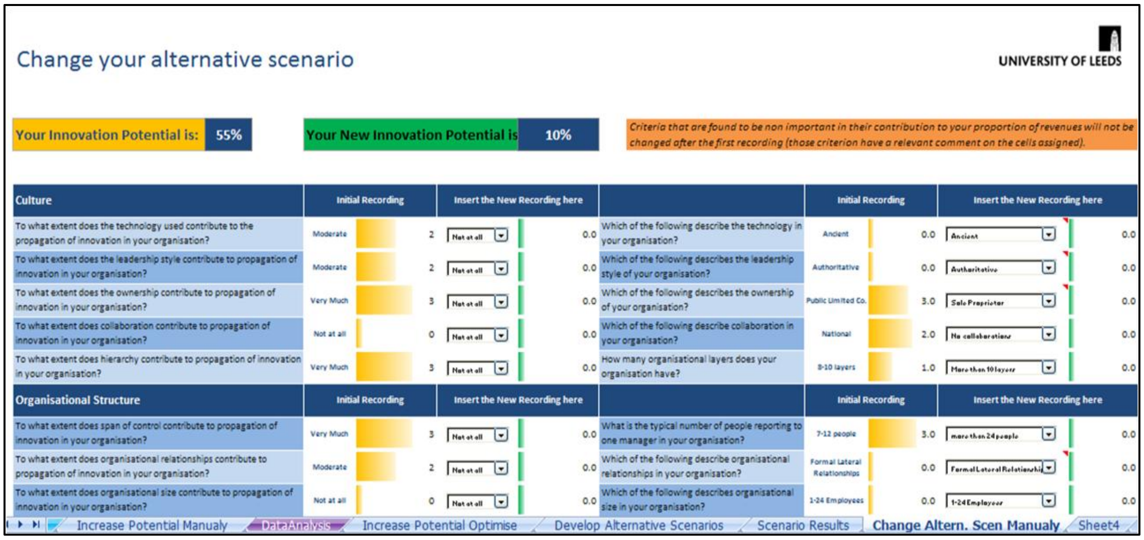

Figure 8.8 The *'Change Alternative Scenario Manually'* worksheet

The *Increase Potential Manually* worksheet (see Figure 8.9) presents data based on calculations carried out in the *Data Analysis* worksheet, and allows for the insertion of new user input for re-evaluating the innovation potential.

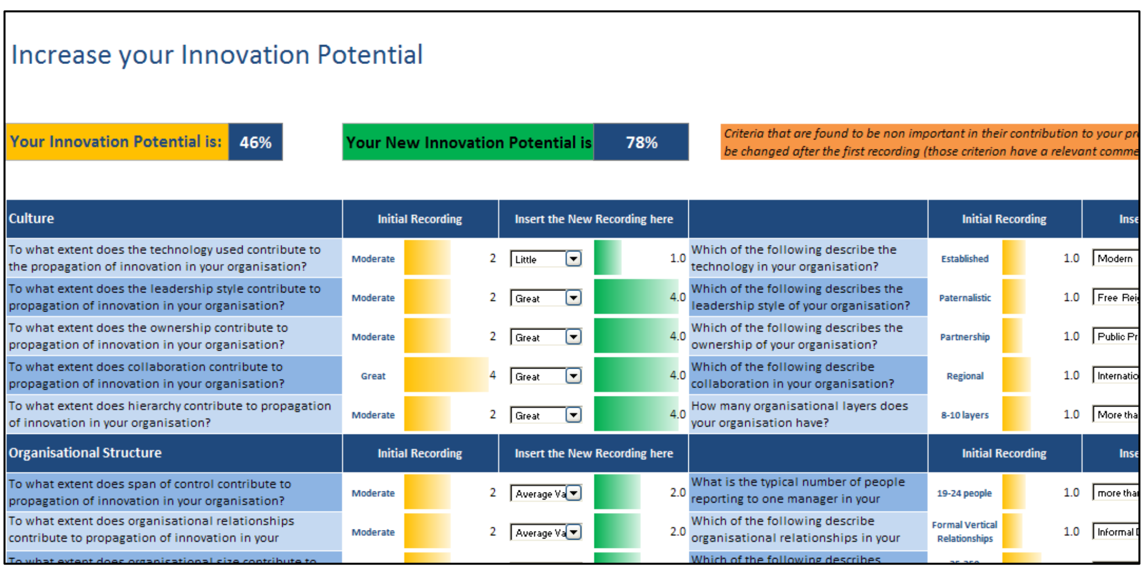

Figure 8.9 The *'Increase Potential Manually'* worksheet

In the *Increase Potential Manually* worksheet the user can decide upon which items he/she would like to change according to the specific competences of each organisation and re-evaluate the innovation potential based on these changes.

The *Data Analysis wor*ksheet (see Figure 8.9) is the database and processing system, where data is stored and manipulated. The algorithm calculation processes, including the mathematical formulas, the interpolation routine, and the optimisation routine are based on this worksheet. When calculations are completed the *Data Analysis* worksheet sends the results to the *Show Results*, *the Increase Potential Manually* and the *Develop Alternative Scenarios* worksheets accordingly.

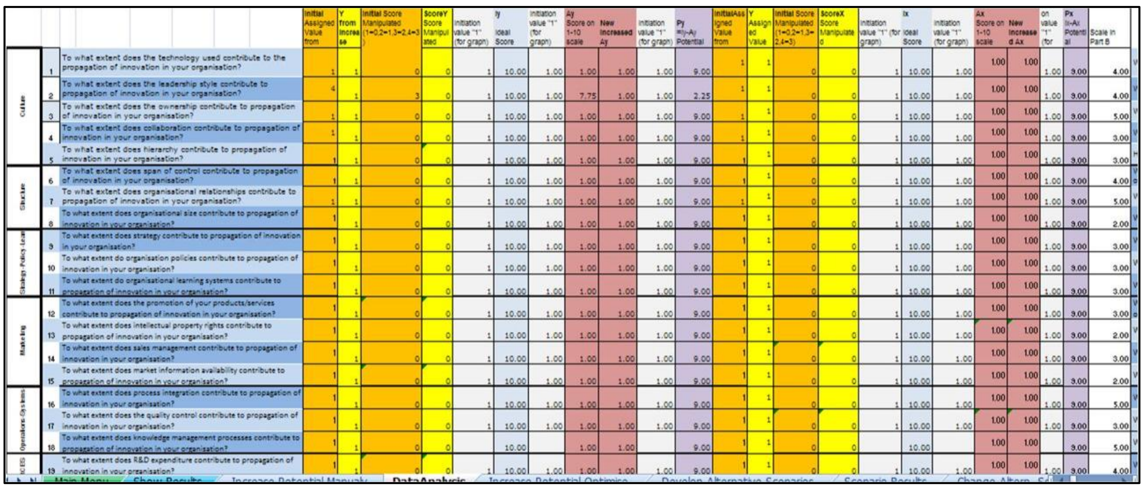

Figure 8.10 The *'Data Analysis'* worksheet

User instructions on using **InnoAct** are provided in Appendix D. The following section explains the optimisation routine that was used and the AddInn that was developed for **InnoAct.**

8.4 Optimisation for increasing innovation potential

An optimisation routine was used to produce different combinations of random scores for each item measuring efficiency and effectiveness towards innovation. The new random scores produced should all be above the initial user inputted scores in order to provide refined scores of innovation potential. The production of different combinations of random scores using an optimisation routine that could integrate such restrictions as the one mentioned above, facilitated the formation of alternative Action Plans based on refined scores that can be offered for adoption and implementation by organisations. The notion of developing alternative Action Plans for increasing innovation potential was grounded on the principles of the systems theory, which highlights that even a small improvement, could affect the final output which in this case is the organisation's innovation potential. Implementation of such an Action Plan that incorporates refined scores of effectiveness and efficiency can be seen to result in increasing the organisation potential to innovate. The optimisation problem and the genetic algorithm used for the optimisation routine are explained in the following sections.

8.4.1 The optimisation problem

A general optimisation problem can be stated as follows:

$$f(\hat{x}) \leq f(x), for\ all\ x\ \in X$$

The set X is usually called the feasible set and the function f is called the objective function. X is often a subset of a finite dimensional real space $\mathbb{R}^n$, which denotes the n-dimensional Euclidean space. In this case, the problem is defined as an unconstrained optimisation problem. If X is a strict subset of real space $\mathbb{R}^n$, then the optimisation problem is called constrained. Constraints are defined by linear equations and inequalities (Ruszczynski, 2006). The most popular optimisation problems are linear programming problems, where the objective function is a linear function. If the objective function f or some of the inequalities function are nonlinear then the optimisation problem is called non linear optimisation problem (Ruszczynski, 2006).

The optimisation problem was the minimisation of the difference between the user defined percentage of innovation potential and the actual innovation potential, $F_0(x)$ subject to $F_j(x)$ constraints. The design variables x are the orientation of the scores in the items measuring efficiency and effectiveness. The constraints allowed the solutions to take values between the initial user input raw score and the maximum raw score on each item scale. It is important to note here that the optimisation problem required the identification of solutions that are integer values. This requirement is based on the fact that any real number that would be constructed on the items' scale would be meaningless.

The percent of the user defined innovation potential can be described as follows:

$$\%\ Optimised\ Innovation\ Potential = \frac{\left\|\vec{A}_{R,Optimised}\right\|}{\left\|\overrightarrow{I_{R,Ideal}}\right\|}$$

The percent of the actual innovation potential can be written as follows:

$$\%\ Actual\ Innovation\ Potential = \frac{\left\|\vec{A}_{R,Actual}\right\|}{\left\|\overrightarrow{I_{R,Ideal}}\right\|}$$

Then the objective function is written as follows:

$$F_o(x) = \frac{\left\|\vec{A}_{R,Optimised}\right\|}{\left\|\overrightarrow{I_{R,Ideal}}\right\|} - \frac{\left\|\vec{A}_{R,Actual}\right\|}{\left\|\overrightarrow{I_{R,Ideal}}\right\|}$$

The optimisation problem can thus be described as:

$$F_0(x) \to min$$

$$F_j(x) \geq R_x\ , \qquad (j = 0,1, \dots, n,)$$

$$F_j(x) \geq R_y, \qquad (j = 0,1, \dots, n)$$

Where:

R_x is the raw score in the initial scale of each item, representing the items measuring the condition of the factors,

R_y is the raw score in the initial scale of each item, representing the items measuring the extent to which factors contribute to innovation,

n is the maximum score on each raw scale

The magnitude for the Actual Innovation Potential from equation (5) is:

$$\text{AIP}=\left\|\overrightarrow{A_{R,Actual}}\right\| = \sqrt{A_x^2 + A_y^2} = \sqrt{\sum_{k=1}^{k=n}(A_{kx})^2 + \sum_{k=1}^{k=n}(A_{ky})^2}$$

The magnitude for the Optimised Innovation Potential from equation is written as follows:

$$\text{OIP}=\left\|\overrightarrow{A_{R,Optimised}}\right\| = \sqrt{A^2_{x,optimised} + A^2_{y,optimised}}, = \sqrt{\sum_{k=1}^{k=n}(A_{kx,optimised})^2 + \sum_{k=1}^{k=n}(A_{ky,optimised})^2}$$

where

$A_{x,optomised} = \sum_{k=1}^{k=n} A_{kx,optimised} = A_{1x,optimised} + A_{2x,optimised} + ... + A_{nx,optimised}$, and

$A_{y,optomised} = \sum_{k=1}^{k=n} A_{ky,optimised} = A_{1y,optimised} + A_{2y,optimised} + ... + A_{ny,optimised}$, are the optimised values provided by the Genetic Algorithm.

The optimisation routine developed and incorporated into the **InnoAct** is able to produce up to one thousand alternative scenarios of Action Plans. The process of optimisation stops when the Genetic Algorithm identifies values that converge to the user defined value of Innovation Potential. Then the AddInn developed also provides the option to rank the Alternative Scenarios according to how close they converge to the user-defined value of Innovation Potential.

8.4.2 The Genetic Algorithm

As seen in Section 3.3.5.2 the optimisation routine incorporated into **InnoAct** was developed using the Genetic Algorithm as the more appropriate method for solving optimisation problems with non-linear functions. The Genetic Algorithm is a machine learning technique modelled upon the natural process of evolution. Genetic algorithms are different from conventional optimisation techniques in that ‘they use a whole population of individual objects of finite length, typically binary strings (chromosomes), which encode candidate solutions using a problem specific representation scheme’ (Toropov, Alvarez and Querin, 2010 p. 138). These strings are decoded and evaluated for their fitness, which is a measure of how good a particular solution is. The AddInn that was developed within the University of Leeds and was incorporated into the software application, **InnoAct**, allowed for the calculation of alternative scenarios of

Action Plans for a user defined Innovation Potential providing solutions that converge to the third decimal place of the user-defined value of Innovation Potential.

8.5 Software Validation and Verification

Software validation and verification (V&V) techniques were employed to ensure that the software application developed was built right and that it was the right product to be built. The validation and verification process outputs are discussed in the following sections.

8.5.1 Verification

Verification ensures that the product is built right and involves checking software specifications and system requirements. Formal methods of verification, such as mathematical analysis of the specifications, have been judged to be very costly, as not reflecting the real environment of a system's users, deriving false proof. The cleanroom approach to software development also uses formal methods, and has been found to successfully produce higher quality applications than those using traditional approaches (Sommerville, 2007). The cleanroom key strategies are: formal specification, incremental delivery, structured programming, statistical testing of the system, and static verification

The system was formally specified from the very beginning of the development. **InnoAct** was tested by inputting real data, to see if the specifications and the system requirements were addressed sufficiently. Adjustments to the code and the design were made until the above requirements were satisfied.

The software application was developed in increments. Each increment was specified at an early stage in the development process. The increments were tested during the development process with real data.

The program development process was a stepwise refinement of the specifications. Limited numbers of constructs were used, with the aim being to systematically transform the specifications into functioning code. The code was refined until the specifications were fully met.

Statistical testing was used to test the reliability of the software. The process was applied when the GA AddInn was incorporated into the software application. Statistical testing was employed by implementing multiple runs of the application using different inputs. This manipulation of the computer application revealed errors when multiple trial runs were carried out. The statistical analysis of the errors appeared, led to careful further refinement of the code. As soon as the corrections were complete, statistical testing with another cycle of multiple runs was applied again until no errors were evident.

Software inspection was both a verification and a validation static process that focused on the code and revealed errors, omissions and anomalies. Inspections were carried out during all phases of the development process, using real data to test if the results that were obtained were correct. The application was also shown to members of the research community. The inspection team was provided with the latest version of the code. A presentation of the software application provided the basis of knowledge for the inspection team, allowing them to focus on: the detection of defects, conformance to standards and for poor quality programming. Following the inspection, changes were applied to correct problems that were identified. Those inspections replacedthe component testing, due to their proved effectiveness and the unjustifiable costs that the later have (Sommerville, 2007).

The stages in static analysis involved control flow analysis and data use analysis, interface analysis, information flow analysis and path analysis (Sommerville, 2007,p. 527).

Control flow analysis revealed any unreachable code that was surrounded with unconditional goto statements, or was in branches of conditional statements but the guarding condition could not be true. Data use analysis highlighted how variables were used, detected variables that were used without previous utilisation, and variables that were written twice. Data use analysis was used to reveal ineffective tests and tests that conditions were not valid. Interface analysis checked for the consistency of the routines and the language of declaring the procedures. Interface analysis was used to detect functions and procedures which though declared, were never used. Information flow analysis identified the dependencies between input variables and output variables. Information flow analysis was used to detect all of the conditions that affected a variable's value, by listing the derivation of the values that were used in the program. Path analysis showed all of the possible paths in the program and was used to set out the statements executed in each path (Sommerville, 2001).

The procedure described above can otherwise be called system testing. VBA also includes tools for checking and correcting syntax errors. Syntax errors include language mistakes and typically spelling mistakes. VBA scans for errors at the end of each code line and reports it in a message box. VBA also offers various integrated tools for error debugging. In order to examine lines of code closely, it was possible to add breakpoints to the specific code lines and check the state of the variables as the code was executed. At the same time, the VBA compiler runs in the background of the application, and so any errors were displayed immediately using underlying lines. This process allowed for the immediate correction of the code, before the application run. Another feature that, allowed for the correction of the code, while on breakpoint and during the execution, was the 'edit and continue' feature. This feature allowed for the addition of new code, the updating of existing code, and the changing of variable values. Then the application could be restarted to execute the newly updated code. Debugger Data Tips also provided support for the quick inspection of the variables, whilst debugging the Windows application.

8.5.2 Validation

Validation deals with whether the product that is being built, is the right product, and involves ensuring that the software meets the needs or expectations of the users (Sommerville, 2001).

In order to demonstrate that the system performed correctly, and met the requirements, a set of cases reflecting the system expected use were used to test it. Software testing processes were applied throughout the development of the software, running implementations with test data in order to examine the outputs and the operational behaviour (Sommerville, 2007). Finally, the computer application was tested with input data that was provided by members of the research community within the School of Civil Engineering in the University of Leeds.. This testing revealed omissions, especially in the user interface. Those omissions mainly concerned with the amount of information that was provided to the user to enable them to perform the tasks. Corrections to the user interface were then incorporated, and the interface was tested again as part of the validation process of the Program Logic Model explained in the next chapter, Chapter 9. This testing did not reveal any requirement problems, or cases in which the system did not meet the user's needs (Sommerville, 2007).

8.6 Software evolution and maintenance

The evolution of software systems is important, as they are critical to an organisation's business assets. Organisations invest highly in systems change, in order to retain the value of those assets. Maintaining or evolving existing software systems accounts for the 90% of the software costs in an organisation (Erlikh, 2000). Changes to the software systems are usually generated by changes in business and user needs. Therefore, the evolution of a system may be conceived as a spiral development process with design, requirements, implementation and testing going on throughout the lifetime of the system. Later releases of the system often deploy the required changes that have emerged.

System evolution involves an understanding of how the program needs to be changed and implementing these changes. This could involve requirements that were not implemented within the initial system, requests for new requirements, bug repairs from the system's stakeholders, or new ideas and improvements from the system's developers (Sommerville, 2007). Maintenance of a system is concerned with changes to coding errors, more extensive changes so as to correct design errors, significant enhancements to correct specification errors, or to accommodate new requirements. The object-oriented design approach used for the realisation of the mathematical model offers the provision of easy maintainability and extensibility, subject to amended requirements.

In a globalised and fast changing environment, software that evaluates innovation potential in organisations should be continuously updated with new factors playing a key role to innovation and new practices that could facilitate the process of innovation and increase innovation potential. Organisations that belong to a specific sector or industry should be able to identify any additional factors that can affect their innovation potential. The software application facilitates the process of updating and integrating new factors or practices into the model providing a function for inserting new factors in the Main Menu worksheet (see Appendix D). The new factors identified can be integrated into the model through the software application that was developed in this research, and can assist the evaluation process of innovation potential by customising it to a specific industry or sector.

8.7 Summary

This chapter has presented the development of the software application **InnoAct** which was designed to facilitate the operationalisation of the mathematical model developed in Chapter 7. The application uses the genetic algorithm for optimisation purposes, which is widely used for non-linear integer optimisation problems. The software application **InnoAct** can be used to help organisations evaluate their innovation potential and assist them to identify suitable scenarios that can be adopted according to their capabilities for increasing their innovation potential. The next chapter, Chapter 9, presents the development of a proposed program that incorporates the use of **InnoAct** to facilitate the transition of an organisation to a more advantageous position in terms of effectiveness and efficiency for managing innovation and creating growth.

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CHAPTER 9: THE PROGRAM LOGIC MODEL

The purpose of this chapter is to explain the development of a systematic program that can describe the sequence of events, as those have been identified within this research. This chapter integrates the outputs of all the previous chapters, chapters 4,5,6,7, and 8, within a proposed program of actions in order to connect the need for creating growth by increasing innovation potential and facilitating the decisions of organisations for achieving these desired results.

Specifically this chapter provides:

- a definition of the word ‘program’ and the use of modelling programs to demonstrate the functionality of this activity;
- the output of the modelling process, that is the Program Logic Model (PLM);
- an explanation of the key elements of a Program Logic Model; and
- a description of the Program Logic Model that was developed.

9.1 Definition of ‘program’ and use of modelling programs

A program refers to an organised ‘collection of activities designed to reach certain objectives’ (Royse, Thyer and Padgett, 2010, p.5). Organised activities in programs mean that activities are not a random set of actions but a series of planned actions expected to have a certain impact (Royse, Thyer and Padgett, 2010). Programs are used to design interventions or services that are expected to have an impact on the participants.

Modelling is a technique that encourages iterative development of an idea, program or project (Wyatt Knowlton and Phillips, 2009). The modelling of programs has been used to allow for the careful consideration of the relationship between activities and results, and offers a way to display thinking and represent planned actions and expected results. A modelling exercise was undertaken to implicitly map the course of activities for measuring innovation potential in organisations and link them with the expected impact that is economic growth. The output of the modelling activity that was undertaken is explained and illustrated in the following sections.

9.2 Output of the modelling process

As seen in section 3.3.6 in order to provide a model that could provide a deeper understanding of the proposed process, entail a coherent logic, and support planning and communication of the proposed activities to achieve the desired results, a program logic model (PLM) was developed. The program logic model that was developed was designed to facilitate the management of innovation and assist in improving organisational performance towards innovation accounting for the different contexts. As not all organisations are the same and one solution could not be appropriate for all organisations, the programme logic model provides a comprehensive and complete tool to help organisations customise the approach of evaluating innovation performance. The program logic model is designed to assist the identification process of more factors that are relevant to the context under study (e.g. sector, country). It helps to explain the methods that can be used to customise the software application developed, it calculates the innovation potential of organisations and produces alternative scenarios for improving organisational performance towards innovation. The program logic model developed was named **InnoGrowth**. **InnoGrowth** is a visual depiction of the resources and activities that organisations need to undertake in order to achieve the desired result that is growth. Overall, **InnoGrowth** is a useful tool that can help an organisation's decision making process towards improving its innovation potential. This can be achieved by providing alternative scenarios of Action Plans with the use of **InnoAct.** Alternative scenarios of Action Plans can facilitate the decision of organisations to employ the necessary actions for improving their innovation potential and obtain the desired results that is efficiency and effectiveness towards innovation in the short term, and economic growth in the long term.

The intended use of **InnoGrowth** is:

- to identify the resources required to achieve intended results;
- to describe a systematic process for achieving the intended results; developing different scenarios of Action Plans
- to convey the purpose of achieving the intended results and creating growth;

- to raise awareness of the factors influencing organisational efficiency and effectiveness towards innovation;
- to assist the decision making process of an organisation towards implementing an appropriate Action Plan.

The following section illustrates how the intended use of the developed PLM fits into its key elements, constituting the blueprint used in operationalising the program.

9.3 Key elements of a program logic model

The primary elements of a program logic model include resources, activities, outputs, outcomes, and intended results.

9.3.1 Resources required to achieve intended results

Resources are essential for activities to occur. Resources include human, organisational, information availability and financial capital.

9.3.2 Activities

Activities are the specific actions that need to be planned so as to achieve the intended results. Activities include processes, events, and technologies that can assist the successful achievement of the intended result. All of the activities together represent the systematic process for achieving the intended results.

9.3.3 Intended results

The intended result is to create growth through more efficient management of the process of innovation. Intended results are the desired outputs, outcomes and impacts. Outputs are indicators of what specific activities can generate i.e. the direct product of the process activities delivered by the program. Outputs can be qualified and quantified so as to test the application of the activities. Outcomes are specific changes in organisational behaviour, increases in awareness, knowledge skills and methods of functioning as a result of the process activities. Outcomes can be described as short term (1-3 years), intermediate term (4-6 years) and long term (7-10 years) (Wyatt Knowlton and Phillips, 2009).

In order to assist the decision-making process of increasing efficiency and effectiveness towards innovation all of the different alternative scenarios of Action Plans should be offered. Having all the possible alternative scenarios assist the decision-making process of selecting an appropriate Action Plan that is applicable to the specific competences and capabilities of an organisation. Then it is likely that the expected impact can be achieved. The impact is the fundamental intended change in an organisation and the long term changes that can occur, as a result of the whole process that has been implemented. This kind of changes to occur often requires a time period of 7-10 years or more.

9.4 The InnoGrowth key elements

The description of the main elements of a program logic model allows their categorisation in terms of their purpose. Therefore, resources, activities and outputs reflect the planned work, whereas outputs, outcomes and impacts reflect the intended results, as illustrated in Figure 7.1. The intended use of **InnoGrowth** is linked to the main elements of a program logic model, revealing the links and the logic between the planned work and the intended results.

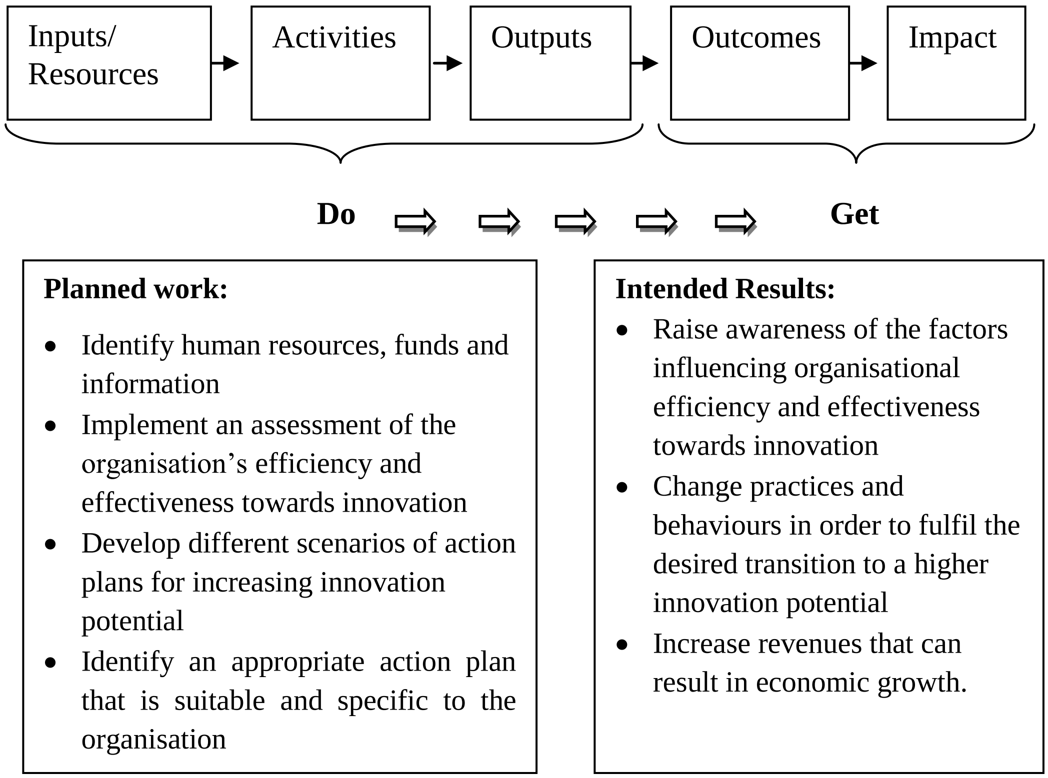


Figure 9.1Key elements of a program logic model and the link to **InnoGrowth** intended use

Besides the main elements of a PLM there are other key elements which do not normally appear in the PLM, however they are of equal importance. These are the assumptions and the environmental factors.

9.4.1 Assumptions

Assumptions represent the beliefs about why the specific interventions and the activities proposed by the PLM can lead to the desired outcomes. Clarity and understanding of the assumptions are fundamental to the program logic modelling process. The assumptions that are made for the **InnoGrowth** are:

- Assumption 1: organisations highly value the importance of innovation as an element of competitive advantage and economic growth;

- Assumption 2: organisations are interested in working on improving innovation and therefore allocate time and the resources needed to develop initiatives; and

- Assumption 3: organisations have the capacity to assess the alternative action plan developed, and decide on appropriate action depending on their specific competences.

The explicit naming of the assumptions help the users to have the same view about what should or could work using the model and why (Wyatt Knowlton and Phillips, 2009).

9.4.2 Environmental factors

The economic, social, and political environments in which the program logic models operate play a key role in the effectiveness of a program (Wyatt Knowlton and Phillips, 2009). The PLM, **InnoGrowth,** designed in this research, is organisation-specific, and its success can be influenced by the individual organisation characteristics such as the capabilities and resources that are needed to plan and implement the desired interventions.

9.5 Development of the Program Logic Model

The development of a program logic model is an iterative process that requires the breaking of the planned work activities into detailed and specific actions, and the breaking of the intended results into detailed and specific outcomes and impacts (see Figure 9.1). Each of the actions and the outcomes were designed in a way that they were comprehensive, illustrating their contribution to each planned work and intended result. In order to develop the program logic model, certain design steps were followed, in the order explained in the following paragraphs.

The first step included the identification of the intended result. The identification of the intended result was informed by the conceptual model. The intended result is to increase economic growth of organisations through a process of increasing innovation potential. This result reflects both the impact and the outcomes that are intended over time.

The second step was to specify and name the outcomes that are part of the progress towards impact. Those outcomes include: increasing the awareness of how factors and their conditions can contribute to innovation; increasing effectiveness and efficiency by employing the most appropriate Action Plan for each organisation; improving the Action Plans for increasing the innovation potential.

The third step was to identify the activities that are required to achieve the specified outcomes. The activities include: the identification of new factors that play a key role in innovation (optional), the evaluation of factors with respect to efficiency and effectiveness; the development of alternative scenarios using the software application **InnoAct;** the integration of the new factors into the application; and the selection and application of the most suitable scenario.

The fourth step was to specify the resources that are essential for the activities to be implemented. The resources include: human resources, financial capital, availability of information and time allocated. Figure 9.2 illustrates all the key components of the program logic model, **InnoGrowth.**

Assumptions	Resources	Activities	Outputs	Short-term Outcomes	Medium-term Outcomes	Long-term Outcomes	Impact
				1-3 years	4-6 years	7-10 years	
Organisations highly value the importance of innovation as an element of competitive advantage and economic growth. Organisations are interested in working on improving innovation and therefore allocate time and resources needed to develop initiatives Organisations have the capacity to assess the alternative action plan developed, and decide on appropriate action depending on their specific competences.	Financial Capital Human Resources Information Time	Identify new factors (optional) Integrate new factors into **InnoAct** (optional) Evaluate efficiency Evaluate effectiveness Identify Innovation Potential Develop alternative scenarios of action plans Select appropriate scenario Implement selected action plan	Number of new factors (optional) A customised software application if new factors identified A cognitive map of efficiency and effectiveness Percent of innovation potential (position of organisation on the map) Alternative scenarios of Action Plans	Increase knowledge of organisation efficiency towards innovation Increase knowledge of organisational effectiveness towards innovation Increase awareness of appropriate action to increase innovation potential	Increase efficiency towards innovation Increase innovation potential	Increase effectiveness towards innovation Increase innovation potential Continuous improvement Evolution of the Action Plan	Increase in Revenues

Figure 9.2 The 'Inno-Growth' model

The key elements of **InnoGrowth** are discussed in the following sections.

9.5.1 Resources

The resources required to apply the program logic model as shown in Figure 9.2 are financial, human, information, and time resources. Financial resources are initially needed to carry out evaluation exercises for efficiency and effectiveness. This exercise can be carried out by the managing director or the R&D manager, or a team of people that have specific knowledge to address the factors included in the evaluation process. Therefore, it is contended that the evaluation exercise does not involve a great cost and it can be delivered internally. As soon as the evaluation exercise is completed, the organisation might be interested in evaluating more factors that are considered to play a key role in its innovation potential. It is then necessary that the organisation be able to invest financial resources in the identification of the factors and their different conditions, using grounded theory and survey techniques (see Chapter 3). Finally, the organisation must assess the financial resources that are needed to apply the selected action plan. The amount of the financial capital required may vary depending on the size of the organisation and size of the transition decided. It might be that large organisations may have more available resources, which can facilitate the transition process without investing a lot of money, whereas, for small organisations it might be necessary to acquire a lot of resources to facilitate the transition process. Each organisation must then assess the resources that are available to them for assisting the transition process, and then decide on the amount of financial resources they can invest when implementing the action plan.

Human resources are necessary for implementing the evaluation exercise, identifying new factors, and facilitating and monitoring the transition process. The evaluation exercise needs at least one person, or, if the organisation is a large one, a team can be assigned instead. One person is needed to identify new factors and their conditions, and to conduct the research. A team of people should be assigned to facilitate the transition process, and to monitor the results using the program logic model. Again, the number of the people comprising this team will be decided depending on the changes required and the size of the organisation.

Information availability, such as access to the scientific journals, books and reports that are relevant to the topic of innovation management and sector information, is necessary when the organisation decides to incorporate new factors and identify the parameters that are specific to the industry or sector being studied.

Time is required for carrying out the evaluation exercise, the research when new factors are decided to be incorporated, and the application of the action plan. The evaluation exercise can be relatively quick and does not require a lot of time. The research needed for incorporating new factors may take up to six months. The time needed to apply the action plan is subsequently decided based upon the transition and the changes required for the transition. Overall, as explained in section 9.3, changes in an organisation may be categorised in short term outputs that can take 1-3 years, intermediate term outcomes that can take 4-6 years, and long term outcomes that can take 7-10 years (Wyatt Knowlton and Phillips, 2009).

If the resources that were explained in this section are allocated, then the following activities can be provided in order to achieve the intended results.

9.5.2 Activities

The activities needed to reach the intended results are the following:

- Activity 1: carry out an evaluation exercise for efficiency and effectiveness towards innovation using the software application **InnoAct**;
- Activity 2: identify new factors contributing to innovation potential;
- Activity 3: integrate the new factors identified into the software application, **InnoAct**;
- Activity 4: carry out again the evaluation exercise of effectiveness and efficiency using the customised software application;
- Activity 5: use **InnoAct** to measure the innovation potential of the organisation;
- Activity 6: use **InnoAct** to develop alternative scenarios for action plans;
- Activity 7: evaluate the action plans and select an appropriate scenario for the organisation; and
- Activity 8: implement the action plan.

Initially, the evaluation exercise of effectiveness and efficiency (Activity 1) familiarises the user with the type of information that is required to assess the innovation potential, it also offers the opportunity to consider whether more factors play a key role to innovation. If so, these factors should be included in the software application. If identified factors are considered to be satisfactory, then this process can continue to the next activity, calculating the innovation potential (Activity 5). However, if more factors are thought to be needed to evaluate the innovation potential of an organisation, then the process should not stop until all of the relevant data is collected (Activity 2). Relevant data can be collected using the research methods described in Chapter 3. The new factors should then be integrated into the software application, **InnoAct** (Activity 3)**.** In this case, the process of evaluation should be re-applied to include the new factors that are inserted (Activity 4). As soon as the evaluation exercise finishes, the innovation potential of the organisation can be calculated using the software application, **InnoAct** (Activity 5)**.** **InnoAct** offers two options for developing alternative scenarios for Action Plans (Activity 6)**.** The first option is to use the optimisation routine for developing as many scenarios as requested. The second option is to develop alternative scenarios manually, depending on the user specific preferences for changing the efficiency and effectiveness of factors. The alternative scenarios must be evaluated according to an organisation's specific capabilities, and the most optimum scenario for each individual organisation should be selected (Activity 7). Finally, the organisation should apply the selected action plan and facilitate the process of the transition in order to increase its innovation potential (Activity 8).

The activities in Figure 9.2 are not illustrated in a hierarchical manner and do not include sub activities. Figure 9.3 below shows the hierarchy and details of activities and sub-activities.

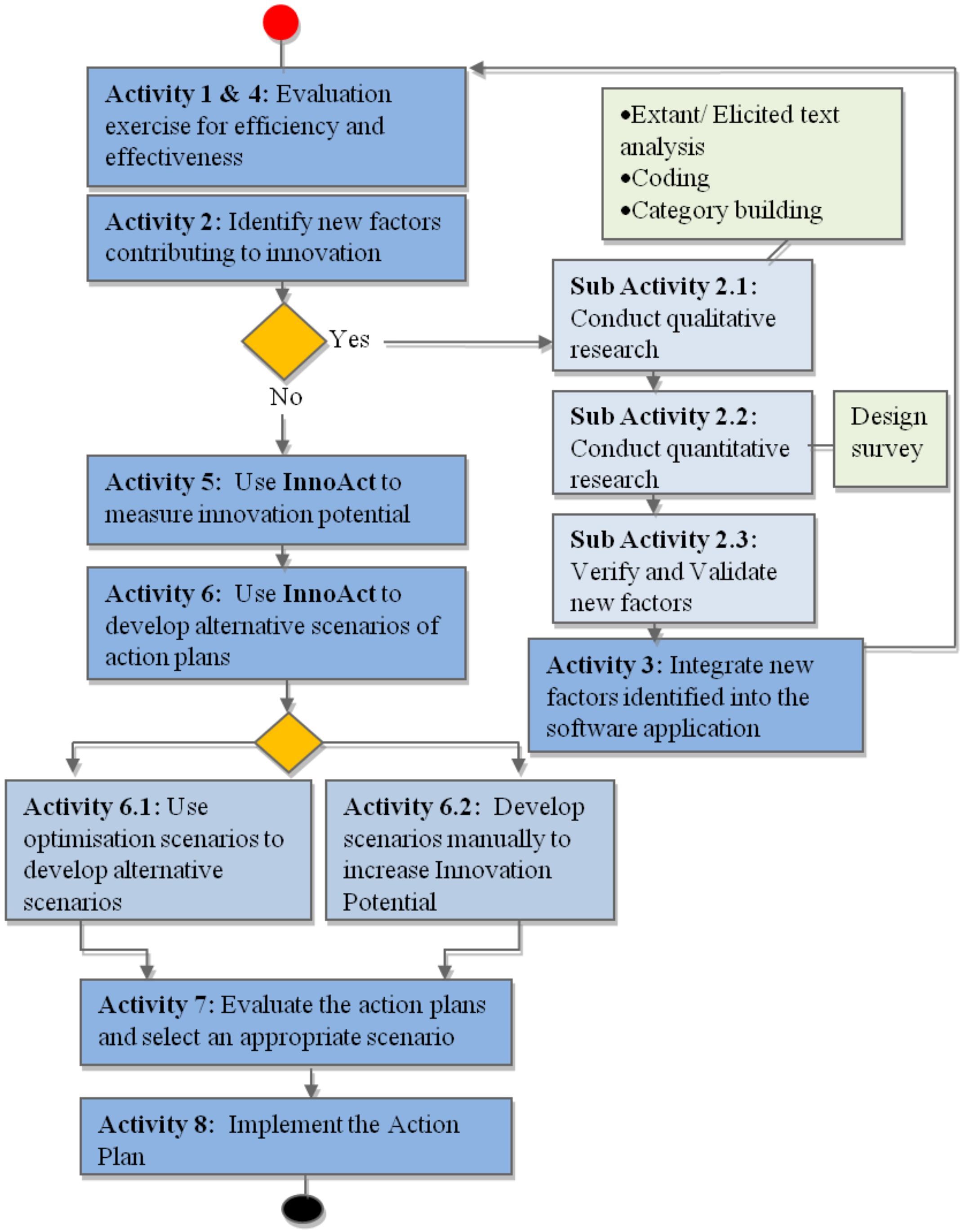


Figure 9.3 Hierarchy of activities and sub-activities.

The activities, if implemented can result to the following outputs.

9.5.3 Outputs

The outputs that can be produced from the application of the activities described above can be: new factors that are identified as playing a key role in innovation (this applies only in cases when an organisation decides to conduct research and include new factors in the software application); a customised software application specific to the characteristics of the organisation or the industry that it belongs to; a cognitive map of its efficiency and effectiveness towards innovation; its position on the cognitive map represented by its innovation potential; a number of different Action Plans developed to inform the selection of an optimum scenario.

Initially, in cases where an organisation decides to incorporate new factors, a direct output will be the number of factors that are identified. This number may vary according to the different environmental settings in which the program is applied (i.e. different sector or country). The integration of the new factors into the application will result in a customised software application that applies to the specific characteristics of the organisation. The evaluation exercise has as an immediate output – a cognitive map that depicts an organisation's efficiency and effectiveness towards innovation. The innovation potential that is calculated shows the position of the organisation on this map. Another direct output is that, based on a desired value of innovation potential, alternative scenarios are developed and available to be assessed. The assessment of the scenarios according to the specific capacities of an organisation can indicate the most optimum scenario of Action Plan that fits the organisation's needs and abilities for increasing innovation potential.

If the outputs described in this section are produced then the following outcomes can be secured.

9.5.4 Short-term outcomes

The short–term outcomes that can be a direct result of activities or results from the outputs are: the increase of an organisation's knowledge on efficiency and effectiveness towards innovation; and the raising of awareness concerning the appropriate actions that should be employed to increase innovation potential using the Action Plans that are developed.

The evaluation exercise and the cognitive map that was produced depict all of the various disciplines and factors that impact innovation, while the alternative scenarios of Action Plans show how the combination of those factors can result in increases to an organisation's innovation potential. This process contributes to increases in an organisation's knowledge relating to aspects that reflect its ability to be efficient and effective when innovating. The cognitive map increases the organisation's awareness of the alternative actions that can be pursued to increase innovation potential. Finally, the action plans produced with the use of the software application **InnoAct** can alert managers, directors and policy makers of the alternative options of actions, which can enhance an organisation's innovation potential.

9.5.5 Intermediate-term outcomes

An intermediate-term outcome of the activities that have been proposed is an increase in an organisation's efficiency towards innovation, and therefore, an increase in its innovation potential. When a selected Action Plan is applied the first action of an organisation is to increase efficiency, meaning best possible exploitation of the conditions that pertain to each factor. Practically, this means that an organisation can increase its innovation potential by making better use of its available resources, and so investing little or no money. Therefore, it is contended that an increase in efficiency can have immediate results, as it can introduce new approaches, or incremental improvements, to the application of existing practices. Increasing efficiency is a good strategy that can be employed in periods of crisis, when new investments for improving conditions (and thus changing practices) are considered by organisations for reasons of austerity.

9.5.6 Long-term outcomes

Long–term outcomes of the proposed activities include: an increased effectiveness towards innovation; an increase of the innovation potential; evolution of the Action Plan; and continuous improvement. An organisation can achieve increases in effectiveness by employing new practices. This involves investment in new resources that can facilitate the applicability of such new practices. As organisations tend to be reluctant to radical changes, it is contended that a transition process that requires the application of new practices usually requires more time, making the results obvious in the longer-term. Moreover, the program logic model can be used during the implementation of the Action Plan for monitoring, and thus can support the continuous evolution of the Action Plan by evaluating and restructuring the transition process. The evolution of the Action Plan can then support the continuous improvement of the organisation's innovation potential in the long term.

9.5.7 Impact

The impact of the proposed activities is to raise the proportion of revenues resulting from innovations. Increasing the potential to innovate can be achieved by increasing the effectiveness and the efficiency of the organisation in all disciplines. Making the most of what is available at all times and facilitating a transition process towards practices that favour innovation can increase innovation potential. The literature has shown that innovation results from the desire to drive economic development. This research has also shown that increasing efficiency and effectiveness towards innovation is positively associated with revenues (see Chapter 5). Although innovation is an unpredictable process, valuing the factors that influence innovation, and providing the appropriate conditions for each factor, can increase the innovation potential of organisations.

9.5.8 General remarks

Together all of the activities illustrated in Figure 9.2 represent a comprehensive strategy that can help an organisation to evaluate its innovation potential. The strategy also illustrates how alternative scenarios of Action Plans can be produced with the use of **InnoAct** in order to assist an organisation in the process of deciding a suitable course of action that is specific to its competences. Figure 9.4 below shows the logic followed and the areas of intervention of the Action Plan.

