MANAGING INNOVATIONS IN ENGINEERING INDUSTRIES

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ABSTRACT

It has been shown in this thesis why innovations are regarded as the lifeline of engineering industries. Continuous flow of novel ideas is the source of innovations but the encouragement, creation and nurturing of such ideas requires many distinct managerial attributes. Hence, management of innovations is complex but an important area of study which is not amenable to standard analyses due to its multidisciplinary nature and dependence on a large number of intangible variables. It has been shown that proper management of innovations would involve at least three distinct but closely linked activities, namely: (a) managing people, in particular the innovators, as well as inspiring others to become innovators; (b) managing the environment so that it is conducive to innovations; and (c) managing innovative processes in order to ensure that innovations are properly nurtured, well targeted and economically implemented within clearly defined time and budgetary constraints. The thesis has been divided into eight chapters; an outline of the chapters is given below.

Chapter 1 is an introduction to the subject of managing innovations in engineering industries. It sets the scene for carrying out research in this field, identifies the problems to be tackled and makes a clear statement of the aims.

Chapter 2 offers a critical review of the published works relevant to the field of research covered in this thesis. The purpose of this study was to understand the *state of the art* approach to: (a) creating and maintaining the innovative environment; (b) inspiring and leading engineers to come up with innovative solutions for engineering problems; (c) managing the innovative processes for better efficiency. Finally, in view of the comprehensive review of the relevant published literature, this chapter justifies the aims of this research.

Chapter 3 describes research methodology i.e. the procedure for conducting this programme of research. The purpose of this study was to ensure that the research programme was conducted in accordance with the scientific method as closely as practicable.

For sake of clarity, chapter 4 first draws distinction between inventions, innovations and engineering design and later identifies a large number of intangible factors that influence the three principal components, i.e. innovative environment, innovators and the innovation process. It is suggested that the innovativeness of engineering companies depends on these three principal components. Hence, innovativeness may be assessed by determining the influence of each on the principal components with the help of suitable computational techniques.

Two computer applications have been developed to: (a) evaluate the innovativeness of engineering organisations; and (b) analyse the risks embedded in either accepting innovative ideas or implementing innovative projects. These applications are based on questionnaires and may serve as computer aided management (*CAM*) tools for dealing with the multidimensional problem of managing innovations speedily and efficiently.

Chapter 5 analyses the influence of factors identified in chapter 4 and uses the two aforementioned applications to survey the innovativeness of four engineering organisations for their innovativeness and evaluate two projects for the risks surrounding them. These assessments were carried in the form of six case studies.

Chapter 6 and Chapter 7 present the results of the six case studies and a focused discussion of the results and other observations made during the course of this research. Chapter 8 draws conclusion from this research and proposes further work that may be carried out in order to study yet unknown factors, refine the questionnaires conduct further tests in different industrial environments to build confidence in the use of *CAM Applications* as tools for rapid response management of innovations in engineering industries.

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CONTENTS

CHAPTER 1

INTRODUCTION AND AIMS

1.1 INTRODUCTION.

Human societies are indebted to scientific and technological inventions and innovations for their style of living and economic progress. Inventions devise new principles, processes or products to achieve certain objectives or perform certain functions. Innovations, on the other hand, usually introduce new applications of well-established principles, processes or products in order to prolong the lifespan on products of engineering by introducing new models and to enhance competitiveness in terms of quality and cost. Due to tremendous advances in science and technology, now a days it is very difficult to come up with new ideas for inventions, but scope for innovations seams to be limitless. For example, King (1904) presented a paper to the Royal Society (UK) in which he described the mechanism of heat transfer from cylinders in cross flows of air. Approximately half a century later, King's idea was used to design a hot wire anemometer to measure air velocities or air mass flow rates with minimum disturbance to flow such as in boundary layers.

Technological innovation gives a sense of both wonder and uncertainty to planning for the future. Technology shapes our lives in countless ways; tomorrow's advancement can make today's achievement obsolete with great rapidity.

Globalisation and agreements of the World Trade Organisation (WTO) have produced a business environment that in order to succeed in highly competitive international markets, technological innovations are of paramount importance for survival and competitiveness.

Today the pressure of international competition has introduced a critical time dimension into the system. For a nation's economic interests, the issue is not simply how much new knowledge is being generated, but also how fast it is being translated into economically and socially attractive products and processes. Organisations have to follow an offensive strategy by continuously offering new or improved products and services that can compete in global markets. A way of achieving this is by focusing on the organisations' ability to innovate.

In addition to this, innovative environment in organisations is also a way to attract and keep the best employees. The labour market now calls for, and increasingly so in the future would call for, employees who can co-operate creatively in diverse work environments whilst they continuously acquire new knowledge. Innovation requires as well as supports these kinds of attributes and qualifications in staff. Therefore, organisations are interested in innovation as a way of creating a virtuous circle of qualified employees.

Innovativeness is a necessity not only for engineering companies but also for the other organisations. It is a means of improving the lives of individuals as well as of attaining self-sufficiency for the nation. The economic well-being of nations depends on their industrial strength and the ability to hold on to a lead in the industrial arena, in turn, depends on innovativeness.

It should be noted that innovativeness is a continuous process; engineering companies, which become complacent soon loose their lead in highly competitive world markets. The challenge for the management of engineering companies is to understand the processes that give birth to innovative ideas for introducing new features in existing products; develop new manufacturing methods or use alternative materials to reduce costs.

In order to meet these challenges, the role of management in engineering companies may be divided into two main functions as follows:

(i) Procedural control of financial and other resources such as personnel, materials, machines, etc.
(ii) Offering leadership to inspire staff in order to maximise their contribution to work and their dedication to projects.

The first has been well covered in the relevant published literature but the second though more important, does not appear to have received adequate attention; consequently published literature related to this area is scarce.

1.2 PROBLEMS IDENTIFICATION.

Inventions as well as innovations rely on creativity; hence, they are a very important part of engineering design. The primary task in managing innovations is to produce an environment that is conducive to creative thinking, particularly in engineering design. At this juncture it would be pertinent to emphasise that creativity should not be confused with originality; the latter is essential for research that is intended for submission for a research degree. Furthermore, opinions differ whether creativity is a natural gift or it can either be taught or acquired through working in the right environment. The challenge in managing innovations in engineering industries is, in the first instance, to understand the nature of the innovative environment and then to create it in order to foster innovations.

Implementation of innovations is a necessary step to extend the life cycle of engineering products in order to recover the high cost of tooling. This is done by introducing new models of the same product or improving techniques to simplify manufacturing processes with the aim of reducing costs. For example, the household washing machine is a well-established product but a Japanese company is about to launch a revolutionary model which would not use detergents; instead it would rely on the ultrasonic technique to clean clothes. Furthermore it would employ electrolysis to clean and recycle the water. In this case the ultrasonic technique and the electrolysis are not new, but their use in this application is indeed novel and a very good example of design innovation. It will enable the company concerned to establish a technological lead in the field of washing machines for many years to come.

The essential ingredients for this type of innovative solutions to problems are:

(a) Full appreciation of the need;

(b) A burning desire to satisfy that need;

(c) A sound understanding of the relevant scientific principles;

(d) The technological competence to design and manufacture products in accordance with the known scientific principles to satisfy the perceived market need within the time and budgetary constraints (like the washing machine in the above example).

To gain full appreciation of market needs is the first and the most important step. The challenging task for the management is to explore how to make innovators aware of human needs which may be related to their own range of products.

It must be understood that all innovations carry an element of risk, therefore it is necessary to conduct a proper analysis in order to minimise the risk and to speed up the decision making process. A risk analysis programme can serve as an analytical tool for a computer-aided management (*CAM*) practice for controlling innovations.