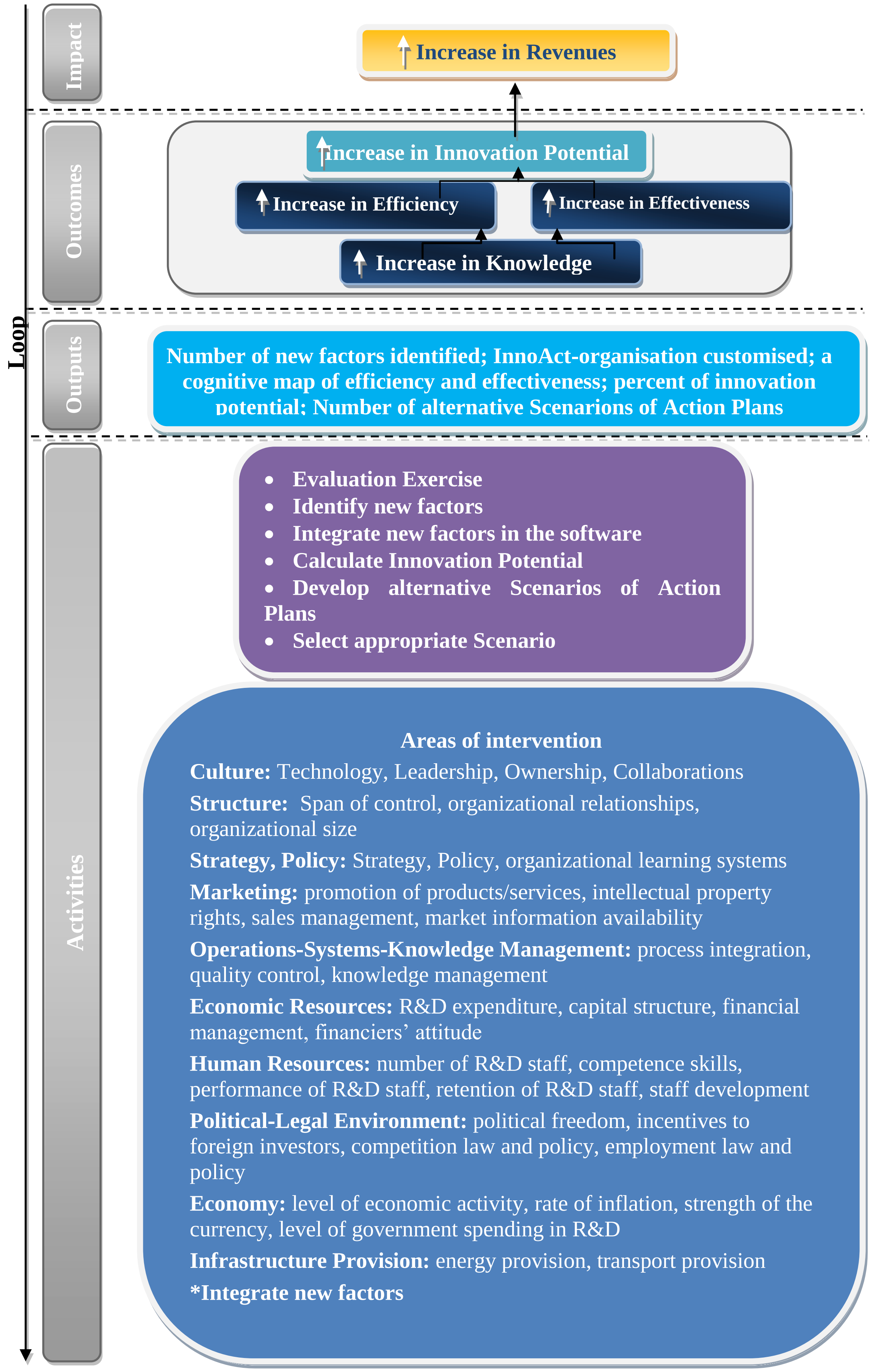


Figure 9.4 Criteria for evaluation and intended results

9.6 Summary

The program logic model, **InnoGrowth,** was developed to provide a visual representation of the resources and activities organisations need to combine in order to be able to assess their innovation potential and assist the decision process for employing necessary actions and improving innovation potential. Furthermore, **InnoGrowth,** involves the software application **InnoAct,** which can be used to develop alternative scenarios of Action Plans. Organisations can use these Action Plans as a platform for conducting an assessment of their capabilities, and then select an optimum Action Plan that applies to their individual characteristics. The **InnoGrowth** developed was evaluated and the evaluation of the **InnoGrowth** is explained and discussed in the next chapter, Chapter 10.

CHAPTER 10: EVALUATION AND IMPLEMENTATION OF THE PROGRAM LOGIC MODEL

This chapter demonstrates the potential usefulness of the program logic model, **InnoGrowth,** and shows how it can assist in the management of innovation within the construction industry.

The following describes the different issues discussed in the chapter:

- Aspects of evaluation and implementation;
- Verification of **InnoGrowth**;
- Validation of **InnoGrowth**;
- General remarks on the evaluation of the program logic model; and
- Implementing the program logic model

10.1 Aspects of evaluation and implementation

The program logic model, **InnoGrowth,** reflects the proposed program for managing innovation and increasing growth. The program logic model, **InnoGrowth** is derived from the combination of activities undertaken in this research to develop different scenarios of Action Plans for increasing innovation potential in organisations. The different Action Plans developed are the product of the software application, **InnoAct**. As can be seen in Chapter 9, **InnoAct** is a part of **InnoGrowth.** The evaluation of the software application as an independent model is covered in Chapter 8. The evaluation, in this chapter, covers the composite proposed program of the **InnoGrowth** model involving the **InnoAct**.

As seen in section 3.3.7 evaluation of the programme logic model **InnoGrowth** included both verification and validation. Verification focused on the program's quality and effectiveness and validation focused on testing whether the program is achieving the intended results. The evaluation established the logical links between the activities that should be performed to calculate innovation potential and the intended short term, intermediate and long term outcomes if the appropriate actions are taken.

10.2 Verification of InnoGrowth

Verification was designed to improve the program and its activities. During verification, questions were designed to help improve the quality of the PLM. Program logic models can often suffer from blind spots, logic scale, specificity or persuasion. Common blind spots can be unintentional omissions in the thinking process, or errors caused by habits. Logic can be the key element in the modelling process, but scale as the relative size of the given effort to achieve intended results can be an obstacle in feasibility. The scale of effort should match some short term outcomes to make feasibility evident. Specificity can also contribute to the success of the programme model if the detail of activities and focus of the intended results informs the best method for delivering those results. Often programme models which feature audacious and significant changes gain a lot of respect when introduced. However success is more likely secured if the model is discrete and seeks short-term outcomes (Wyatt Knowlton and Phillips, 2009). Persuasion can also be ensured when a model conveys consistent messages, not only for those for whom it is created but for others who are not participating in the process. To overcome the issue of persuasion and secure quality and effectiveness the developed model needed to reflect strategic thinking, and choices that were capable of securing the intended results (Wyatt Knowlton and Phillips, 2009).

In order to increase the quality of the **InnoGrowth** in a constructive way that reflects evidence, strategic choices and better thinking, important questions were addressed guided by the SMART (Specific, Measurable, Action oriented, Realistic, Timed) and FIT (Frequency of occurrence, Intensity of strength of the given effort, Targeted at a specific market or audience) principles (Wyatt Knowlton and Phillips, 2009).

SMART analysis was mainly focused on the feasibility of outcomes. SMART was applied to check if the parts of the **InnoGrowth** were aligned and work together to secure the intended results. Feasibility was tested in terms of justifying that the problem is tackled with the right strategies and the right depth of intervention.

FIT analysis aims primarily at the quality of the process and the dose of the intervention. FIT was applied to the process elements of the programme model assessing: a) if the programme logic model repeats, occurs with appropriate volume, or happens often so that results are likely, b) if the programme logic model has enough depth or concentration that results are likely, c) if the programme logic model addresses a specific audience or market. The FIT principles can reveal if the intervention that the model suggests was both appropriate and adequate.

The PLM' s outcomes can be influenced also by the real time issues and the context in which the PLM is applied. The context of the framework was also evaluated by examining how the PLM could function within different industries or sectors, and different social and political environments.

As such, the questions that were developed so as to address the quality of the PLM, addressed the context of the PLM, and the FIT and SMART principles. Those questions represented the formative evaluation conducted during the development and the maturing process of the **InnoGrowth.**

10.2.1 Questions addressing the context of the PLM

The following questions were designed to test the context of the PLM. The answers to the questions reflected the contextual issues addressed within the questions.

- **Question C1:** The **InnoGrowth** model emphasises the change in efficiency and effectiveness in order to increase innovation potential. To what extent has the community been involved in developing it? This question shows the shared understanding about the program and how its outcomes are defined and represented.

Answer to C1: The factors found to play an important role in organisational innovation have been identified using grounded theory techniques, and based on the methodological framework of deriving categories from data in social research (Bryant and Charmaz, 2007). The process of extant text analysis stopped when saturation levels were achieved. The factors addressed were as numerous as the extant literature suggests. The mechanism that combines the factors and the condition of the factors representing the theory of change model was derived from the need to use a holistic approach for managing innovation. This need derived from the lack of research in addressing innovation management in such a holistic way, as shown in Sections 1.4.

- **Question C2:** What theories inform the choices about the proposed activities? This question shows the relationship with the theory of change model and the shared meaning that leads the activities.

Answer to C2: The theories informing the choice of proposed activities are: the systems theory, the diffusion theory and the resource-based theory. The systems theory invokes the holism of the systems approach, providing insights into an organisation and its environment as a whole, requiring the consideration of the resulting changes from an initial change (Askarany and Smith, 2008). The diffusion theory suggests that there are contextual factors affecting the diffusion of innovation (Rogers, 2003; Askarany, 2005; Askarany and Smith, 2008). The resource-based approach postulates that the ability of organisations to change is based upon their strategic resources (Kristandl and Bontis, 2007). These theories are complementary to the philosophical approach of the realist explanation, contributing to the development of the theory of change model, which constitutes the conceptual framework as explained in Section 3.2.

- **Question 3:** Does it make sense that the activities that were identified can contribute to the specified outcomes? Is the whole programme as specified feasible?

Answer to Q3*:* The activities that were identified reflect the grand theories and the philosophical approach of the conceptual model. The feasibility of the whole programme relies on the fact that all of the proposed activities had already been accomplished during this research, resulting in the development of the PLM for measuring the innovation potential in organisations.

10.2.2 Questions addressing FIT principles

The following questions test if the PLM, **InnoGrowth**, is FIT. The answers are the reflection to the FIT questions raised:

- **FIT Question strand 1:** How are the frequency and intensity specified? Is there sufficient evidence that the dose, as the size of the given effort, will be enough to achieve outcomes? Do we assume that the cognitive map of efficiency and effectiveness will include this information?

Answer to FIT Question strand 1: The programme model can be used to assess the innovation potential in an organisation, providing a cognitive map that shows the levels of efficiency and effectiveness towards innovation. The alternative Action Plans that can be developed provide the different options that an organisation can examine in order to increase its innovation potential. The amount of effort needed to carry out the proposed activities to achieve the outcomes can be specified. This can be informed by the real activities that were performed during this research and from the methodologies that were applied. The amount of effort required to carry out the application of an appropriate Action Plan is not specified as it can vary depending on the capabilities of the organisation. Furthermore, that is beyond the intended use of this PLM. The use of the PLM stops at the point where the alternative scenarios are developed and the different options are offered for further exploration. This means that the PLM can be used as a complementary tool to the decision process of implementing an appropriate Action Plan. It is then up to the individual organisation to apply the effort required to support the chosen transition towards a higher innovation potential.

- **FIT Question strand 2:** Who is the best target for this? Who isn't? Being eligible and willing may be insufficient. What about being "able"? Are the intended activities appropriate, safe and effective for this target? Do we assume that these details are in the narrative that accompanies the PLM?

Answer to FIT Question strand 2: The research has been conducted in the construction industry. However, the software application, **InnoAct,** developed for operationalising the mathematical model, allows for the insertion of new factors into the model, which can make the PLM be specific and appropriate to other sectors or industries as well. Therefore the model has the ability to be adapted by actors in different sectors or industries. The factors identified in this research are informed by fundamental strategic management practices and theories, which can be applied safely to any business sector. However, the importance of the different factors may vary depending on the sector or industry. This adds to the reasons behind why the application was specifically designed to integrate different factors, and address the needs of the particular sector/ industry under study. All organisations are able to use this PLM irrespective of their decision to apply a selected Action Plan. Then, the different Action Plans developed can be organisation-specific, they can offer the opportunity to organisations to select an appropriate one depending on their capabilities. In this context, the proposed activities are considered to be appropriate, safe and effective for the target.

10.2.3 Questions addressing SMART principles

The following questions test if the PLM, InnoGrowth, is SMART. The answers are the reflection to the SMART questions raised.

- **SMART Question strand 1:** The short and intermediate–term outcomes and impacts are specific, measurable, and action-oriented.

Answer to SMART Question strand 1: The short and intermediate-term outcomes and impacts are specific and measurable because the innovation potential calculated by **InnoAct** represents the percentage of an organisation's efficiency and effectiveness towards innovation. The calculation is derived from the mathematical model, developed in Chapter 7, which is informed by the theory of change model (the conceptual model). The alternative scenarios proposed using the optimisation procedure are also measurable results. However, as stated earlier, the model does not test at this stage the implementation of an Action Plan. In order to test the results of an implemented Action Plan, a longitudinal study would be required. However, this is outside the timeframe of this study.

- **SMART Question strand 2:** This PLM shows different options on how to maximise an organisation's efficiency and effectiveness in order to increase an organisation's potential to innovate. What else might help or hinder from participants making progress toward improving innovation potential?

Answer to SMART Question strand 2: The research was designed to be able to address every factor that the literature suggests and was found to influence innovation potential. However, in the dynamic nature of the globalised, competitive and intense market environment there are new factors that will have the potential to influence the innovation process within organisations. The software application, **InnoAct,** is developed in such a way so as to be customisable. New factors can be added into the **InnoAct** according to the different context in which the PLM is applied.

- **SMART Question strand 3:** What level of budget is needed/ available to support the achievement of these outcomes? How long is reasonably expectable regarding the time that it will take to see progress toward these outcomes? How far away is the impact?

Answer to SMART Question strand 3: The budget, required to achieve the intended results, reflects the amount spent on applying all of the planned activities. However, the activity that refers to the implementation of the Action Plan needs to be evaluated separately by each organisation. This budget can be organisation specific, depending on the selected Action Plan and the size of the required intervention.

The short-term outcomes can be seen as soon as the self-evaluation tool is used. The application of the proposed activities is directly linked to increasing knowledge regarding efficiency and effectiveness. However, the decision on an appropriate Action Plan requires a self assessment of the capabilities of the organisation that can support the required transition. It is contended that the short-term outcomes can have a time frame of one to three years.

The application of any changes to strategies, as proposed by the Action Plan, might be categorised into two strands: the intermediate-term and the long-term outcomes. The intermediate-term outcomes describe the increase in efficiency. Increasing efficiency refers to the changes that focus on making the most out of what is already available. This implies that no immediate investment in new resources is required. However, it also implies that a change in the behaviour of an organisation must occur, and therefore it is contended that results from increasing efficiency can be achieved within a timeframe of four to six years.

In order to achieve a desired percentage of innovation potential an Action Plan must be applied. Since changes in organisational practice occur slowly, the final impact, which is the increase of the proportion of revenue, can occur in a longer timeframe of seven to ten years or more. It is recognised that the impact can differ depending upon the organisation. Organisational cultures or resources may vary, and the transformation process can be easier for some organisations than for others. The important issue is to let organisations conduct a self-evaluation activity and assess their innovation potential. This increases the awareness concerning the current status of innovation and assists the process of change.

The context, the FIT and the SMART questions that were addressed provided insight into the key components of the PLM and assisted in increasing the quality of the design. Further to the questions addressed above, other verification questions were addressed during the presentation of the PLM to other research community members.

10.2.4 Other verification questions

External reviewers can offer objective critiques, which can often uncover blind spots, identify weaknesses, flaws, leaps of faith, ambiguity and fiction. It is acknowledged that people may read the model differently to the creator. For that reason an external review was valued as offering a greater insight into improved model content (e.g. resources, activities, outputs) and relative display (Wyatt Knowlton and Phillips, 2009). The PLM was presented to research community members and subject experts during a workshop that was organised within the School of Engineering in the University of Leeds. A list of the participants and the minutes of the workshop are provided in Appendix E. During this workshop, there were no specific questions addressed by the researcher to the audience. The reason for that was that the researcher was seeking to understand the reactions of people to the PLM, and to offer an open space for discussion in any kind of issue. Some of the important questions raised during the workshop from the participants were:

- **Question O1:** ‘Do all of the factors carry the same weight?’ This question addressed whether innovation potential is measured correctly and therefore whether the PLM was built is right.

Answer to O2: There are two reasons that justify the decision to design all of the factors carry the same weight within the mathematical model. The first reason is based upon the principles of systems theory, which recognises that a small change in one discipline of an organisation may have a big impact and chained effects on many other disciplines of the organisation (see Section 2.2).

The second reason is that the process of weighting the factors would treat an organisation as being one case of a homogeneous sample. However, different factors may be of different importance within different organisations. This means that weighting of factors should be organisation-specific; this logic is encouraged by the recognition that one solution cannot fit all organisations - even if they are of the same type or have similar characteristics. Therefore, weighting is intentionally avoided in order to keep the individuality of an organisation. Adding to this discussion the developed PLM does not offer a solution as to which Action Plan should be employed by the organisation. The PLM offers the option of alternative Action Plans; it is up to the discretion of an organisation to decide which Action Plan is more appropriate, judged on their individual capabilities. Building upon the specific context that applies to each organisation, the PLM provides the base for evaluating an organisation's competences and resources, and assesses the capacity to move from a lower position of innovation potential to a higher position.

- **Question O2:** Do organisations need the same amount of effort to move from a lower percentage of innovation potential to a higher percentage of innovation potential? This question addresses the FIT principles, and intends to show if the PLM is built right.

Answer to O2: The reflection to question 2, is that the amount of effort required to make the transformation steps proposed by an Action Plan is based on the individual organisation. It might be that large organisations have the resources to, in less time, easily achieve the desired position, whereas smaller organisations might have to identify and invest in more resources to achieve that same position. The nature of the PLM does not capture the amount of effort required for a particular change. The PLM depicts the current position and provides the alternative options for action, offering a tool to assist the decision process of improving the innovation potential in an organisation. It is up to the organisation to decide whether it possesses the required resources to achieve the desired transformation, and therefore evaluate whether a transformation is appropriate.

- **Question O3:** Can the organisation reach to the same percentage of innovation potential by addressing fewer factors? This question refers to the context of the PLM and intends to show if the software application, **InnoAct** is built right.

Answer to O3: The reflection to this question is that the literature has shown that innovation is an integrated process involving all organisational disciplines, and is related to all of the interacting factors, contributing to the efficiency and effectiveness of an organisation (see Chapter 4). Thus, it is supported that the more factors that are addressed and the most favourable to innovation the conditions of those factors are, the more likely it is that innovation will emerge. However, organisations can reach the same innovation potential via totally different ‘routes’. This process is otherwise called ‘equifinality’. Equifinality is described as being a state that can be reached from different initial conditions and in different ways (Dekkers, 2005).

Overall, the workshop was very helpful in understanding the reaction of people to the PLM. The questions that were raised led to the decision to adopt an extended version of a PLM, including a separate column that explicitly names the assumptions related to the PLM. The inclusion of the assumptions in the graphical illustration (see Figure 9.2) provided a general understanding of the PLM’s overall purpose. The workshop also offered the opportunity to identify two members of staff that would like to participate in a one to one evaluation process. This process included a validation process and is described in the next section.

10.3 Validation of InnoGrowth

Validation was conducted to produce accountability and to increase the understanding of the assessed PLM. During validation, information was collected in order to demonstrate that the program could achieve its intended results. Although it is difficult to demonstrate the success of the program in achieving the long-term outcomes and impacts, the identification of the logical links between resources and activities that lead to the short-term and intermediate-term outcomes can be used to demonstrate the progress towards the long-term outcomes and the establishment of the theory of change.

The validation process of the PLM, **InnoGrowth,** included two phases. In phase one of validation, a one-to-one evaluation session was applied between the researcher and two members of the research community. Initially, a presentation of the PLM was given to provide the general concepts and ideas. Then, an interview was conducted in order to provide information on whether the intended results of the PLM can be achieved. The interview questions that were developed were designed to address the PLM's merit, need, feasibility, and significance, as defined in the definition of the evaluation in section 3.3.7 (Stufflebeam and Shinkfield, 2007).

The second phase of the validation included a one to one basis evaluation session that was applied between the researcher and a professional from the construction industry. Professionals from the industry were treated as potential users of the PLM and therefore their view on the PLM and its usefulness was important in the validation of the PLM. During the evaluation session, an introduction to the basic principles of the **InnoGrowth** model and an explanation of the sequence of activities and the expected outputs, outcomes and impact of the process was provided. Then, professionals had the opportunity to engage in the process of evaluation using the software and by calculating their innovation potential.

The process of identifying professionals of the industry to participate in the evaluation process was rather challenging. A network for leading and supporting construction companies was identified to have its offices in Leeds. The network is called: Construction Sector Network (Construction Sector Network, 2010). After communication with the manager, a poster that was created to advertise the evaluation process was uploaded on their website. The poster advertised a free evaluation session for calculating innovation potential of the organisations that would like to participate (see the poster in Appendix F). Unfortunately, this approach has not attracted the interest of the construction professionals. A second attempt to attract professionals of the construction industry was to contact the School's Industrial Advisory Committee and offer them a session for evaluating the innovation potential of their organisation. This approach has attracted two professionals of the construction industry. Structured interviews were arranged with the professionals who hold a managerial position in their organisation and are involved with the management of innovation. The structured interview involved the rating of basic principles addressing validation as shown in Table 10.1.

Table 10.1 illustrates the questions that were addressed during the interviews and presents the results of the four interviewees. The questions were seeking information about the PLM's merit, need, need assessment, significance, feasibility, and plausibility. Merit is defined as the evaluand (the object of evaluation process) does well on what it is supposed to do. Need is defined as something that is necessary or worthy for fulfilling a purspose. Need assessment is defined as a systematic assessment of the extent to which outcomes are met. Plausibility tests if the PLM is logical. Significance refers to potential important of mission, structure and outcomes. Feasibility refer to whether the PLM is possible to be implemented (Stufflebeam and Shinkfield, 2007).

Table 10.1 Validation results

Variables	**Respondent score on scale**[1]					**Comments**
	Low				**High**	
Questions	**1**	**2**	**3**	**4**	**5**	
Merit (implementation level)						
The PLM represents the purpose of providing alternative scenarios to assist the decision process for increasing an organisation's innovation potential?				(4)		
Need (implementation level)						
Is the PLM a useful tool for identifying the alternative options towards increasing innovation potential?				(4)		
Would you use the PLM to identify different options for increasing innovation potential in your organisation?			(1)	(3)		
Needs Assessment (implementation level)						
To what extent can the PLM increase knowledge of the organisation relating to				(4)		

[1] The respondent score on the scale are the score given by respondent to reflect to each question; the number of individuals who gave a particular score is given in brackets underneath the respective score.

efficiency and effectiveness towards innovation?						
To what extent can the PLM assist the organisation to increase efficiency and effectiveness towards innovation?			(1)	(3)		
Feasibility (outcome level)						
Are outcomes clear, specific and complete?				(4)		
Are activities and outcomes realistic given the resources?				(4)		
Significance (outcome level)						
Can the PLM influence the decision process of organisations in terms of actions taken to increase innovation potential?				(4)		
Outcomes are of significant benefit?				(4)		
Plausibility (context level)						
Are the relationships causally connected?				(4)		
Is there anything missing (what else?)?			(1)	(3)		Risk
Are all assumptions valid?				(4)		Specific to individual

Clearly, the validation process did not indicate any serious perceptions of inconsistency or incompleteness among the respondents. The few suggestions on the plausibility in terms of anything missing and the validity of the assumptions can be attributed to the capacity of each organisation to assess the alternative options offered and the person who is interviewed. The suggested modifications are tactical rather than ideological; they therefore do not suggest that any changes in the **InnoGrowth** are necessary. The results of the validation process in combination with the results of the verification of the **InnoAct** suggest that the **InnoGrowth** was built right.

The validation process did not include an examination of the extent to which an increase in the proportion of revenues associated with innovation can be achieved, as this is outside of the timeframe of the research. Validation focused on short and intermediate-term outcomes, as these items were more closely connected with the programme logic model itself in increasing innovation potential, which could in turn increase the proportion of revenues associated with innovation.

It is also important to note how the outcomes meet the SMART criteria. The outcomes as addressed in the PLM were designed to be specific in that they name what can be measured; they were action-oriented and realistic by pointing to attributes that demonstrated the accomplishments that could occur. They were timed in that they showed the order of occurrence.

10.4 New understanding and enlightenment as a rResult of the evaluation

The third main purpose of evaluation is to foster enlightenment, that is, new understanding and new insights. Both the verification and the validation processes provided useful insights. The design of the evaluation process itself has led to refinement of the **InnoGrowth.** The implementation of the PLM would provide further information but this was not possible within the timeframe of this research. However, the evaluation process of the **InnoGrowth** has demonstrated that the PLM is a useful tool that could be used for generating the expected results that is growth through innovation.

An important question that addresses the fourth main purpose of the evaluation is whether there are different ways innovation management can or should be addressed (Wyatt Knowlton and Phillips, 2009). The different ways innovation management needs to, can be or should be addressed is a topic that can lead to endless discussion. Innovation has already been seen and researched through various forms (product, process or service), it has been approached in different ways (technology push, market pull, incremental, radical) and has been modelled variously. It is clear that innovation can be researched and explained using multiple approaches. The PLM presents a generic process for managing innovation. Multiple factors and the condition of those factors are forming the mechanism of innovation and can explain why innovation is more likely to occur in some organisations and not in others. The extent to which organisations make the most of what they already posses, represents its efficiency towards innovation. Parallel to that, increasing effectiveness through changing practices requires a transition phase, which also requires appropriate organisational capabilities in order to be able to change. Previous research in innovation management has revealed that innovation can often emerge as an event of luck.

Innovation can be spontaneous and, according to Bessant and Tidd (2007), the best thing to hope for is to spot its early emergence and develop an analogous response towards it. By all means, innovation is something new. If spotting new opportunities requires the existing companies to reinvent themselves and allow at least part of the business to behave as a start-up (Bessant and Tidd, 2007) then this has to do with the ability to manage innovation. This can, therefore, be related to the contextual characteristics of an organisation's environment, its ability to make the most out of what is practiced using the resources that are available, and its ability to change and adapt in order to manage the new challenges. The PLM, **InnoGrowth** that was developed has provided a useful tool to facilitate increase in innovation potential that can eventually lead to growth.

10.5 Summary

The evaluation issues of the **InnoGrowth** were discussed in this chapter. The **InnoGrowth** was tested using both verification and validation techniques. The **InnoGrowth** was tested in the construction industry and the results were very encouraging. The testing also offered new understanding and enlightenment relating to how efficiency and effectiveness towards innovation can be managed but also on how innovation management could otherwise be addressed.

CHAPTER 11: CONCLUSIONS AND RECOMMENDATIONS

The purpose of this chapter is to provide an overview of how the objectives of the research were accomplished, and to present recommendations for future work. Specifically, this chapter focuses on:

- Providing a step-by-step overview on why and how this research was undertaken;
- Describing the key issues on how each of the seven objectives of the research were accomplished; and
- Outlining the key areas for enriching this work or applying the concepts of the work to other key areas.

11.1 Overview of the research

Innovation has been ranked as being one of the key sources for organisational competitiveness for many years now. However, deficiencies still remain in the conceptualisation of innovation. The focus in this research was to describe the mechanism of innovation using a holistic approach, and to develop a program for managing innovation in the construction industry.

The conceptual model that was developed attempted to move from partially capturing innovation to encapsulating its multidimensionality. It took into account that innovation can be distributed across many actors, has socioeconomic and political influences, and is affected by practices in each organisational discipline. The conceptual model was based on the realist philosophical approach and innovation is seen as resulting from a mechanism. This mechanism is powered by factors that facilitate innovation, and by the particular conditions that apply to each factor, which explains the causality of innovation. The model was built on heuristic concepts of systems theory, diffusion theory and strategic management theory.

The research presented in this thesis was undertaken to investigate how innovation can be holistically managed. This was illustrated with the conceptual model, and was achieved by capturing as many of the contributing factors as the extant literature suggests. It also captured the condition of these factors, facilitating at the same time the examination of particular contexts within which innovation can flourish.

The factors included in the conceptual model were identified using grounded theory techniques, and covered the internal organisational context, the strategic resources, and the wider external environment of the organisation.

The conditions of the factors were identified by developing a system of attitude scales, which reflect practices that were to a greater or lesser extent favourable to innovation. Each scale was designed to measure an underlying dimension that was found to contribute to innovation. All the factors that were identified, and the system that was developed to identify the condition of the factors, described the generic holistic model of innovation.

The pertaining current practices relevant to each factor were identified, conducting a survey in the construction industry in the UK. The exploration of the survey data facilitated the understanding of the patterns of association between the items that were measured.

The extent to which factors were perceived as contributing to innovation and as pertaining to the conditions of the practices employed were translated into efficiency and effectiveness towards increasing innovation potential. The two entities were described mathematically using vector theory principles. The mathematical model that was developed encapsulated the multidimensionality of the factors which contribute to innovation, and accounted for the pertaining conditions by measuring efficiency and effectiveness and by calculating the innovation potential of organisations.

A computer application, **InnoAct,** was developed to facilitate the manipulation of the mathematical formulas. It also offered alternative scenarios of Action Plans relating to increasing innovation potential in organisations. The alternative scenarios of Action Plans were produced using a genetic algorithm for optimisation problems.

The computer application was integrated into a program logic model, **InnoGrowth,** developed to describe the action organisations need to undertake in order to facilitate self-audit activities. This self-audit activity can help organisations to recognise suboptimal practice and offer alternative options for transformation towards more effective and efficient innovation, and thus better management of innovation.

The program logic model was taken through verification and validation with members of the academic community and professionals from the construction industry in the UK. The results of the exercises indicated that the proposed program logic model is a complete and consistent tool, which can improve the management of innovation in the construction industry.

The research was undertaken with specific and clear objectives. The achievements of the overall aim of the research could be assessed on the achievement of each objective. Continuous auditing and confirmation of progress was carried out throughout the research. The systematic nature of the work that was undertaken ensured the robustness of the research process.

11.2 Conclusions

It is contended that the outcome of this research contributes to the knowledge for managing innovation. This contribution is demonstrated with details throughout this thesis from Chapter 1 to Chapter 10. The conclusions that follow reflect each objective of this research:

- A generic holistic model of innovation;
- A generic system for depicting innovation practice and for describing the condition of factors playing a key role to innovation for the development of the generic mechanism of innovation in the construction industry in the UK;
- Identification of the innovation practice in the construction industry in the UK and the development of the specific mechanism of innovation for the construction industry in the UK;
- Development of a mathematical model to describe the generic mechanism of innovation;
- Development of a generic systematic procedure for managing the innovation mechanism in the construction industry in the UK;
- Development of a program logic model for facilitating the management of innovation;
- Evaluation of the program logic model; and

- Overall remarks

11.2.1 A generic holistic model of innovation

Grounded theory techniques were used to identify the factors that play an important role in innovation. Forty one factors were revealed, via, an extensive extant text analysis and coding of the emergent categories. The factors that were identified were categorised into three key areas of focus: the internal environment, the strategic resources, and the external environment of an organisation. The identified factors were not tenuous, and they were very well described and justified in the literature for their contributions to innovation. However, the literature research showed that the study of the factors was rather sporadic. It focused on either only one of the factors, or groups of factors, were studied together within the scope of their contribution to innovation. The approach of studying all the factors that were found to contribute to propagation of innovation together represented a holistic approach, considered to be unique. This holistic approach is adding to the knowledge of looking into the area of innovation management in a way that has not previously been done by providing the holistic model of innovation.

11.2.2 A generic system for depicting innovation practice in the construction industry in the UK

The mechanism of innovation is described as being powered by all of the factors that contribute to innovation and by the condition of each factor, as demonstrated in the conceptual model (see Chapter 3). Two types of measurement were obtained to describe this mechanism. The two types of measurements were linked to the attitude components of an organisation. The first type of measurement reflects the extent to which each factor identified is considered, by the professionals in the industry, to contribute to the propagation of innovation. This first type of measurement is linked with the cognitive component of an organisation's attitude. The second type of measurement reflects the condition of the factors that was reflected by the practices that were employed. This second type of measurement is linked to the behavioural component of an organisation's attitude.

It is the first time that innovation, which is very often cited as being a process that is impacted by and impacts upon other business processes, is conceived as being an attitude. It is also the first time that this attitude is systematically studied by combining the two components of attitude into one mechanism, explaining the causality of innovation. The disadvantage of seeing innovation strictly as a process disregards the fact that the process of innovation is also powered by the beliefs of people. These beliefs are related with whether people who are managing innovation are regarding factors found to be contributing to innovation, as important. Beliefs have a direct influence on the decisions that are taken to manage the innovation process. The approach of studying the innovation mechanism in such a systematic way provides a synthesis that has not been made before and contributes to the knowledge of understanding innovation better and managing it more effectively.

Different scales were constructed in order to identify the condition of the factors that could be linked with the behavioural component of an organisation's attitude. The scales were designed to measure an underlying dimension as described in Chapter 5. The construction of the scales involved an intensive literature research, in order to justify the order of the different conditions that measure each underlying dimension. The different scales that were constructed represent a system that provides, for the first time, a clear picture on which conditions are more or less favourable to innovation, for a total of forty one factors.

The two components that describe the attitude of the organisation towards innovation were used for the first time in such a novel way in order to describe the generic mechanism of innovation for the construction industry in the UK. Such a description is considered to be unique.

11.2.3 Innovation practice in the construction industry

A common scale was constructed to identify the extent to which factors are perceived as being important by professionals, and this was linked with the cognitive component of the organisation's attitude. This scale was a 5-point Likert scale (0-4) having as the two extremes 'Not at all' and 'Great' to denote the extent to which each factor contributes to the propagation of innovation. This measurement scale, coupled with the system for identifying the condition of the factors as explained in Chapter 5, was used within a survey carried out in the construction industry in the UK. From the data collected on the two types of measurement, the specific mechanism of innovation in the construction industry in the UK was described. This mechanism provided a clear description, for the first time, of how and why innovation in the construction industry in the UK occurs.

11.2.4 A mathematical model describing the generic mechanism of innovation

The two types of measurement for each factor resulted in 82 measured items. When addressing the large number of items there are two main strategies available. The first strategy is to reduce the number of factors by either discarding the factors found to have lower importance, or by grouping the factors into higher level factors (Tutesigensi, 1999). This first strategy was not suitable for this research as this would contradict with the general principles of systems theory, which indicates that a small change can have a large impact on the innovation process. In addition, the forty one factors that were identified were significantly important to the items that measured the extent to which the factors contributed to the propagation of innovation. Therefore, reducing the factors would result in loss of detail and in a reduction of sensitivity. The second strategy is to keep all the factors that were identified in the holistic model of innovation, but ensuring that they are treated in a manner that does not compromise validity (Tutesigensi, 1999). For the purposes of this research, it was considered that the second strategy was less compromising than the first. As such, all of the factors were kept for the modelling process, but careful consideration was given to how these factors were treated and how the results were interpreted. It is therefore important to note that the results are subject to the context within which the innovation mechanism is applied.

The principles of the Multi-Attribute-Utility Theory (MAUT) and the vector theory provided the basis for developing a mathematical description of the mechanism of innovation. According to the Simple Additive Weighting (SAW) method, which is very frequently used in MAUT, the two types of measurement obtained for the forty one factors were converted to normalised scales in order to be aggregated. Although, the SAW method weights the different factors, this was not followed in this case. Although, weighting the factors would show which factors were (according to this study) more important to an organisation's innovation potential, these weights would be the result of treating all organisations as being the same, which would not represent reality. As such, weighting the factors according to their importance would result in compromising the individuality of the organisation, as within different organisations different factors might be more important to innovation, according to their specific competences. The equal weighting of the factors implies that all the factors are of equal importance. Although it can be argued that this is not the case for all the factors, waiting the factors would compromise the systems theory principles, highlighting the importance of some factors whilst underestimating the importance or the impact of less important factors. This would have also resulted in reduced sensitivity. The approach for non-weighting the factors were less compromising than the alternative. A mathematical model was developed using the principles of vector theory. The model calculated the innovation potential of an organisation, combining the behavioural and cognitive components of the organisational attitude towards innovation.

This is the first time that a model for studying innovation has taken into account the individuality of an organisation, which supports the notion that one solution does not fit all. The mathematical model that was developed accounts for the possible effects that the factors contributing to innovation might have, leaving out the items which, according to the data, are not associated with the proportion of revenues. As these items may change depending on the context in which the mechanism is applied, the mathematical model was designed to incorporate a mechanism for either including or excluding the non-associated items in the calculations of the innovation potential.

11.2.5 A system for managing the mechanism of innovation

The usability and the operationalisation of the mathematical formulas that were developed would be maximised if an effective system was developed, one that could carry out all of the necessary calculations. The **InnoAct** application was developed to facilitate the calculation of an organisation's innovation potential. The **InnoAct** offered the option to produce a variety of alternative scenarios of Action Plans that could then be evaluated by organisations and could form the basis for the transition process towards increased innovation potential.

The alternative scenarios of Action Plans could be produced in two ways. The first way is to manually alter the initial scores that are inputted when calculating the innovation potential for the first time until they reach a desired percentage value of innovation potential. These manual alterations should be according to the changes of what an individual organisation is willing to implement. The second way is to provide the software with a desired percentage value of innovation potential, one that is higher than the one that was calculated with the initial input values. The **InnoAct** is then calculating alternative scenarios of different Action Plans using an optimisation routine. The optimisation routine allows the organisation to select which items can be optimised, or which ones should be held constant according to the organisation-specific requirements. The **InnoAct** also allows for the introduction of new factors into the model. These new factors might be applicable to the specific organisation, or to the specific context in which the model is applied.

The **InnoAct** enhances the usability of the mathematical model and offers a useful tool to assist with the decision-making process of incorporating appropriate changes so as to increase innovation potential. The design of the system is caring for the individuality of organisations and the research towards that end contributes to knowledge by understanding innovation through focusing on construction organisations as the unit of analysis. The **InnoAct** allows for personalisation of the model depending upon which changes are appropriate and valid for a specific organisation. The use of the **InnoAct** can lead to better decisions, and to a higher level of systematic control of performance in managing innovation. Moreover it is the first time that a software is constructed to assist the evaluation of the innovation potential of organisations. As such it can be offered for wide usage and can assist the evolution of managing innovation in a more systematic way.

11.2.6 A Program Logic Model for facilitating the management of innovation in the construction industry

Organisations can benefit from the software application, **InnoAct,** and can produce alternative scenarios of Action Plans, which can assist the management of innovation. In order to offer a complete and useful tool for facilitating the management of innovation, a systematic procedure was designed to explain the step by step actions. A program logic model (PLM), the **InnoGrowth,** was developed. The **InnoGrowth** explains the step-by-step process for measuring an organisation's innovation potential. It incorporates the **InnoAct** which can be customised according to the context in which the **InnoGrowth** is employed. It also demonstrates the benefits for an organisation by its use.

The PLM, **InnoGrowth,** is a useful tool for managing innovation. The **InnoGrowth** increases an organisation's knowledge relating to the management of efficiency and effectiveness with regard to the organisation's innovation potential. It provides the methods and the techniques for customisation, and describes the outcomes and the impacts of taking appropriate initiatives. **InnoGrowth** is designed to act as a complementary tool in the decision process of managing innovation by facilitating the evaluation of innovation potential. Such a tool is constructed for the first time.

11.2.7 Evaluation of the Program Logic Model

The PLM, **InnoGrowth** was tested to identify whether it was built right. SMART and FIT principles were applied in order to test the quality of the **InnoGrowth.** Addressing the questions raised through the formative evaluation and reflecting on the questions raised during the workshop has helped to refine the PLM.

The usefulness of the PLM, **InnoGrowth**, was demonstrated by members of the academic community and professionals from the construction industry. The PLM was evaluated as being of significant importance in assisting the decision making process in assisting innovation management and in indicating the alternative options an organisation has in order to increase its innovation potential.

The PLM provides a novel way of managing the process of innovation, it makes a positive contribution to construction organisations when facing globalised competition, and it assists their growth and proliferation. **InnoGrowth** analyses the innovation potential of organisations, and can be used to alert managers, directors and policy makers of their need to take appropriate actions to increase efficiency and effectiveness towards innovation, and to enhance business success and economic growth.

11.2.8 Overall remarks

It is contended that the objectives that were initially set for this research were achieved. The successful achievement of the objectives of this research contributes to the knowledge relating to the management of innovation in the construction industry. It also provides a wider framework for managing innovation in different contexts, such as in different countries or different industries.

The following represents the issues that can be addressed with the use of the outcomes of this research:

- A holistic model of innovation in the construction industry has not been developed until now;
- A system that can identify the condition of the factors that play a key role in innovation has not been developed until now;
- The mechanism of innovation in the construction industry has not been studied before, using such a holistic approach;
- A system for managing the mechanism of innovation has not been developed before; and
- A program logic model that describes the activities for customising the system for managing innovation and assist the decision making process of the transition process towards increasing innovation potential has not been developed before.

The results of this research and their use in different contexts are demonstrated below:

- A holistic model of innovation now exists; this model represents a major development in the management of innovation. The holistic model of innovation can be used as a useful tool from innovation training providers to design academic modules, continuous professional development sessions and business training sessions in a structured and a holistic way. The holistic model of innovation provides the opportunity to apply future research, for enriching the holistic model with more factors that will be found to contribute to innovation. Moreover, further research can be applied to examine and compare the application of the holistic model of innovation within the context of different industries or different countries, which was not previously possible.

- A system that can be used to identify the condition of the factors that play a key role in innovation is now available. This system can be used by future researches to monitor the condition of the factors that contribute to innovation. Such studies were not possible before. Moreover the methodologies used during this research for developing this system can be replicated to enrich the system with more factors and their conditions.
- The generic holistic model of innovation and the conceptual model developed in this study resulted in the explicit description of the innovation mechanism. This mechanism can be applied by future researchers within the context of different industries or different countries to identify the innovation mechanism of a specific industry or a country and monitor or compare them. Such studies were not possible until now.
- The mechanism of innovation in the construction industry can now be studied and monitored by researchers on a consecutive basis, in a holistic way, as described within this research. Such monitoring could increase knowledge relating to how the mechanism of innovation in the construction industry can change or evolve. Such studies could not be carried out before.
- A system, the **InnoAct,** for managing the mechanism of innovation now exists. The system is designed in order to be used in different contexts, allowing for the insertion of new factors. The system also provides the opportunity to be applied and customised according to the specific needs of the organisation using it. Such a system, which can facilitate the monitoring of the innovation mechanism for each organisation, and can be customised to be used in different contexts, now exists for the first time and can be used to facilitate monitoring of the innovation mechanism in the construction industry in the UK
- A detailed and generic systematic procedure for facilitating the management of innovation now exists due to the development of the program logic model, **InnoGrowth.** Such a systematic procedure can be used by future researchers as a blueprint for studying the management of innovation more effectively. **InnoGrowth** is a visual and narrative explanation of the step-by-step activities needs for managing the innovation process more effectively. Experience of the actual use of the procedure proposed from **InnoGrowth** can enlighten the

process of innovation from lessons learnt during the implementation stage, and offer useful insights for improvement. **InnoGrowth** can also be used to inform policy makers and Construction Industry Councils in designing intervention initiatives that shall provide external environmental conditions that favour organisations' potential to innovate. It can also be used from managers to design and maintain an environment that can increase the organisation's potential to innovate by increasing its effectiveness and efficiency.

The issues that are raised above, describing the pre-research issues and the post-research achievements, demonstrate the fundamental contribution of this research to knowledge and to the future research agendas.

11.3 Recommendations for future research

All of the seven research objectives were successfully achieved. However, there were issues that could not be handled, given the time frame allowed for the completion of the research for the award of the degree of a PhD. Those issues were recognised during the research and are put forward as recommendations for future work. Those issues are addressed below:

- **More investigation into the factors that influence innovation**

  It is contended that the factors identified as playing a key role in innovation during this research represent the totality of the factors that can influence innovation. However, according to the relativist approach that was adopted for this research, it could be that those factors differ depending on time and context. Furthermore, innovation is seen to be a complex, context sensitive, social and organisational process, and it is therefore doubtful if there is one best theory that can explain successful innovation processes within any organisation (Hamel and Prahalad, 1996). Future researchers might be interested in enriching the factors that have been studied, and in using the methodologies that were used in this research to calculate innovation potential.