It would be pertinent to mention also that the terms such as *management, inventions, innovations,* have not been defined precisely in the published literature consequently they are prone to several interpretations. For this reason, precise definitions are given in Appendix A in order to avoid any ambiguity and for ease of reference.

1.3 AIMS OF THIS RESEARCH.

The aims for the research programme reported in this thesis were as follows:

(a) To carry out a comprehensive and critical review of the relevant literature in order to understand the state of the art practices for managing innovations in engineering industries.

(b) To produce computer analyses as an aid to the managing of innovations in order to speed up the decision-making processes.

(c) To validate the analyses against case studies of representative engineering organisations with respect to innovativeness.

(d) To develop a risk analysis application as a tool for computer-aided management of innovations in engineering industries.

It is envisaged that this study would provide management with a methodology for a systematic approach to fostering and managing technological innovations thereby to improve the performance, profitability and competitiveness of their companies.

CHAPTER 2

LITERATURE REVIEW

2.1 BACKGROUND.

It is widely accepted that the success of engineering products depends on design elegance, competitive pricing, and reputation of the manufacturing company for quality, reliability and durability of its products. Innovation or novelty of design, high quality standards through continuous improvements in manufacturing processes and above all competitive pricing are of paramount importance for success. Hence, progressive companies are always on the lookout for innovations and they will have a policy of encouraging their staff to maintain a regular flow of innovative ideas.

Management of innovations in engineering industries has four components, which form the basis of maintaining the continuity of flow of innovative ideas. These components are:

- Managing the creation and maintenance of innovative environment;
- Managing and inspiring people through leadership to be innovative;
- Managing the technical novelty and commercial viability of innovative ideas. This may need risk assessment before embarking on implementation of innovations;
- Managing the marketing of innovation.

The last component was seen to have been covered thoroughly by others and many papers and books had been published on the various aspects of marketing; therefore, it was not considered in the research reported in this thesis.

Because of the importance of innovations to industry, many textbooks and research papers have been written on factors that lead to innovations and the innovative processes. However, most publications have dealt with innovations in general and have tended to overlook innovations in engineering industries. The questions such as how innovative ideas originate, what processes they go through to reach the product design stage, how are innovative projects implemented and what risks are involved in their implementation have not been answered.

In this chapter, a critical review of some of the important, though general, papers and publications is presented. Notwithstanding the fact that these papers were not directly relevant to the scope of this thesis, the review was carried out with the aim that it would provide a useful background study of the management of innovations in general.

2.2 CREATIVITY AND INNOVATION.

In the literature review conducted by Glor [12], he stated that Amabile [15] had identified the factors that promoted problem solving or personal creativity by studying a group of 120 innovators working in research and development fields. The results of the survey were given as percentage values of 120 who took part in the survey. Personal characteristics such as self-motivation, special cognitive abilities, risk orientation, diverse experiences, expertise, social skill, brilliance and naiveté were related to creativity. The qualities of problem solvers that inhibited creativity, on the other hand, were lack of motivation (30%), unskilled (24%), inflexible (22%), externally motivated (14%) and socially unskilled (7%). Individual creativity was enhanced by domain relevant skills, creativity-relevant skills and intrinsic task motivation.

While individual factors and initiative were important to creativity, social environments also made a difference. Environments that encouraged creativity for these innovators were: exhibited freedom (74%), good project management (65%), and sufficient resources (52%). A one-half to one third of the innovators identified the need for encouragement (47%), specific organisational characteristics (42%), recognition (35%) and sufficient time (33%), whereas only (22%) identified the need for challenge and (12%) for pressure. They felt that organisations required a mechanism for considering new ideas. A corporate climate was necessary marked by co-operation and collaboration across levels and divisions, and an atmosphere where innovation was prized and failure was not considered as fatal.

The qualities of environments that inhibited creativity were various organisational characteristics, constraints, organisational disinterest, poor project management, poor evaluation, and insufficient resources including a corporate climate marked by a lack of co-operation across divisions and levels and overemphasis on the status quo. Two factors, sometimes described as innovation motivators, were found not to be constraints and competition.