- **More testing on the InnoGrowth model**

  While the **InnoGrowth** model was evaluated in the construction industry and the results were encouraging, those results can only be treated as initial results. Future researchers might be interested in testing the **InnoGrowth,** so as to demonstrate stronger supporting evidence. Future researchers interested in testing further the **InnoGrowth** would need to apply it within construction firms by using longitudinal research designs, in order to ascertain its effectiveness.

- **Future research on identifying a suitable Action Plan**

  The implementation of **InnoGrowth** provides alternative scenarios for Action Plans, and acts as a complementary tool in assisting the decision-making process for managing innovation more effectively. Future researchers might be interested in continuing to the next stage of the decision support system, and identifying which Action Plan is appropriate, according to the specific characteristics of an organisation.

- **Carrying out similar studies in other industries**

  Innovation is a necessary process, which applies to any sector or industry. Managing innovation is one of the high priority strategic issues for organisations at a global level. Therefore, similar studies could be undertaken in different industries in order to increase the effectiveness of managing innovation.

- **Developing a Help System for InnoAct**

  A Help System that would guide the user and offer quick references has not been developed for **InnoAct** due to time limitations. Future work is recommended to evolve the application of the software by including a Help System.

11.4 Summary

This chapter overviewed how each of the objectives that were decided upon in the beginning of this research was successfully achieved. It demonstrated the fundamental contributions of this research to knowledge and explained the suggestions for the future recommended work.

12. REFERENCES

ACS, Z. 2002. *Innovation and the growth of cities.* Cheltenham: Edward Elgar.

ADAIR, J. 2007. *Leadership for Innovation. How to organise team creativity and harvest ideas.* London: Kogan Page

AHN, S. 2002. Competition, Innovation and Productivity Growth: A Review of Theory and Evidence. *IN: OECD Economics Department Working Papers*, OECD Publishing.

ALRECK, P.L. and R.B. SETTLE. 2004. *The survey research handbook.* New York: MacGraw-Hill.

AMABLE, B.; R. BARRÉ and R. BOYER. 1997. *Les Systhèmes d'Innovation à l'Ere de la Globalisation.* Paris: Economica.

ANDERSEN, B. 2005. *Intellectual property rights. Innovation, governance, and the institutional environment.* Cheltenham: Edward Elgar.

ANDERSON, F. and A. MANSEU. 1999. A systemic approach to generation/ transmission/ use of innovation in construction activities. *IN: Third International Conference on Technology Policy and Innovation: Global Knowledge Partnership - Creating Value for the 21st Century*.

ANON. 2004. *Handling Missing or incomplete data* [online]. [Accessed March 25]. Available from World Wide Web: <Information Technology Services Web Site http://www.utexas.edu/its/rc/answers/general/gen25.hthttp://www.utexas.edu/its/rc/answers/general/gen25.html>

ANTA. 2002. *Innovation Ideas that work.* Brisbane: Australian National Training Authority.

ANTONAKIS, J.; A.T. CIANCIOLO and R.J. STERNBERG. 2004. *The nature of leadership.* Thousand Oaks: Sage Publications.

ARAGON-CORREA, J.A.; V.J. GARCIA-MORALES and E. CORDON-POZO. 2005. Leadership and organizational learning's role on innovation and performance: Lessons from Spain. *Industrial Marketing Management*.

ARAGÓN-CORREA, J.A.; V.J. GARCÍA-MORALES and E. CORDÓN-POZO. 2005. Leadership and organizational learning's role on innovation and performance: Lessons from Spain. *Industrial Marketing Management*.

ARIAS-ARANDA, D.; B. MINGUELA-RATA and A. RODRÍGUEZ-DUARTE. 2001. Innovation and firm size: an empirical study for Spanish engineering consulting companies. *European Journal of Innovation Management,* **4** (3), pp.133-142.

ARITUA, B.; N.J. SMITH and D. BOWER. 2009. Construction client multi-projects - A complex adaptive systems perspective. *International Journal of Project Management*, **27** (1), pp.72-79.

ARMBRUSTER, H.; A. BIKFALVI; S. KINKEL and G. LAY. 2008. Organizational innovation: The challenge of measuring non-technical innovation in large-scale surveys. *Technovation,* **28** (10), pp.644-657.

ASHEIM, B.T. and L. COENEN. 2005. Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy,* **34** (8), pp.1173-1190.

ASHWORTH, A. 2006. *Contractual procedures in the construction industry.* 5th ed. Harlow: Pearson/Prentice Hall.

ASKARANY, D., ed. 2005. *Diffusion of innovations in organizations.* Hershey, PA: IDEA Group Publishing.

ASKARANY, D. and M. SMITH. 2008. Diffusion of innovation and business size: a longitudinal study of PACIA. *Managerial Auditing Journal,* **23** (9), pp.900-916.

AUDRETSCH, D.B. and M.P. FELDMAN. 1996. R&D Spillovers and the Geography of Innovation and Production. *The American Economic Review,* **86** (3), pp.630-640.

BABBIE, E.R. 2007. *The practice of social research.* 11th ed. Belmont: Thomson.

BARLOW, J.; M. COHEN; A. JASHAPARA and Y. SIMPSON. 1997. *Towards Positive Partnering.* Bristol: The Policy Press.

BARNEY, J.; M. WRIGHT; J. KETCHEN and J. DAVID. 2001. The resource-based view of the firm: Ten years after 1991. *Journal of Management,* **27**, pp.625–641.

BARNEY, J.B. and D.N. CLARK. 2007. *Resource-based theory: creating and sustaining competitive advantage.* Oxford: Oxford University Press.

BASS, B.M. and B.J. AVOLIO. 1994. *Improving organizational effectiveness through transformational leadership.* SAGE.

BATESTONE, G. 1972. *Steps to an Ecology of the Mind.* New York, NY.: Ballantine.

BERENTE, N.; B. VANDENBOSCH and B. AUBERT. 2009. Information flows and business process integration. *Business Process Management Journal,* **15** (1), pp.119 - 141.

BERGER, A. and G. UDELL. 1998. The economics of small business finance: The roles of private equity and debt markets in the financial growth cycle. *Journal of Banking and Finance,* **22** (6-8), pp.613-673.

BERNROIDER, E.W.N. and E.W.N. BERNROIDER. 2005. Characteristics of the Multiple Attribute Decision Making Methodology in Enterprise Resource Planning Software Decisions. *Communications of the IIMA,* **5** (1), pp.49-58.

BESSANT, J. and J. TIDD. 2007. *Innovation and Entrepreneurship.* Chichester: Wiley.

BETTLEY, A.; D. MAYLE and T. TANTOUSH, eds. 2005. *Operations management. A strategic approach.* London: SAGE.

BEYERLEIN, M.; S. BEYRLEIN and F. KENNEDY, eds. 2006. *Innovation through collabration.* Oxford: Esevier.

BICKMAN, L. and D.J. ROG. 1997. *Handbook of applied social research methods.* Thousand Oaks, Calif: SAGE.

BRATTON, J. and J. GOLD. 1999. *Human Resource Management: Theory and Practice.* London: McMillan.

BRENKERT, G. 1991. *Political freedom.* London: Routledge.

BRENNAN, A. and L. DOOLEY. 2004. Networked creativity: a structured management framework for stimulating innovation. *Technovation*.

BROWN, S. 2000. *Manufacturing the Future—Strategic Resonance for Enlightened Manufacturing.* London: Financial Times/Pearson Books.

BROWN, S.; R. LAMMING; J. BESSANT and P. JONES. 2000. *Strategic operations management.* Oxford: Butterworth-Heinneman.

BROWN, S. and H. MAYLOR. 2005. Strategic resonant firms, mass producers, big fish & flat liners: a study of policies, practices & performance in innovation.
. *Technovation,* **25** (4), pp.307-319.

BRYANT, A. and K. CHARMAZ. 2007. *The Sage handbook of grounded theory.* Los Angeles: Sage.

BRYMAN, A. and E. BELL. 2007. *Business research methods.* New York: Oxford University Press.

BUCHANAN, D. and A. HUCZYNSKI. 2004. *Organizational behaviour.* 5th ed. Pearson Education, Financial Times, Prentice Hall.

BUSINESS DICTIONARY. 2010a. *Capital Structure*. WebFinance.

BUSINESS DICTIONARY. 2010b. *Sales management*. WebFinance.

CARASSUS, J. 2004. *Construction sector system, innovation and services.* Canada: Conseil International du Batiment.

CARASSUS, J. 2005. Public Private Partership: A service innovation. The treasury building case. *IN: Conseil International du Bâtiment, Helsinki.*

CARBONELL, P. and A.I. RODRNGUEZ-ESCUDERO. 2009. Relationships among team's organizational context, innovation speed, and technological uncertainty: An empirical analysis. *Journal of Engineering and Technology Management,* **26** (1-2), pp.28-45.

CARNEIRO, A. 2008. When leadership means more innovation and development. *Business Strategy* **9**(4), pp.176-184.

CARRILLO, P. and C. ANUMBA. 2002. Knowledge Management in the AEC Sector: an Exploration of the Mergers and Acquisitions Context. *Knowledge and Process Management,* **9** (3), pp.149–161.

CHAN, A.; D. CHAN and K. HO. 2003. An empirical study of the benefits of construction partnering in Hong Kong. *Construction Management and Economics,* **21** (5), pp.523–33.

CHANDLER, P. 2003. *Waud's employment law: the practical guide for human resource managers.* 14th ed. London: Kogan Page.

CHANG, S.-C. and M.-S. LEE. 2008. The linkage between knowledge accumulation capability and organizational innovation. *Journal of knowledge management,* **12** (1), pp.3-20.

CHARMAZ, K. 2007. *Constructing grounded theory a practical guide through qualitative analysis.* Los Angeles, Calif.: Sage.

CHAUFFOUR, J.-P. 2009. *The power of freedom: uniting human rights and development.* Washington: Cato Institute.

CHRISTOU, R. 2005. *Boilerplate: practical clauses.* London: Thompson.

CHURCH, A.H. 1993. Estimating the effects of incentives on mail survey response rates: A meta-analysis. *Public Opinion Quarterly,* **57** (1), pp.62-79.

CIOB. 2008. *Skills Shortages in the UK construction industry.* Ascot: CIOB.

CIVIL ENGINEERING RESEARCH FOUNDATION. 1993. *A Nation-wide Survey of Civil Engineering-related R&D.* Washington, USA.

COHEN, W.M. and D.A. LEVINTHAL. 1990. Absorptive capacity: A new percpective on learning and innovation. *Administrative Science Quarterly,* **35**, pp.128-152.

COLLINS, L.M.; J.L. SCHAFER and C.M. KAM. 2001. A comparison of inclusive and restrictive strategies in modern missing data procedures. *Psychological Methods,* **6** (4), pp.330-351.

CONSTRUCTION RESEARCH AND INNOVATION STRATEGY PANEL. 1997. *Creating climate of innovation in construction.* London, UK, draft working document.

CONSTRUCTION SECTOR NETWORK. 2010. *Construction Sector Network, Yorkshire and the Hamber* [online]. [Accessed 01 June]. Available from World Wide Web: <http://www.constructionsectornetwork.org/opportunities/innovation/20904>

CRESWELL, J.W. 2003. *Research design : qualitative, quantitative, and mixed methods approaches.* Thousand Oaks, California: Sage.

CROSS, R.L. and S.B. ISRAELIT. 2000. Strategic learning in a knowledge economy: Individual, collective and organizational learning process. Butterworth-Heinemann, CROSTHWAITE, D. 2000. The global construction market: a cross-sectional analysis. *Construction Management and Economics*, **18** (5), pp.619 - 627.

DAFT, R.L. 1983. *Organisation theory and design.* St. Paul: West Publishing.

DAHLANDER, L. and D.M. GANN. 2010. How open is innovation? *Research Policy,* **39** (6), pp.699-709.

DAINTY, A.; S. GREEN and B. BAGILHOLE. 2007. *People & Culture in Construction.* Oxon: Taylor and Francis.

DALE, J. 2007. *Innovation in Construction: Ideas are the currency of the future*. CIOB.

DAMANPOUR, F. and S. GOPALAKRISHNAN. 1998. Theories of organisational structure and innovation adoption: the role of environmental change. *Journal of Engineering and Technology Management,* **15**, pp.1-24.

DAVENPORT, T.H. 1998. Putting the enterprise into the enterprise system. *Harvard Business Review,* **76** (4), pp.121–131.

DAVID SKYRME & ASSOCIATES. 2002. *Insights: The learning organization* [online]. [Accessed 23 April]. Available from World Wide Web: <http://www.skyrme.com/insights/index.htm >

DAY, J.D., MANG, P., RICHTER, A. AND ROBERTS, J. 2001. The innovative organization: why new ventures need more than a room of their own. *The McKinsey Quarterly*, **2**, pp.21-31.

DE VAUS, D.A. 2002. *Surveys in social research.* 5th ed. London: Routledge.

DE WIT, B. and R. MEYER. 2004. *Strategy: Process, Content, Context.* Italy: Thomson.

DEBELLE, G.; P. MASSON; M. SAVASTANO and S. SHARMA. 1998. *Inflation Targeting as a Framework for Monetary Policy*. *Economic Issues.* International Monetary Fund.

DEKKERS, R. 2005. *Evolution: organizations and the dynamics of the environment.* New York: Springer Science + Business Media.

DEPARTMENT FOR BUSINESS INNOVATION & SKILLS. 2009. *The Future of EU Competitiveness: From Economic Recovery to Sustainable Growth.* Crown.

DEPARTMENT FOR ENVIRONMENT FOOD AND RURAL AFFAIRS. 2008. *Sustainable Develeopment*.

DEPARTMENT OF INNOVATION UNIVERSITIES & SKILLS. 2008. *Innovation Nation*. *In:* DEPARTMENT OF INNOVATION UNIVERISTIES & SKILLS, ed.: Crown.

DTI. 2003. *Competing in the global economy: The innovation challenge.* HMSO, London: Department of Trade and Industry

DUBRIN, A. 2010. *Leadership: research findings, practice and skills.* Mason: Cengage Learning.

DWIVEDI, D.N. 2005. *Macroeconomics: theory and policy.* 2nd ed. Delhi: McGraw HIll.

DYM, C.L. 2004. *Principles of Mathematical Modeling.* London: Elsevier Inc.

EDQUIST, C.; L. HOMMEN; B. JOHNSON; T. LEMOLA; F. MALERBA; T. REISS and K. SMITH, eds. 1998. *The ISE Policy Statement: The Innovation Policy Implications of the 'Innovation Systems and European Integration (ISE) Research Project'.* Linköping: Linköping University.

EGAN, J. 1998. *Rethinking Construction.* London: Construction Task Force.

EGBU, C. 2005. Knowledge management as a driver for innovation. *In:* ANUMBA, C., C. EGBU and C. PATRICIA, eds. *Knowledge management in construction.* Oxford: Blackwell, EGBU, C.O. 2004. Managing knowledge and intellectual capital for improved organizational innovations in the construction industry: an examination of critical success factors. *Engineering, Construction and Architectural Management*, **11** (5), pp.301–315.

ENDERS, C.K. 2004. The impact of missing data on sample reliability estimates: Implications for reliability reporting practices. *Education and Psycological Measurement*, **64** (3), pp.419-436.

ENDERS, C.K. 2010. *Applied Missing Data Analysis.* New York: The Guildford Press.

ENGEL, J.S. and I. DEL-PALACIO. 2009. Global networks of clusters of innovation: Accelerating the innovation process. *Business Horizons*, **52** (5), pp.493-503.

ERIKSSON, P.E. and O. PESÄMAA. 2007. Modelling procurement effects on cooperation. *Construction Management and Economics*, **25** (8), pp.893 - 901.

ERLIKH, L. 2000. *Leveraging legacy systems dollars for e-business*. *IT Pro.*

EUROPEAN COMMISSION DIRECTORATE-GENERAL FOR RESEARCH. 2005. *Key Figures 2005. Towards a European Research Area Science, Technology and Innovation.* Italy.

EUROPEAN COMMISSION. 2003. Commission recommendation concerning the definition of micro, small and medium-sized enterprises. *Official Journal of the European Union*.

EUROPEAN COMMISSION. 2005. *Towards a european research area science, technology and innovation* [online]. [Accessed 7 January]. Available from World Wide Web: <ftp://ftp.cordis.lu/pub/indicators/docs/2004_1857_en_web.pdf>

EUROPEAN COMMISSION. 2006. *Creating an innovative Europe* [online]. [Accessed 17 January]. Available from World Wide Web: <http://europa.eu.int/invest-in-research/pdf/060119Aho%20report%20final.pdf>

EUROPEAN FOUNDATION FOR THE IMPROVEMENT OF LIVING AND WORKING CONDITIONS. 1997. *New forms of work organization. Can Europe realize its potential? Results of a survey of direct employee participation in Europe, Ireland.*

FAGERBERG, J. 2003. Innovation: A Guide to the Literature. *IN: The Many Guises of Innovation: What we have learnt and where we are heading*, *23-24.2003, Ottawa.*

FAGERBERG, J.; D.C. MOWERY and R.R. NELSON, eds. 2005. *The Oxford Hanbook of Innovation.* New York: Oxford University Press.

FAN, Q.; L. KOUQING; Z.Z. DOUGLAS; D. YANG and P. RUNZHONG, eds. 2009. *Innovation for development and the role of government: a perspective from the East Asia and Pasific Region.* Wahington: The World Bank.

FARR, W.K.; R.A. LORD and J.L. WOLFENBARGER. 1998. Economic freedom, poritical freedom, and economic well-being: A causality analysis. *Cato Journal*, **18** (247-262).

FAULKNER, D. 2002. *Strategy. Critical perspectives on business and management* Routledge.

FAULKNER, D.O. and A. CAMPBELL. 2006. *The Oxford Handbook of Strategy: A Strategy Overview and Competitive Strategy*. Oxford University Press.

FELDMAN, M.P. and D.B. AUDRETSCH. 1999. Innovation in cities:: Science-based diversity, specialization and localized competition. *European Economic Review*, **43** (2), pp.409-429.

FELLOWS, R.; D. LANGFORD; R. NEWCOMBE and S. URRY. 2002. *Construction Management in Practice*. 2 ed. Oxford, England: Blackwell Science.

FIEDLER, T. and C. DEEGAN. 2007. Motivations for environmental collaboration within the building and construction industry. *Managerial Auditing Journal*, **22** (4), pp.410-441.

FIELD, A. 2005. *Discovering statistics using SPSS.* London: Sage Publications.

FINLAY, P. 2000. *Strategic management.* Pearson Education, Financial Times, Prentice Hall.

FLOOD, R.L. and E.R. CARSON. 1993. *Dealing with complexity. An introduction to the theory and application to the system science.* New York: Plenum Press. Available from World Wide Web: <http://books.google.com/books?id=kD-ODIuU9tEC&lpg=PP1&dq=dealing%20with%20complexity&hl=el&pg=PA8#v=onepage&q=&f=false>

FORD, A. 2009. *Modelling the environment.* Washington: Island Press.

FOX, W. and G.V.D. WALDT. 2007. *A Guide to Project Management.* Cape Town: Juta & Co. .

FRENKEL, A.; D. SHEFER; K. KOSCHALZKY and G.H. WALTER. 2001. Firm characteristics, location and regional innovation: a comparison between Israeli and German industrial firm. *Regional Studies,* **35** (5), pp.413–427.

FRISCHER, J. 1993. Empowering management in new product development units. *Journal of Product Innovation Management,* **10**, pp.393-401.

FRISCHER, J. 2006. *Laissez-faire Leadership versus Empowering Leadership in New Product Developing.*

FUNK, P. and B. KROMEN. 2005. Inflation and innovation driven growth. *Working paper series in economics*.

GANN, M.D. and A.J. SALTER. 2000. Innovation in project-based, service-enhanced firms: the construction of complex products and systems. *Research Policy*, **29** (7-8), pp.955-972.

GAO, X. and J. GUAN. 2009. A scale-independent analysis of the performance of the Chinese innovation system. *Journal of Informetrics,* **3** (4), pp.321-331.

GARAVAN, T. 1997. The learning organization: a review and evaluation. *The Learning Organization,* **4** (1), pp.18-29.

GARCIA, R. and R. CALANTONE. 2002. A critical look at technological innovation typology and innovativeness terminology: a literature review. *Journal of Product Innovation Management,* **19** (2), pp.110-132.

GARSON, D. 2007. *Data Imputation for Missing Values* [online]. [Accessed March 27]. Available from World Wide Web: <http://www2.chass.ncsu.edu/garson/pa765/missing.htm>

GASPER, D. 2000. Evaluating the 'logical framework approach' towards learning-oriented development evaluation. *Public Administration and Development*, **20** (1), pp.pp.17-28.

GAYNOR, G.H. 2002. *Innovation and design. What takes to keep your company on the cutting edge.* New York: Gaynor and Associates.

GELDEREN, M.V.; M. FRESE and R. THURIK. 2000. Strategies, Uncertainty and Performance of Small Business Startups. *Small Business Economics,* **15**, pp.165–181.

GIDADO, K.I. 1996. Project complexity: the focal point of construction planning. *Construction Management and Economics*, **14** (3), pp.213–25.

GILBERT, J.T. and BIRNBAUM-MORE. 1996. Innovation timing advantages: From economic theory to strategic application. *Journal of Engineering and Technology Management*, **12** (4), pp.245-266.

GILBERT, N., ed. 2008. *Researching social life.* 3rd ed. London: Sage.
GILLEN, T. 2005. *Winning new business in construction.* Aldershot: Gower
GILLESPIE, A. 2007. *The English legal system.* New York: Oxford University Press.
GILLMAN, M.; M. HARRIS and L. MÁTYÁS. 2004. Inflation and Growth: Explaining a Negative Effect. *Empirical Economics*, **29** (1), pp.149-167.
GILLMAN, M. and M. KEJAK. 2005. Inflation and Balanced-Path Growth with Alternative Payment Mechanisms. *The Economic Journal*, **115** (1), pp.247-270.
GITTLEMAN, M. and E.N. WOLFF. 1995. R&D activity and cross-country growth comparisons. *Camb. J. Econ.*, **19** (1), pp.189-207.
GKIOURKA, P.; A. TUTESIGENSI and K. MOODLEY. 2009. A holistic conceptual model for managing innovation. *26 Annual ARCOM Conference, 6-8 September 2010, Leeds, UK.* Association of Researchers in Construction Management. pp.967-976.
GLASER, B. and A. STRAUSS. 1967. *The discovery of grounded theory. Strategies for qualitative research.* London: Weidenfeld and Nicholson.
GOMN, R. 2008. *Social Research methodology. A critical introduction.* 2nd ed. New York: Palgrave MacMillan.
GOMULKA, S. 1990. *The theory of technologic change and economic growth.* New York: Routledge.
GRANT, W.E.; E.K. PEDERSEN and S.L. MARÍN. 1997. *Ecology and natural resource management: systems analysis and simulation.* New Jersey: John Wiley & Sons.
GRECO, J. 2008. *Succesful direct martketing methods. Interactive, Database, and Customer marketing for the multichannel communication age.* 8th edition ed. U.S.: McGraw HIll Available from World Wide Web: <http://books.google.com/books?id=XFzSesIQJwYC&lpg=PT58&dq=innovative%20business%20and%20marketing&hl=el&pg=PT4#v=onepage&q=&f=false>
GUAN, J.C.; C.K. MOK; R.C.M. YAM; K.S. CHIN and K.F. PUN. 2006a. Technology transfer and innovation performance: Evidence from Chinese firms. *Technological Forecasting and Social Change*, **73** (6), pp.666-678.
GUAN, J.C.; R.C.M. YAM; C.K. MOK and N. MA. 2006b. A study of the relationship between competitiveness and technological innovation capability based on DEA models. *European Journal of Operational Research*, **170** (3), pp.971-986.
GUEST, D.E.; J. MICHIE; N. CONWAY and M. SHEEHAN. 2003. Human Resource Management and Corporate Performance in the UK. *British Journal of Industrial Relations*, **41** (2), pp.291-314.
GUPTA, P. 2004. *Six Sigma Business Scorecard.* U.S.: McGraw Hill.
HALPER, M.; L.-M. LIU; J. GELLER and Y. PERL. 2007. Ownership as a conceptual modeling construct. *Data Knowl. Eng.*, **62** (2), pp.248-273.
HAMEL, G. and C.K. PRAHALAD. 1996. Competing for the Future. Boston: Harvard Business School Press,
HANNAH, S.T.; B.J. AVOLIO; F. LUTHANS and P.D. HARMS. 2008. Leadership efficacy: Review and future directions. *The Leadership Quarterly*, **19** (6), pp.669-692.
HANNAN, M.T. and J. FREEMAN. 1984. Structural Inertia and Organizational Change. *American Sociological Review*, **49** (2), pp.149-164.
HARGADON, A. 2005. Technology brokering and innovation: linking strategy, practice, and people. *STRATEGY & LEADERSHIP*, **33** (1), pp.32-36.

HARTMANN, A. 2006. The role of organizational culture in motivating innovative behaviour in construction firms. *Construction Innovation: Information, Process, Management*, **6** (3), pp.159,172.

HARVARD BUSINESS SCHOOL. 2005. *Strategy: Create and Implement the Best Strategy for Your Business.* Boston: Harvard Business School.

HENDRIKS, P.H.J. and D.J. VRIENS. 1999. Knowledge-based systems and knowledge management: Friends or foes? *Information & Management*, **35** (2), pp.113-125.

HERRMANN, H. and R.E. LIPSEY. 2003. *Foreign and direct investment of the real and finacial sector of industrial countries.* Germany: Springer.

HIVNER, W.; W.E. HOPKINS and S.A. HOPKINS. 2003. Facilitating, accelerating, and sustaining the innovation diffusion process: an epidemic modeling approach *European Journal of Innovation Management*, **6** (2), pp.80-89.

HM GOVERENEMENT. 2009. *Building Britain's Future: New Industry, New Jobs.*

HM GOVERNMENT. 2009. *Building Britain's Future: New Industry, New Jobs.*

HOBDAY, M. 2000. The project-based organisation: An ideal form for managing complex products and systems? *Research Policy*, **29**, pp.871–893.

HOFTEDE, G. 1997. *Cultures and organizations: Software of the mind.* New york: McGraw Hill. Available from World Wide Web: <http://www.tamu.edu/classes/cosc/choudhury/culture.html>

HONAKER, J. and G. KING. 2006. *What to do about Missing Values in Time Series Cross-Section Data* [online]. [Accessed April 1]. Available from World Wide Web: <http://tercer.bol.ucla.edu/papers/pr.pdf>

HOUCKA, P.R.; S. MAZUMDARB; T. KORU-SENGULC; G. TANGB; B.H. MULSANTA; B.G. POLLOCKA and C.F. REYNOLDS. 2004. Estimating treatment effects from longitudinal clinical trial data with missing values: comparative analyses using different methods. *Phychiatry Research*, **129**, pp.209-215.

HOUSE OF COMMONS. 2008. *Construction matters.* London.

HOWEL, D. 2007. *Treatment of missing data* [online]. [Accessed March 27]. Available from World Wide Web: <Statistical Home Page Web Site: http://www.uvm.edu/~dhowell/StatPages/More_Stuff/Missing_Data/Missing.html>

HUGHES, P. and E. FERRET. 2009. *Introduction to Health and Safety at Work.* Oxford: Butterworth-Heinemann.

HYLAND, P. and R. BECKETT. 2005. Engendering an innovative culture and maintaining operational balance. *Journal of Small Business and Enterprise Development*, **12** (3), pp.336-352.

HYYTINEN, A. and O. TOIVANEN. 2005. Do financial constraints hold back innovation and growth?: Evidence on the role of public policy. *Research Policy*, **34** (9), pp.1385-1403.

INSTITUTE OF INDUSTRIAL ENGINEERING. 2009. *Knowledge Cetner, Terminology* [online]. Available from World Wide Web: <http://www.iienet2.org/Landing.aspx?id=260>

IRISH COUNCIL. 1998. *Science, technology and innovation culture.* A statement issued by the Irish Counsil for science, technology and innovation on the occasion of science week Ireland.

ITAYA, J.-I. and K. MINO. 2003. Inflation, Transaction Costs and Indeterminacy in Monetary Economies with Endogenous Growth. *Economica*, **70**, pp.451-470.

JACKSON, M.C. 1991. *Systems Methodology for the Management Sciences. Contemporary Systems Thinking.* New York: Plenum Press.

JACKSON, M.C. 2000. *Systems approaches to management.* New York: Kluwer Academic/ Plenum Publishers.

JIA, H.; X. YU; Y. YU and C. WANG. 2008. Power system small signal stability region with time delay. *International Journal of Electrical Power & Energy Systems,* **30** (1), pp.16-22.

JOHNSTON JR., R.E. and J.D. BATE. 2003. *The Power of Strategy Innovation: A New Way of Linking Creativity and Strategic Planning to Discover Great Business Opportunities.* New York: American Management Association.

JONES, M. and M. SAAD. 2003. *Managing innovation in the construction industry.* London: Telford.

JONG, J.P.J. and D.N. HARTOG. 2007. How leaders influence employees' innovative behaviour. *European Journal of Innovation Management,* **10** (1), pp.41-64.

JUDGE, W.Q.; G.E. GRYXELL and R.S. DOOLEY. 1997. The new task of R&D management: creating goal-directed communities for innovation. *California Management Review,* **39**, pp.72-85.

JUPP, V. 2006. *The Sage dictionary of social research methods.* London: Sage.

KASH, D.E.; R.N. AUGER and N. LI. 2004. An exceptional development pattern. *Technological Forecasting and Social Change,* **71** (8), pp.777-797.

KASH, D.E. and R. RYCROFT. 2002. Emerging patterns of complex technological innovation. *Technological Forecasting and Social Change,* **69** (6), pp.581-606.

KATZ, J.S. 2006. Indicators for complex innovation systems. *Research Policy,* **35** (7), pp.893-909.

KEARNS, P. 2003. *HR strategy. Business focused, individually centered.* Oxford: Paul Kerns.

KEEGAN, A. and J.R. TURNER. 2002. The Management of Innovation in Project-Based Firms. *Long Range Planning,* **35** (4), pp.367-388.

KHAN, M.Y. 2004. *Financial management. Text, problems and cases.* New Delhi: McGraw Hill.

KLEIN WOOLTHUIS, R.; M. LANKHUIZEN and V. GILSING. 2005. A system failure framework for innovation policy design. *Technovation,* **25** (6), pp.609-619.

KOBERG, C.S.; D.R. DETIENNE and K.A. HEPPARD. 2003. An empirical test of environmental, organizational, and process factors affecting incremental and radical innovation. *The Journal of High Technology Management Research,* **14** (1), pp.21-45.

KOONTZ, H. and C. O'DONNELL. 1968. *Principles of management.* 4th ed. McGraw-Hill.

KOONTZ, H. and H. WEIHRICH. 2007. *Essentials of Management.* 7th Edition ed. New Delhi: Tata McGraw-Hill.

KOTLER, P. 2003. *Marketing management.* Pearson Education, Prentice Hall.

KRANTZ, M. 2008. *Investing online for dummies.* Indianapolis: Willey.

KRAUSE, D.E. 2004. Influence-based leadership as a determinant of the inclination to innovate and of innovation-related behaviors: An empirical investigation. *The Leadership Quarterly,* **15** (1), pp.79-102.

KRISTANDL, G. and N. BONTIS. 2007. Constructing a definition for intangibles using the resource based view of the firm. *Management Decision,* **45** (9), pp.1510-1524.

KUMARASWAMY, M.M.; S.T. NG; O.O. UGWU; E. PALANEESWARAN and M.M. RAHMAN. 2004. Empowering collaborative decisions in complex construction project scenarios. *Engineering, Construction and Architectural Management,* **11** (2), pp.133 - 142.

LAGNEVIK, M. 2003. *The dynamics of innovation clusters: a study of the food industry*. Glos: Edward Elgar.

LAM. 2005. *Organizational Innovation*. *In:* FAGERBERG, J., D.C. MOWERY and R.R. NELSON, eds. *The Oxford Handbook of Innovation.* Oxford: Oxford University Press.

LANDRY, R.; N. AMARA and M. LAMARI. 2002. Does social capital determine innovation? To what extent? *Technological Forecasting and Social Change,* **69** (7), pp.681-701.

LANGFORD, D. and S. MALE. 2001. *Strategic management in construction.* 2nd ed. Wiley Blackwell

LANGFORD, D. and M. MURRAY. 2003. *Construction Reports 1944-98.* Oxford: Blackwell.

LATHAM, M. and GREAT BRITAIN DEPARTMENT OF THE ENVIRONMENT. 1994. *Constructing the team : final report ; joint review of procurement and contractual arrangements in the United Kingdom construction industry*. London: H.M.S.O.

LAU, C. and H. NGO. 2004. The HR system, organizational culture, and product innovation. *International Business Review,* **13** (6), pp.685-703.

LEEDE, J.C.; J.C. DE LOOISE and B.C.M. ALDERS. 2002. Innovation, improvement and operations: an exploration of the management of alignment. *International Journal of Technology Management* **23**, pp.353-368.

LEMON, M. and P.S. SAHOTA. 2004. Organizational culture as a knowledge repository for increased innovative capacity. *Technovation,* **24** (6), pp.483-498.

LEONARD, B. 1998. *What Do CEOs Want from HR? HR Magazine.*

LEVY, S.M. 2000. *Project Mangement in Construction.* New York: McGraw-Hill.

LI, M. and R.L. SIMERLY. 2002. Environmental dynamism, capital structure and innovation: an empirical test. *International Journal of Organizational Analysis,* **10** (2), pp.156 - 171.

LITTLE, R.J.A. 1988. A test of missing completely at random for multivariate data with missing values. *Journal of the American Statistical Association,* **83**, pp.1198-1202.

LIU, G. and A.L. GOULD. 2002. Comparison of alternative strategies for analysis of longitudinal trials with dropouts. *Journal of Biopharmaceutical Statistics,* **12** (2), pp.207-226.

LONGINO, E. 2007. *Sales management control, territory design, sales force performace, and sales organsational effectiveness in the pharmaceutical industry*. Florida: Eric Longino.

LOVE, P.D.; Z. IRANI; E. CHENG and H. LI. 2002. A model for supporting inter-organizational relations in the supply chain. *Engineering, Construction and Architectural Management,* **9** (1), pp.2-15.

LOWSON, R. 2002. *Strategic operations management: The new competitve advantage.* New York: Routledge.

LUNDVALL, B.-A. and P. NIELSEN. 2007. Knowledge management and innovation performance. *International Journal of Manpower*.

LIVESQUE, M. 2004. Mathematics, theory, and entrepreneurship. *Journal of Business Venturing,* **19** (5), pp.743-765.

MAKI, D. and M. THOMPSON. 2006. *Mathematical modeling and computer simulation.* London: Bob Pirtle.

MANSEAU, A. and G. SEADEN. 2001. *Innovation in construction. An international review of pubilc policies.* London: Spon Press

MANSEAU, A. and R. SHIELDS. 2005. *Building tomorrow: Innovation in Construction and Engineering.* Ashgate.

MANU, F.A., & SRIRAM, V. 1996. Innovation, marketing strategy, environment, and performance. *Journal of Business Research*, **35** (1), pp.79-91.

MARCEAU, J.; J. HOUGHTON; P. TONER; K. MANLEY; E. GERASIMOU and N. COOK. 1999. *Mapping the Building and Construction Product System in Australia.* Sydney: Commonwealth Department of Industry, Science and Resources.

MCADAM, R., MCCLELLAND, J. 2002. Individual and team-based idea generation within innovation management: organizational and research agendas. *European Journal of Innovation Management*, **5** (2), pp.86-97.

MCDERMEIT, M.; R. FUNK and M. DENNIS. 1999. Data Cleaning and replacement of missing values. *LI Analysis Training Series*.

MEDINA, R. 2006. *Business Finance.* Quezon City: Rex Printing Company.

MEYER, T. 2008. Venture Capital: Bridge betweeen idea and innovation? *Deutche Bank Research, Digital economy and structural change* [online]. Available from World Wide Web: <www.dbresearch.com>

MEYER, W.J. 2004. *Concepts of mathematical modeling*

Mineola, N.Y: Dover.

MILES, R.E. and C.C. SNOW. 1978. *Organizational Strategy, Structure and Process.* New York: McGraw-Hill.

MILLAR, A.; R.S. SIMEONE and J.T. CARNEVALE. 2001. Logic models: a systems tool for performance management. *Evaluation and Program Planning*, **24** (1), pp.73-81.

MINTZBERG, H. 1979. *The structuring of organisations.* International ed. Prentice Hall.

MIOZZO, M. and P. DEWICK. 2002. Building competitive advantage: innovation and corporate governance in European construction. *Research Policy,* **31** (6), pp.989-1008.

MIOZZO, M. and P. DEWICK. 2004a. *Innovation in construction.* Edward Elgar.

MIOZZO, M. and P. DEWICK. 2004b. Networks and innovation in European construction: benefits from inter-organisational cooperation in a fragmented industry. *International Journal of Technology Management*, **27** (1), pp.68 - 92.

MORDEN, T. 2007. *Principles of Strategic Management* Aldershot: Ashgate Ltd.

MOTTA, M. 2004. *Competition policy: theory and practice.* Cambridge: Cambridge University Press.

MUELLER, D.C. and J. CUBBIN. 1990. *The Dynamics of company profits: an international comparison.* Cambridge: Cambridge University Press.

MUIJS, D. 2004. *Doing quantitative research in education with SPSS.* London: SAGE.

MUMFORD, M.D. 2000. Managing creative people: strategies and tactics for innovation. *Human Resources Management Review,* **10** (3), pp.313-51.

MURRAY, M. and D. LANGFORD. 2003. *Construction Reports: 1944-98.* Oxford: Blackwell.

NAGENDRA, S. and V.S. MANJUNATH. 2008. *Entrepreneurship & Management.* Bangalore: Sanguine.

NAO. 2001. *Modernising Construction*. London: National Audit Office.

NATIONAL STATISTICS. 2005. Research and development spending 2003. Economic Trends: August 2005. *News release* [online]. [Accessed 4 August 2010], Available from World Wide Web: <http://www.statistics.gov.uk/pdfdir/et0805.pdf>

NATIONAL STATISTICS. 2007. *Research and Development in UK Businesses, 2005 (Business Monitor, MA14)*. Unpublished.

NEUENDORF, K.A. 2002. *The content analysis guidebook.* London: Sage Publications.

NIJHOF, A.; K. KRABBENDAM and J.C. LOOISE. 2002. Innovation through exemptions: building upon the existing creativity of employees. *Technovation,* **22** (11), pp.675-683.

NOOTEBOOM, B.; W. VAN HAVERBEKE; G. DUYSTERS; V. GILSING and A. VAN DEN OORD. 2007. Optimal cognitive distance and absorptive capacity. *Research Policy,* **36** (7), pp.1016-1034.

NORAD. 1999. *Logical Framework Approach. Hoandbook for objectives-oriented planning.* 4th ed. Oslo: NORAD.

O' SULLIVAN, M. 2005. Finance and innovation. *In:* FAGERBERG, J., D. MOWERY and R. NELSON, eds. *The Oxford handbook of innovation.* Oxford: Oxford Univeristy Press,

O'BRIEN, J. 2003. The capital structure implications of persuing a strategy of innovation. *Strategic Management Journal,* (24), pp.415-431.

OECD. 1998. *Science, technology and industry outlook.* Paris: OECD.

OECD. 2002. *Frascati Manual. Proposed Standard Practice for Surveys on Research and Experimental Development.* Paris: OECD.

OECD. 2003a. *International Investment perspectives.* Paris: OECD.

OECD. 2003b. *Knowledge management. Measuring knowledge management in the business sector.* Paris: OECD.

OECD. 2004. *Economic Outlook.* Paris: OECD.

OECD. 2006. *Decoupling the environmental impacts of transport from economic growth.* Paris: OECD.

OECD. 2007. *Science, technology and innovation indicators in a changing world. Responding to policy needs.* OECD. Available from World Wide Web: <http://213.253.134.43/oecd/pdfs/browseit/9207121E.PDF>

OECD. 2009a. *Patent Statistics Manual.* OECD.

OECD. 2009b. *Science Technology and Industry Scoreboard, Tax treatment of R&D.* OECD. Available from World Wide Web: <http://www.oecdilibrary.org/oecd/content/chapter/sti_scoreboard-2009-31-en http://dx.doi.org/10.1787/sti_scoreboard-2009-31-en>

OECD SCIENCE TECHNOLOGY AND INDUSTRY SCOREBOARD. 2009. *Tax treatment of R&D.* Available from World Wide Web: <http://www.oecdilibrary.org/oecd/content/chapter/sti_scoreboard-2009-31-en http://dx.doi.org/10.1787/sti_scoreboard-2009-31-en>

OFFICE FOR PUBLIC SECTOR INFORMATION. 2004. *Housing Act 2004*. The Stationery Office.

OFFICE FOR PUBLIC SECTOR INFORMATION. 2007. *The Energy Performance of Buildings (Certificates and Inspections) (England and Wales) Regulations 2007*. O.P.S.I.

OFFICE FOR PUBLIC SECTOR INFORMATION. 2008. *Climate Change Act*. The Stationery Office.

OFFICIAL JOURNAL OF THE EUROPEAN UNION. 2007. *Treaty of Lisbon amending the Treaty on European Union and the Treaty establishing the European Community, signed at Lisbon, 13 December 2007*.

OKE, A. 2007. Innovation types and innovation management practices in service companies. *International Journal of Operations & Production Management,* **27** (6), pp.564-587.

OPPENHEIMER, A. 2010. Commentary: Latin America's strong currency may hinder its growth. *McClatchy* [online]. Available from World Wide Web:

<http://www.mcclatchydc.com/2010/03/19/90469/commentary-latin-americas-strong.html>

ORLIKOWSKI, W.J. 1992. The duality of technology: rethinking the concept of technology in organisations. *Organisation Science*, **3** (3).

ORTENBLAD, A. 2004. The learning organization: towards an integrated model. *The Learning Organization*, **11** (2), pp.129-144.

OSHAGBEMI, T. and S.A. OCHOLI. 2006. Leadership styles and behaviour profiles of managers. *Journal of Management Development*, **25** (8), pp.748 - 762.

PAPIER, J. 2010. *The incredible shrinking dollar*. Sunnyvale: PW Johnson.

PAVITT, K., & WALKER, W. 1976. Government policies towards industrial innovation: A review. *Research Policy*, **5** (1), pp.11-97.

PAYNE, G. and J. PAYNE. 2004. Key concepts in social research. London: SAGE,

PERDOMO-ORTIZ, J.; J. GONZALEZ-BENITO and J. GALENDE. 2006. Total quality management as a forerunner of business innovation capability. *Technovation*, **26** (10), pp.1170-1185.

PETERS, J. 1996. A learning organization's syllabus. *The Learning Organization*, **3** (1), pp.4–10.

PEZZULLO, M.A. 1998. *Marketing Financial Services*. Washington: American Bankers Association.

PIERRE, G. and S. SCARPETTA. 2004. Employment Regulations through the Eyes of Employers: Do They Matter and How Do Firms Respond to Them? *IN: Bonn*. Institute for the study of Labor.

PIETROFORTE, R. 1997. Communication and governance in the building process. *Construction Management and Economics*, **15** (1), pp.71–82.

PISANO, G.P. 1997. *The Development Factory*. Boston, MA: HBS Press.

PORTER, M. 1980. *Competitive strategy: Techniques for analysing industries and competitors*. Free Press.

PORTER, M. 1985. *Competitive advantage: Creating and sustaining superior performance*. Free Press.

PRAJOGO, D.I. and A.S. SOHAL. 2006. The integration of TQM and technology/R&D management in determining quality and innovation performance. *Omega*, **34** (3), pp.296-312.

PREECE, C.N.; K. MOODLEY and P. SMITH. 2003. *Construction business development : meeting new challenges, seeking opportunity*. Oxford [England] ; Boston Elsevier/Butterworth-Heinemann.

PRIETO, I.M. and E. REVILLA. 2006. Learning capability and business performance: a non-financial and financial assessment. *The Learning Organization*, **13** (2), pp.166-185.

RAHMAN, M. and M. KUMARASWAMY. 2002. Joint risk management through transactionally efficient relational contracting. *Construction Management and Economics*, **20** (1), pp.45-54.

RAJAGOPAL, P. 2002. An innovation--diffusion view of implementation of enterprise resource planning (ERP) systems and development of a research model. *Information & Management*, **40** (2), pp.87-114.