One notable aspect of these responses about environments was that the innovators found the social factors to be more important than the personal characteristics. The largest number of innovators, who chose any single personal characteristic, was 41%, while the top five of the group characteristics received a higher rating. Therefore, there was greater consensus about social factors than individual ones. Another striking element was how many of the group factors could be influenced by management and how few by the innovators themselves. Management usually determined the organisational characteristics, set the tone for the corporate climate, and determined whether the organisation was interested in innovation. It also controlled whether there was a competent project management, evaluation, sufficient resources, and an emphasis on the status quo, constraint and competition.

While Amabile [15] studied the characteristics of individuals and environments contributing to and interfering with individual and organisational creativity, Brown [19] and Harrington [22] understood organisational creativity as a combination of the creative process, creative product, creative person, creative situation, and how these components interacted, Woodman, et. al. [30]. Individual creativity is a function of antecedent conditions, e.g. past reinforcement history, biographical variables, cognitive style and ability, divergent thinking, ideational fluency, personality factors such as self-esteem, focus of control, relevant knowledge, motivation, social influences i.e. social facilitation, social rewards, and contextual influences including physical environment, task and time constraints, Woodman et. al. [30]. It is notable that the manager and employees trying to encourage innovation cannot affect the past, cognitive style, ability or personality of employees, but can influence knowledge, motivation, and social and contextual influences. What the manager can conceivably do is to choose employees with certain historical, cognitive ability and personality profiles. However, a homogeneous and exclusionary work force could thereby be created, thus losing the potential benefits of diversity.

Amabile focused on personal and social environmental characteristics, Brown and Harrington investigated the creative process combining the product, person and situation. Like Amabile, et. al, [23] they pointed to work group characteristics as being the key. Further, they described the conditions of group creativity as leadership, especially when democratic and collaborative, cohesiveness, group longevity, group composition, group structure that is organic rather than mechanistic, and membership from diverse fields or functional backgrounds is considered. Group cohesiveness and longevity seemed important group characteristics, but their relationship to creativity was not very clear. Nystrom [25] suggested that there was a curvilinear relationship between group cohesiveness and creative performance. Examining research teams, Payne [27] came to similar conclusions, identifying the key role of resources availability, leadership, group size, cohesiveness, communication patterns, and group diversity as crucial factors in creative performance Woodman et. al. If King, Anderson, and Payne were correct, then the recruiting strategies identified and formulated by Amabile, Brown and Harrington's work, where managers would attempt to find creative staff, might in fact be destructive for innovation.

The key aspects were rather the way groups functioned. This consideration led to the development of creativity enhancing group techniques such as brainstorming and mind mapping. Following development of these strategies, a review of literature by Stein [29] found that individuals actually generated fewer ideas in such groups. Hackman and Morris [21] proposed that group performance was reduced not only because of motivational losses, but also surprisingly by processes and co-ordination. Problem-solving groups could improve their effectiveness by training individuals in problem solving skills Bottger, Yetton [18].

The identified techniques for enhancing organisational creativity included the separation of solution generation and evaluation of solutions. Cummings, O'Connell, [20], Basadur et. al., [16], Basadur et. al., [17], risk taking, free exchange of ideas, legitimisation of conflict, stimulation of participation, and reliance on intrinsic as opposed to extrinsic rewards. Woodman et al. inferred, however, that there was little empirical support for these conclusions, except for that provided by Amabile [14]; although evidence of correlation with ratings of overall innovation had been provided by Paolillo & Brown [26] and Abbey & Dickson [13], Woodman et al., [30].

This conclusion continued to be challenged by those who taught creativity methods and trained groups to be more creative, i.e. those focusing on the process rather than the product. Their approach treated creativity, at least in part, as a set of thinking skills. For Basadur, et. al. [17], creativity was enhanced when more time was spent producing ideas, since the quality of ideas was the same throughout ideation, and when the group avoided making premature critical evaluations of ideas. These authors found that training focused on developing the thinking skills associated with creativity, such as active divergence, deferral of judgment, and active convergence, lead to tangible outcomes in terms of the quantity and quality of creative output. Trainers at the Manchester Business School Creativity Research Unit, using methods developed by the pioneering programs of the Creative Problem Solving Institute, Buffalo, which was also the basis of Basadur's approach, found that a one-day training program heightened awareness of personal capacity for creative action but did not have any impact without reinforcing factors being in place in the workplace. A three-day program might achieve valuable results if the person developed a critical mass of trained people through formal or informal networking. The outputs of a ten-day program included both tangible products such as contributions to corporate innovation success and evidence of changes in behaviours and problem-solving strategies of participants Rickards, [28]. The significant part was that group creativity was not the sum of the individuals' creativity within the group. Rather, creative behaviour was mediated through the group and was influenced by the group's composition, characteristics and processes, as well as the context of the larger organisation. In short, the group mediated individual behaviour, which ultimately affected organisational creativity.

Amabile [15] has demonstrated that the intrinsically motivated person was more creative than someone who was extrinsically motivated. An important consequence of this conclusion was that hierarchical direction to innovate and top-down innovation would presumably not produce very creative solutions. On the assumption that more creative ideas were at least sometimes better ideas, how could the creativity of innovations be enhanced? Amabile [15] identified domain relevant skills, creativity-relevant skills and intrinsic task motivation as the key elements. She suggested that each one of the three components of her creativity model, (she called it a multiplicative model, applied to individuals and small groups), was necessary for creativity to occur. The higher the degree of each (all must be present) of the three components, more would be the creativity. Conceptualised as circles, individual creativity or organisational innovation would be greatest where the circles overlapped; hence the creativity intersection. The implications of the "Creative Intersection", applicable to both individual creativity and organisational innovation, suggested that one should look for task skills, creative skills and intrinsic motivation, when recruiting; environmental factors that promote creativity should be bolstered; and information should be used to remove inhibitors to creativity, i.e. to remove obstacles before putting new things in place.

If for the organisation the key aspect of intrinsic motivation was that the individual was then willing to make personal knowledge available to the organisation, what could be done to support and enhance that willingness? One approach was to value the contribution of employees, clients and the public, and to consult with staff and clients, in order to have access to their ideas. This was a key aspect of the quality movement and an approach used in many innovations as well. Another approach was used in many innovative Japanese companies, where management and teams were oriented toward working with staff to access their personal knowledge. Nonaka explored the process, which occurred interior to creativity. According to Nonaka, [24], making personal knowledge available to others was the central activity of the knowledge-creating company. It was of primary importance to recognize that creating new knowledge did not simply mean processing information, but tapping the tacit and often highly subjective insights, intuitions, and hunches of individual employees and making those insights available for testing and use by the company as a whole. To do this, employees should feel a personal commitment and bond with the company and its mission. Nonaka saw this as the organisational equivalent of self-knowledge, a shared sense of what the company stood for, where it was going, what kind of world it wanted to live in and, most important, how to make that vision a reality Nonaka, [24].

Nonaka described four basic patterns for creating knowledge: converting tacit knowledge to tacit knowledge (socialization), explicit to explicit (combination), tacit to explicit (externalisation), and explicit to tacit (internalisation). In a knowledge-creating organisation all four of these interchanges would occur. The Japanese are particularly good at the interchange between tacit and explicit information, the critical step in knowledge creation Nonaka, [24].

The knowledge-creating process which converts tacit knowledge into explicit knowledge operates first, by linking contradictory things and ideas through metaphor; then, by resolving these contradictions through analogy; and, finally, by crystallizing the created concepts and embodying them in a model, which makes the knowledge available to the rest of the company. Nonaka, [24]. In attempting to design a new and different car, for example, the project leader of Honda's engineering team charged with the task developed the slogan: *Theory of Automobile Evolution*. The question was asked, if the automobile were an organism, how should it evolve? Nonaka. The analogy required reconciling the differences and similarities of the two ideas expressed in the metaphor, "car" and "evolution." In the creative context, managers must take a more holistic approach, which includes creating images, symbols and slogans.