RAMA, R. 2008. Foreign investment innovation: a review of selected policies. *The Journal of Technology Transfer*, **33** (4), pp.353-363.

REED, A. 2001. *Innovation in human resource management*. London: Chartered Institute for Research and Development.

REICHSTEIN, T.; A.J. SALTER and D.M. GANN. 2008. Break on Through: Sources and Determinants of Product and Process Innovation among UK Construction Firms. *Industry & Innovation*, **15** (6), pp.601 - 625.

REID, M.A. and H. BARRINGTON. 1999. *Training Interventions. Promoting learning opportunities.* Trowbridge: Chartered Institute of Personnel and Development

RESEARCH AND MARKETS. 2009. *Construction Industry Market Review 2009* [online]. [Accessed 02 July]. Available from World Wide Web: <http://www.researchandmarkets.com/reportinfo.asp?report_id=834893>

RESEARCH AND MARKETS. 2010. *Anlysing the European Construction Industry* [online]. [Accessed 3rd July]. Available from World Wide Web: <http://www.researchandmarkets.com/reportinfo.asp?report_id=465060&fsr=true&q=analysing%20the%20European%20construction%20market>

REUTERS. 2000. Positive approaches to staff retention. [online]. Available from World Wide Web: <http://www.flexfs.com/pdf/FLEXBENEFITS%20HR_Positive_Approaches.pdf>

RHODES, R.A.W.; S.A. BINDER and B.A. ROCKMAN, eds. 2008. *The Oxford Handbook of Political Institutions.* New York: Oxford University Press.

RILEY, M.J. 2000. *Researching and writing dissertations in business and management.* London: Thomson Learning.

RITCHIE, J. 2006. *Qualitative research practice a guide for social science students and researchers.* London: Sage.

ROBSON, C. 2002. *Real world research : a resource for social scientists and practitioner-researchers.* 2nd ed. Oxford: Blackwell.

ROGERS, E.M. 2003. *Diffusion of Innovations.* New York, NY, : The Free Press.

ROGERS, M. 2001. *Engineering Project Appraisal.* London: Blackwell Science Ltd.

ROMAN, S. 2002. *Writing Excel with VBA.* Sebastopol, CA: O'Reilly Media, Inc.

ROYSE, D.; B.A. THYER and D.K. PADGETT. 2010. *Program evaluation: An introduction.* 5th ed. Belmont: Wadsworth.

RUSZCZYNSKI, P.A. 2006. *Nonlinear optimisation* New Jersey: Princeton University Press.

SANGHOON, A. 2002. *Competition, Innovation and Productivity Growth: A Review of Theory and Evidence.* Paris.

SAPSFORD, R. 2007. *Survey research.* London: SAGE.

SARKEES, M. and J. HULLAND. 2009. Innovation and efficiency: It is possible to have it all. *Business Horizons*, **52** (1), pp.45-55.

SCHAFER, J.L. and J.W. GRAHAM. 2002. Missing data: our view of the state of the art. *Psychological Methods*, **7** (2), pp.147-177.

SCHMIEDEBERG, C. 2008. Complementarities of innovation activities: An empirical analysis of the German manufacturing sector. *Research Policy*, **37** (9), pp.1492-1503.

SCHUMPETER, J.A. 1934. *The Theory of Economic Development.* Cambridge: Harvard University Press.

SCHUMPETER, J.A. 1942. *Capitalism , Socialism and Democracy.* New York: Harper and Row.

SCLOVE, R. 1995. *Democracy and technology*. New York: The Guildford Press.

SCOTT, D. 2010. *The American Heritage Dictionary of Business Terms* Orlando: Houghton Mifflin Harcourt.

SEADEN, G. and A. MANSEAU. 2001. Public policy and construction innovation. *Building Research & Information*, **29** (3), pp.182 - 196.

SENGE, P. 1991. *The fifth discipline - The art and practise of the learning organisation.* Doubleday.

SEXTON, M. and P. BARRETT. 2004. The role of technology transfer in innovation within small construction firms. *Engineering, Construction and Architectural Management*, **11** (5), pp.342-348.

SHEFER, D. and A. FRENKEL. 1998. Local milieu and innovations: some empirical results. *The Annals of Regional Science*, **32**, pp.185-200.

SHEFER, D. and A. FRENKEL. 2005. R&D, firm size and innovation: an empirical analysis. *Technovation*, **25** (1), pp.25-32.

SHIN, J.; H. JIN KIM; S. PARK and Y. KIM. 2009. Model predictive flight control using adaptive support vector regression. *Neurocomputing*, **In Press, Accepted Manuscript**.

SHNEIDERMAN, B. 1998. *Designing the interface.* 3rd ed. MA: Addison-Wesley.

SILVERSTEIN, D.; P. SAMUEL and N. DECARLO. 2009. *The innovators Toolkit: 50+ techniques for predictable and sustainable organic growth.* United Stated: John Wiley.

SIMMIE, J.; J. SENNET; P. WOOD and G. HART. 2002. Innovation in Europe. A Tale of Networks, Knowledge and Trade in five Cities. *Regional Studies*, **36** (1), pp.pp. 47-64.

SLAUGHTER, E.S. 1993. Builders as Sources of Construction Innovation. *Journal of Construction Engineering and Management*, **119** (3), pp.532-549.

SLAUGHTER, E.S. 1998. Models of Construction Innovation. *Journal of Construction Engineering and Management*, **124** (3), pp.226-231.

SMYTH, H. 2000. *Marketing and selling construction services.* London: Blackwell.

SOMMERVILLE, I. 2001. *Software engineering.* 6 ed. Harlow, Essex: Pearson.

SOMMERVILLE, I. 2004. *Software Engineering.* Harlow: Pearson.

SOMMERVILLE, I. 2007. *Software engineering.* 8 ed. Harlow, Essex: Pearson Available from World Wide Web: <http://books.google.co.uk/books?id=B7idKfL0H64C&lpg=PP1&dq=software%20engineering%2C%20Sommerville&lr=&hl=el&pg=PP1>

SPENCE, R. and H. MULLIGAN. 1995. Sustainable development and the construction industry. *Habitat International*, **19** (3), pp.279-292.

STEELE, J.L. and M.A.P. MURRAY. 2000. Constructing the team: A multicultural experience. *Chartered Institute of Building Services Engineers (CIBSE) National Conference, Dublin.*

STOREY, J. and G. SALAMAN. 2005. *Managers of innovation insights into making innovation happen.* Malden, MA Blackwell. Available from World Wide Web: <http://books.google.com/books?id=gGU2JBkUWVkC&lpg=PA5&dq=organisational%20innovation&hl=el&pg=PA5>

STRATEGIC FORUM FOR CONSTRUCTION. 2002. *Accelerating change.* London.

STUFFLEBEAM, D.L. and A.J. SHINKFIELD. 2007. *Evaluation, Theory, Models and Applicatin.* San Francisco: Jossey-Bass.

SUMI, C. and T. ITOH. 2009. Spatially variant regularization of lateral displacement measurement using variance. *Ultrasonics*, **49** (4-5), pp.459-465.

SWANSON, R.A. and E.F. HOLTON. 2009. *Foundations of Human Resource Development.* 2nd ed. California: Berrett-Koehler.

TANG, H.K. 1998. An integrative model of innovation in organizations. *Technovation*, **18** (5), pp.297-309.

TASHAKKORI, A. and C. TEDDLIE. 2003. *Handbook of mixed methods in the social and behavioral research.* Thousand Oaks, CA: SAGE.

TATUM, C.B. 1987. Potential mechanisms for construction innovation. *Journal of Construction Engineering and Management* **112** (2), pp.178–91.

TAYLOR, J. 2007. *Principles of Macroeconomics.* 5th ed. Boston: Houghton Mifflin.

TAYLOR, J.E. and R. LEVITT. 2005. *Modelling systemic innovation in design and construction networks.* Stanford: CIFE.

THOMPSON, J.L. 2003. *Strategic management.* 4th ed. Italy: Gray Publishing.

TOOLE, T.M. 1998. Uncertainty and Home Builders' Adoption of Technological Innovations. *Journal of Construction Engineering and Management,* **124** (4), pp.323-332.

TOOR, S.-U.-R. and G. OFORI. 2008. Leadership for future construction industry: Agenda for authentic leadership. *International Journal of Project Management,* **26** (6), pp.620-630.

TOROPOV, V.V.; L.F. ALVAREZ and O.M. QUERIN. 2010. Advances of soft computing in engineering. *In:* WASZCZYSZYN, Z., ed. Wien: Springer Wien New York,

TRAVERS, M. 2001. *Qualitative research through case studies.* London: SAGE.

TROTT, P. 2002. *Innovation management and new product development.* Pearson education, Financial Times , Prentice Hall.

TURNER, J.R. and S.J. SIMISTER. 2000. *Gower handbook of project management.* 3 ed. Aldershot: Gower.

TUTESIGENSI, A. 1999. *Managing project identification : an investigation into the effective management of the identification phase of building projects in Uganda*. Ph.D. thesis, University of Leeds.

UHER, T.E. and M. LOOSEMORE. 2004. *Essentials of construction project management.* Sydney: Univeristy of New South Wales Press.

UNITED NATIONS. 1998. *Kyoto Protocol to the United Nations Framework Convention on Climate Change* [online]. [Accessed 25 June]. Available from World Wide Web: <http://unfccc.int/resource/docs/convkp/kpeng.pdf>

UNITED NATIONS. 2000. Tax Incentives and Foreign Direct Investment. A Global Survey. *IN: United Nations conference on trade and development, Geneva.* United Nations.

VALLE, S. and D. VAZQUEZ-BUSTELO. 2009. Concurrent engineering performance: Incremental versus radical innovation. *International Journal of Production Economics,* **119** (1), pp.136-148.

VAN DE VEN, A.H.; D. POLLEY; R. GARUD and S. VENKATARAMAN. 1999. *The Innovation Journey.* New York: Oxford University Press.

VAN HORNE, J.C. and J.M. WACHOWICZ. 2009. *Fundamentals of Financial Management.* 13th ed. Harlow: Pearson.

VAN RIEL, A.C.R.V. 2005. Service innovation management. *Managing service quality,* **15** (6).

VINDING, A.L. 2006. Absorptive capacity and innovative performance: A human capital approach. *Economics of Innovation and New Technology,* **15** (4), pp.507-517.

WALKENBACH, J. 2007. *Excel 2007 power programming with VBA.* Indianapolis: Wiley Publishing Inc. Available from World Wide Web: <http://books.google.com/books?id=HxhXwdUSTe0C&lpg=PR37&dq=excel%20vba&lr=&pg=PR4#v=onepage&q=&f=false>

WALKER, A. 2007. *Proect management in construction* Singapore: Blackwell.

WANG, X. and D. PULLAR. 2005. Describing dynamic modeling for landscapes with vector map algebra in GIS. *Computers & Geosciences,* **31** (8), pp.956-967.

WEST, M.A. and M. WALLACE. 1992. Innovation in health care systems. *European Journal of Social Psychology*, **21**, pp.303-15.

WHYTE, A.V.T. 2000. *Assessing community telecenters: guidelines for researchers.* Ottawa: International Development Research Center.

WILHELMSSON, M. 2007. The spatial distribution of innovative networks. *CESIS* [online]. (91), Available from World Wide Web: <http://www.infra.kth.se/cesis/documents/WP91.pdf>

WORLD BANK. n.d. *The LogFrame Handbook. A logical Framework Approach to project cycle management.* Washington: World Band.

WORTHINGTON, I. and C. BRITTON. 2000. *The business environment.* 3rd ed. Financial Times, Prentice Hall.

WRIGHT, P.M.; B.B. DUNFORD and S.A. SNELL. 2001. Human resources and the resource based view of the firm. *Journal of Management*, **27** (6).

WYATT KNOWLTON, L. and C. PHILLIPS. 2009. *The logic model guidebook. Better strategies for better results.* Thousand Oaks: Sage.

YANKOV, L. and B.H. KLEINER. 2001. Human resources issues in the construction industry. *Management Research News*, **24** (3), pp.101-105.

YUKL, G. 2002. *Leadership in Organizations.* Englewood Cliffs, NJ, . Prentice-Hall.

ZIKMUND, W. 2003. *Business research methods.* 7th ed. Ohio: Thomson.

APPENDIX A

A.1 The questionnaire

A.2 The Cover Letter

Sender Direct line: (023) 9284 2428
Email: Paraskevi.Gkiourka@port.ac.uk

«Title»
«Company_Name»
«Address_Line_1»
«Address_Line_2»
«Address_line_3»
«City»
«ZIP_Code»

26 May 2006

Dear Sir/Madam,

I am writing to ask for your contribution in my research project concerning the management of innovation in the construction industry. The research will help me to evaluate factors that contribute to propagation of innovation in the construction industry. This is a project I am pursuing for my PhD studies and it is a purely academic project.

Your organisation has been identified as engaged in activities under the General Civil Engineering Industry and your participation is very important to me.

Your answers will remain completely confidential. Results will be presented as summaries and individual respondents will not be identified. I am happy to send you the summary of the results when the study is completed. If you wish to receive a copy please indicate as appropriate on Section A of the questionnaire. I appreciate that you have a very busy schedule, and I am therefore grateful for your time in assisting me implement this survey successfully.

For your convenience I have included a self-addressed and stamped envelope for the return of the questionnaire. If you would rather fax the questionnaire please find my fax number at the top of this letter.

I would be grateful if you could return the questionnaire by Friday, 16 June 2006.

Please do not hesitate to contact me should you have any queries.

Once again, thank you for your time and I hope to hear from you soon.

Yours faithfully,

Paraskevi Gkiourka

PhD Student

APPENDIX B

B.1 The factor names

Table B.1a Codes of factors in the key area of internal environment

techcont	*assesses the extent to which technology contributes to propagation of innovation*
techtype	*describes the technology used by the organisation*
leadcont	*assesses the extent to which the leadership style contributes to propagation of innovation*
leadstyl	*describes the leadership style used by the organisation*
ownecont	*assesses the extent to which the ownership type contributes to propagation of innovation*
ownetype	*describes the ownership type of the organisation*
collcont	*assesses the extent to which the collaborations contributes to propagation of innovation*
colltype	*describes the extent to which the collaboration types of the organisation*
hiercont	*assesses the extent to which the hierarchy contributes to propagation of innovation*
layernum	*describes the number of hierarchy layers of the organisation*
spancont	*assesses the extent to which the span of control contributes to propagation of innovation*
peoplrep	*describes typical number of people reporting to one manager of the organisation*
relacont	*assesses the extent to which organisational relationships contribute to propagation of innovation*
relatype	*describes organisational relationships of the organisation*
sizecont	*assesses the extent to which organisational size contributes to propagation of innovation*
orgasize	*describes organisational size of the organisation*
stracont	*assesses the extent to which the organisational strategy contributes to propagation of innovation*
stratype	*describes the strategy of the organisation*
policont	*assesses the extent to which the policy contributes to propagation of innovation*

politype	*describes the policy type of the organisation*
learcont	*assesses the extent to which organisational learning systems contributing to propagation of innovation*
learsyst	*describes organisational learning systems of the organisation*

Table B.1b Codes of factors in the key area of strategic resources

promcont	*assesses the extent to which the promotion of products/services contribute to propagation of innovation*
promprod	*describes the promotion of products/services of the organisation*
propcont	*assesses the extent to which the intellectual property rights contribute to propagation of innovation*
intelrig	*describes the intellectual property rights of the organisation*
salecont	*assesses the extent to which sales management contribute to propagation of innovation*
salemana	*describes sales management of the organisation*
infocont	*assesses the extent to which market information availability contribute to propagation of innovation*
infoavai	*describes market information availability of the organisation*
proccont	*assesses the extent to which process integration contribute to propagation of innovation*
procinte	*describes process integration of the organisation*
qualcont	*assesses the extent to which quality control contribute to propagation of innovation*
qualdesc	*describes quality control of the organisation*
rdexcont	*assesses the extent to which R&D expenditure contribute to propagation of innovation*
rdexpend	*describes R&D expenditure of the organisation*
knowcont	*assesses the extent to which knowledge management processes contribute to propagation of innovation*
knowmana	*describes knowledge management processes of the organisation*
capicont	*assesses the extent to which the capital structure contribute to propagation of innovation*
debtrati	*describes the capital structure of the organisation*
finacont	*assesses the extent to which the financial management contribute to*

	propagation of innovation
finamana	*describes the financial management of the organisation*
fiatcont	*assesses the extent to which the financiers attitude contribute to propagation of innovation*
finattit	*describes the financiers attitude of the organisation*
rdnucont	*assesses the extent to which the number of R&D staff contribute to propagation of innovation*
rdstaffn	*describes the number of R&D staff of the organisation*
skilcont	*assesses the extent to which the competence skills of R&D staff contribute to propagation of innovation*
rdskills	*describes the competence skills of R&D staff of the organisation*
perfcont	*assesses the extent to which the performance of R&D staff contribute to propagation of innovation*
rdperfor	*describes the performance of R&D staff of the organisation*
profcont	*assesses the extent to which the age profile of R&D staff contribute to propagation of innovation*
ageprofi	*describes the age profile of R&D staff of the organisation*
retecont	*assesses the extent to which retention of R&D staff contribute to propagation of innovation*
retedesc	*describes the retention of R&D staff of the organisation*
stafcont	*assesses the extent to which staff development processes contribute to propagation of innovation*
stafdeve	*describes staff development of the organisation*

Table B.1c Codes of factors in the key area of external environment

pofrcont	*assesses the extent to which the political freedom contributes to propagation of innovation*
polifree	*describes the political freedom on the organisation*
invecont	*assesses the extent to which do incentives to foreign investors contribute to propagation of innovation*
inveince	*describes the incentives to foreign investors*
compcont	*assesses the extent to which does competition law and policy contribute to propagation of innovation*

compelaw	*describes competition law and policy*
emplcont	*assesses the extent to which does employment law and policy contribute to propagation of innovation*
emplolaw	*describes employment law and policy*
regucont	*assesses the extent to which does health and safety regulations contribute to propagation of innovation*
hsregula	*describes health and safety regulations*
econcont	*assesses the extent to which the level of economic activity contribute to propagation of innovation*
econacti	*describes the level of economic activity*
gdpcont	*assesses the extent to which the trend in Gross Domestic Product contribute to propagation of innovation*
gdptrend	*describes the trend in Gross Domestic Product*
inflcont	*assesses the extent to which the rate of inflation contribute to propagation of innovation*
inflrate	*describes the rate of inflation*
currcont	*assesses the extent to which the strength of the currency contribute to propagation of innovation*
currstre	*describes the strength of the currency*
taxacont	*assesses the extent to which the rates of taxation contribute to propagation of innovation*
taxarate	*describes the rates of taxation*
gordcont	*assesses the extent to which the level of government spending in R&D contribute to propagation of innovation*
gordspen	*describes the level of government spending in R&D*
enercont	*assesses the extent to which the energy provision contribute to propagation of innovation*
enerprov	*describes the energy provision*
trancont	*assesses the extent to which the transport provision contribute to propagation of innovation*
tranprov	*describes the transport provision*

B.2 Frequency Tables

Table B.2 Frequency Table for all factors

		technology contribution	technology description	leadership contribution
N	Valid	51	51	51
	Missing	0	0	0
Mean		1.627	1.882	2.098
Median		2.000	2.000	2.000
Mode		1.0	1.0	3.0
Std. Deviation		1.0576	1.0516	1.1359
Variance		1.118	1.106	1.290
Skewness		0.073	0.673	-0.370
Std. Error of Skewness		0.333	0.333	0.333
Kurtosis		-0.852	-0.587	-0.595
Std. Error of Kurtosis		0.656	0.656	0.656
Minimum		0.0	0.0	0.0
Maximum		4.0	4.0	4.0
Sum		83.0	96.0	107.0

Table B.2 Frequency Table for all factors (continued)

		leadership style	ownership contribution	ownership type	collaboration contribution	collaboration type
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		2.000	1.980	1.922	1.824	1.039
Median		2.000	2.000	2.000	2.000	1.000
Mode		2.0	3.0	2.0	3.0	0.0
Std. Deviation		0.9592	1.2568	0.5601	1.1782	1.0190
Variance		0.920	1.580	0.314	1.388	1.038
Skewness		-0.283	-0.276	-1.455	-0.101	0.627
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		0.595	-1.085	4.960	-1.172	-0.710
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656
Minimum		0.0	0.0	0.0	0.0	0.0
Maximum		4.0	4.0	3.0	4.0	3.0
Sum		102.0	101.0	98.0	93.0	53.0

Table B.2 Frequency Table for all factors (continued)

		hierarchy contribution	number of hirerarchy layers	span of control	number of people reporting to a	organisational relationships contribution

					manager	
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		1.412	0.216	1.549	0.686	1.784
Median		1.000	0.000	2.000	0.000	2.000
Mode		2.0	0.0	2.0	0.0	3.0
Std. Deviation		1.0987	0.4610	1.0453	1.0486	1.2855
Variance		1.207	0.213	1.093	1.100	1.653
Skewness		0.234	2.042	-0.190	1.757	0.010
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		-0.873	3.615	-1.121	2.727	-1.185
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656
Minimum		0.0	0.0	0.0	0.0	0.0
Maximum		4.0	2.0	3.0	4.0	4.0
Sum		72.0	11.0	79.0	35.0	91.0

Table B.2 Frequency Table for all factors (continued)

		organisational relationships	size of organisation contribution	organisation size	strategy contribution	strategy type
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		2.392	1.549	0.510	2.039	1.431
Median		2.000	1.000	0.000	2.000	1.000
Mode		1.0	1.0	0.0	3.0	1.0
Std. Deviation		1.6980	1.1369	0.7314	1.1826	1.0441
Variance		2.883	1.293	0.535	1.398	1.090
Skewness		0.142	0.214	1.082	-0.154	0.244
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		-1.362	-1.120	-0.243	-0.845	-1.096
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656
Minimum		0.0	0.0	0.0	0.0	0.0
Maximum		5.0	4.0	2.0	4.0	3.0
Sum		122.0	79.0	26.0	104.0	73.0

Table B.2 Frequency Table for all factors (continued)

		policies contribution	policies type	organisational learning systems contribution	organisational learning systems	political freedom contribution
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		1.725	1.275	1.451	1.196	1.176

Median	2.000	1.000	1.000	1.000	1.000
Mode	1.0	1.0	2.0	1.0	0.0
Std. Deviation	1.2662	0.7504	1.0828	0.8490	1.2443
Variance	1.603	0.563	1.173	0.721	1.548
Skewness	0.175	-0.209	0.180	0.014	0.689
Std. Error of Skewness	0.333	0.333	0.333	0.333	0.333
Kurtosis	-1.134	-0.654	-0.835	-0.876	-0.747
Std. Error of Kurtosis	0.656	0.656	0.656	0.656	0.656
Minimum	0.0	0.0	0.0	0.0	0.0
Maximum	4.0	3.0	4.0	3.0	4.0
Sum	88.0	65.0	74.0	61.0	60.0

Table B.2 Frequency Table for all factors (continued)

		political freedom	incentives to foreign investors contribution	incentives to foreign investors	competition law and policy contribution	employment law and policy contribution
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		1.725	0.275	0.059	0.706	1.137
Median		2.000	0.000	0.000	0.000	1.000
Mode		2.0	0.0	0.0	0.0	.0(a)
Std. Deviation		0.4931	0.6349	0.3106	0.8317	1.0587
Variance		0.243	0.403	0.096	0.692	1.121
Skewness		-1.551	2.630	5.654	0.826	0.663
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		1.543	7.229	33.120	-0.384	-0.282
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656
Minimum		0.0	0.0	0.0	0.0	0.0
Maximum		2.0	3.0	2.0	3.0	4.0
Sum		88.0	14.0	3.0	36.0	58.0

Table B.2 Frequency Table for all factors (continued)

		describe employment law and policy	health and safety regualtions contribution	describe health and safety regulations	level of economic activity contribution	describe economic activity
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		0.843	2.216	0.941	1.980	1.882
Median		1.000	3.000	1.000	2.000	2.000
Mode		1.0	3.0	0.0	2.0	2.0
Std. Deviation		0.7582	1.3163	0.8582	1.1746	0.9088
Variance		0.575	1.733	0.736	1.380	0.826

Skewness	0.273	-0.252	0.116	-0.269	-0.426
Std. Error of Skewness	0.333	0.333	0.333	0.333	0.333
Kurtosis	-1.188	-1.172	-1.648	-0.686	0.228
Std. Error of Kurtosis	0.656	0.656	0.656	0.656	0.656
Minimum	0.0	0.0	0.0	0.0	0.0
Maximum	2.0	4.0	2.0	4.0	4.0
Sum	43.0	113.0	48.0	101.0	96.0

Table B.2 Frequency Table for all factors (continued)

		GDP conntribution	trend in GDP	rate of inflation contribution	describe rate of inflation	strength of currency contribution
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		1.275	1.000	1.451	1.588	0.941
Median		1.000	1.000	1.000	2.000	1.000
Mode		1.0	1.0	1.0(a)	2.0	0.0
Std. Deviation		1.0016	0.4000	1.0828	0.9418	1.0471
Variance		1.003	0.160	1.173	0.887	1.096
Skewness		0.407	-0.001	0.377	-0.415	1.100
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		-0.287	3.858	-0.403	-0.696	0.565
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656
Minimum		0.0	0.0	0.0	0.0	0.0
Maximum		4.0	2.0	4.0	3.0	4.0
Sum		65.0	51.0	74.0	81.0	48.0

Table B.2 Frequency Table for all factors (continued)

		strenth of currency	rates of taxation contribution	describe rates of taxation	level of government spending in R&D contribution	government spending in R&D
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		1.176	1.765	2.039	1.157	0.941
Median		1.000	2.000	2.000	1.000	1.000
Mode		1.0	2.0(a)	2.0	.0(a)	1.0
Std. Deviation		0.9530	1.2898	0.9992	1.1022	0.8345
Variance		0.908	1.664	0.998	1.215	0.696
Skewness		0.353	-0.006	-0.957	0.796	0.543
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		-0.780	-1.155	-0.005	0.064	-0.314
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656

Minimum	0.0	0.0	0.0	0.0	0.0
Maximum	3.0	4.0	3.0	4.0	3.0
Sum	60.0	90.0	104.0	59.0	48.0

Table B.2 Frequency Table for all factors (continued)

		energy provision contribution	describe energy provision	transport provision contribution	describe transport provision	promotion of products/services contribution
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		1.294	1.176	1.392	1.353	1.667
Median		1.000	1.000	1.000	1.000	2.000
Mode		1.0	1.0	1.0	2.0	2.0
Std. Deviation		0.9653	0.8650	1.1328	1.0163	1.0893
Variance		0.932	0.748	1.283	1.033	1.187
Skewness		0.338	0.222	0.450	0.061	-0.061
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		-0.766	-0.648	-0.583	-1.112	-0.950
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656
Minimum		0.0	0.0	0.0	0.0	0.0
Maximum		3.0	3.0	4.0	3.0	4.0
Sum		66.0	60.0	71.0	69.0	85.0

Table B.2 Frequency Table for all factors (continued)

		describe the promotion of products/services	intellectual property rights contribution	describe intellectual property rights	sales management contribution	describe sales management
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		1.882	1.176	1.118	1.333	1.667
Median		2.000	1.000	1.000	1.000	2.000
Mode		3.0	0.0	1.0	1.0	3.0
Std. Deviation		1.1601	1.1262	0.6526	1.0708	1.2111
Variance		1.346	1.268	0.426	1.147	1.467
Skewness		-0.562	0.425	-0.120	0.200	-0.302
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		-1.165	-1.219	-0.581	-1.192	-1.479
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656
Minimum		0.0	0.0	0.0	0.0	0.0
Maximum		3.0	3.0	2.0	3.0	3.0
Sum		96.0	60.0	57.0	68.0	85.0

Table B.2 Frequency Table for all factors (continued)

		market information availability contribution	describe market information availability	process integration contribution	level of process integration	quality control contribution
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		1.706	1.314	1.157	1.980	1.902
Median		2.000	1.000	1.000	2.000	2.000
Mode		2.0	1.0	.0(a)	3.0	1.0
Std. Deviation		1.0449	0.5828	0.9874	1.1746	1.1001
Variance		1.092	0.340	0.975	1.380	1.210
Skewness		-0.028	-0.164	0.321	-0.346	0.013
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		-0.834	-0.563	-0.972	-0.834	-0.820
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656
Minimum		0.0	0.0	0.0	0.0	0.0
Maximum		4.0	2.0	3.0	4.0	4.0
Sum		87.0	67.0	59.0	101.0	97.0

Table B.2 Frequency Table for all factors (continued)

		describe quality control	R&D expenditure contribution	describe R&D expinditure	knowledge management processes contribution	describe knowledge management processes
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		1.882	1.137	0.549	1.961	2.176
Median		2.000	1.000	0.000	2.000	2.000
Mode		2.0	0.0	0.0	2.0(a)	1.0(a)
Std. Deviation		0.8160	1.0958	0.8078	1.2643	1.5324
Variance		0.666	1.201	0.653	1.598	2.348
Skewness		-0.466	0.477	1.257	-0.047	0.454
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		-0.061	-1.099	0.544	-1.013	-0.663
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656
Minimum		0.0	0.0	0.0	0.0	0.0
Maximum		3.0	3.0	3.0	4.0	5.0
Sum		96.0	58.0	28.0	100.0	111.0

Table B.2 Frequency Table for all factors (continued)

		capital structure	describe capital	financial management	describe financial	financiers attitude

		contribution	structure	contribution	management	contribution
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		1.529	0.569	1.961	1.353	1.392
Median		1.000	0.000	2.000	1.000	1.000
Mode		.0(a)	0.0	3.0	2.0	0.0
Std. Deviation		1.2059	0.6710	1.1993	0.6877	1.2818
Variance		1.454	0.450	1.438	0.473	1.643
Skewness		0.213	0.773	-0.067	-0.594	0.339
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		-1.070	-0.466	-1.113	-0.705	-1.224
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656
Minimum		0.0	0.0	0.0	0.0	0.0
Maximum		4.0	2.0	4.0	2.0	4.0
Sum		78.0	29.0	100.0	69.0	71.0

Table B.2 Frequency Table for all factors (continued)

		describe financiers attitude	number of R&D staff contribution	describe percentage of R&D staff	competence skills of R&D staff contribution	describe compete nce skills of R&D staff
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		2.255	0.960	0.412	0.863	0.647
Median		2.000	0.970	0.000	0.000	0.000
Mode		2.0	0.0	0.0	0.0	0.0
Std. Deviation		0.5947	1.1482	0.6686	1.2003	1.0550
Variance		0.354	1.318	0.447	1.441	1.113
Skewness		-0.136	0.906	1.381	0.924	1.829
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		-0.434	-0.336	0.663	-0.853	2.879
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656
Minimum		1.0	0.0	0.0	0.0	0.0
Maximum		3.0	4.0	2.0	3.0	4.0
Sum		115.0	49.0	21.0	44.0	33.0

Table B.2 Frequency Table for all factors (continued)

		performance of R&D staff contribution	describe performan ce of R&D staff	age profile of R&D staff contribution	describe age profile of R&D staff	retention of R&D staff contributi

						on
N	Valid	51	51	51	51	51
	Missing	0	0	0	0	0
Mean		0.804	1.000	0.667	0.647	0.706
Median		0.000	0.000	0.000	0.000	0.000
Mode		0.0	0.0	0.0	0.0	0.0
Std. Deviation		1.1493	1.5748	1.0132	1.0163	1.0449
Variance		1.321	2.480	1.027	1.033	1.092
Skewness		0.977	1.247	1.205	1.486	1.176
Std. Error of Skewness		0.333	0.333	0.333	0.333	0.333
Kurtosis		-0.700	-0.050	0.030	1.469	-0.046
Std. Error of Kurtosis		0.656	0.656	0.656	0.656	0.656
Minimum		0.0	0.0	0.0	0.0	0.0
Maximum		3.0	5.0	3.0	4.0	3.0
Sum		41.0	51.0	34.0	33.0	36.0

Table B.2 Frequency Table for all factors (continued)

		describe retention of R&D staff	staff development contribution	hours of typical staff development
N	Valid	51	51	51
	Missing	0	0	0
Mean		0.863	1.686	1.275
Median		0.000	2.000	1.000
Mode		0.0	2.0	.0(a)
Std. Deviation		1.5877	1.2246	1.2662
Variance		2.521	1.500	1.603
Skewness		1.482	-0.112	0.871
Std. Error of Skewness		0.333	0.333	0.333
Kurtosis		0.322	-1.155	0.095
Std. Error of Kurtosis		0.656	0.656	0.656
Minimum		0.0	0.0	0.0
Maximum		4.0	4.0	5.0
Sum		44.0	86.0	65.0

B.3 Variation of responses

Tables in this section illustrate the variation of the responses for both the measure of the extent to which each factor contributes to propagation of innovation and the condition of the factor.

Table B.3 Technology contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	8	15.7	15.7	15.7
	Little	16	31.4	31.4	47.1
	Moderate	15	29.4	29.4	76.5
	Very Much	11	21.6	21.6	98.0
	Great	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.4 Technology description

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Ancient	1	2.0	2.0	2.0
	Established	23	45.1	45.1	47.1
	Modern	13	25.5	25.5	72.5
	New	9	17.6	17.6	90.2
	Emerging	5	9.8	9.8	100.0
	Total	51	100.0	100.0	

Table B.5 Leadership contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	6	11.8	11.8	11.8
	Little	8	15.7	15.7	27.5
	Moderate	16	31.4	31.4	58.8
	Very Much	17	33.3	33.3	92.2
	Great	4	7.8	7.8	100.0
	Total	51	100.0	100.0	

Table B.6 Leadership style

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Authoritative	5	9.8	9.8	9.8
	Paternalistic	5	9.8	9.8	19.6
	Participative	29	56.9	56.9	76.5
	Delegate	9	17.6	17.6	94.1
	Free Reign	3	5.9	5.9	100.0
	Total	51	100.0	100.0	

Table B.7 Ownership contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	9	17.6	17.6	17.6
	Little	9	17.6	17.6	35.3
	Moderate	11	21.6	21.6	56.9
	Very Much	18	35.3	35.3	92.2
	Great	4	7.8	7.8	100.0
	Total	51	100.0	100.0	

Table B.8 Ownership type

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Sole Proprietor	2	3.9	3.9	3.9
	Partnership	4	7.8	7.8	11.8
	Private Limited Co.	41	80.4	80.4	92.2
	Public Limited Co.	4	7.8	7.8	100.0
	Total	51	100.0	100.0	

Table B.9 Collaboration contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	8	15.7	15.7	15.7
	Little	14	27.5	27.5	43.1
	Moderate	10	19.6	19.6	62.7
	Very Much	17	33.3	33.3	96.1
	Great	2	3.9	3.9	100.0
	Total	51	100.0	100.0	

Table B.10 Collaboration type

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	None	19	37.3	37.3	37.3
	Regional	17	33.3	33.3	70.6
	National	9	17.6	17.6	88.2
	International	6	11.8	11.8	100.0
	Total	51	100.0	100.0	

Table B.11 Hierarchy contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	13	25.5	25.5	25.5
	Little	14	27.5	27.5	52.9
	Moderate	15	29.4	29.4	82.4
	Very Much	8	15.7	15.7	98.0
	Great	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.12 Number of hierarchy layers

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	8-10 layers	1	2.0	2.0	2.0
	5-7 layers	9	17.6	17.6	19.6
	2-4 layers	41	80.4	80.4	100.0
	Total	51	100.0	100.0	

Table B.13 Span of control

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	11	21.6	21.6	21.6
	Little	11	21.6	21.6	43.1
	Moderate	19	37.3	37.3	80.4
	Very Much	10	19.6	19.6	100.0
	Total	51	100.0	100.0	

Table B.14 Number of people reporting to a manager

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	more than 24 people	2	3.9	3.9	3.9
	19-24 people	2	3.9	3.9	7.8
	13-18 people	4	7.8	7.8	15.7
	7-12 people	13	25.5	25.5	41.2
	1-6 people	30	58.8	58.8	100.0
	Total	51	100.0	100.0	

Table B.15 Organisational relationships contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	11	21.6	21.6	21.6
	Little	11	21.6	21.6	43.1
	Moderate	11	21.6	21.6	64.7
	Very Much	14	27.5	27.5	92.2
	Great	4	7.8	7.8	100.0
	Total	51	100.0	100.0	

Table B.16 Organisational relationships

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Formal Lateral Relationships	7	13.7	13.7	13.7
	Formal Vertical Relationships	14	27.5	27.5	41.2
	Formal Diagonal Relationships	6	11.8	11.8	52.9
	Informal Lateral Relationships	7	13.7	13.7	66.7
	Informal Vertical Relationships	10	19.6	19.6	86.3
	Informal Diagonal Relationships	7	13.7	13.7	100.0
	Total	51	100.0	100.0	

Table B.17 Size of organisation contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	10	19.6	19.6	19.6
	Little	18	35.3	35.3	54.9
	Moderate	9	17.6	17.6	72.5
	Very Much	13	25.5	25.5	98.0
	Great	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.18 Organisation size

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-24 employees	32	62.7	62.7	62.7
	25-250 employees	12	23.5	23.5	86.3
	250<employees	7	13.7	13.7	100.0
	Total	51	100.0	100.0	

Table B.19 Strategy contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	6	11.8	11.8	11.8
	Little	11	21.6	21.6	33.3
	Moderate	14	27.5	27.5	60.8
	Very Much	15	29.4	29.4	90.2
	Great	5	9.8	9.8	100.0
	Total	51	100.0	100.0	

Table B.20 Strategy type

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Environmental/Opportunistic Strategies	10	19.6	19.6	19.6
	Entrepreneurial/Visionary Strategies	20	39.2	39.2	58.8
	Learning and Capabilities Learning Strategies	10	19.6	19.6	78.4
	Competitive/Positioning Strategies	11	21.6	21.6	100.0
	Total	51	100.0	100.0	

Table B.21 Policies contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	10	19.6	19.6	19.6
	Little	15	29.4	29.4	49.0
	Moderate	9	17.6	17.6	66.7
	Very Much	13	25.5	25.5	92.2
	Great	4	7.8	7.8	100.0
	Total	51	100.0	100.0	

Table B.22 Policies type

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Always Mandatory	1	2.0	2.0	2.0
	Mainly Mandatory	20	39.2	39.2	41.2
	Mainly Advisory	22	43.1	43.1	84.3
	Always Advisory	8	15.7	15.7	100.0
	Total	51	100.0	100.0	

Table B.23 Organisational learning systems contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	12	23.5	23.5	23.5
	Little	14	27.5	27.5	51.0
	Moderate	16	31.4	31.4	82.4
	Very Much	8	15.7	15.7	98.0
	Great	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.24 Organisational learning systems

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Learning facts, knowledge, processes and procedures	12	23.5	23.5	23.5
	Learning new job skills that are transferable to other situations	19	37.3	37.3	60.8
	Learning to adapt	18	35.3	35.3	96.1
	Learning to learn	2	3.9	3.9	100.0
	Total	51	100.0	100.0	

Table B.25 Political freedom contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	21	41.2	41.2	41.2
	Little	12	23.5	23.5	64.7

	Moderate	8	15.7	15.7	80.4
	Very Much	8	15.7	15.7	96.1
	Great	2	3.9	3.9	100.0
	Total	51	100.0	100.0	

Table B.26 Political freedom

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Fully Restricted	1	2.0	2.0	2.0
	Partially Restricted	12	23.5	23.5	25.5
	Unrestricted	38	74.5	74.5	100.0
	Total	51	100.0	100.0	

Table B.27 Incentives to foreign investors' contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	41	80.4	80.4	80.4
	Little	7	13.7	13.7	94.1
	Moderate	2	3.9	3.9	98.0
	Very Much	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.28 Incentives to foreign investors

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	49	96.1	96.1	96.1
	Physical Assets	1	2.0	2.0	98.0
	Tax Relief	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.29 Competition law and policy contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	26	51.0	51.0	51.0
	Little	15	29.4	29.4	80.4
	Moderate	10	19.6	19.6	100.0
	Total	51	100.0	100.0	

Table B.30 Describe competition law and policy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Restrictive	17	33.3	33.3	33.3
	Facilitating	21	41.2	41.2	74.5
	Supportive	12	23.5	23.5	98.0
	Not Applicable	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.31 Employment law and policy contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	17	33.3	33.3	33.3
	Little	17	33.3	33.3	66.7
	Moderate	11	21.6	21.6	88.2
	Very Much	5	9.8	9.8	98.0
	Great	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.32 Describe employment law and policy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Restrictive	19	37.3	37.3	37.3
	Facilitating	21	41.2	41.2	78.4
	Supportive	11	21.6	21.6	100.0
	Total	51	100.0	100.0	

Table B.33 Health and safety regulations contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	6	11.8	11.8	11.8
	Little	12	23.5	23.5	35.3
	Moderate	7	13.7	13.7	49.0
	Very Much	17	33.3	33.3	82.4
	Great	9	17.6	17.6	100.0
	Total	51	100.0	100.0	

Table B.34 Describe health and safety regulations

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Restrictive	20	39.2	39.2	39.2
	Facilitating	14	27.5	27.5	66.7
	Supportive	17	33.3	33.3	100.0
	Total	51	100.0	100.0	

Table B.35 Level of economic activity contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	8	15.7	15.7	15.7
	Little	7	13.7	13.7	29.4
	Moderate	18	35.3	35.3	64.7
	Very Much	14	27.5	27.5	92.2
	Great	4	7.8	7.8	100.0
	Total	51	100.0	100.0	

Table B.36 Describe economic activity

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	5	9.8	9.8	9.8
	Low	8	15.7	15.7	25.5
	Medium	27	52.9	52.9	78.4
	High	10	19.6	19.6	98.0
	Very High	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.37 GDP contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	13	25.5	25.5	25.5
	Little	17	33.3	33.3	58.8
	Moderate	16	31.4	31.4	90.2
	Very Much	4	7.8	7.8	98.0
	Great	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.38 Trend in GDP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Falling	4	7.8	7.8	7.8
	Steady	41	80.4	80.4	88.2
	1.0	1	2.0	2.0	90.2
	1.0	1	2.0	2.0	92.2
	Rising	4	7.8	7.8	100.0
	Total	51	100.0	100.0	

Table B.39 Rate of inflation contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	11	21.6	21.6	21.6
	Little	16	31.4	31.4	52.9
	Moderate	16	31.4	31.4	84.3
	Very Much	6	11.8	11.8	96.1
	Great	2	3.9	3.9	100.0
	Total	51	100.0	100.0	

Table B.40 Describe rate of inflation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	9	17.6	17.6	17.6
	Low	10	19.6	19.6	37.3
	Medium	25	49.0	49.0	86.3
	High	7	13.7	13.7	100.0
	Total	51	100.0	100.0	

Table B.41 Strength of currency contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	21	41.2	41.2	41.2
	Little	19	37.3	37.3	78.4
	Moderate	5	9.8	9.8	88.2
	Very Much	5	9.8	9.8	98.0
	Great	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.42 Strength of currency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	14	27.5	27.5	27.5
	Low	19	37.3	37.3	64.7
	Medium	13	25.5	25.5	90.2
	High	5	9.8	9.8	100.0
	Total	51	100.0	100.0	

Table B.43 Rates of taxation contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	12	23.5	23.5	23.5
	Little	9	17.6	17.6	41.2
	Moderate	13	25.5	25.5	66.7
	Very Much	13	25.5	25.5	92.2
	Great	4	7.8	7.8	100.0
	Total	51	100.0	100.0	

Table B.44 Describe rates of taxation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High	19	37.3	37.3	37.3
	Medium	22	43.1	43.1	80.4
	Low	3	5.9	5.9	86.3
	Very Low	7	13.7	13.7	100.0
	Total	51	100.0	100.0	

Table B.45 Level of government spending in R&D contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	17	33.3	33.3	33.3
	Little	17	33.3	33.3	66.7
	Moderate	11	21.6	21.6	88.2
	Very Much	4	7.8	7.8	96.1
	Great	2	3.9	3.9	100.0
	Total	51	100.0	100.0	

Table B.46 Government spending in R&D

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	17	33.3	33.3	33.3
	Low	22	43.1	43.1	76.5
	Medium	10	19.6	19.6	96.1
	High	2	3.9	3.9	100.0
	Total	51	100.0	100.0	

Table B.47 Energy provision contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	11	21.6	21.6	21.6
	Little	21	41.2	41.2	62.7
	Moderate	12	23.5	23.5	86.3
	Very Much	7	13.7	13.7	100.0
	Total	51	100.0	100.0	

Table B.48 Describe energy provision

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	12	23.5	23.5	23.5
	Low	21	41.2	41.2	64.7
	Medium	15	29.4	29.4	94.1
	High	3	5.9	5.9	100.0
	Total	51	100.0	100.0	

Table B.49 Transport provision contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	13	25.5	25.5	25.5
	Little	16	31.4	31.4	56.9
	Moderate	13	25.5	25.5	82.4
	Very Much	7	13.7	13.7	96.1
	Great	2	3.9	3.9	100.0
	Total	51	100.0	100.0	

Table B.50 Describe transport provision

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very Low	13	25.5	25.5	25.5
	Low	14	27.5	27.5	52.9
	Medium	17	33.3	33.3	86.3
	High	7	13.7	13.7	100.0
	Total	51	100.0	100.0	

Table B.51 Promotion of products/services contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	9	17.6	17.6	17.6
	Little	13	25.5	25.5	43.1
	Moderate	16	31.4	31.4	74.5
	Very Much	12	23.5	23.5	98.0
	Great	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.52 Describe the promotion of products/services

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	10	19.6	19.6	19.6
	Amateur	7	13.7	13.7	33.3
	Semi-Professional	13	25.5	25.5	58.8
	Professional	21	41.2	41.2	100.0
	Total	51	100.0	100.0	

Table B.53 Intellectual property rights contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	19	37.3	37.3	37.3
	Little	13	25.5	25.5	62.7
	Moderate	10	19.6	19.6	82.4
	Very Much	9	17.6	17.6	100.0
	Total	51	100.0	100.0	

Table B.54 Describe intellectual property rights

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Restrictive	8	15.7	15.7	15.7
	Facilitating	29	56.9	56.9	72.5
	Supportive	14	27.5	27.5	100.0
	Total	51	100.0	100.0	

Table B.55 Sales management contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	14	27.5	27.5	27.5
	Little	15	29.4	29.4	56.9
	Moderate	13	25.5	25.5	82.4
	Very Much	9	17.6	17.6	100.0
	Total	51	100.0	100.0	

Table B.56 Describe sales management

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	14	27.5	27.5	27.5
	Amateur	6	11.8	11.8	39.2
	Semi-Professional	14	27.5	27.5	66.7
	Professional	17	33.3	33.3	100.0
	Total	51	100.0	100.0	

Table B.57 Market information availability contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	7	13.7	13.7	13.7
	Little	15	29.4	29.4	43.1
	Moderate	16	31.4	31.4	74.5
	Very Much	12	23.5	23.5	98.0
	Great	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.58 Describe market information availability

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Never Available	3	5.9	5.9	5.9
	Sometimes Available	29	56.9	56.9	62.7
	Always Available	19	37.3	37.3	100.0
	Total	51	100.0	100.0	

Table B.59 Process integration contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	16	31.4	31.4	31.4
	Little	16	31.4	31.4	62.7
	Moderate	14	27.5	27.5	90.2
	Very Much	5	9.8	9.8	100.0
	Total	51	100.0	100.0	

Table B.60 Level of process integration

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Initiation	8	15.7	15.7	15.7
	Adoption	8	15.7	15.7	31.4
	Adaption	15	29.4	29.4	60.8
	Acceptance	17	33.3	33.3	94.1
	Reutilization	3	5.9	5.9	100.0
	Total	51	100.0	100.0	

Table B.61 Quality control contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	5	9.8	9.8	9.8
	Little	15	29.4	29.4	39.2
	Moderate	14	27.5	27.5	66.7
	Very Much	14	27.5	27.5	94.1
	Great	3	5.9	5.9	100.0
	Total	51	100.0	100.0	

Table B.62 Describe quality control

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	3	5.9	5.9	5.9
	Non-Advanced	11	21.6	21.6	27.5
	Semi-Advanced	26	51.0	51.0	78.4
	Very Advanced	11	21.6	21.6	100.0
	Total	51	100.0	100.0	

Table B.63 R&D expenditure contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	19	37.3	37.3	37.3
	Little	14	27.5	27.5	64.7
	Moderate	10	19.6	19.6	84.3
	Very Much	8	15.7	15.7	100.0
	Total	51	100.0	100.0	

Table B.64 Describe R&D expenditure

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Non R&D Performers	32	62.7	62.7	62.7
	Under £1m	11	21.6	21.6	84.3
	£1m to £10m	7	13.7	13.7	98.0
	£10m to £100m	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.65 Knowledge management processes contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	8	15.7	15.7	15.7
	Little	11	21.6	21.6	37.3
	Moderate	13	25.5	25.5	62.7
	Very Much	13	25.5	25.5	88.2
	Great	6	11.8	11.8	100.0
	Total	51	100.0	100.0	

Table B.66 Describe knowledge management processes

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Obtain/Capture knowledge	6	11.8	11.8	11.8
	Locate and Access Knowledge	16	31.4	31.4	43.1
	Propagate Knowledge	6	11.8	11.8	54.9
	Transfer Knowledge	16	31.4	31.4	86.3
	Maintain Knowledge	7	13.7	13.7	100.0
	Total	51	100.0	100.0	

Table B.67 Capital structure contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	13	25.5	25.5	25.5
	Little	13	25.5	25.5	51.0
	Moderate	12	23.5	23.5	74.5
	Very Much	11	21.6	21.6	96.1
	Great	2	3.9	3.9	100.0
	Total	51	100.0	100.0	

Table B.68 Describe capital structure

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Higher than 10	5	9.8	9.8	9.8
	2-10	19	37.3	37.3	47.1
	0 to 2	27	52.9	52.9	100.0
	Total	51	100.0	100.0	

Table B.69 Financial management contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	6	11.8	11.8	11.8
	Little	15	29.4	29.4	41.2
	Moderate	9	17.6	17.6	58.8
	Very Much	17	33.3	33.3	92.2
	Great	4	7.8	7.8	100.0
	Total	51	100.0	100.0	

Table B.70 Describe financial management

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Amateur	6	11.8	11.8	11.8
	Semi-Professional	21	41.2	41.2	52.9
	Professional	24	47.1	47.1	100.0
	Total	51	100.0	100.0	

Table B.71 Financier's attitude contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	18	35.3	35.3	35.3
	Little	10	19.6	19.6	54.9
	Moderate	10	19.6	19.6	74.5
	Very Much	11	21.6	21.6	96.1
	Great	2	3.9	3.9	100.0
	Total	51	100.0	100.0	

Table B.72 Describe financier's attitude

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Undecided	4	7.8	7.8	7.8
	Supportive	30	58.8	58.8	66.7
	Highly Supportive	17	33.3	33.3	100.0
	Total	51	100.0	100.0	

Table B.73 Number of R&D staff contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	26	51.0	51.0	51.0
	Little	10	19.6	19.6	70.6
	Moderate	8	15.7	15.7	86.3
	Very Much	6	11.8	11.8	98.0
	Great	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.74 Describe percentage of R&D staff

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not applicable	35	68.6	68.6	68.6
	0%-20%	11	21.6	21.6	90.2
	20%-40%	5	9.8	9.8	100.0
	Total	51	100.0	100.0	

Table B.75 Competence skills of R&D staff contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	31	60.8	60.8	60.8
	Little	5	9.8	9.8	70.6
	Moderate	6	11.8	11.8	82.4
	Very Much	9	17.6	17.6	100.0
	Total	51	100.0	100.0	

Table B.76 Describe competence skills of R&D staff

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	32	62.7	62.7	62.7
	Non-degree holders	11	21.6	21.6	84.3
	Bachelor's degree holders	4	7.8	7.8	92.2
	Master's degree holders	2	3.9	3.9	96.1
	PhD degree holders	2	3.9	3.9	100.0
	Total	51	100.0	100.0	

Table B.77 Performance of R&D staff contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	32	62.7	62.7	62.7
	Little	4	7.8	7.8	70.6
	Moderate	8	15.7	15.7	86.3
	Very Much	7	13.7	13.7	100.0
	Total	51	100.0	100.0	

Table B.78 Describe performance of R&D staff

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	33	64.7	64.7	64.7
	Very Low	5	9.8	9.8	74.5
	Low	1	2.0	2.0	76.5
	Medium	5	9.8	9.8	86.3
	High	6	11.8	11.8	98.0
	Very High	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

Table B.79 Age profile of R&D staff contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	33	64.7	64.7	64.7
	Little	6	11.8	11.8	76.5
	Moderate	8	15.7	15.7	92.2
	Very Much	4	7.8	7.8	100.0
	Total	51	100.0	100.0	

Table B.80 Describe age profile of R&D staff

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	33	64.7	64.7	64.7
	Older than 55 years old	1	2.0	2.0	66.7
	45-55 years old	2	3.9	3.9	70.6
	34-44 years old	8	15.7	15.7	86.3
	23-33 years old	7	13.7	13.7	100.0
	Total	51	100.0	100.0	

Table B.81 Retention of R&D staff contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	32	62.7	62.7	62.7
	Little	7	13.7	13.7	76.5
	Moderate	7	13.7	13.7	90.2
	Very Much	5	9.8	9.8	100.0
	Total	51	100.0	100.0	

Table B.82 Describe retention of R&D staff

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	37	72.5	72.5	72.5
	Tend to stay for 1-6 months	4	7.8	7.8	80.4
	Tend to stay for more than 2 years	10	19.6	19.6	100.0
	Total	51	100.0	100.0	

Table B.83 Staff development contribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	13	25.5	25.5	25.5
	Little	7	13.7	13.7	39.2
	Moderate	16	31.4	31.4	70.6
	Very Much	13	25.5	25.5	96.1
	Great	2	3.9	3.9	100.0
	Total	51	100.0	100.0	

Table B.84 Hours of typical staff development

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not Applicable	17	33.3	33.3	33.3
	0-20 hours	17	33.3	33.3	66.7
	20-40 hours	6	11.8	11.8	78.4
	40-60 hours	9	17.6	17.6	96.1
	60-80 hours	1	2.0	2.0	98.0
	80-100 hours	1	2.0	2.0	100.0
	Total	51	100.0	100.0	