Based on the literature reviewed in his paper, Glor [12] concluded that it was possible to support creativity and innovation. Individual creativity was found by Amabile to be mediated by the group and could be supported by the social environment and management. Woodman et. al. also found that the elements influencing creativity, which employees and management could influence, were knowledge, motivation, social and, to some extent, contextual influences. Some studies reported contradictory findings on whether managers should build teams of creative people, a kind of homogeneity, or teams with a diversity of backgrounds and skills. Likewise, there was no consensus on whether the way in which groups functioned and the processes used with groups affected creativity, but it was clear that the group mediated individual creativity.

Glor's paper focussed on the environment surrounding the innovator, and did not pay much attention to individual creativity of the innovator who was the nucleus of the organisational creativity. Little was discussed about the factors that enhanced individual creativity of the innovator, which at the end, added a great deal to organisational creativity. Ahmad & Abdalla [50] mentioned that certain organisations like Toshiba, Shell International and Pepsi Cola have learned to create hospitable working environment that harnesses creativity to achieve innovation and growth. Other authors did not consider how to implement the management of enhancing organisational creativity according to a prepared plan.

The author of this thesis considers creativity as the nucleus of innovativeness; therefore, it should be given special attention. The author also considers organisational creativity to be a combination of individual creativity (personal characteristics), group creativity (group characteristics) and creative environment (environmental conditions). The three factors react with each other to provide an overall organisational creativity. Group creativity and organisational environmental factors have greater influence relative to individual creativity. Previous research did not discuss group creativity in sufficient depth. The author feels that creativity can also be enhanced and improved by good planning and management, but further work is needed to support this hypothesis.

2.3 THE INNOVATIVE ENVIRONMENT.

Taylor [31] asked Paoul M. Cook, founder and CEO of Raychem Corporation, *what was the secret to being an innovative company*? Cook answered: there was no secret. To be an innovative company, you have to ask for innovation. You assemble a group of talented people who are eager to do new things, and put them in an environment where innovation is expected. It is that simple and that hard.

In this short question and answer, Cook mentioned the principal components of managing innovations, which required good management for the success of innovations. In another question, Cook was asked: *How do you motivate people over a long haul to keep them focused on innovation*? Cook answered: the most important factor was individual recognition, more important than salaries, bonuses, or promotions Taylor [31].

The successful firm of the future will be one, which, is structured in such a manner that both external and internal problems are given appropriate and continuous attention. Beyond this, the management structure will be conducive to innovation. The search for opportunities and problems will be institutionalised and continuous, the internal productive cycle will be R&D oriented, and manufacturing & marketing will be flexible and responsive to change in product-market mix. H. Igor Ansoff, Twiss [5].

According to Lampikoski & Emden, [32] a high level of innovation will be reached in an organisation by achieving the following: identifying core skills and knowledge gaps, recruiting top creative talents and supporting them in their creative and innovative efforts, offering proper career paths to innovators, granting measurable privileges such as slack-time and extra rewards to innovative individuals, attaching specific importance to the development of managers' creativity and their innovative skills, attaching great importance to product innovation activities, devoting special attention to borrowing and buying ideas, developing and maintaining formal internal innovation programmes, stimulating operational and situational creativity and a readiness to grasp opportunities and maintaining effective ideas management.

Michael et. al., [34] reported a set of norms associated with innovation, as identified by managers from five very different samples, as shown in table 2.1 below. Although the collected suggestions came from widely differing national cultures and industries, there was a great deal of consistency in how these managers thought about promoting innovations.

Roberts [51] described the innovative environments as "Innovative Intense Environments (IIEs). He defined them as special spaces, which purportedly increased the rate of innovation and proliferation of new, high technology industries. IIEs were referred to in the literature in a variety of ways including science or technology parks, science cities or technopolises.