B.4 Frequency Graphs for Part B of the questionnaire

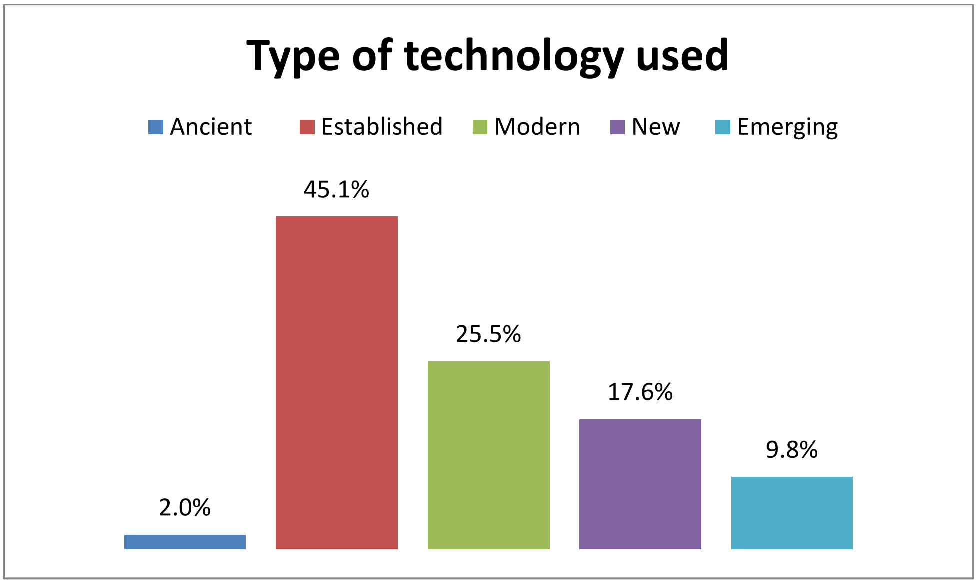


Figure B.1 Technology type

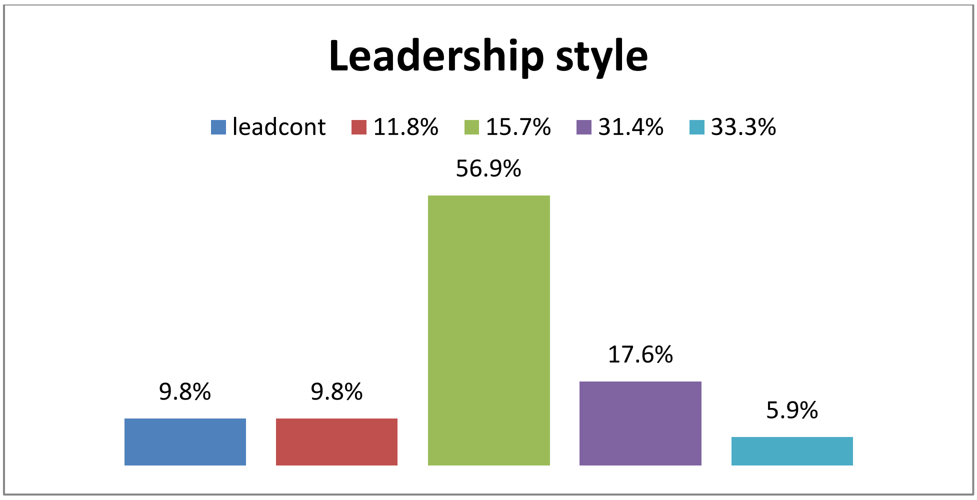


Figure B.2 Leadership style

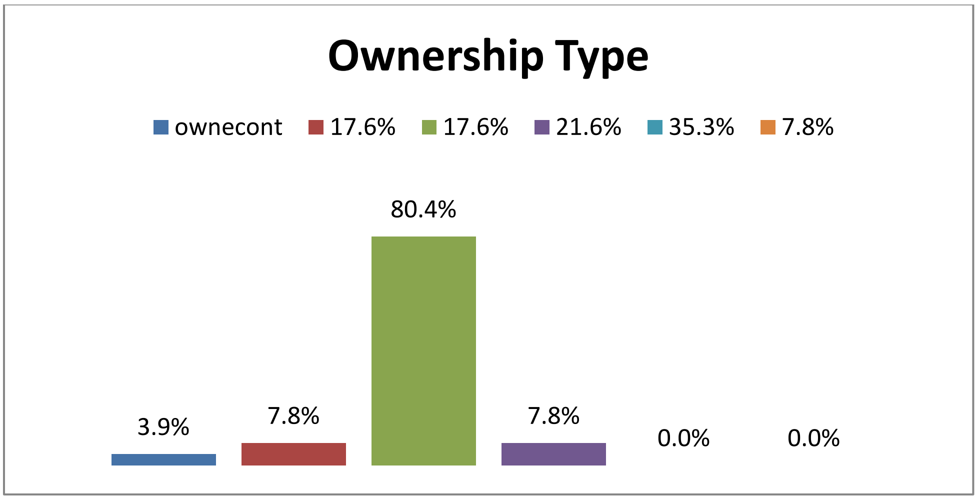


Figure B.3 Ownership type

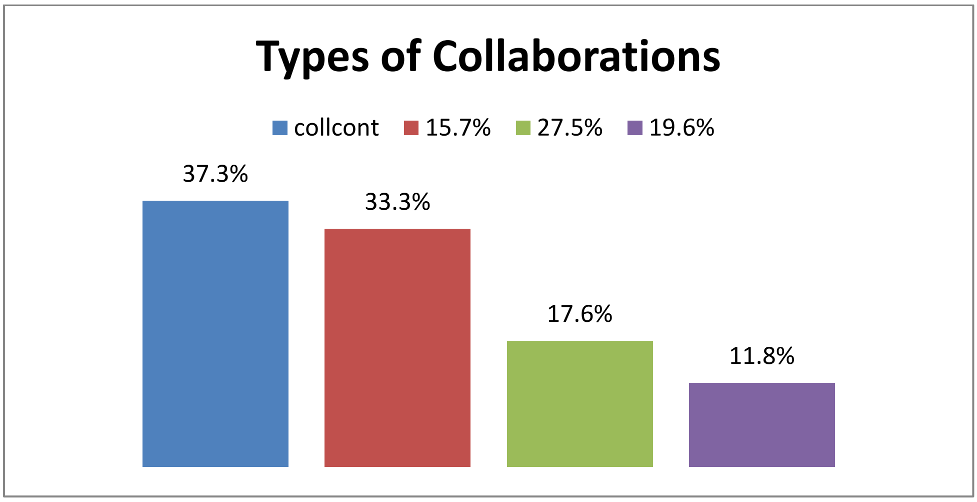


Figure B.4 Types of collaborations

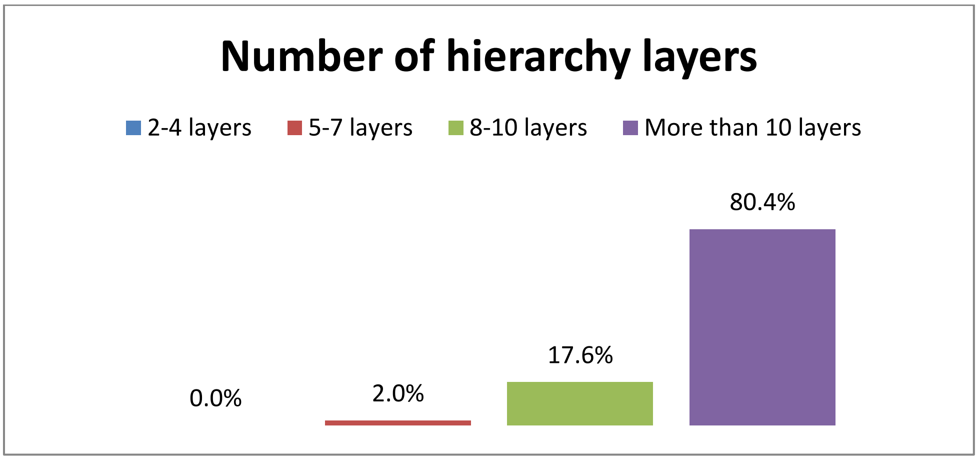


Figure B.5 Number of hierarchy layers

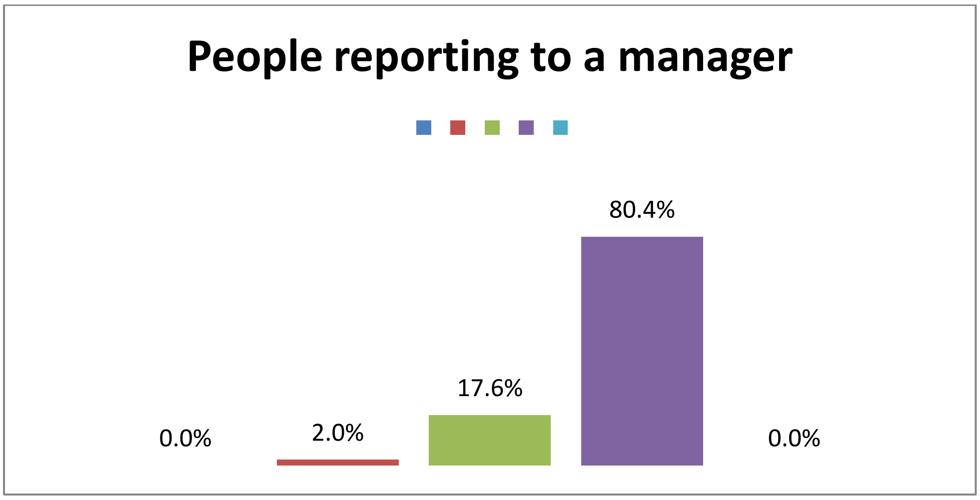


Figure B.6 People reporting to a manager

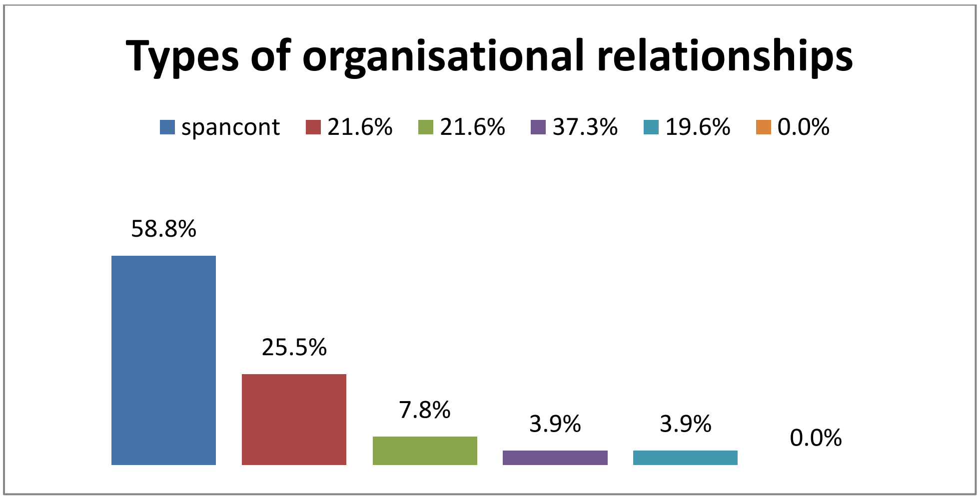


Figure B.7 Types of organisational relationships

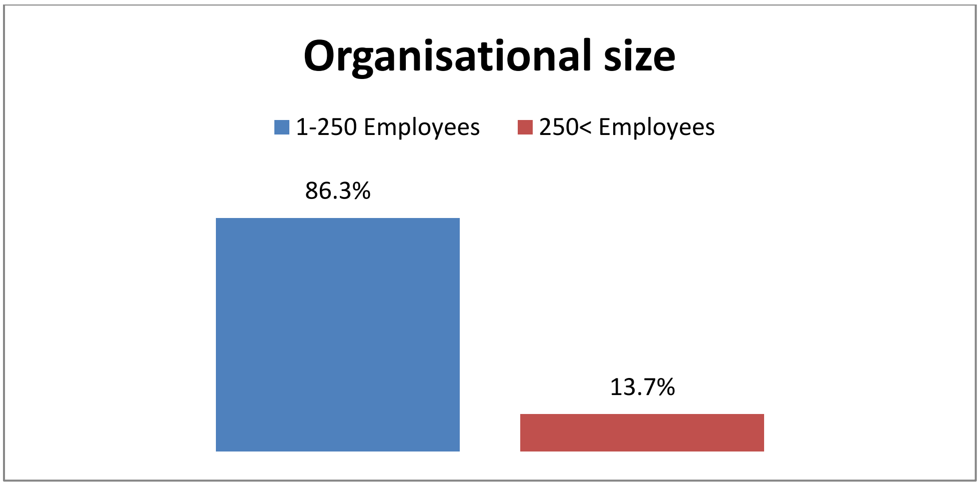


Figure B.8 Organisational size

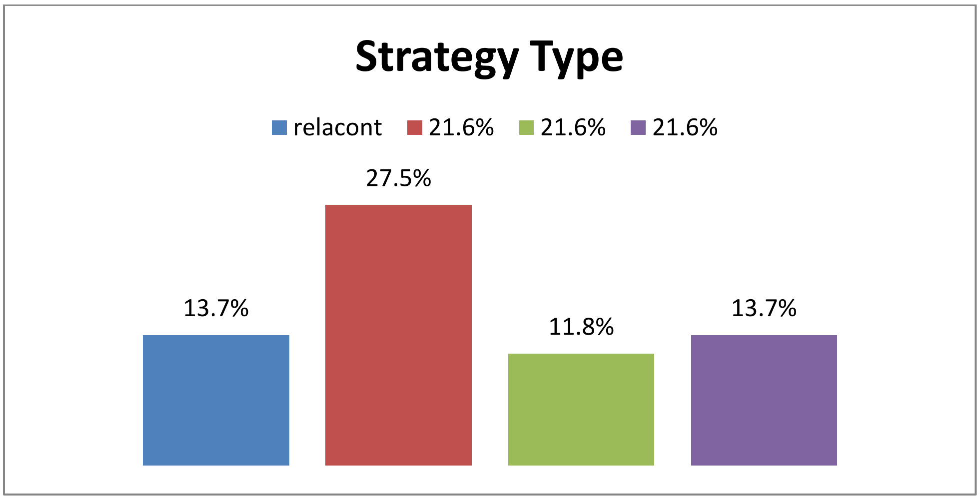


Figure B.9 Strategy Type

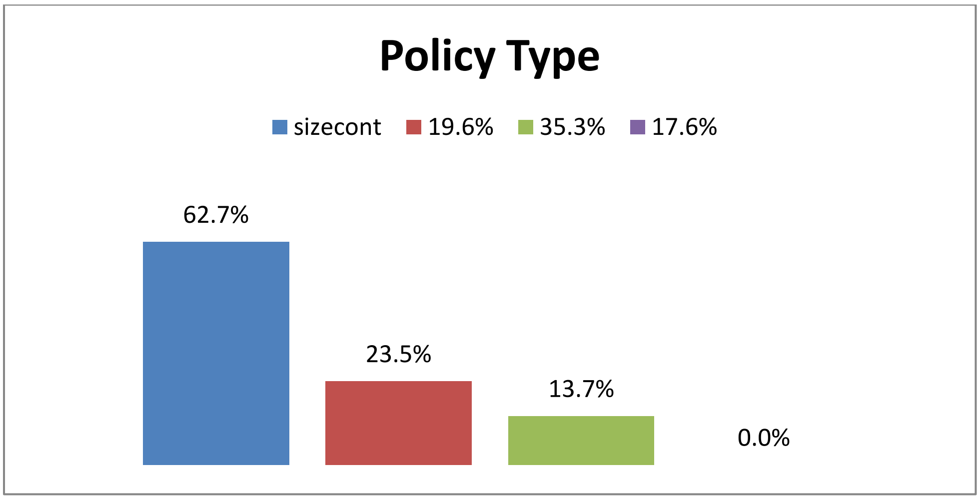


Figure B.10 Policy Type

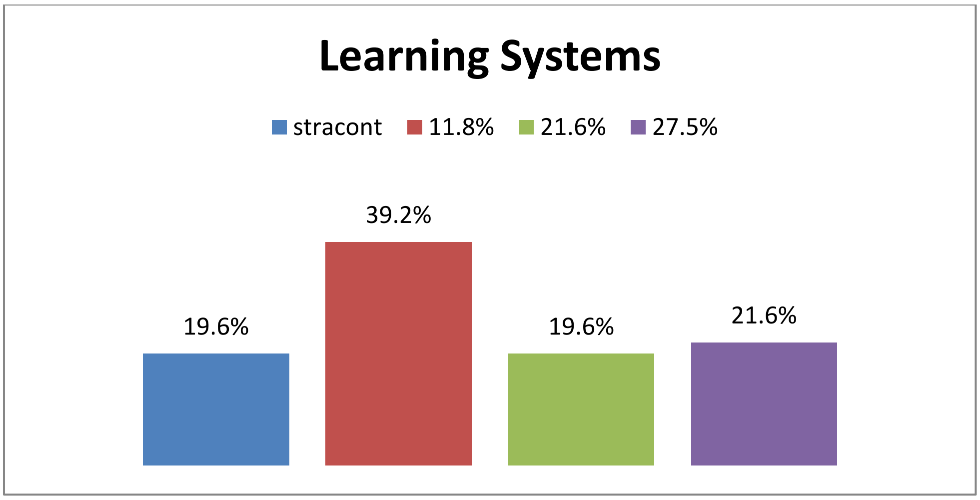


Figure B.11 Learning systems

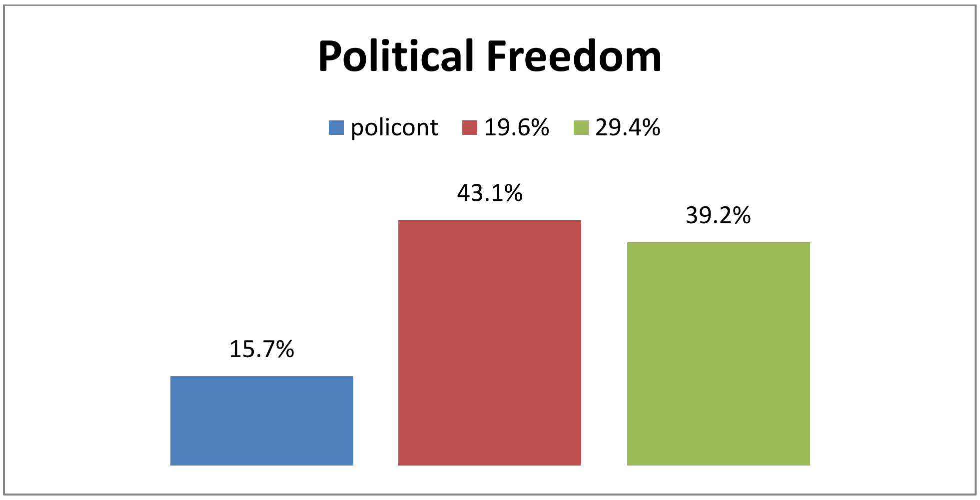


Figure B.12 Political Freedom

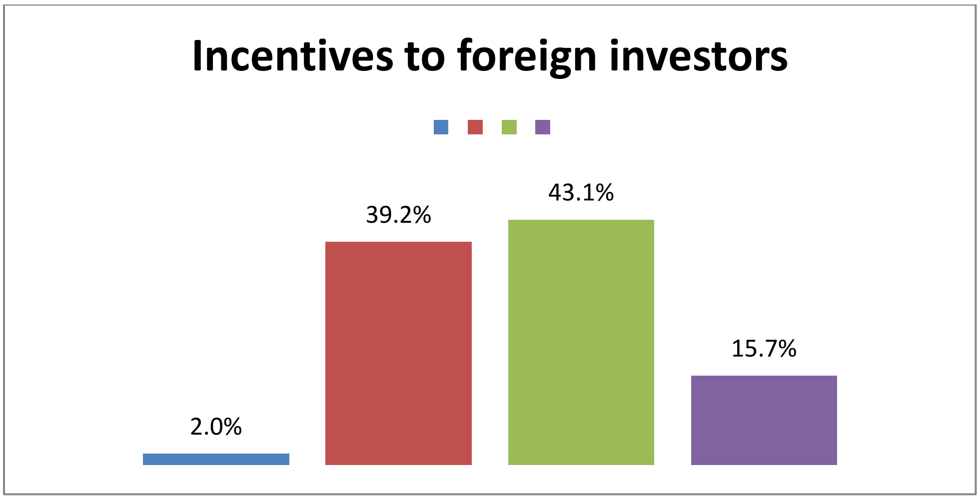


Figure B.13 Incentives to foreign investors

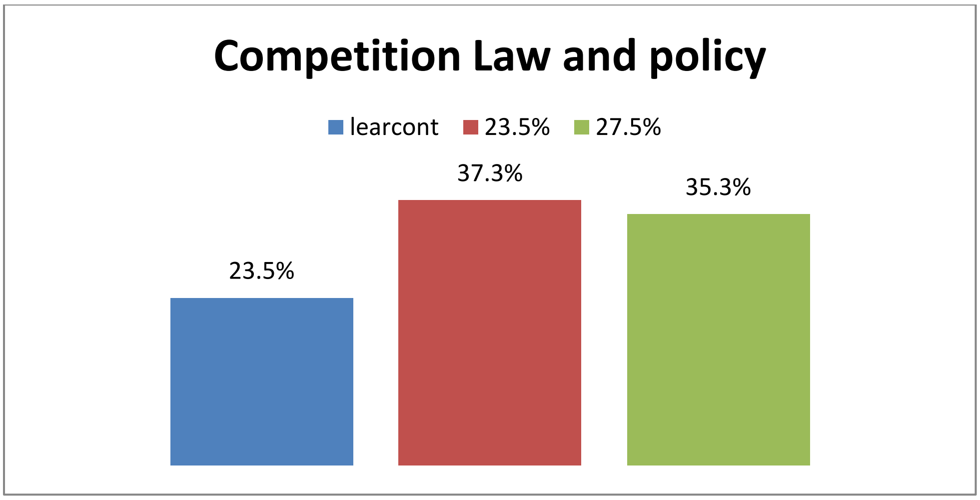


Figure B.14 Competition Law and policy

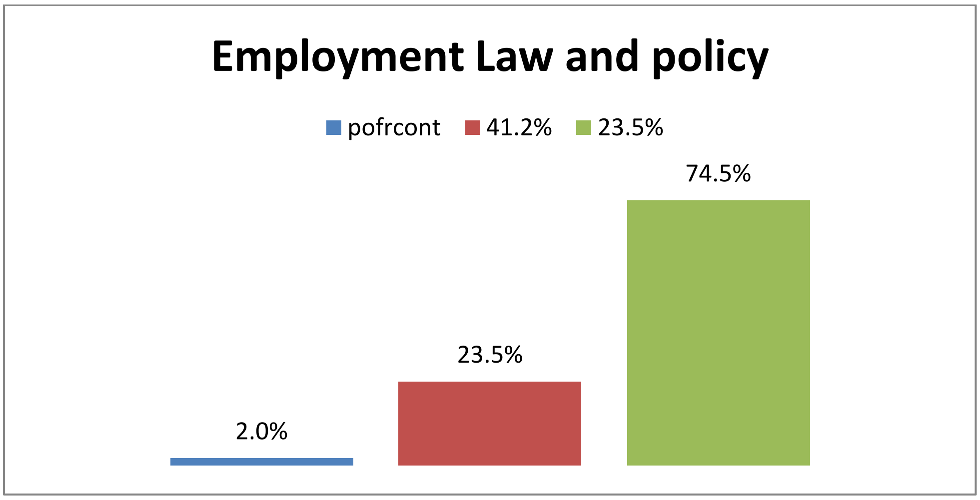


Figure B.15 Employment Law and Policy

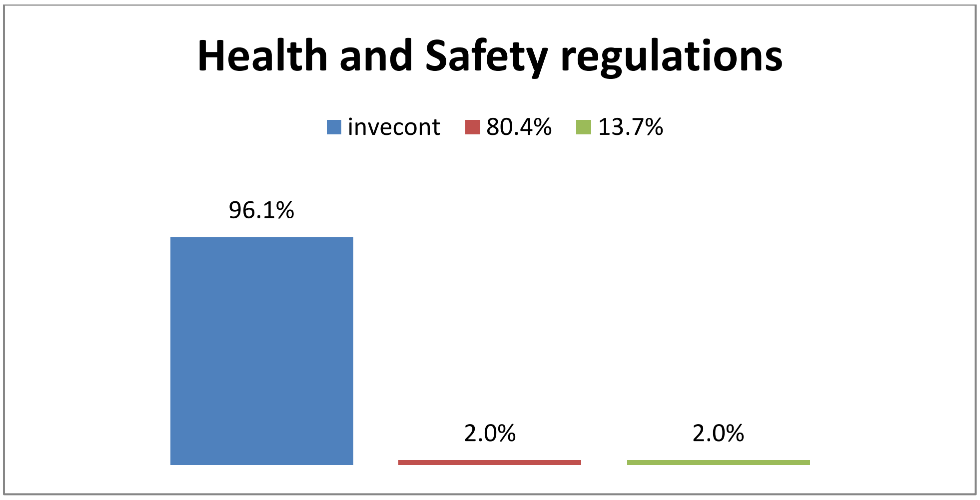


Figure B.16 health and safety regulations

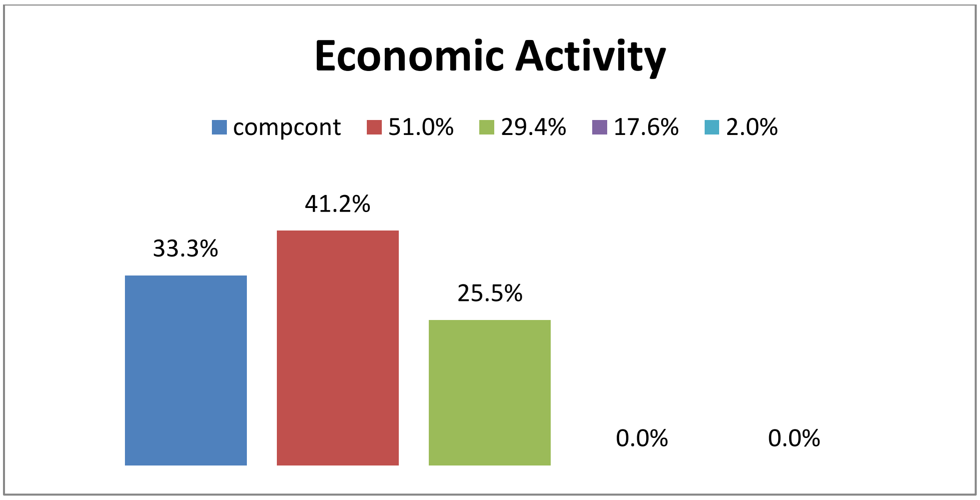


Figure B.17 Economic Activity

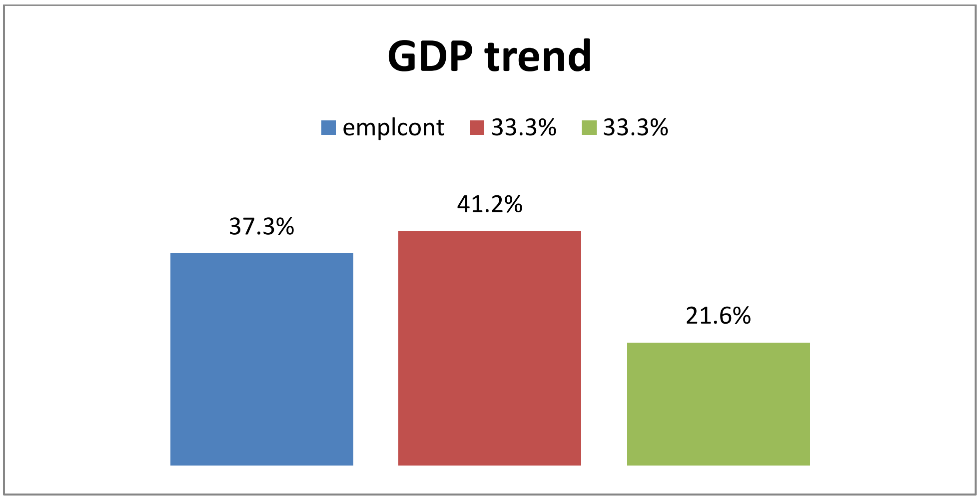


Figure B.18 GDP Trend

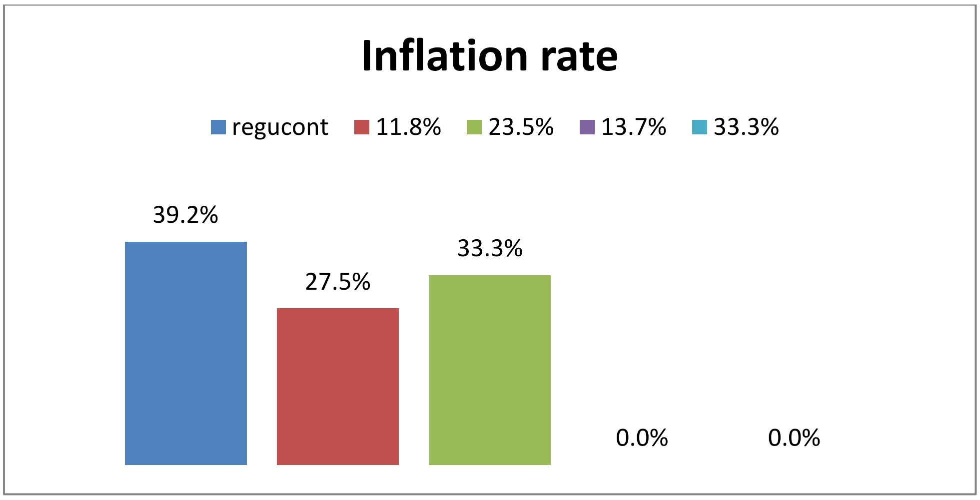


Figure B.19 Inflations rate

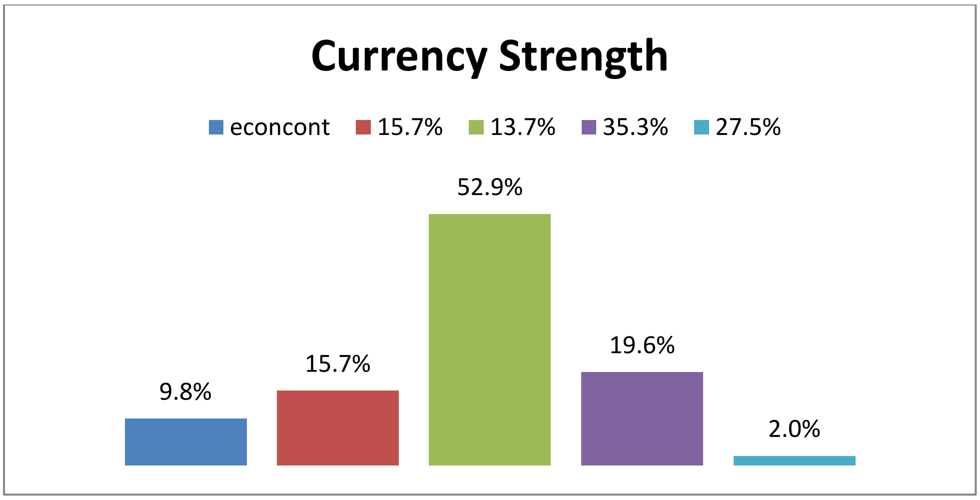


Figure B.20 Currency strength

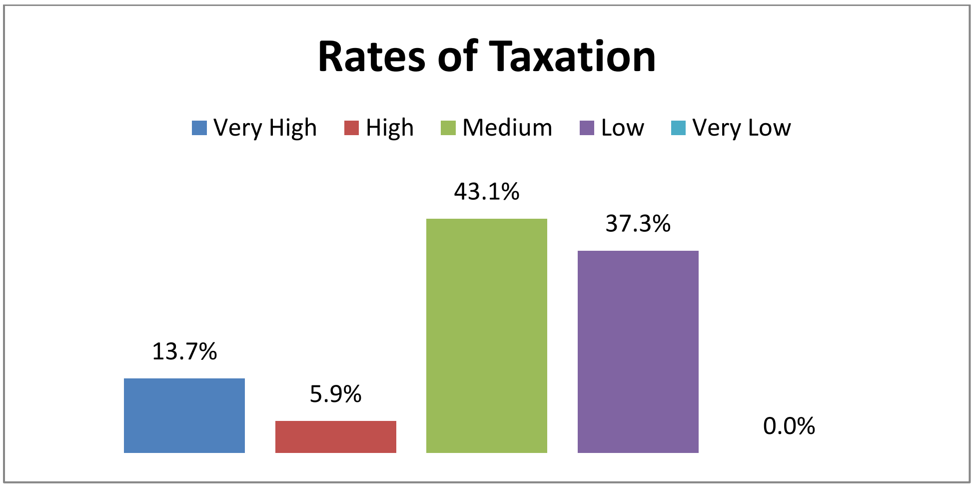


Figure B.21 Rates of Taxation

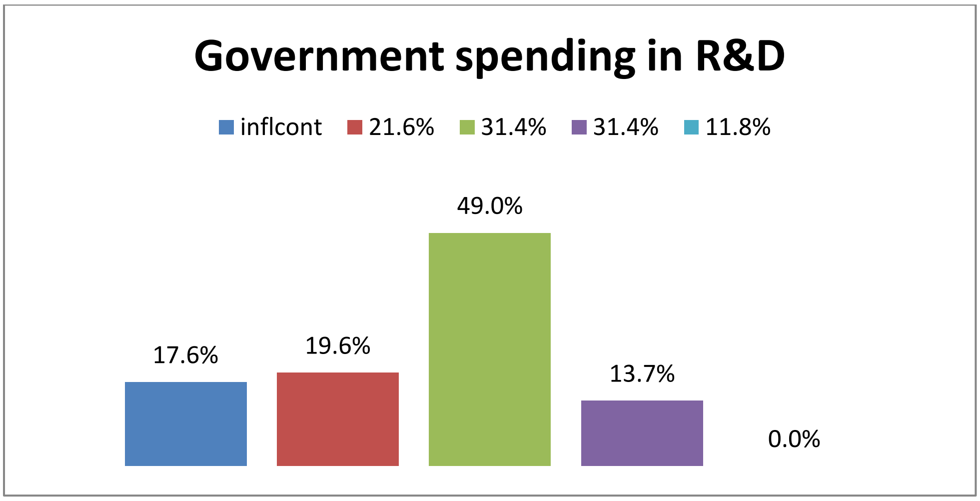


Figure B.22 Government spending in R&D

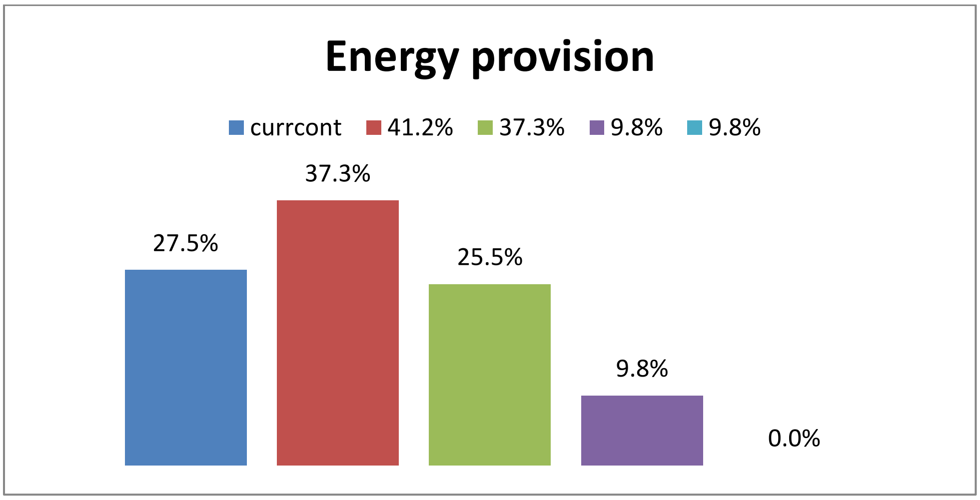


Figure B.23 Energy provision

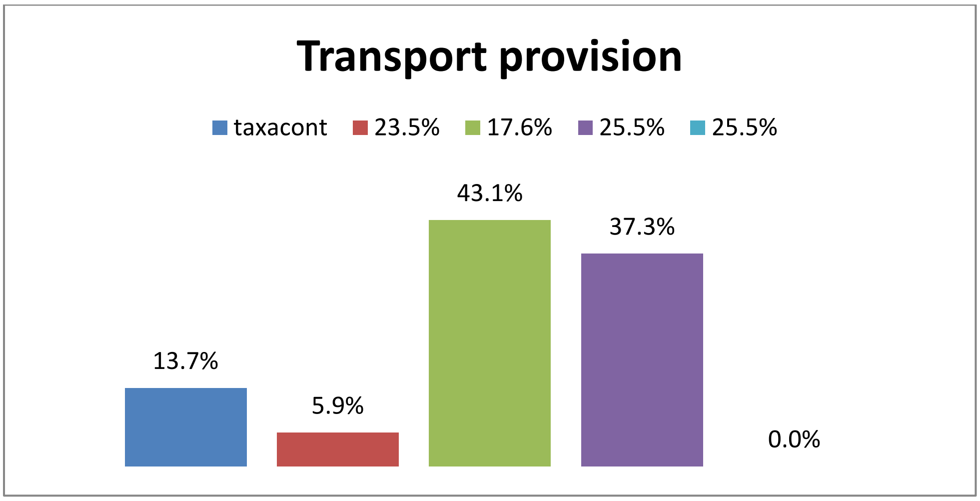


Figure B.24 Transport provision

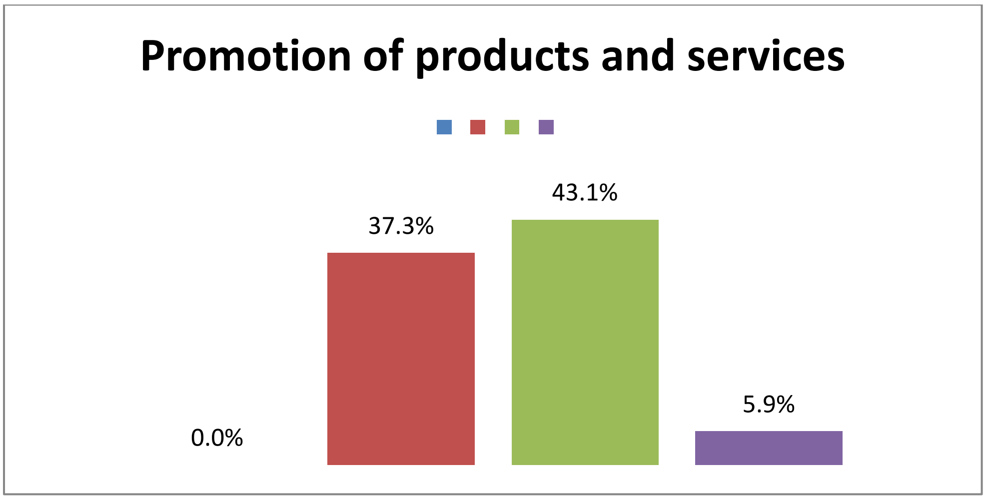


Figure B.25 Promotion of products and services

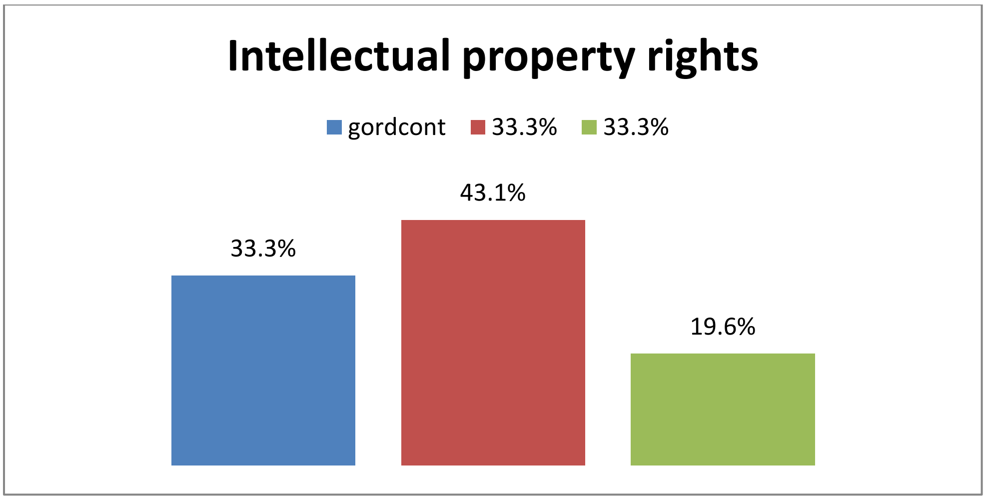


Figure B.26 Intellectual property rights

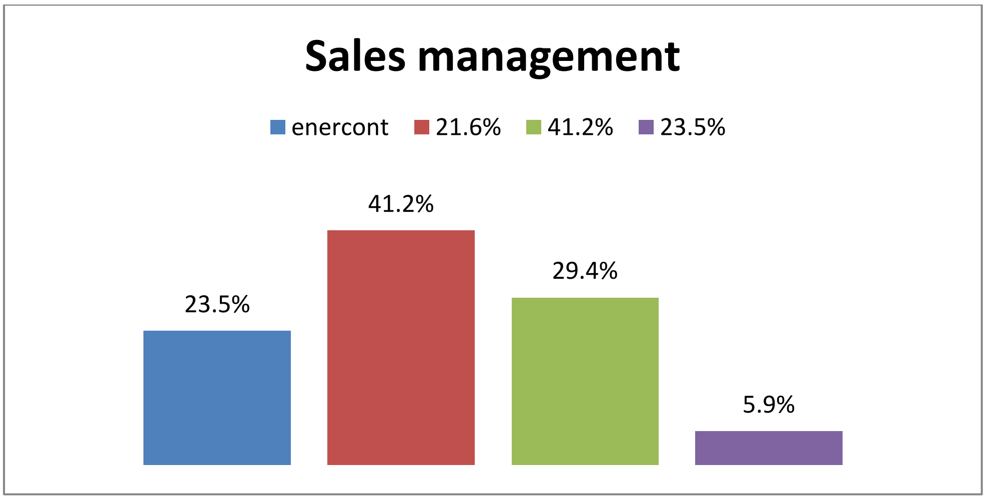


Figure B.27 Sales management

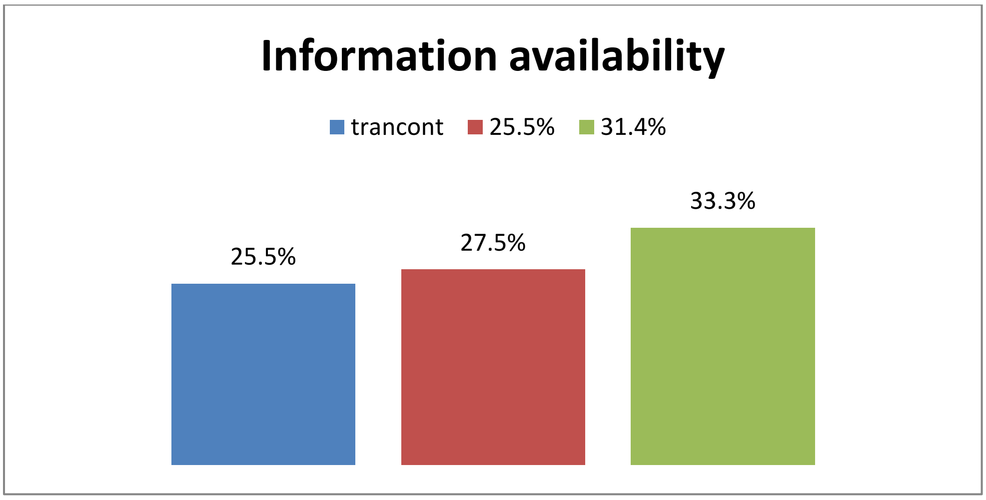


Figure B.28 Information availability

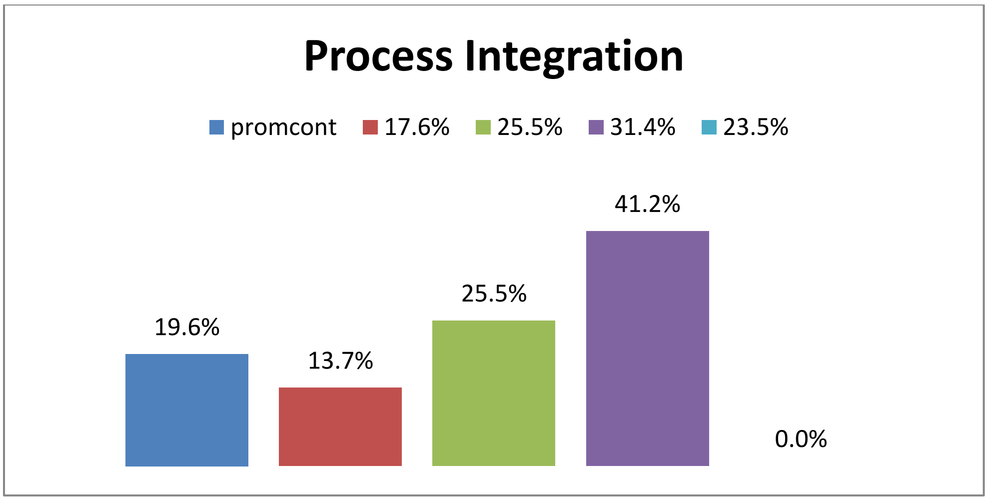


Figure B.29 Process Integration

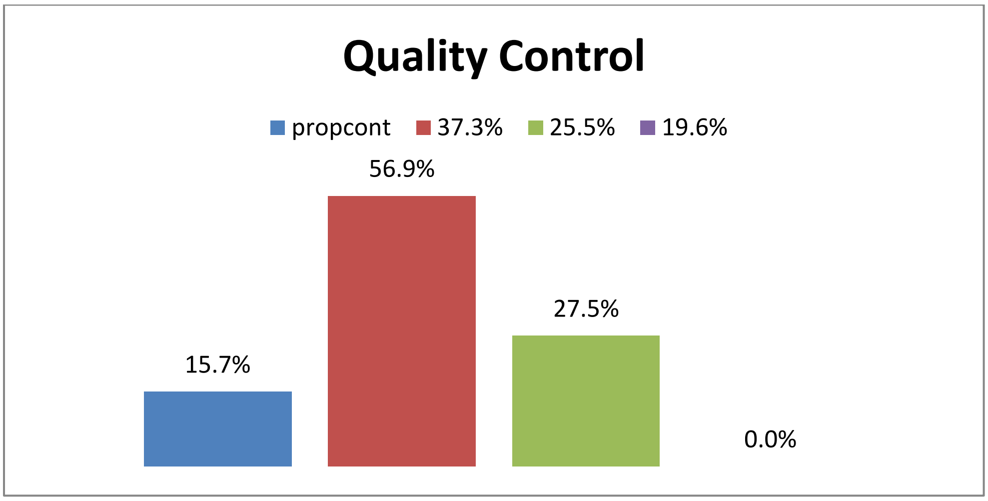


Figure B.30 Quality control

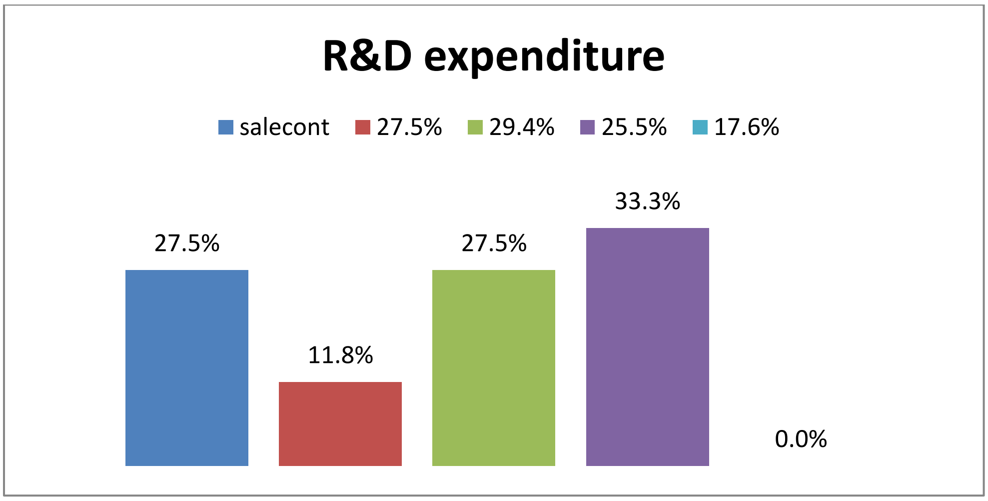


Figure B.31 R&D expenditure

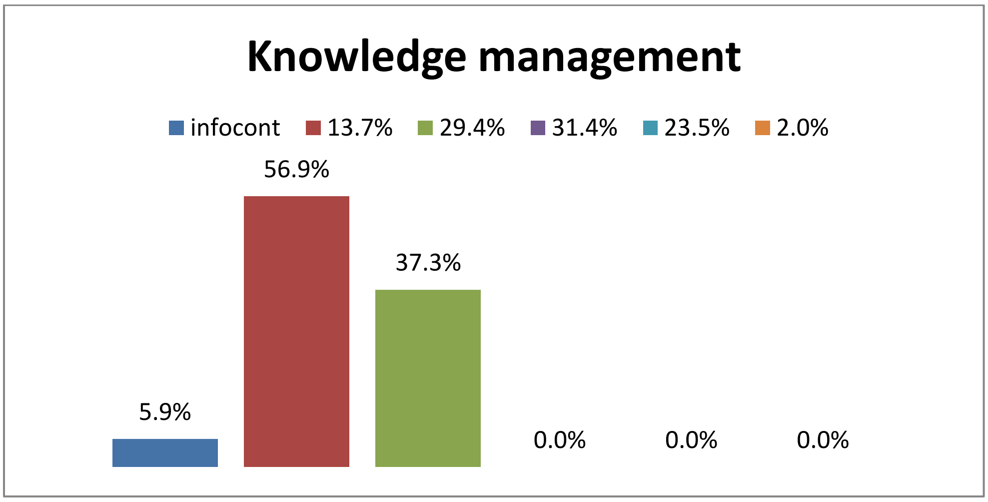


Figure B.32 Knowledge management

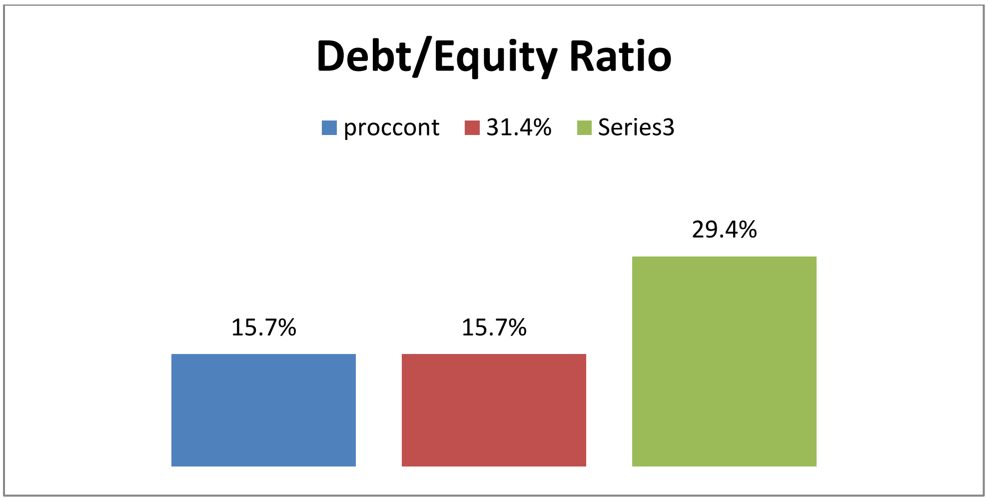


Figure B.33 Debts /Equity Ratio

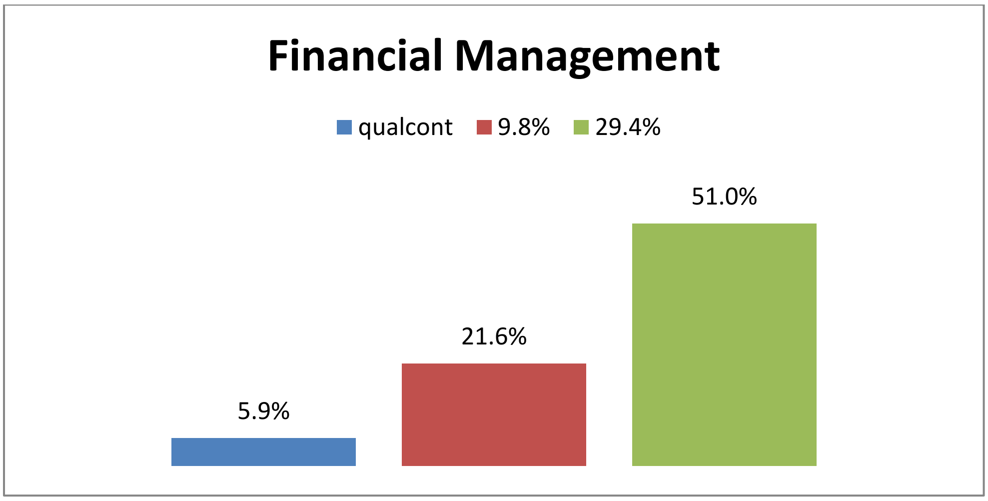


Figure B.34 Financial Management

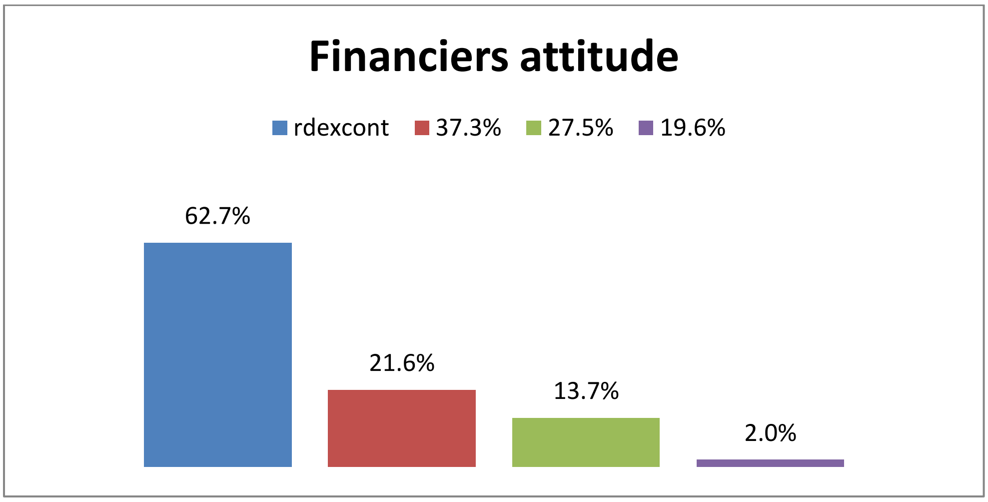


Figure B.35 Financiers attitude

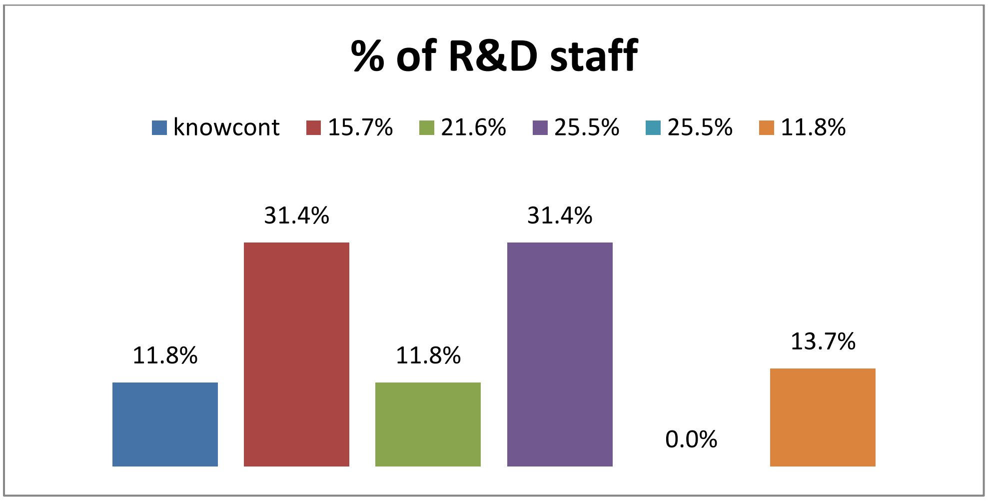


Figure B.36 Percentage of R&D staff

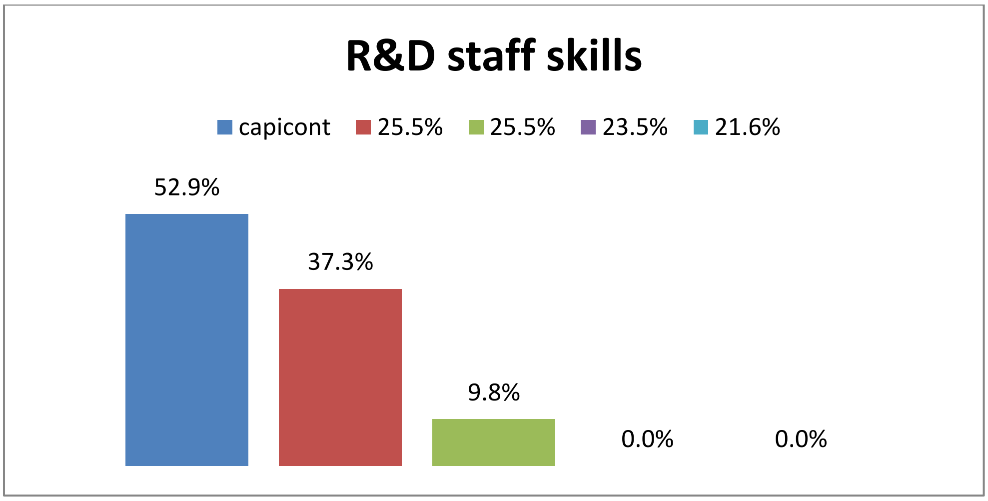


Figure B.37 R&D staff skills

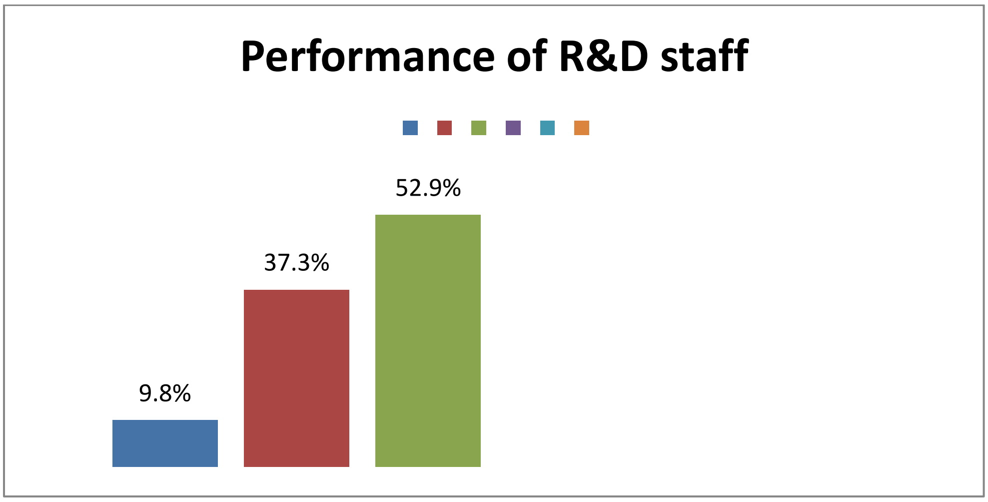


Figure B.38 Performance of R&D staff

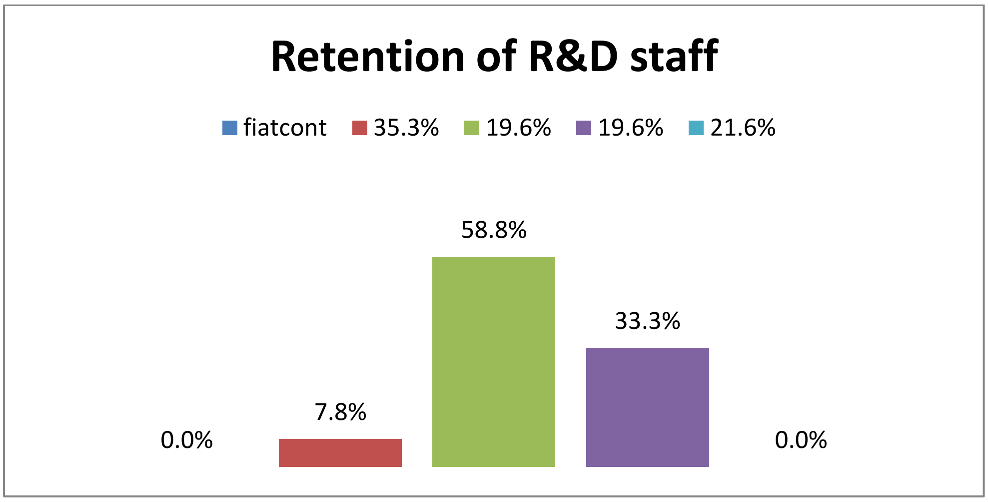


Figure B.39 Retention of R&D staff

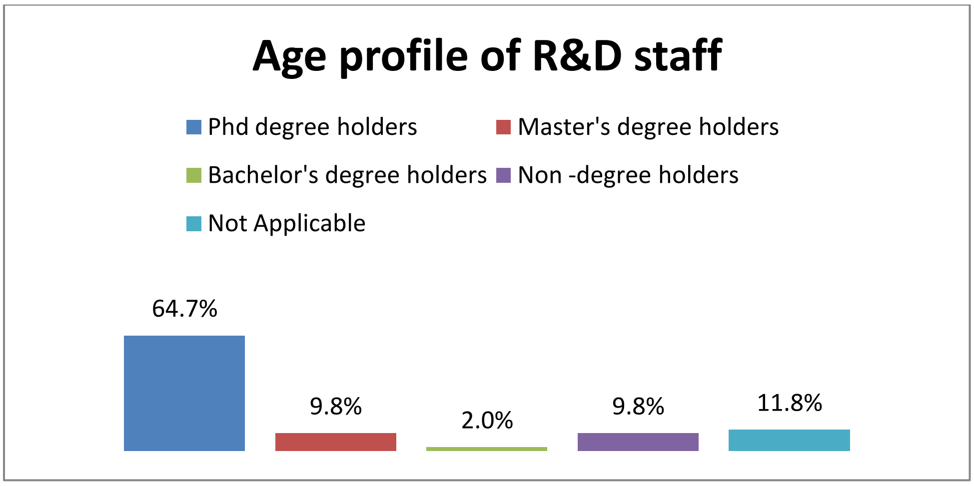


Figure B.40 Age profile of R&D staff

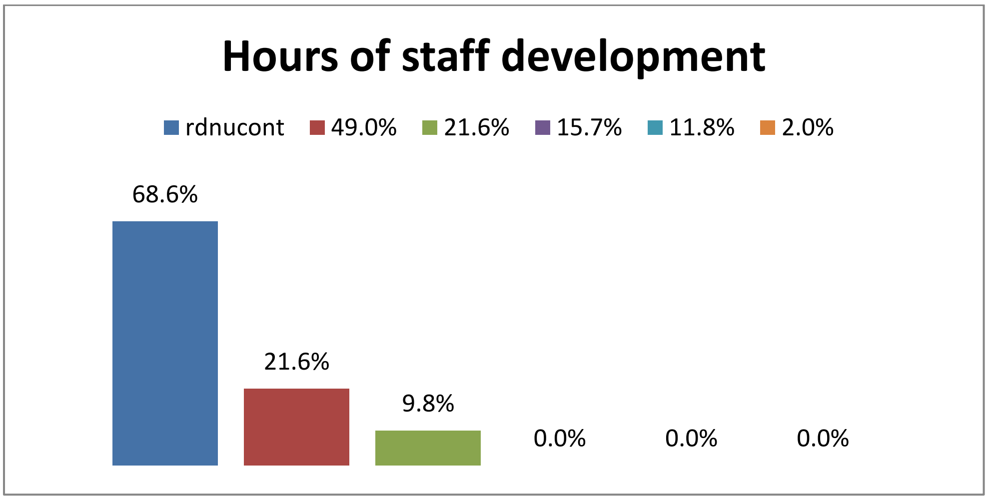


Figure B.41 Hours of staff development

B.5 Results of the Kolmogorov- Smirnov test of normality

Table B.85 Kolmogorov-Smirnov and Shapiro-Wilk test of normality

	Kolmogorov-Smirnov(a)		
	Statistic	df	Sig.
geographical coverage	,269	51	,000
professional background	,242	51	,000
post in the organisation	,325	51	,000
describe organisation	,291	51	,000
years in the organisation	,147	51	,007
proportion of revenue	,241	51	,000
proportion of expenditures	,258	51	,000
technology contribution	,194	51	,000

technology description	,270	51	,000
leadership contribution	,198	51	,000
leadership style	,304	51	,000
ownership contribution	,223	51	,000
ownership type	,438	51	,000
collaboration contribution	,214	51	,000
collaboration type	,221	51	,000
hierarchy contribution	,176	51	,000
number of hierarchy layers	,484	51	,000
span of control	,236	51	,000
number of people reporting to a manager	,332	51	,000
organisational relationships contribution	,181	51	,000
organisational relationships	,206	51	,000
size of organisation contribution	,234	51	,000
organisation size	,385	51	,000
strategy contribution	,184	51	,000
strategy type	,248	51	,000
policies contribution	,207	51	,000
policies type	,245	51	,000
organisational learning systems contribution	,184	51	,000
organisational learning systems	,220	51	,000
political freedom contribution	,240	51	,000
political freedom	,456	51	,000
incentives to foreign investors contribution	,471	51	,000
incentives to foreign investors	,536	51	,000
competition law and policy contribution	,312	51	,000
describe competition law and policy	,216	51	,000
employment law and policy contribution	,218	51	,000
describe employment law and policy	,239	51	,000
health and safety regulations contribution	,234	51	,000
describe health and safety regulations	,256	51	,000
level of economic activity contribution	,213	51	,000
describe economic activity	,297	51	,000
GDP contribution	,196	51	,000
trend in GDP	,421	51	,000
rate of inflation contribution	,191	51	,000
describe rate of inflation	,296	51	,000

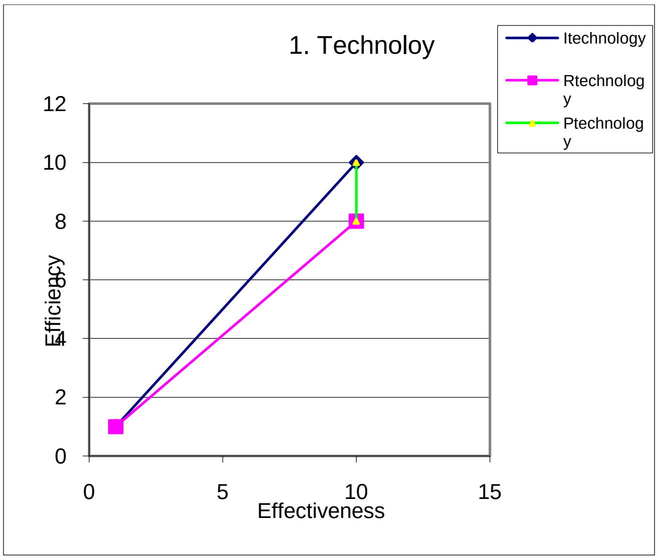
strength of currency contribution	,262	51	,000
strength of currency	,221	51	,000
rates of taxation contribution	,164	51	,001
describe rates of taxation	,288	51	,000
level of government spending in R&D contribution	,223	51	,000
government spending in R&D	,237	51	,000
energy provision contribution	,247	51	,000
describe energy provision	,228	51	,000
transport provision contribution	,204	51	,000
describe transport provision	,208	51	,000
promotion of products/services contribution	,189	51	,000
describe the promotion of products/services	,244	51	,000
intellectual property rights contribution	,224	51	,000
describe intellectual property rights	,297	51	,000
sales management contribution	,191	51	,000
describe sales management	,216	51	,000
market information availability contribution	,182	51	,000
describe market information availability	,332	51	,000
process integration contribution	,193	51	,000
level of process integration	,199	51	,000
quality control contribution	,186	51	,000
describe quality control	,283	51	,000
R&D expenditure contribution	,223	51	,000
describe R&D expenditure	,379	51	,000
knowledge management processes contribution	,167	51	,001
describe knowledge management processes	,210	51	,000
capital structure contribution	,179	51	,000
describe capital structure	,331	51	,000
financial management contribution	,219	51	,000
describe financial management	,297	51	,000
financiers attitude contribution	,214	51	,000
describe financiers attitude	,333	51	,000
number of R&D staff contribution	,289	51	,000
describe percentage of R&D staff	,417	51	,000
competence skills of R&D staff contribution	,372	51	,000
describe competence skills of R&D staff	,358	51	,000
performance of R&D staff contribution	,385	51	,000

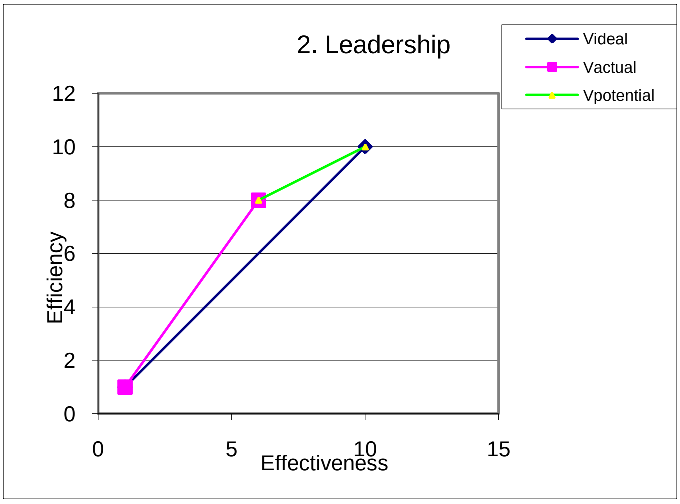
describe performance of R&D staff	,384	51	,000
age profile of R&D staff contribution	,392	51	,000
describe age profile of R&D staff	,385	51	,000
retention of R&D staff contribution	,378	51	,000
describe retention of R&D staff	,432	51	,000
staff development contribution	,209	51	,000
hours of typical staff development	,252	51	,000

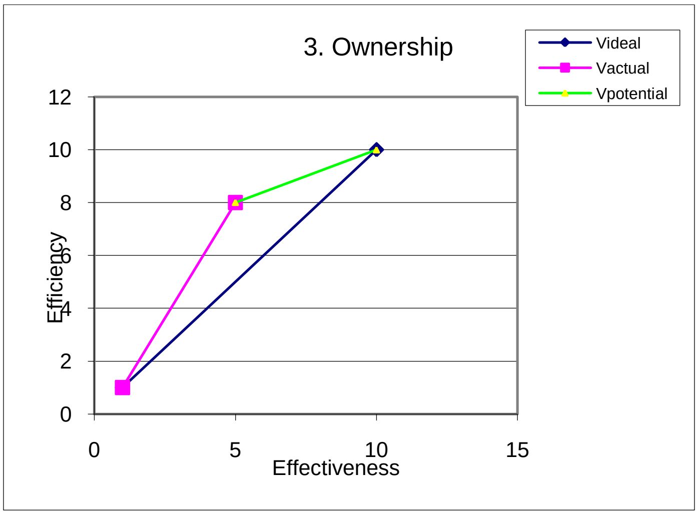
a Lilliefors Significance Correction

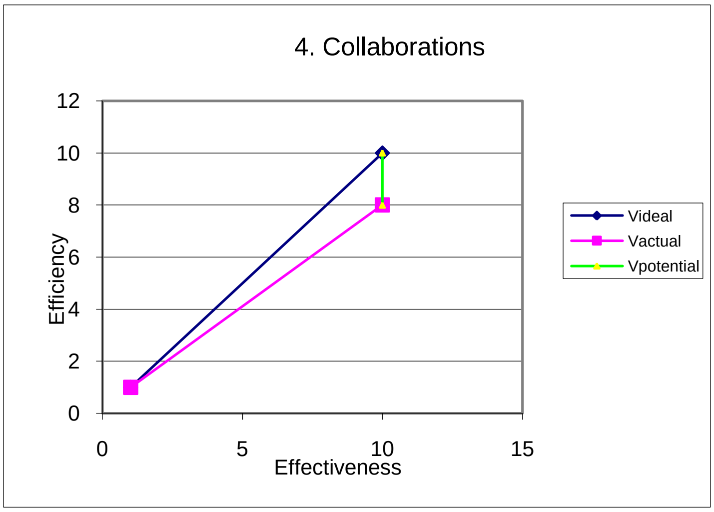
APPENDIX C

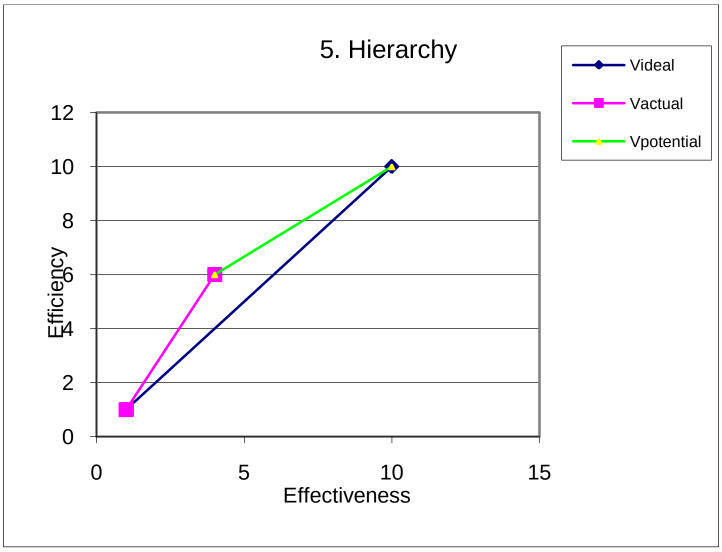
C.1 Graphs showing vectors for each factor for Case 1

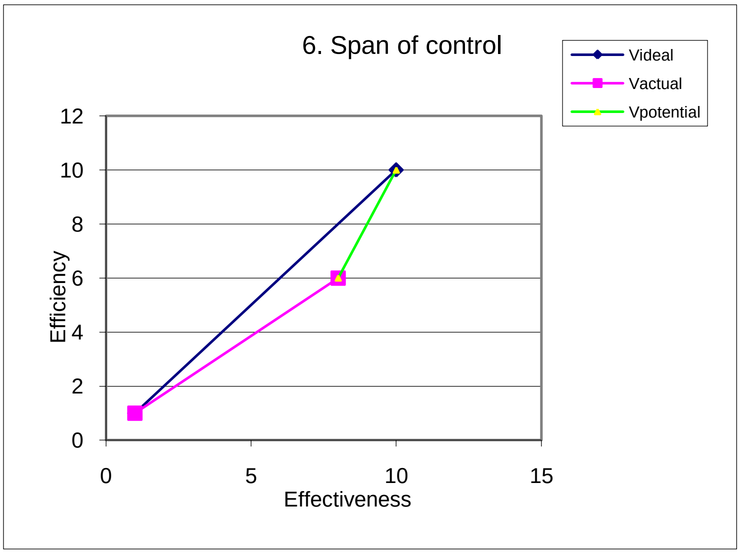


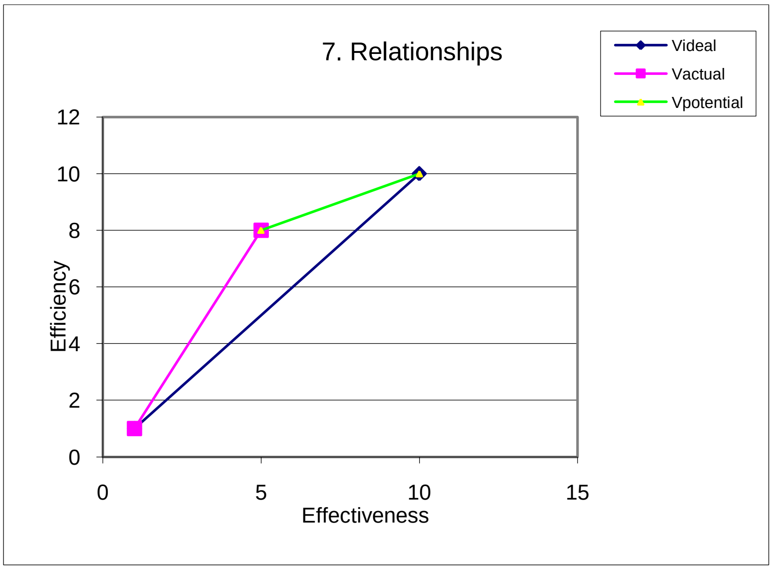




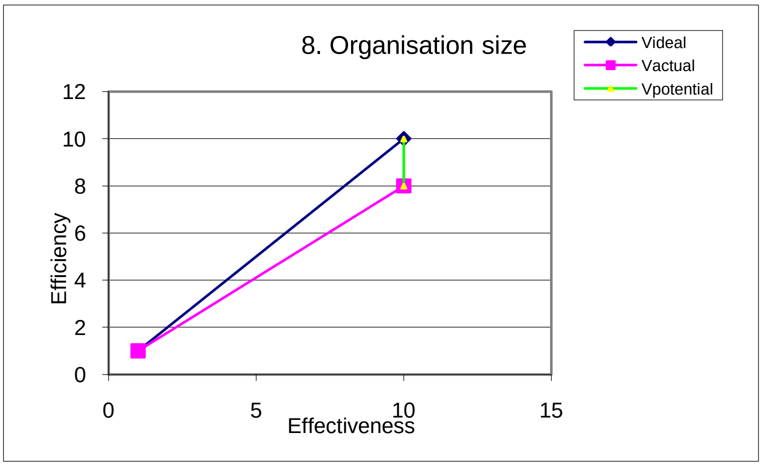

4. Collaborations
Efficiency
Effectiveness
0
2
4
6
8
10
12
0
5
10
15
Videal
Vactual
Vpotential


5. Hierarchy
Efficiency
Effectiveness
0
2
4
6
8
10
12
0
5
10
15
Videal
Vactual
Vpotential

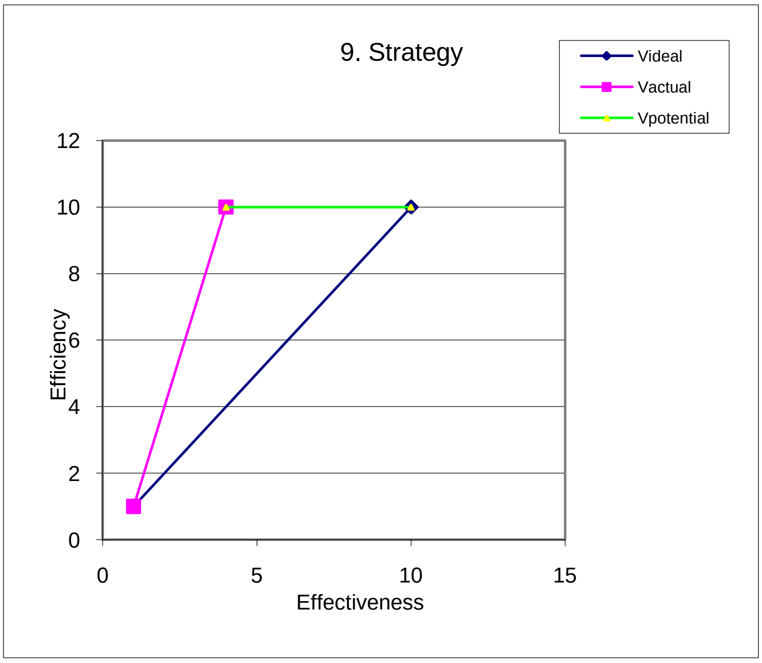

6. Span of control
Efficiency
Effectiveness
0
2
4
6
8
10
12
0
5
10
15
Videal
Vactual
Vpotential



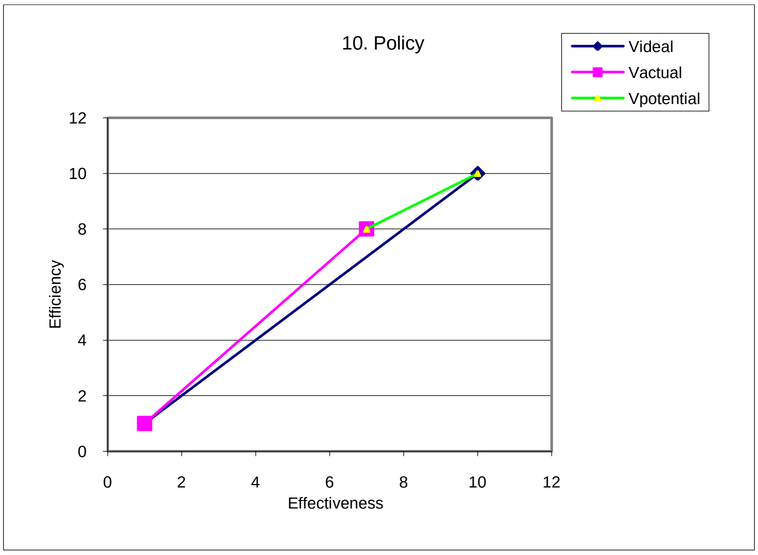
7. Relationships
Videal
Vactual
Vpotential
Efficiency
0
2
4
6
8
10
12
0
5
10
15
Effectiveness

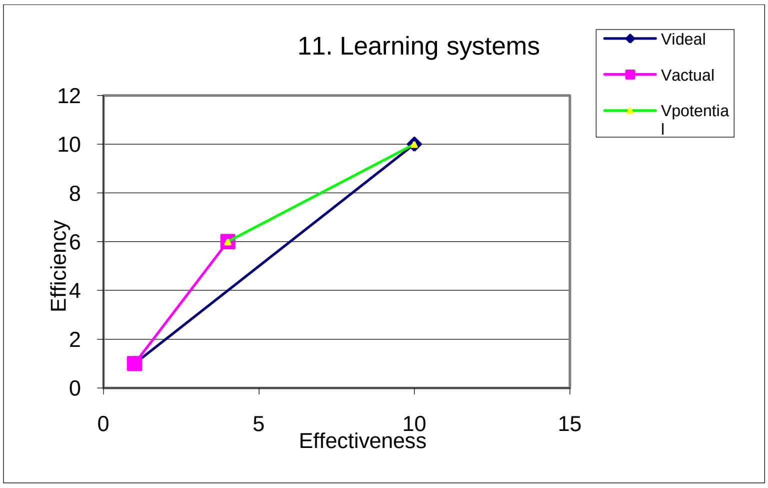


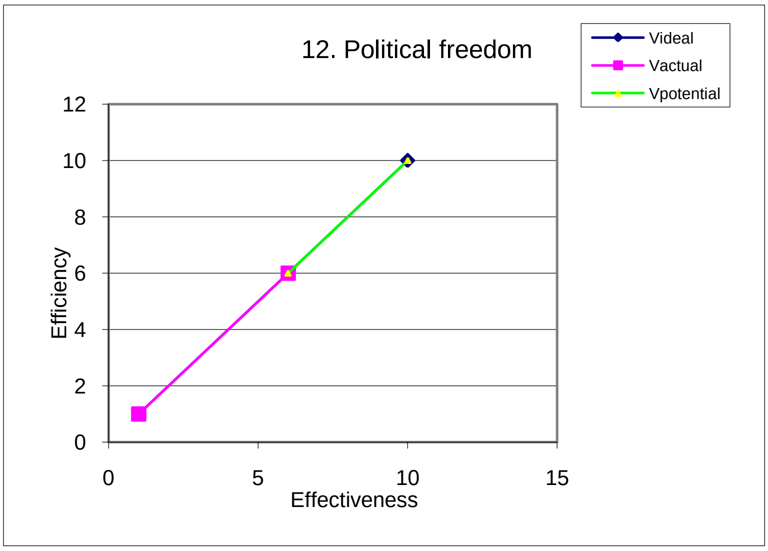
8. Organisation size
Videal
Vactual
Vpotential
Efficiency
0
2
4
6
8
10
12
0
5
10
15
Effectiveness

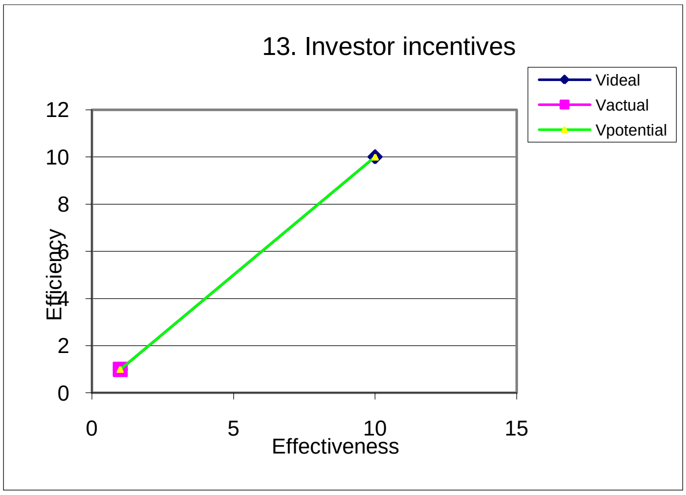


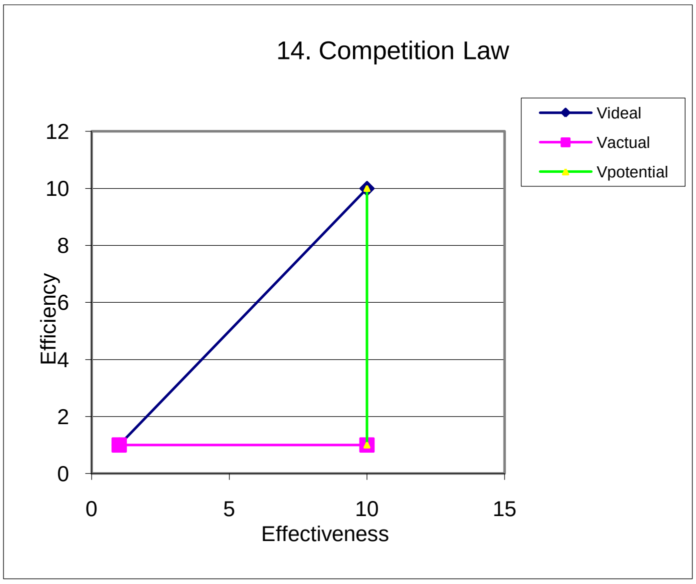
9. Strategy
Videal
Vactual
Vpotential
Efficiency
0
2
4
6
8
10
12
0
5
10
15
Effectiveness

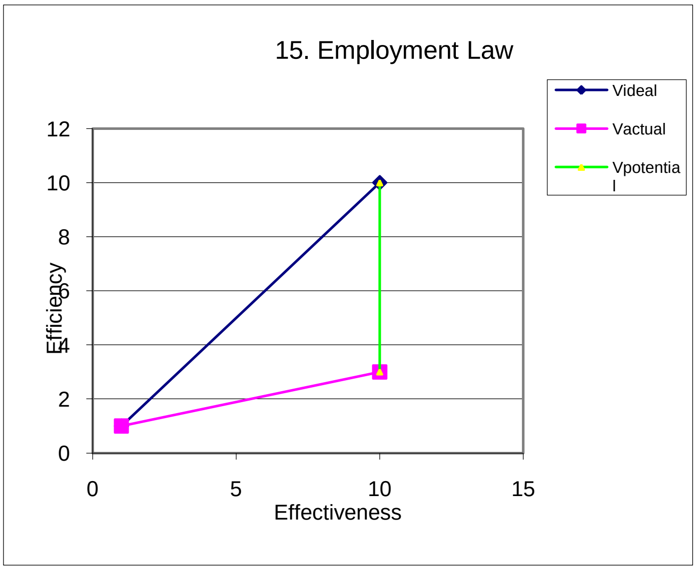

10. Policy
Videal
Vactual
Vpotential
Efficiency
0
2
4
6
8
10
12
Effectiveness
0
2
4
6
8
10
12


11. Learning systems
Videal
Vactual
Vpotentia l
Efficiency
0
2
4
6
8
10
12
Effectiveness
0
5
10
15

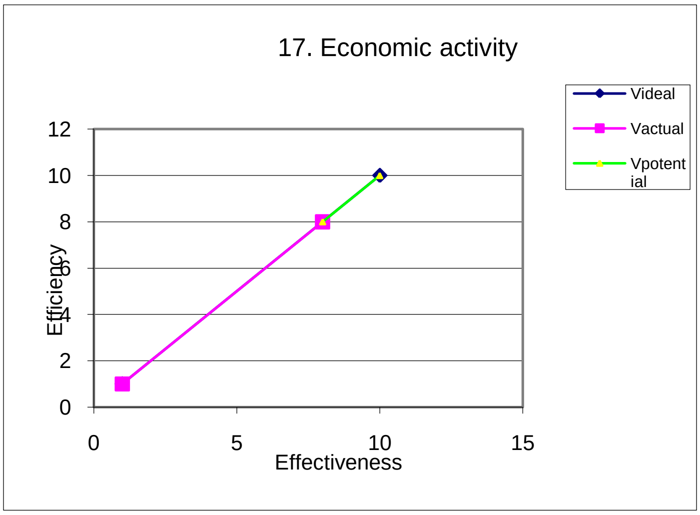

12. Political freedom
Videal
Vactual
Vpotential
Efficiency
0
2
4
6
8
10
12
Effectiveness
0
5
10
15

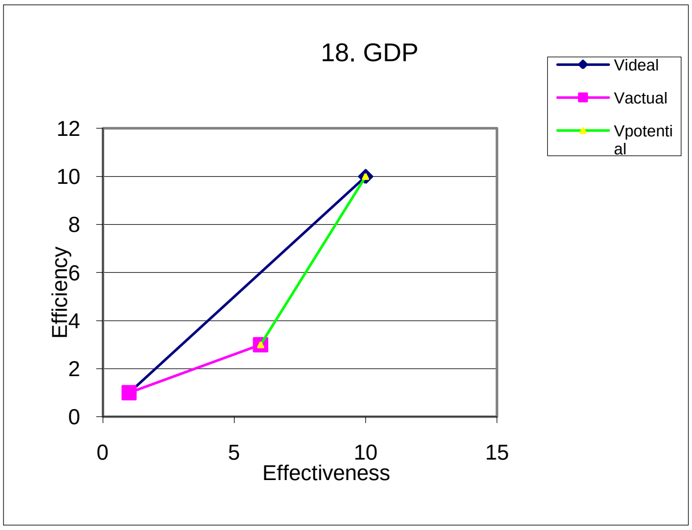

13. Investor incentives
Videal
Vactual
Vpotential
12
10
8
6
4
2
0
Efficiency
0
5
10
15
Effectiveness

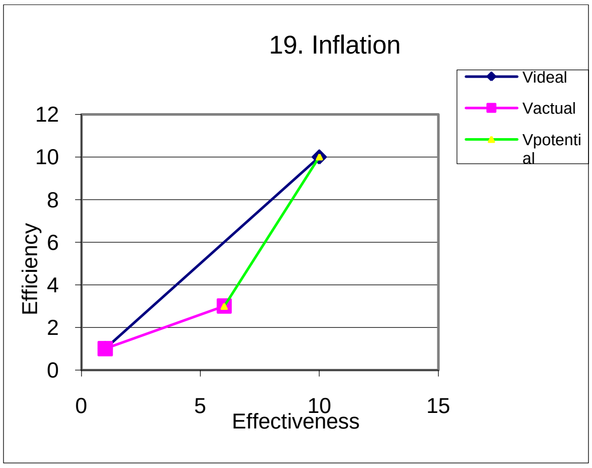

14. Competition Law
Videal
Vactual
Vpotential
12
10
8
6
4
2
0
Efficiency
0
5
10
15
Effectiveness

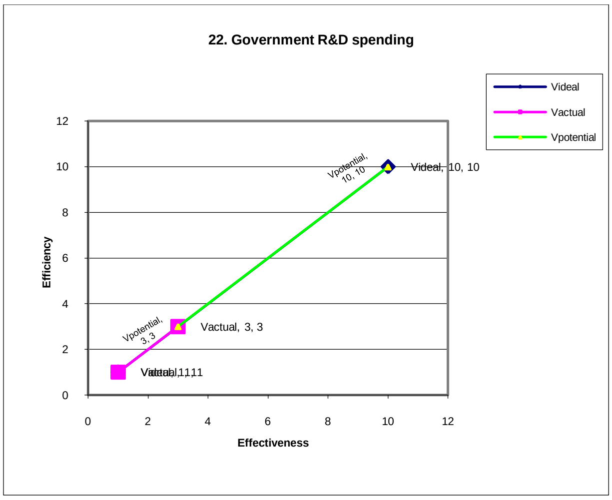

15. Employment Law
Videal
Vactual
Vpotentia
l
12
10
8
6
4
2
0
Efficiency
0
5
10
15
Effectiveness

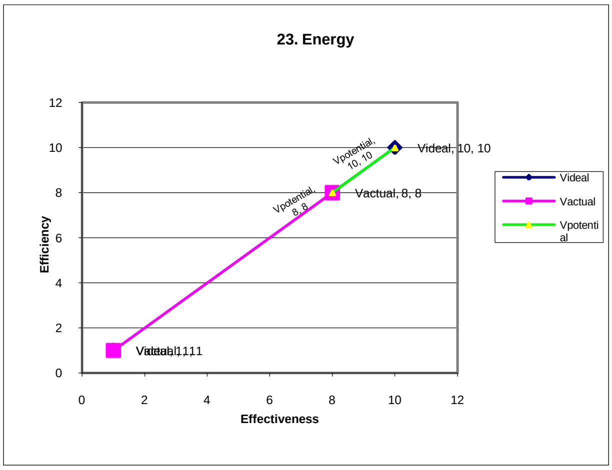

16. Health & Safety regulations
Videal
Vactual
Vpotential
Efficiency
Effectiveness
0
2
4
6
8
10
12
0
5
10
15

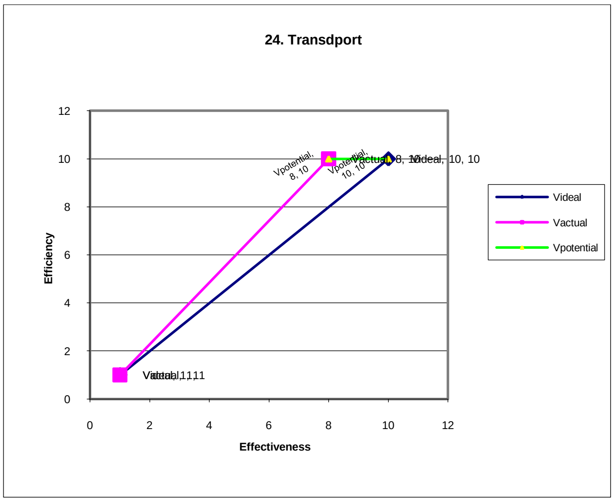

17. Economic activity
Videal
Vactual
Vpotential
Efficiency
Effectiveness
0
2
4
6
8
10
12
0
5
10
15

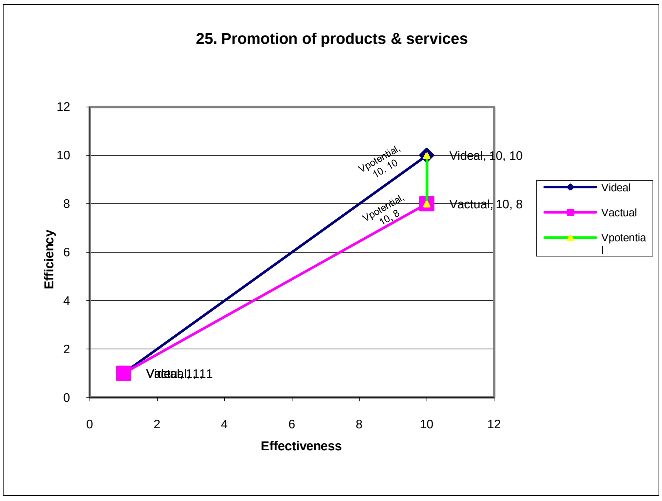

18. GDP
Videal
Vactual
Vpotential
Efficiency
Effectiveness
0
2
4
6
8
10
12
0
5
10
15

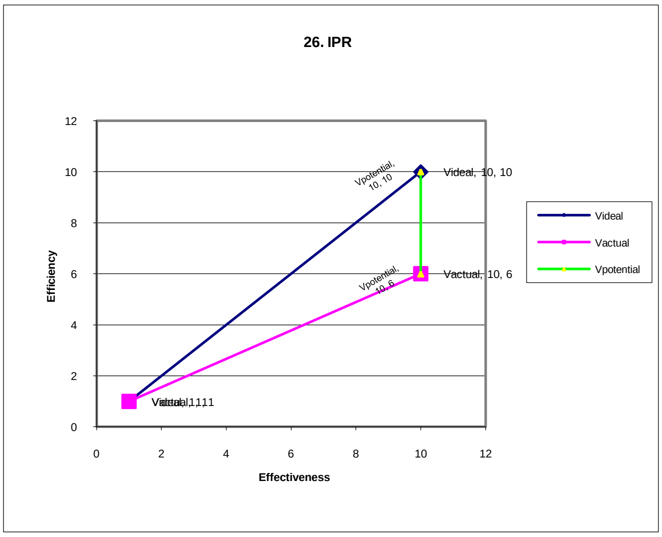

19. Inflation
Videal
Vactual
Vpotential
Efficiency
12
10
8
6
4
2
0
0
5
10
15
Effectiveness

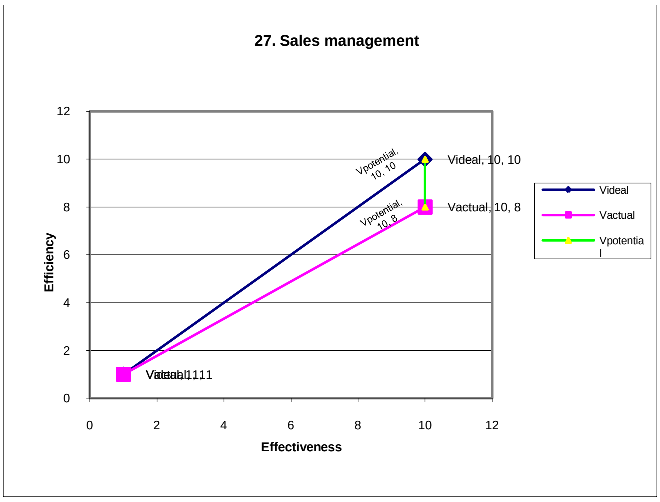

22. Government R&D spending
Videal
Vactual
Vpotential
Efficiency
12
10
8
6
4
2
0
Vpotential, 10, 10
Videal, 10, 10
Vpotential, 3, 3
Vactual, 3, 3
0
2
4
6
8
10
12
Effectiveness

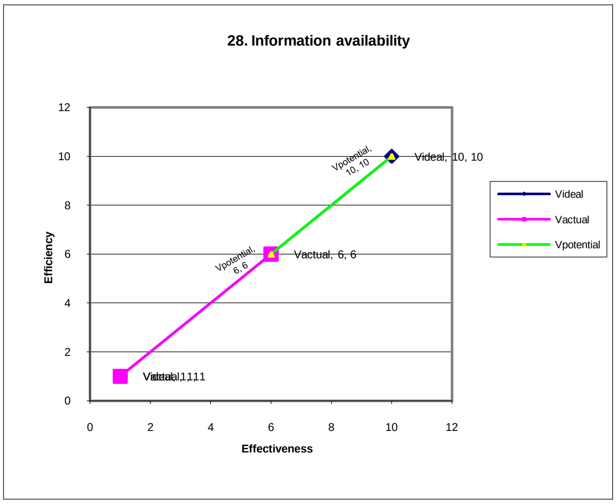

23. Energy
Videal
Vactual
Vpotential
Efficiency
12
10
8
6
4
2
0
Vpotential, 10, 10
Videal, 10, 10
Vpotential, 8, 8
Vactual, 8, 8
0
2
4
6
8
10
12
Effectiveness

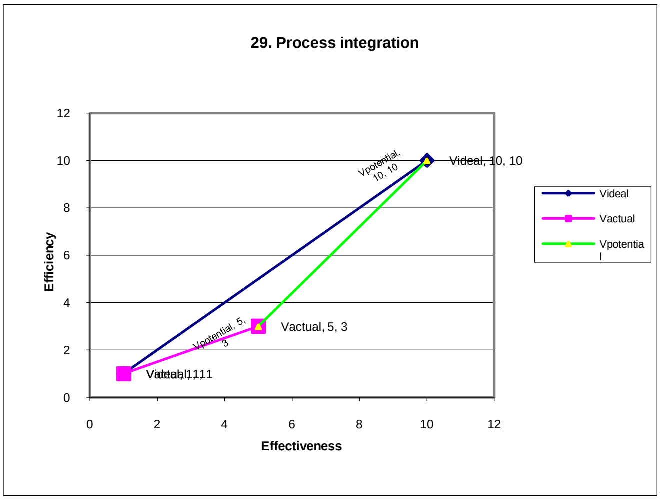

24. Transdport
Efficiency
Effectiveness
Videal
Vactual
Vpotential
Videal, 10, 10
Vpotential, 8, 10
Vpotential, 10, 10

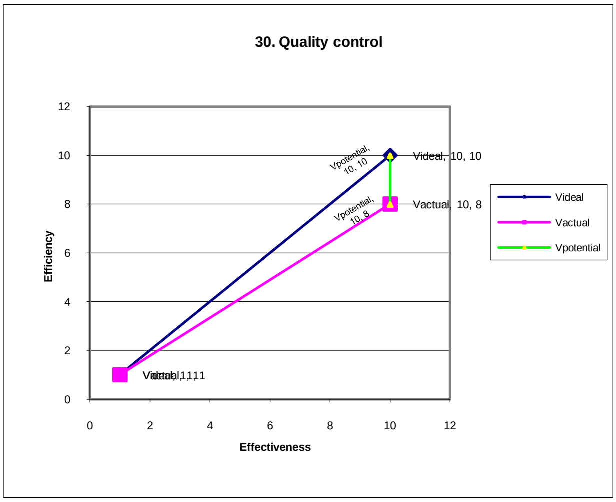

25. Promotion of products & services
Efficiency
Effectiveness
Videal
Vactual
Vpotential
Videal, 10, 10
Vactual, 10, 8
Vpotential, 10, 10
Vpotential, 10, 8

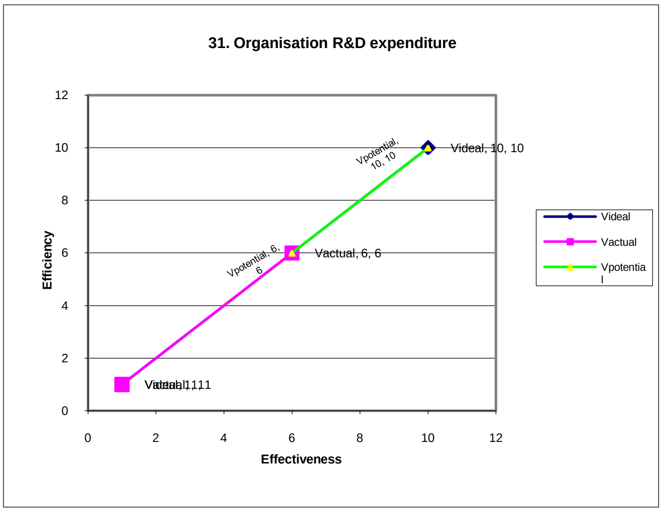

26. IPR
Efficiency
Effectiveness
Videal
Vactual
Vpotential
Videal, 10, 10
Vactual, 10, 6
Vpotential, 10, 10
Vpotential, 10, 6

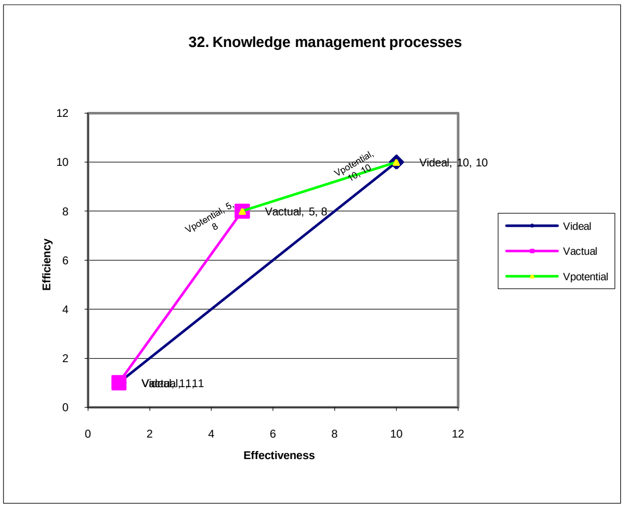

27. Sales management
Efficiency
Effectiveness
Vpotential, 10, 10
Videal, 10, 10
Vpotential, 10, 8
Vactual, 10, 8
0
2
4
6
8
10
12
Videal
Vactual
Vpotential

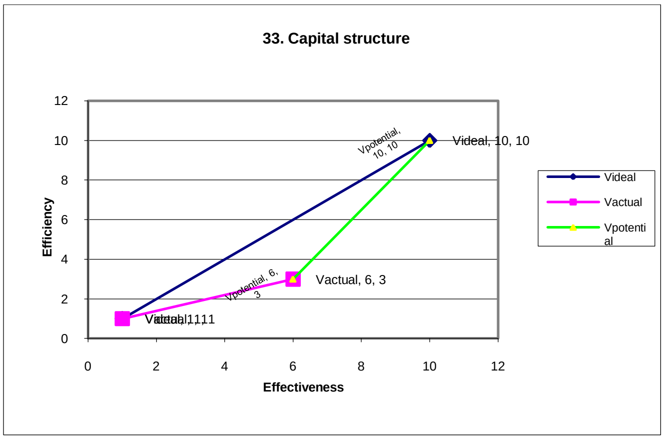

28. Information availability
Efficiency
Effectiveness
Vpotential, 10, 10
Videal, 10, 10
Vpotential, 6, 6
Vactual, 6, 6
0
2
4
6
8
10
12
Videal
Vactual
Vpotential

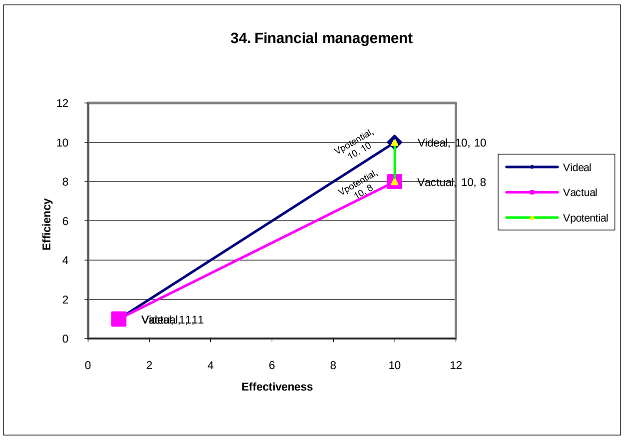

29. Process integration
Efficiency
Effectiveness
Vpotential, 10, 10
Videal, 10, 10
Vpotential, 5, 3
Vactual, 5, 3
0
2
4
6
8
10
12
Videal
Vactual
Vpotential

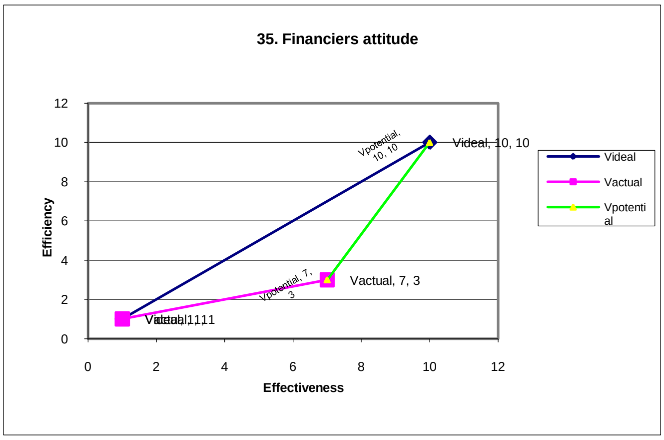

30. Quality control
Efficiency
Effectiveness
Videal, 10, 10
Vactual, 10, 8
Vpotential, 10, 10
Vpotential, 10, 8
Videal
Vactual
Vpotential
0 2 4 6 8 10 12
0 2 4 6 8 10 12

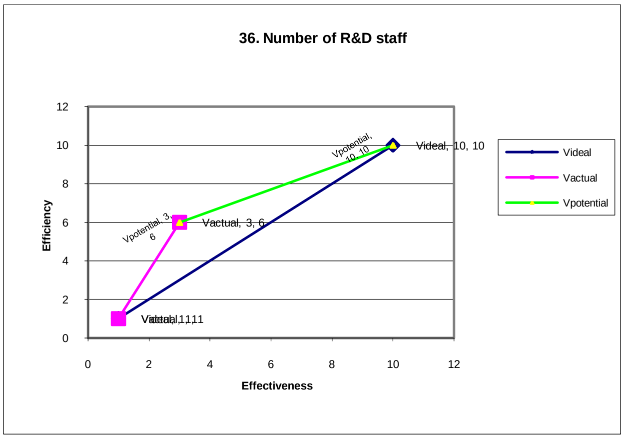

31. Organisation R&D expenditure
Efficiency
Effectiveness
Videal, 10, 10
Vactual, 6, 6
Vpotential, 10, 10
Vpotential, 6, 6
Videal
Vactual
Vpotentia l
0 2 4 6 8 10 12
0 2 4 6 8 10 12

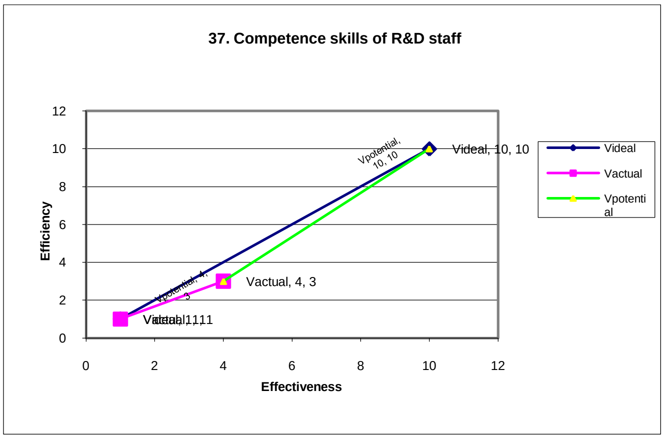

32. Knowledge management processes
Efficiency
Effectiveness
Videal, 10, 10
Vactual, 5, 8
Vpotential, 10, 10
Vpotential, 5, 8
Videal
Vactual
Vpotential
0 2 4 6 8 10 12
0 2 4 6 8 10 12

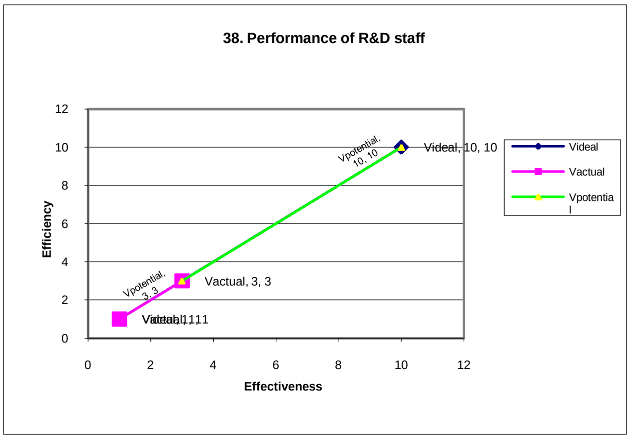

33. Capital structure
Efficiency
Effectiveness
Videal, 10, 10
Vpotential, 10, 10
Vactual, 6, 3
Vpotential, 6, 3
Videal
Vactual
Vpotential

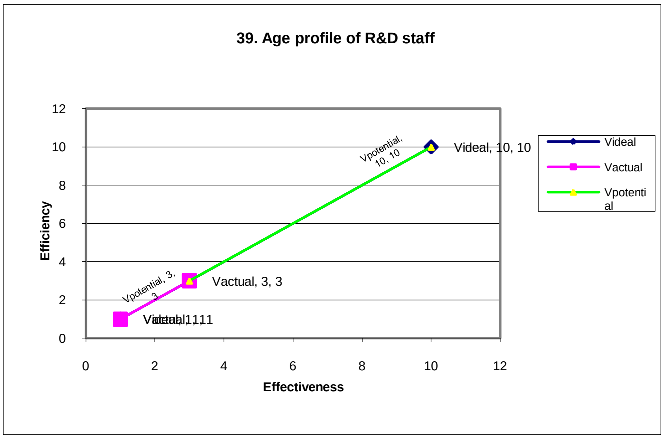

34. Financial management
Efficiency
Effectiveness
Videal, 10, 10
Vpotential, 10, 10
Vactual, 10, 8
Vpotential, 10, 8
Videal
Vactual
Vpotential

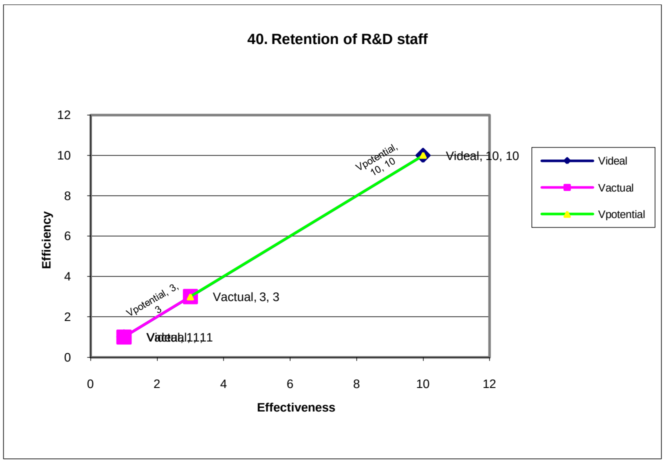

35. Financiers attitude
Efficiency
Effectiveness
Videal, 10, 10
Vpotential, 10, 10
Vactual, 7, 3
Vpotential, 7, 3
Videal
Vactual
Vpotential

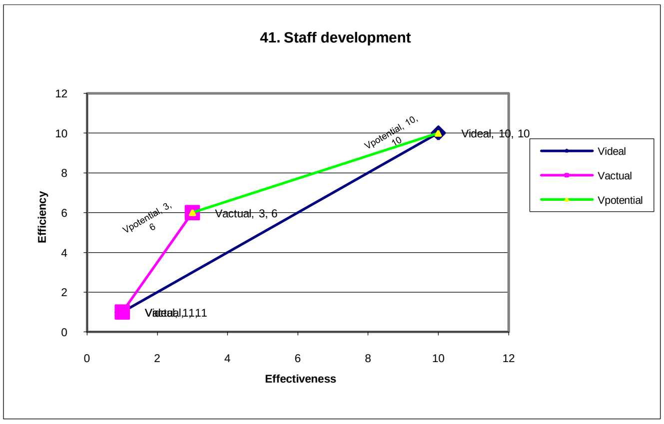

36. Number of R&D staff
Efficiency
Effectiveness
Videal, 10, 10
Vpotential, 10, 10
Vactual, 3, 6
Vpotential, 3, 6
Videal
Vactual
Vpotential


37. Competence skills of R&D staff
Efficiency
Effectiveness
Videal, 10, 10
Vpotential, 10, 10
Vactual, 4, 3
Videal
Vactual
Vpotential


38. Performance of R&D staff
Efficiency
Effectiveness
Videal, 10, 10
Vpotential, 10, 10
Vactual, 3, 3
Vpotential, 3, 3
Videal
Vactual
Vpotential







C.2 Possible alternative scenarios for Case 1

Table C.1 Possible alternative scenarios

Vectors $\overrightarrow{A_k}$	**Alternative Scenarios**	**Vectors** $\overrightarrow{A_k}$	**Alternative Scenarios**
$\vec{A}_1 = 10\hat{x} + 8\hat{y}$, (10,8)	(10,9), (10,10)	$\vec{A}_{22} = 3\hat{x} + 3\hat{y}$,	(3,4), (3,5),(3,6),(3,7),(3,8),

Y:9,10		X:3,4,5,6,7,8,9,10 Y:3,4,5,6,7,8,9,10	(3,9),(3,10) (4,3),(4,4),(4,5),(4,6),(4,7),(4,8),(4,9),(4,10),(5,3),(5,4),(5,5),(5,6),(5,6),(5,7),(5,8),(5,9),(5,10),(6,3),(6,4),(6,5),(6,6),(6,7),(6,8),(6,9),(6,10),(7,3),(7,4),(7,5),(7,6),(7,7),(7,8),(7,9),(7,10),(8,3),(8,4),(8,5),(8,6),(8,7),(8,8),(8,9),(8,10),(9,3),(9,4),(9,5),(9,6),(9,7),(9,8),(9,9),(9,10),(10,3),(10,4),(10,5),(10,6),(10,7),(10,8),(10,9),(10,10)
$\vec{A}2 = 6\hat{x}+8\hat{y}$, (6,8) X:6,7,8,9,10 Y:8,9,10	(6,9),(6,10),(7,8),(7,9),(7,10),(8,8)(8,9),(8,10),(9,8) (9,9),(9,10),(10,8),(10,9),(10,10),	$\vec{A}_{23} = 8\hat{x}+8\hat{y}$, X:8,9,10 Y: 8,9,10	(8,9),(8,10),(9,8),(9,9),(9,10),(10,8)(10,9),(10,10),
$\vec{A}_3 = 5\hat{x}+8\hat{y}$, X:5,6,7,8,9,10 Y:8,9,10	(5,9), (5,10), (6,8),(6,9),(6,10),(7,8),(7,9),(7,10), (8,8)(8,9),(8,10),(9,8)(9,9),(9,10),(10,8)(10,9),(10,10),	$\vec{A}_{24} = 8\hat{x}+10\hat{y}$, X:9,10	(9,10), (10,10)
$\vec{A}_4 = 10\hat{x}+8\hat{y}$, Y:9,10	(10,9), (10,10)	$\vec{A}_{25} = 10\hat{x}+8\hat{y}$, Y: 9,10	(10,9), (10,10)
$\vec{A}_5 = 4\hat{x}+6\hat{y}$, X:4,5,6,7,8,9,10 Y:6, 7,8,9,10	(4,7),(4,8), (4,9),(4,10),(5,6),(5,7),(5,8),(5,9),(5,10),(6,6),(6,7),(6,8),(6,9),(6,10), (7,6),(7,7),(7,8),(7,9),(7,10), (8,6),(8,7),(8,8),(8,9),(8,10),(9,6) (9,7),(9,8),(9,9),(9,10),(10,6),(10,7),(10,8),(10,9),(10,10)	$\vec{A}_{26} = 10\hat{x}+6\hat{y}$, Y: 7,8,9,10	(10,7),(10,8),(10,9),(10,10),
$\vec{A}_6 = 8\hat{x}+6\hat{y}$,	(8,7),(8,8),(8,9),(8,10),(9,6),(9,7),(9,8),(9,9),(9,10),	$\vec{A}_{27} = 10\hat{x}+8\hat{y}$,	(10,9), (10,10)

X:8,9,10 Y:6,7,8,9,10	(10,6)(10,7),(10,8), (10,9),(10,10)	Y: 9,10	
$\vec{A}_7 = 5\hat{x}+8\hat{y}$, X:5,6,7,8,9,10 Y:8,9,10	(5,9),(5,10),(6,8) (6,9),(6,10), (7,8),(7,9),(7,10), (8,8),(8,9),(8,10), (9,8),(9,9),(9,10), (10,8),(10,9),(10,10)	$\vec{A}_{28} = 6\hat{x}+6\hat{y}$, X:6,7,8,9,10 Y:,6,7,8,9,10	(6,7),(6,8), (6,9),(6,10), (7,6),(7,7),(7,8), (7,9),(7,10),(8,6),(8,7),(8,8), (8,9),(8,10),(9,6)(9,7),(9,8) , (9,9),(9,10),(10,6),(10,7),(10,8), (10,9),(10,10)
$\vec{A}_8 = 10\hat{x}+8\hat{y}$, Y: 9,10	(10,9), (10,10)	$\vec{A}_{29} = 5\hat{x}+3\hat{y}$, X:5,6,7,8,9,10 Y:3,4,5,6,7,8,9,10	(5,4), (5,5),(5,6),(5,6),(5,7),(5,8), (5,9),(5,10),(6,3),(6,4), (6,5),(6,6),(6,7),(6,8), (6,9),(6,10),(7,3),(7,4), (7,5),(7,6),(7,7),(7,8), (7,9),(7,10),(8,3),(8,4), (8,5),(8,6),(8,7),(8,8), (8,9),(8,10),(9,3),(9,4), (9,5),(9,6),(9,7),(9,8), (9,9),(9,10),(10,3),(10,4),(10,5),(10,6),(10,7),(10,8), (10,9),(10,10)
$\vec{A}_9 = 4\hat{x}+10\hat{y}$, X:5,6,7,8,9,10	(5,10),(6,10), (7,10),(8,10), (9,10), (10,10)	$\vec{A}_{30} = 10\hat{x}+8\hat{y}$, Y: 9,10	(10,9), (10,10)
$\vec{A}_{10} = 7\hat{x}+8\hat{y}$, X:7,8,9,10 Y:8, 9,10	(7,9), (7,10),(8,8), (8,9),(8,10), (9,8), (9,9),(9,10), (10,8),(10,9), (10,10)	$\vec{A}_{31} = 6\hat{x}+6\hat{y}$, X:6,7,8,9,10 Y: 6,7,8,9,10	(6,7),(6,8), (6,9),(6,10), (7,6),(7,7),(7,8), (7,9),(7,10),(8,6),(8,7),(8,8), (8,9),(8,10),(9,6)(9,7),(9,8) , (9,9),(9,10),(10,6),(10,7),(10,8), (10,9),(10,10)
$\vec{A}_{11} = 4\hat{x}+6\hat{y}$, X:4,5,6,7,8,9,10 Y:6,7,8,9,10	(4,7),(4,8),(4,9), (4,10),(5,6),(5,7),(5,8),(5,9), (5,10),(6,6,)(6,7),(6,8), (6,9),(6,10),(7,6),(7,7),(7,8), (7,9),(7,10),(8,6),(8,7),(8,8), (8,9),(8,10),(9,6)(9,7),(9,8), (9,9),(9,10),(10,6),(10,7),(10,	$\vec{A}_{32} = 5\hat{x}+8\hat{y}$, X:5,6,7,8,9,10 Y: 8,9,10	(5,9),(5,10),(6,8),(6,9),(6,1 0),(7,8),(7,9),(7,10),(8,8),(8,9),(8,10), (9,8),(9,9),(9,10), (10,8), (10,9),(10,10)