Taylor was able to identify two principal components of managing innovations. These components were the innovators and the environment. Lampikoski & Emden identified several factors that should be embedded in the innovative organisation in order to become innovative. Michael was able to point out different norms of innovations that constituted some of the expectations from the innovative environment and Roberts went a little further by pointing out that there was more to the innovative environment than we imagined when he introduced the innovative intense environments (IIEs).

The author of this thesis thinks that previous research in the same area was successful in two things: the first it highlighted the importance of innovative environment; and the second it identified several factors that influenced it. However, it was not able to identify all or most of the factors that influenced this environment and neither did it discuss the magnitude and direction of such influence.

South African Natural Resources Company	European Pharmaceutical Company	U.S. Financial Services Firm	International R&D Managers	Japanese Beer Company
Mistakes are OK	Rewards	Accept failure	Freedom to fail	Cooperation
Recognition	Accept failure Careful Learn Calculated	Free to try things Time Support Resources	Risk taking Fast Prudent Cheap	Mistakes are OK
Rewards	Clear objectives	Clear goals	Rewards	Openness
Mutual respect	Share information	Celebrate success	Involvement	Flexibility
Open communication	Team work	Remove barriers to change	Tolerate dissent	Clear direction
Freedom to experiment	Commitment for the top	Set the example	Listen	Ideas are valued
Expect change	Empowerment		Positive attitude	Rewards for innovations
Challenge the status quo			Resources	Resources
Equal partner				

Table 2.1 Norms for innovation

2.4 THE INNOVATOR.

Taylor [31] asked Paoul M. Cook: *Can a company teach its people to be innovative*? Cook answered: no. Innovation was an emotional experience. You could train people technically, but you could not teach them curiosity. The desire to innovate came partly from the genes; you were born with it. It also came from your early life, your education, and the kind of encouragement you were given to be creative and original.

Cook pointed out that encouragement influenced innovativeness. From this, one could learn that some of the innovativeness came with the genes, and some could be acquired by learning. Reference to obstacles to innovation, Cook mentioned mainly size of the organisation; large size was the enemy of innovation. "You can't get effective innovation in environments of more than a few hundred people," Taylor [31].

Twiss [5] highlighted what distinguished successful innovators, relying on the results of a project conducted at the University of Sussex, which could be summarized in the following statements: successful innovators were seen to have much better understanding of user needs, pay more attention to marketing, perform development work more efficiently than failures, but not necessarily more quickly, make more effective use of outside technology and outside advice, and successful innovation projects are managed by responsible senior individuals.

Highly motivated people drive themselves to overachieve, while many of their brighter and more capable associates accomplish far less. In addition, some people are so motivated that they overcome great personal disadvantages to achieve impressive success. People seek challenges and strive to overcome obstacles not because they want an external reward or benefit but they find satisfaction in their own achievements. Watts, Humphrey [33].

The author of this thesis is in agreement with Cook up to point. A classical example is that of Gauss, a brilliant mathematician from Austria. When Gauss was, only five years old, his teacher asked all children in his class to find the sum of number from 1 to 100. Gauss could see immediately the symmetry of numbers on both sides of 50. Therefore, leaving 50 &100 out, there were 49 pairs, each equal to 100 leaving 50 and 100 out. He gave the answer as 5050. Some of the attributes, which may lead to innovativeness and creativity, may be genetically inherited, but it does not mean that creativity cannot be learned and enhanced by training. Outright acceptance of Cook's hypothesis would diminish the contribution of that education and environment make to the formation of a creative mind.

In conclusion it may be said that previous research did neither identify all or most of the factors that influence innovativeness nor analyse such factors to find out how they influence innovators. Creativity was the only factor, which was studied in sufficient depth, but other factors were not given due attention.