	8), (10,9),(10,10)		
$\vec{A}_{12} = 6\hat{x} + 6\hat{y}$, X:6,7,8,9,10 Y:6,7,8,9,10	(6,7),(6,8), (6,9),(6,10) (7,6),(7,7),(7,8), (7,9),(7,10),(8,6),(8,7),(8,8), (8,9),(8,10),(9,6)(9,7),(9,8), (9,9),(9,10),(10,6),(10,7),(10, 8), (10,9),(10,10)	$\vec{A}_{33} = 6\hat{x} + 3\hat{y}$, X:6,7,8,9,10 Y:3,4,5,6,7,8,9,10	(6,4),(6,5),(6,6),(6,7),(6,8), (6,9),(6,10), (7,3),(7,4),(7,5),(7,6),(7,7), (7,8),(7,9),(7,10), (8,3),(8,4),(8,5),(8,6),(8,7), (8,8),(8,9),(8,10), (9,3),(9,4),(9,5),(9,6),(9,7), (9,8),(9,9),(9,10), (10,3),(10,4),(10,5),(10,6), (10,7),(10,8), (10,9),(10,10)
$\vec{A}_{13} = 1\hat{x} + 1\hat{y}$, X:1,2,3,4,5,6,7,8, 9,10 Y:1,2,3,4,5,6,7,8, 9,10	(1,2),(1,3),(1,4), (1,5),(1,6),(1,7), (1,8),(1,9),(1,10), (2,1),(2,2),(2,3),(2,4), (2,5),(2,6),(2,7), (2,8),(2,9),(2,10), (3,1),(3,2),(3,3),(3,4), (3,5),(3,6),(3,7), (3,8),(3,9),(3,10), (4,1),(4,2),(4,3),(4,4), (4,5),(4,6), (4,7),(4,8),(4,9),(4,10), (5,1),(5,2),(5,3),(5,4), (5,5),(5,6),(5,6),(5,7),(5,8),(5 ,9),(5,10),(6,1),(6,2),(6,3),(6, 4), (6,5),(6,6),(6,7),(6,8), (6,9),(6,10), (7,1),(7,2),(7,3),(7,4), (7,5),(7,6),(7,7),(7,8), (7,9),(7,10), (8,1),(8,2),(8,3),(8,4), (8,5),(8,6),(8,7),(8,8), (8,9),(8,10), (9,1),(9,2),(9,3),(9,4), (9,5),(9,6),(9,7),(9,8), (9,9),(9,10),(10,1),(10,2),(10, 3),(10,4),(10,5),(10,6),(10,7), (10,8), (10,9),(10,10)	$\vec{A}_{34} = 10\hat{x} + 8\hat{y}$, Y: 9,10	(10,9), (10,10)

$\vec{A}_{14} = 10\hat{x}+1\hat{y}$, Y:2,3,4,5,6,7,8,9,10	(10,2),(10,3),(10,4),(10,5),(10,6),(10,6),(10,7),(10,8),(10,9),(10,10)	$\vec{A}_{35} = 7\hat{x}+3\hat{y}$, X:7,8,9,10 Y:3,4,5,6,7,8,9,10	(7,3),(7,4),(7,5),(7,6),(7,7),(7,8),(7,9),(7,10),(8,3),(8,4),(8,5),(8,6),(8,7),(8,8),(8,9),(8,10),(9,3),(9,4),(9,5),(9,6),(9,7),(9,8),(9,9),(9,10),(10,3),(10,4),(10,5),(10,6),(10,7),(10,8),(10,9),(10,10)
$\vec{A}_{15} = 10\hat{x}+3\hat{y}$, Y:4,5,6,7,8,9,10	(10,4),(10,5),(10,6),(10,6),(10,7),(10,8), (10,9),(10,10)	$\vec{A}_{36} = 3\hat{x}+6\hat{y}$, X:3,4,5,6,7,8,9,10 Y: 6,7,8,9,10	(3,7),(3,8),(3,9),(3,10),(4,6),(4,7),(4,8),(4,9),(4,10),(5,6),(5,6),(5,7),(5,8),(5,9),(5,10),(6,6),(6,7),(6,8),(6,9),(6,10),(7,6),(7,7),(7,8),(7,9),(7,10),(8,6),(8,7),(8,8),(8,9),(8,10),(9,6),(9,7),(9,8),(9,9),(9,10),(10,6),(10,7),(10,8), (10,9),(10,10)
$\vec{A}_{16} = 1\hat{x}+8\hat{y}$, X:1,2,3,4,5,6,7,8,9,10 Y:8,9,10	(1,9),(1,10),(2,8),(2,9),(2,10),(3,8),(3,9),(3,10),(4,8),(4,9),(4,10),(5,8),(5,9),(5,10),(6,1),(6,2),(6,8),(6,9),(6,10),(7,8),(7,9),(7,10),(8,8),(8,9),(8,10),(9,8),(9,9),(9,10),(10,8),(10,9),(10,10)	$\vec{A}_{37} = 4\hat{x}+3\hat{y}$, X: 4,5,6,7,8,9,10 Y:3,4,5,6,7,8,9,10	(4,4), (4,5),(4,6),(4,7),(4,8),(4,9),(4,10),(5,3),(5,4),(5,5),(5,6),(5,6),(5,7),(5,8),(5,9),(5,10),(6,3),(6,4),(6,5),(6,6),(6,7),(6,8),(6,9),(6,10),(7,3),(7,4),(7,5),(7,6),(7,7),(7,8),(7,9),(7,10),(8,3),(8,4),(8,5),(8,6),(8,7),(8,8),(8,9),(8,10),(9,3),(9,4),(9,5),(9,6),(9,7),(9,8),(9,9),(9,10),(10,3),(10,4),(10,5),(10,6),(10,7),(10,8),(10,9),(10,10)
$\vec{A}_{17} = 8\hat{x}+8\hat{y}$, X: 8,9,10 Y: 8,9,10	(8,9),(8,10),(9,8),(9,9),(9,10),(10,8)(10,9),(10,10),	$\vec{A}_{38} = 3\hat{x}+3\hat{y}$, X:3,4,5,6,7,8,9,10 and Y:3,4,5,6,7,8,9,10	(4,3),(4,4), (4,5),(4,6),(4,7),(4,8),(4,9),(4,10),(5,3),(5,4),(5,5),(5,6),(5,6),(5,7),(5,8),(5,9),(5,10),(6,3),(6,4),(6,5),(6,6),(6,7),(6,8),(6,9),(6,10),(7,3),(7,4),(7,5),(7,6),(7,7),(7,8),

			(7,9),(7,10),(8,3),(8,4),(8,5),(8,6),(8,7),(8,8),(8,9),(8,10),(9,3),(9,4),(9,5),(9,6),(9,7),(9,8),(9,9),(9,10),(10,3),(10,4),(10,5),(10,6),(10,7),(10,8),(10,9),(10,10)
$\vec{A}_{18} = 6\hat{x} + 3\hat{y}$, X:6,7,8,9,10 Y:3,4,5,6,7,8,9,10	(6,4),(6,5),(6,6),(6,7),(6,8),(6,9),(6,10),(7,3),(7,4),(7,5),(7,6),(7,7),(7,8),(7,9),(7,10),(8,3),(8,4),(8,5),(8,6),(8,7),(8,8),(8,9),(8,10),(9,3),(9,4),(9,5),(9,6),(9,7),(9,8),(9,9),(9,10),(10,3),(10,4),(10,5),(10,6),(10,7),(10,8),(10,9),(10,10)	$\vec{A}_{39} = 3\hat{x} + 3\hat{y}$, X:3,4,5,6,7,8,9,10 Y:3,4,5,6,7,8,9,10	(4,3),(4,4), (4,5),(4,6),(4,7),(4,8),(4,9),(4,10),(5,3),(5,4),(5,5),(5,6),(5,6),(5,7),(5,8),(5,9),(5,10),(6,3),(6,4),(6,5),(6,6),(6,7),(6,8),(6,9),(6,10),(7,3),(7,4),(7,5),(7,6),(7,7),(7,8),(7,9),(7,10),(8,3),(8,4),(8,5),(8,6),(8,7),(8,8),(8,9),(8,10),(9,3),(9,4),(9,5),(9,6),(9,7),(9,8),(9,9),(9,10),(10,3),(10,4),(10,5),(10,6),(10,7),(10,8),(10,9),(10,10)
$\vec{A}_{19} = 6\hat{x} + 3\hat{y}$, X:6,7,8,9,10 Y:3,4,5,6,7,8,9,10	(6,4),(6,5),(6,6),(6,7),(6,8),(6,9),(6,10),(7,3),(7,4),(7,5),(7,6),(7,7),(7,8),(7,9),(7,10),(8,3),(8,4),(8,5),(8,6),(8,7),(8,8),(8,9),(8,10),(9,3),(9,4),(9,5),(9,6),(9,7),(9,8),(9,9),(9,10),(10,3),(10,4),(10,5),(10,6),(10,7),(10,8),(10,9),(10,10)	$\vec{A}_{40} = 3\hat{x} + 3\hat{y}$, X:3,4,5,6,7,8,9,10 Y:3,4,5,6,7,8,9,10	(4,3),(4,4), (4,5),(4,6),(4,7),(4,8),(4,9),(4,10),(5,3),(5,4),(5,5),(5,6),(5,6),(5,7),(5,8),(5,9),(5,10),(6,3),(6,4),(6,5),(6,6),(6,7),(6,8),(6,9),(6,10),(7,3),(7,4),(7,5),(7,6),(7,7),(7,8),(7,9),(7,10),(8,3),(8,4),(8,5),(8,6),(8,7),(8,8),(8,9),(8,10),(9,3),(9,4),(9,5),(9,6),(9,7),(9,8),(9,9),(9,10),(10,3),(10,4),(10,5),(10,6),(10,7),(10,8),(10,9),(10,10)

$\vec{A}_{20} = 6\hat{x}+3\hat{y}$, X:6,7,8,9,10 Y:3,4,5,6,7,8,9,10	(6,4),(6,5),(6,6),(6,7),(6,8), (6,9),(6,10),(7,3),(7,4), (7,5),(7,6),(7,7),(7,8), (7,9),(7,10),(8,3),(8,4), (8,5),(8,6),(8,7),(8,8), (8,9),(8,10),(9,3),(9,4), (9,5),(9,6),(9,7),(9,8), (9,9),(9,10),(10,3),(10,4),(10,5),(10,6),(10,7),(10,8), (10,9),(10,10)	$\vec{A}_{41} = 3\hat{x}+6\hat{y}$, X:3,4,5,6,7,8,9,10 Y:6,7,8,9,10	(4,6), (4,7),(4,8),(4,9),(4,10), (5,6),(5,6),(5,7),(5,8),(5,9), 5,10),(6,6),(6,7),(6,8), (6,9),(6,10),(7,6),(7,7),(7,8),(7,9),(7,10), (8,6),(8,7),(8,8), (8,9),(8,10),(9,6),(9,7),(9,8),(9,9),(9,10),(10,6),(10,7), (10,8), (10,9),(10,10)
$\vec{A}_{21} = 6\hat{x}+3\hat{y}$, X:6,7,8,9,10 Y:3,4,5,6,7,8,9,10	(6,4),(6,5),(6,6),(6,7),(6,8), (6,9),(6,10),(7,3),(7,4), (7,5),(7,6),(7,7),(7,8), (7,9),(7,10),(8,3),(8,4), (8,5),(8,6),(8,7),(8,8), (8,9),(8,10),(9,3),(9,4), (9,5),(9,6),(9,7),(9,8), (9,9),(9,10),(10,3),(10,4),(10,5),(10,6),(10,7),(10,8), (10,9),(10,10)		

APPENDIX D

D.1 The InnoAct Manual

Insert Data

In the '*Main Menu'* worksheet select use the quick reference links to go to the section that you would like to complete and compute the information that are apply to your organisation.

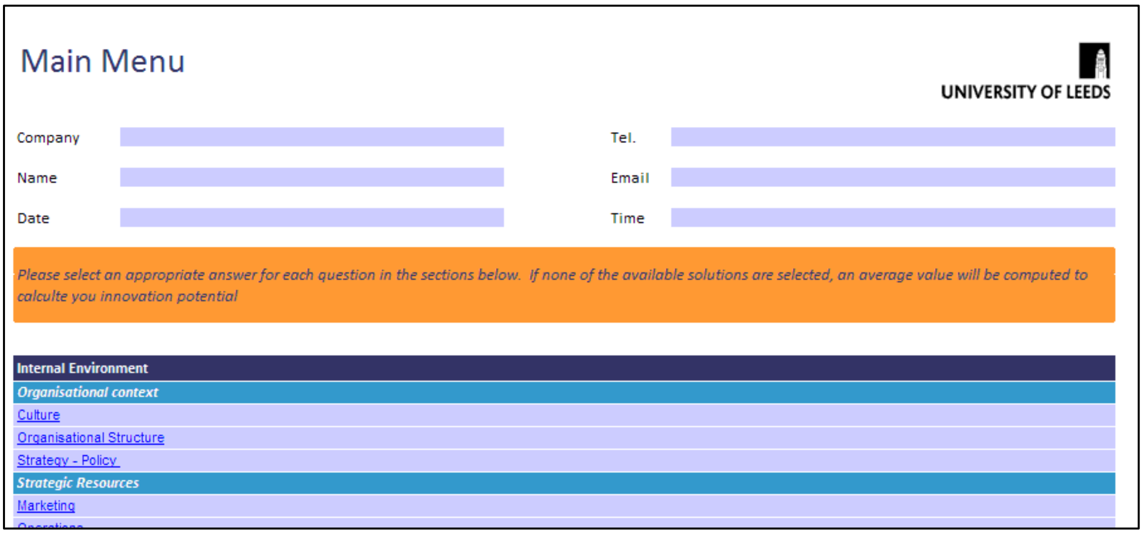


Figure D.1 The *'Main Menu'*

Add New Factors

If new factors need to be added in the model use the section at the end of the *Main Menu* to add or delete factors

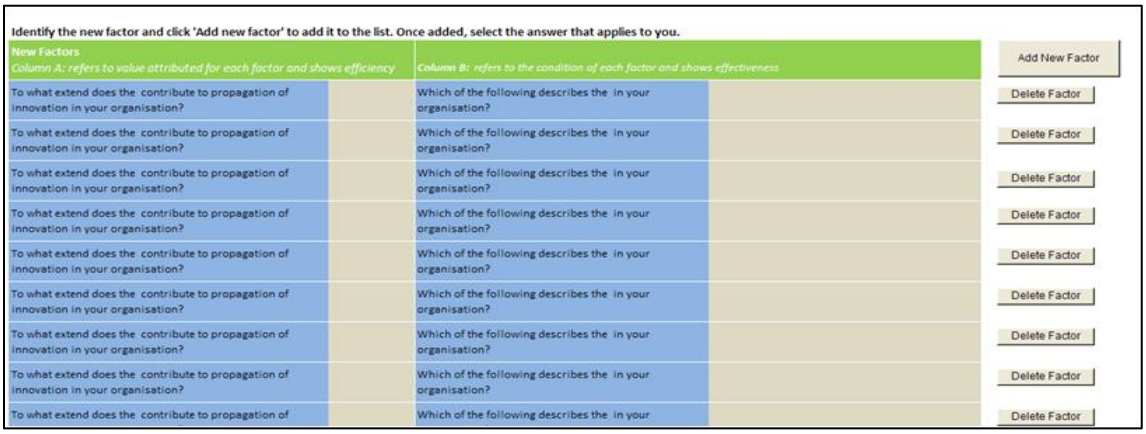


Figure D.2 Add New Factors

Show Results

In order to see the results use the button after the section of adding new factors as shown in Figure D.3. In order to return to the Main Menu use the Button 'Main Menu'

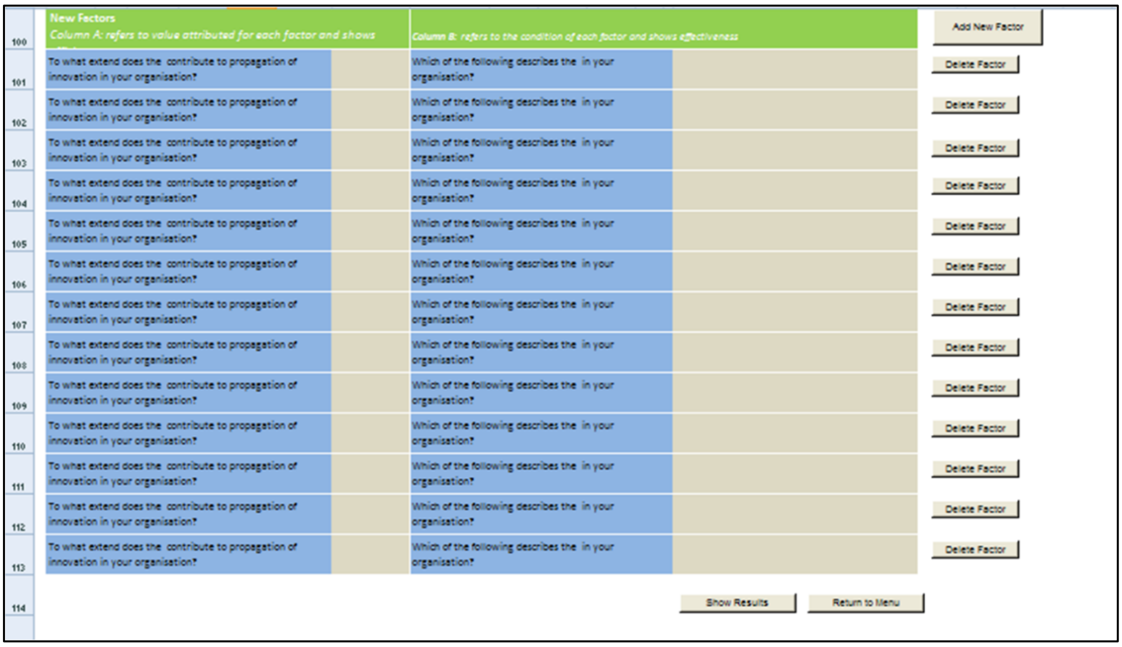


Figure D.3 ‘*Show results*’ and ‘*Return to main Menu’* buttons

The *Show results* worksheet (see Figure 8.6) presents the results of the calculation of the innovation potential.

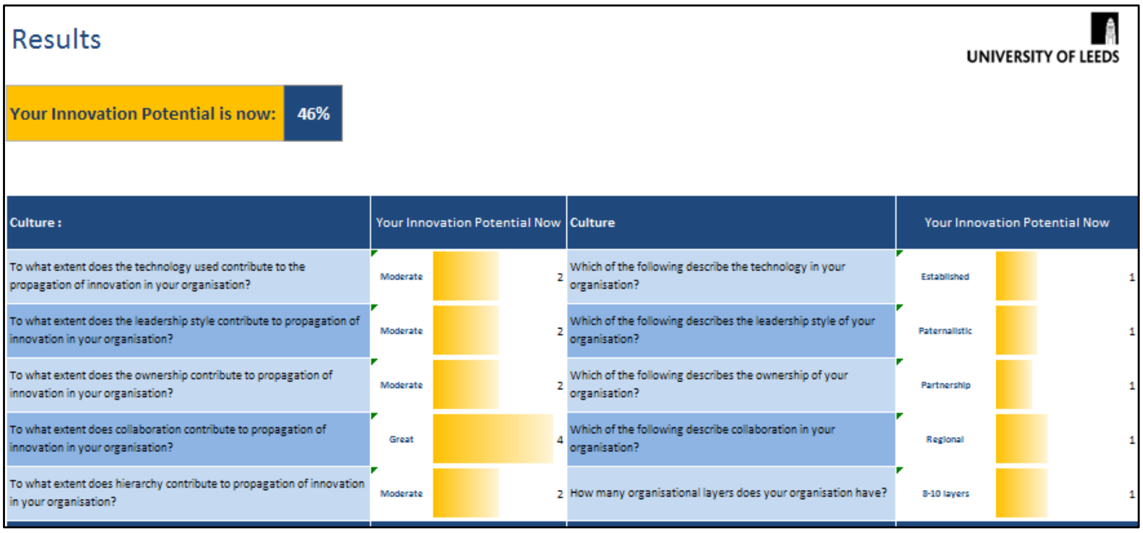


Figure D.4 The *‘Show Results’* worksheet

Use the buttons: ‘*Develop alternative scenarios manually’* or ‘*Develop alternative scenarios using optimisation’*, at the end of the *‘Show Results’* worksheet to calculate the innovation potential either manually or using an optimisation routine (see Figure D.5).

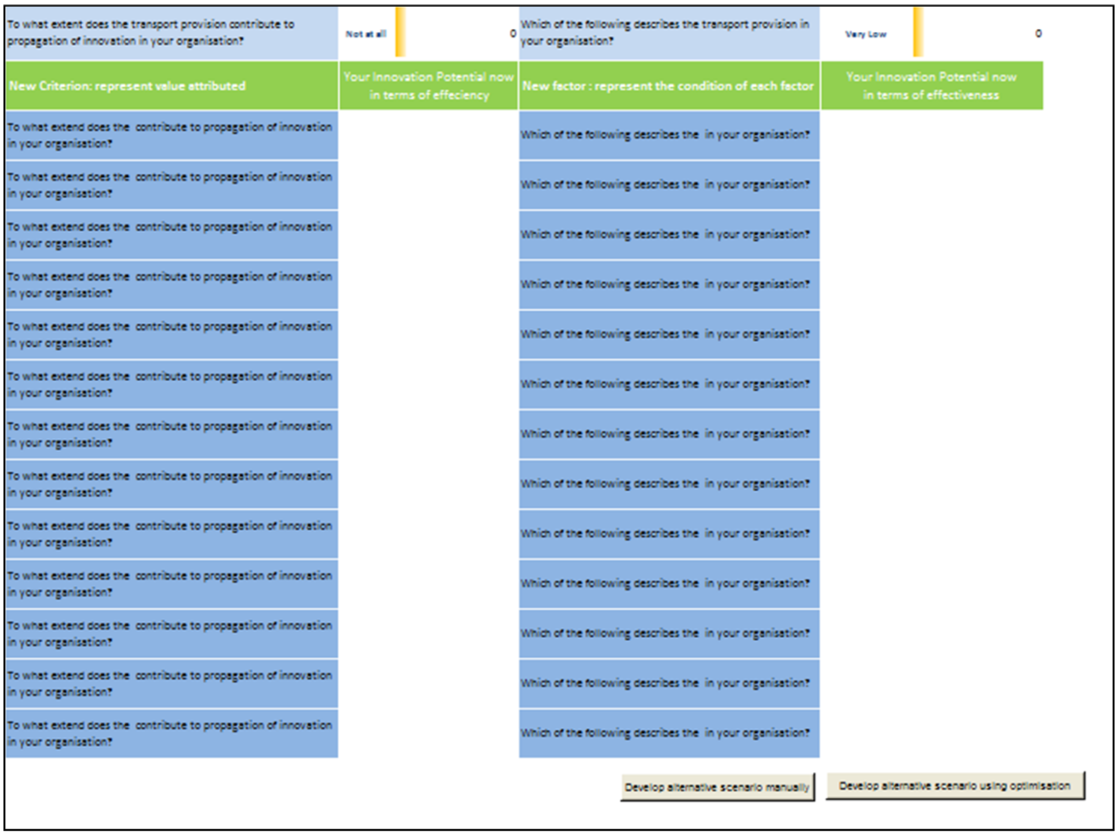


Figure D.5 The '*Develop alternative scenarios manually'* and '*Develop alternative scenarios using optimisation'* buttons

Develop alternative Scenarios Manually

The '*Increase Potential Manually'* worksheet (see Figure D.6) presents the data entered and the initial calculation of the innovation potential (yellow bars). In order to modify each measurement manually use the combo boxes provided next to the yellow bars. The green bars shows the manual alterations on each item.

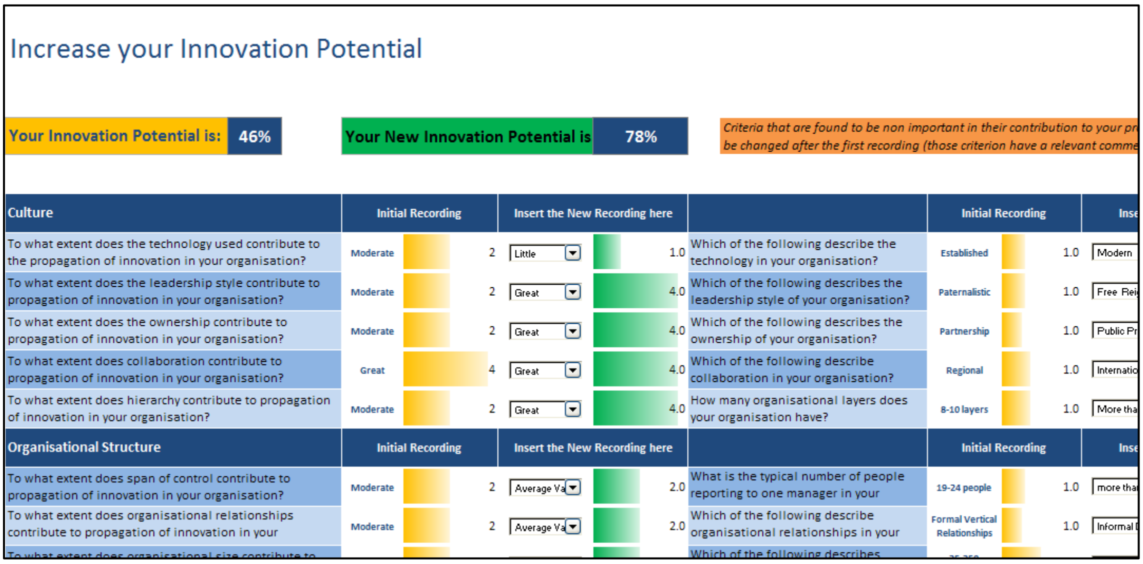


Figure D.6 The *'Increase potential manually'* worksheet

The Microsoft Excel provides the utility to save the results produced.

Develop alternative Scenarios using optimisation (GA algorithm)

In the '*Develop Alternative Scenarios* worksheet (see Figure D.8) the user can choose which of the items will be included in the optimisation algorithm. The user can choose from the following options:

1. **Contribution**. Refers to efficiency and is associated with column A of the Main Menu. It reflects the question: Is it possible to change the attitude towards each factor in order to maximise the benefit of the current value attributed?
2. **Type:** Refers to effectiveness and is associated with column B of the Main Menu. It reflects the question: Is it possible to change the condition representing the current practice of each factor?
3. **All** = Refers both the dimensions of efficiency and effectiveness. If this option is chosen both efficiency and effectiveness will be entered into the algorithm.

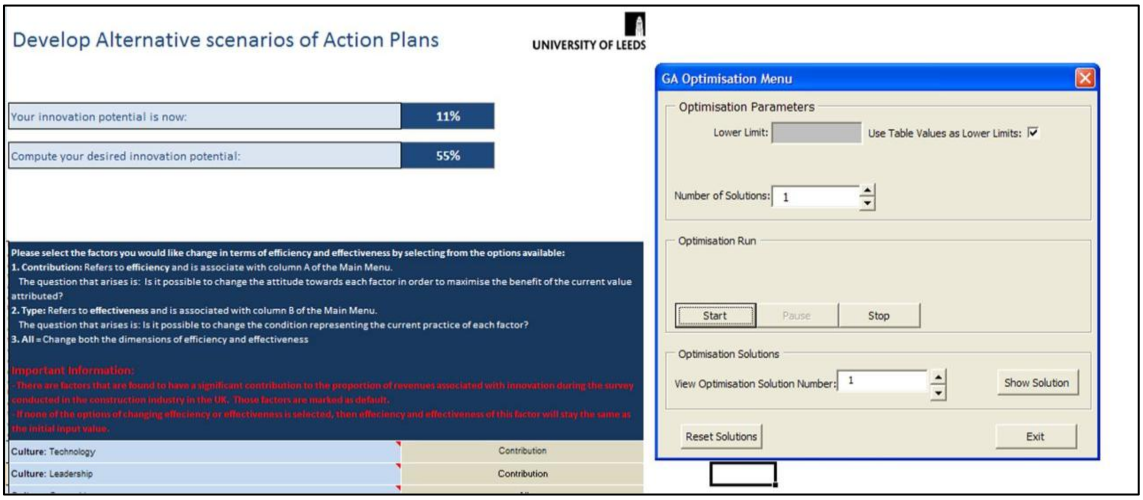


Figure D.7 The *'Develop alternative scenarios'* worksheet

In order to launch the GA, on the excel ribbon, chose Add-Inns and select *'Run GA'* as shown in Figure D.9

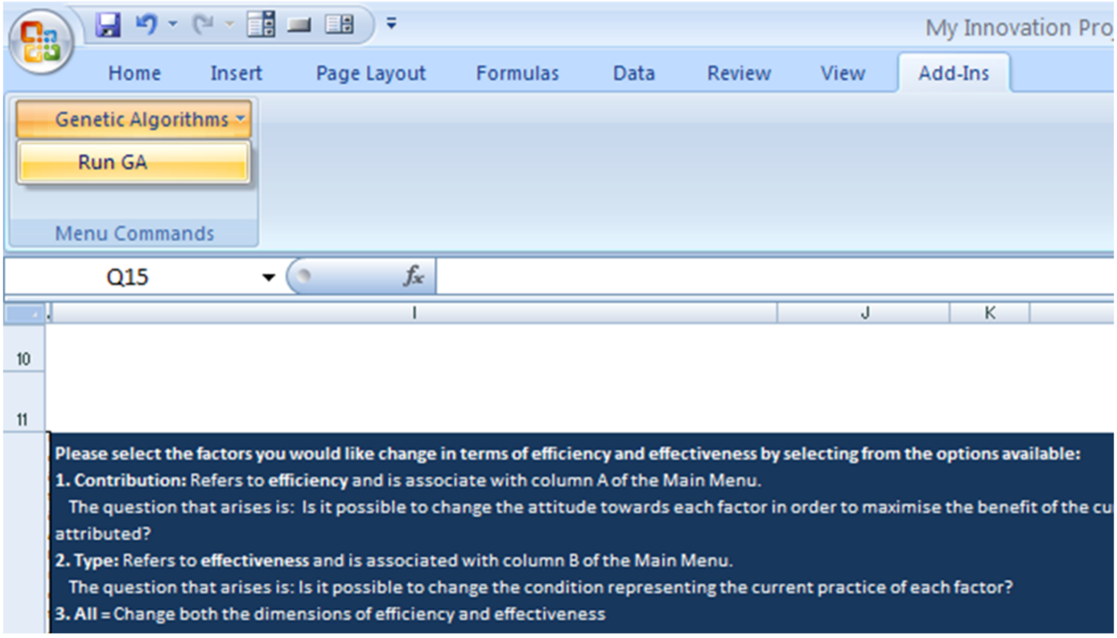


Figure D.8 The *'Run GA'* function

In the dialog Box of the GA (see Figure D.10), insert the number of alternative scenarios you would like to produce in the 'Number of Solution' box and the click 'Start'

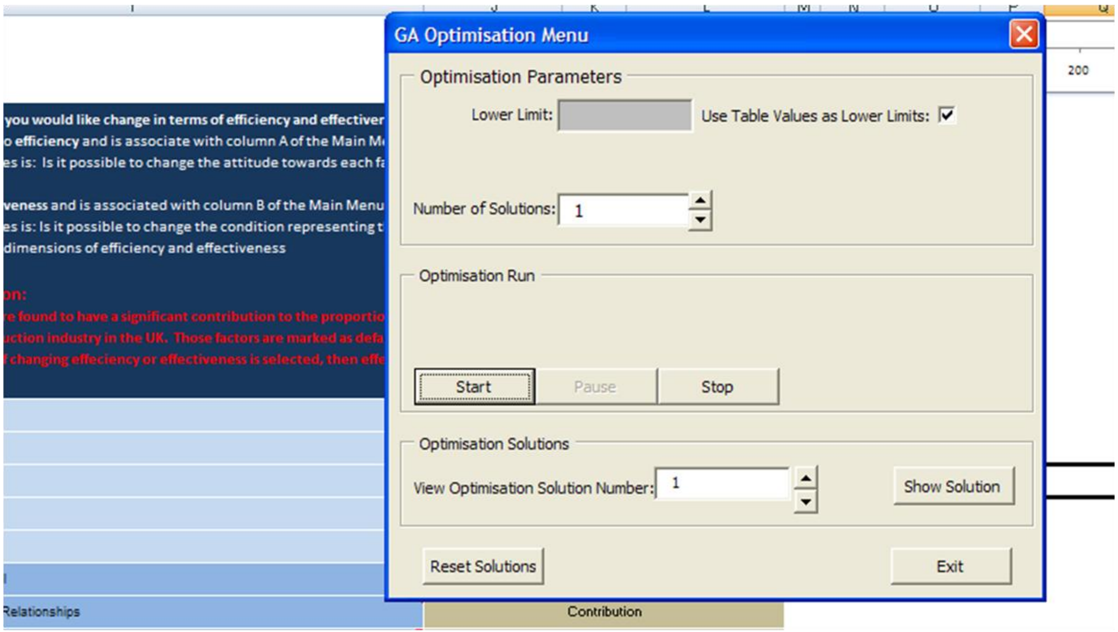


Figure D.9 The GA dialog box

Use the 'Show Solution' button to see the alternative scenarios. Use the 'Reset Solutions' button to reset the solutions.

Use 'Exit' to exit the GA function.

Change Alternative Scenario Manually

The alternative scenarios produced can be manually modified in the worksheet '*Change Alternative Scenario Manually'* as shown in Figure D.11 below.

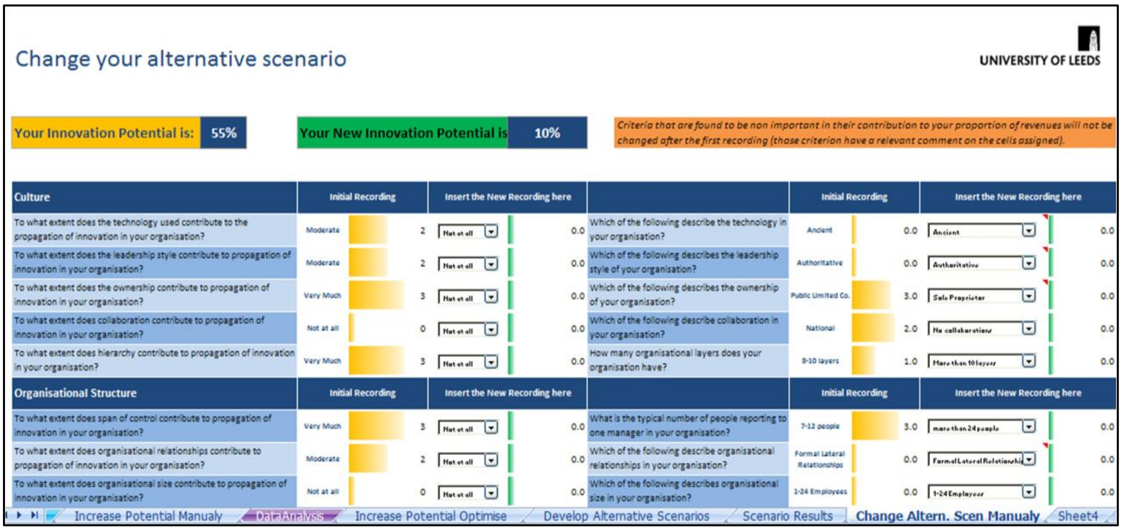


Figure D.10 The *'Change alternative Scenario manually'* worksheet

The *Change Alternative Scenario Manually* worksheet (see Figure 8.8) presents the data obtained from the optimisation routine and in and allows for the changing of the data manually to manipulate the innovation potential.

Enter the GA into your ribbon

In order to add the GA Add-Inn into your ribbon, follow the steps below.

1. **Click** the Office button on the left right corner of the InnoAct (see Figure D.12)

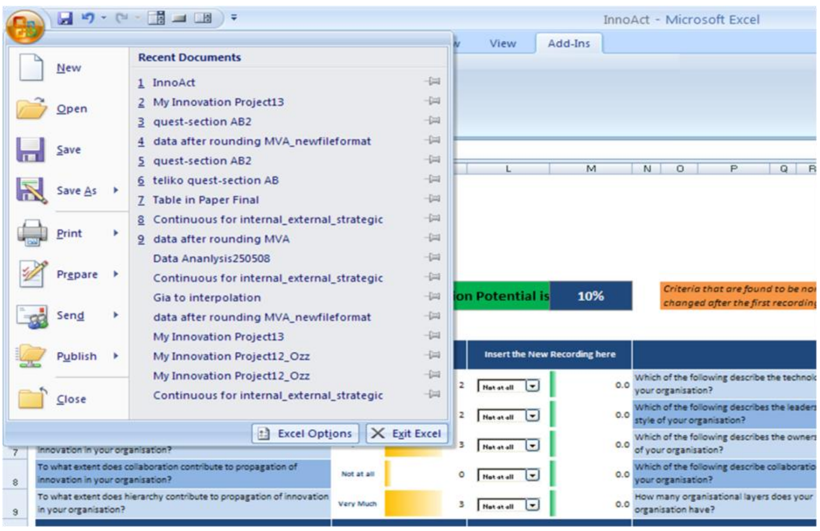


Figure D.11 The Office Button

3. **Select** Excel Option
4. In the dialog box opened **choose Add-Inns**
5. Click on ‘Go’

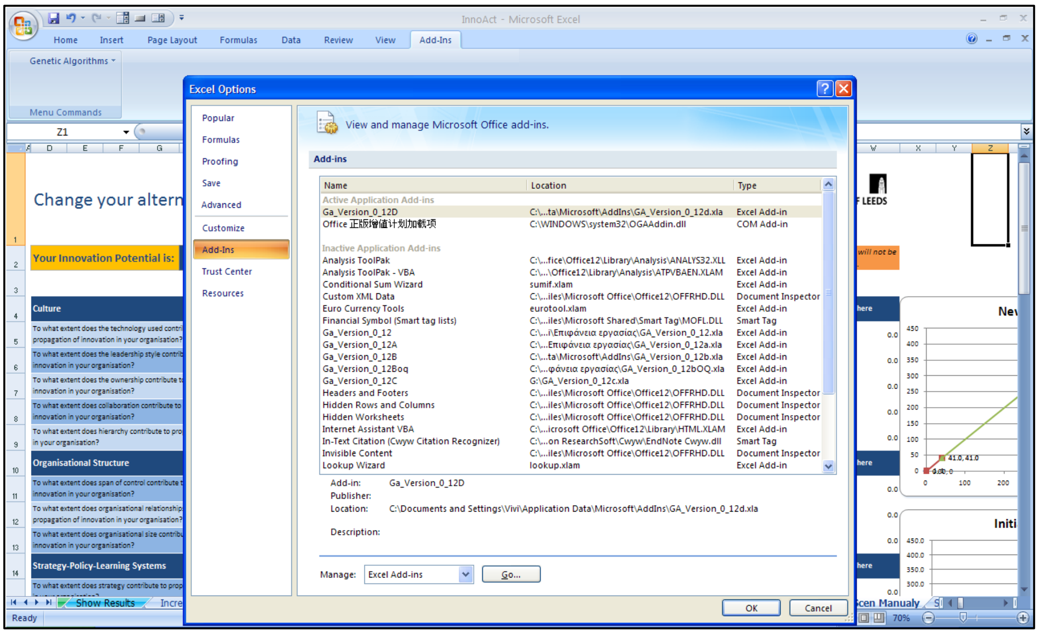


Figure D.12 The Add-Inn

6. **Browse** the Add-Inn in your computer.
7. **Tick the box** of the GA

APPENDIX E

E.1 Workshop Minutes

Workshop Minutes

21 July 2010

School of Electrical Engineering

Venue: 3.52, Time 11.00 a.m.

Workshop Title: Orchestrating opportunities that can be found in the internal environment, the strategic resources and the external environment of organisations.

List of Participants

Professor NG Wright, Professor of Water and Environmental Engineering, n.g.wright@leeds.ac.uk

Professor SP Male, Professor of Property and Infrastructure Asset Management, s.male@leeds.ac.uk

Dr. TW Cousens, Senior Lecturer in Geotechnics, t.w.cousens@leeds.ac.uk

Dr. P Purnell, Reader in Civil Engineering Materials, p.purnell@leeds.ac.uk

Mr. Moodley, Senior Lecturer, k.moodley@leeds.ac.uk

Dr. L Black, Lecturer in Civil Engineering Materials, l.black@leeds.ac.uk

Dr. A Tutesigensi, Senior Lecturer in Engineering Project Management, a.tutesigensi@leeds.ac.uk

Dr. B Aritua, Research Assistant, b.aritua@leeds.ac.uk

Presenter: P Gkioura, PhD Student

Main topics presented:

1. Research problem, aim and objectives
2. Conceptual model
3. Holistic model of innovation in the construction industry
4. System to identify the condition of each factor
5. Calculation method to identify innovation potential
6. Software

7. Program logic model

The main issues/questions raised during the workshop were:

1. **Do all the factors carry the same weight?**

The reflection to this question is that all factors are designed to carry the same weight. This decision is based on systems theory which recognises that a small change in one discipline of an organisation may have a big impact and chained effects on many other disciplines of the organisation (see Section 2.2). This shows the technical difficulty to isolate and measure the impact of a change in a single factor to the innovation process.

Moreover, the process of weighting the factors would treat an organisation as being one case of a homogeneous sample. However, different factors may be of different importance within different organisations. This means that weighting of factors should be organisation specific and this logic is encouraged by the recognition that one solution cannot fit all organisations-even if they are of the same type or have similar characteristics. Therefore, weighting is intentionally avoided in order to keep the individuality of organisations. Adding to this discussion the PLM developed in this research is not offering the solution to which Action Plan produced should be employed by the organisation. The PLM offers the alternative options of Action Plans and it depends on the organisation to decide which Action Plan is more appropriate to employ judging on the individual capabilities. Building on the specific context that applies for each organisation, the PLM provide the base to evaluate the organisation’s competences and resources and assess the capacity to move from a lower position in innovation potential to a higher.

2. **Do organisations need the same amount of effort to move from a lower percentage in innovation potential to a higher percentage in innovation potential?**

The reflection to this question is that the amount of effort required to make the steps proposed by the action plan is based on the individual organisation. It might be that large organisations can have the resources to achieve easier and in less time the desired position whereas smaller organisations might have to identify and invest in more resources to achieve that same position. The nature of the model does not capture the amount of effort required for a particular change. The model depicts the current position and provides the alternative options for action offering a tool to assist the decision process on improving the innovation potential. It is up to the organisation to decide whether it posses the resources required to achieve the desired improvement and therefore evaluate if the desired change is appropriate for it.

3. **Can the organisation reach to the same percentage by addressing fewer factors?**

The reflection to this question is that the literature has shown that innovation is an integrated process involving all organisational disciplines and is related to all the factors that interact contributing to the efficiency and effectiveness of the organisation. Thus, it is supported that the more factors addressed and the most favourable to innovation the conditions of those factors, the more likely it is for innovation to emerge.

4. **Can an organisation retain innovation potential by reducing the amount of effort provided to some of the factors?**

The reflection to that question is that the optimisation routine can do that incorporated in the **InnoAct** can do that. The organisation needs to decide which factors wants to change. The application can provide that option.

APPENDIX F

F.1 Advertisement Poster

In order to attract construction professional a poster was created to advertise the offering of a session for evaluating innovation potential in organisations. The poster is illustrated in Figure F1.

Figure F.1 The advertising poster