2.5 THE INNOVATION PROCESS.

Ahmad & Abdullah [50] stated that in principle innovation consisted of 10% inspiration and 90% perspiration. This is a very crude notion of innovation therefore, it is subject to misinterpretation. For instance, no amount of perspiration could have produced innovative ideas that led to the manufacture of a revolutionary washing machine mentioned earlier without a very sound knowledge of both the ultrasonic and the electrolysis. However, there might some truth in this statement if 10% applies to the task of generating an innovative idea and 90% transforming that idea in a successful product. Deschamps and Nayak [58] remarked that innovation process could be achieved in three stages, fertilisation, seeding and incubation. Each stage consisted of a number of phases that required different kind of attention and involvement from management. The innovation process during the fertilisation stage attempted to create a concrete organisational vision. Ideas were collected and generated in the seeding stage, Wheelwright & Clark [57] described this stage as a *development funnel* by which a company collected ideas or generated new ones; screened, enriched, evaluated, validated and ranked them for future investment. In the incubation stage ideas were studied for technical and commercial viability and projects were prioritised for execution.

Eric A. Von Hippel examined the sources of innovative ideas in several industries, and found that, when the users were technically competent, they originated the bulk of the innovations. See table 2.2 below, Watts, Humphrey [33].

Twiss [5] saw the innovation process from his own perspective as shown in Fig. 2.1 below. He looked at the innovation process as a conversion process, which converted knowledge and materials (inputs) into innovations and products (output) to be sold to customers. His definition embraced all stages; form the idea to the product for the end user. However, in reality engineering products represent an assembly of many parts; some of these parts may embody innovations; each starting from an idea. Thus Twiss's model would be an over simplification of the innovation problems as practiced in the engineering industry.

Field Of Innovation	User	Manufacturer
Instrumentation:		
First of a type	100%	0%
Major improvements	82%	18%
Minor improvements	70%	30%
Process Equipment:		
First of a type	100%	0%
Major improvements	63%	21%, (others 16%)
Minor improvements	20%	29%, (others 51%)
Polymers:		
All major since 1955	0%	100%
Additives:		
All since 1945	0%	100%

Table 2.2 Sources of ideas / innovations

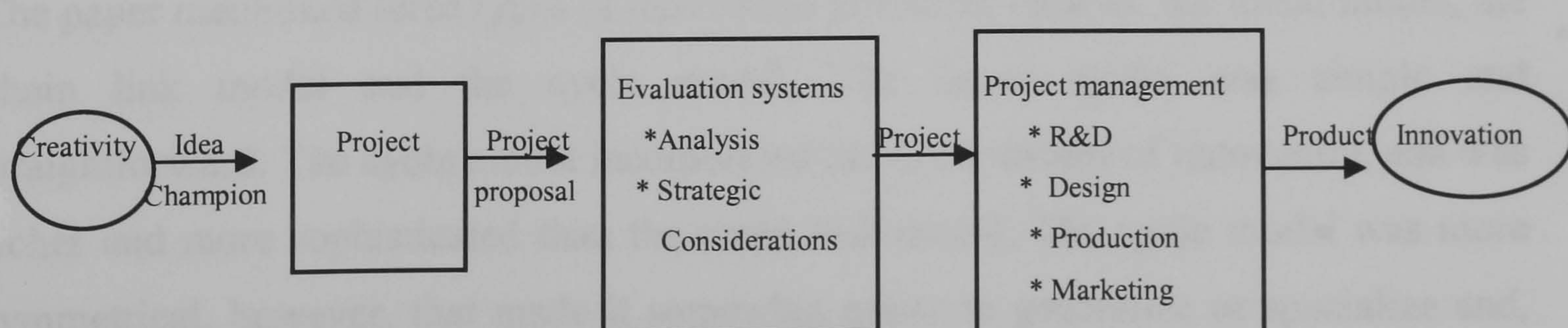


Fig. 2.1 The innovation / conversion process

Martin [37] suggested Bright's stages, which was an innovation process of eight stages as follows:

Stage 1. The innovation begins in one or two ways. One is by suggestion and/or discovery; another by the perception of an environmental, market or potential opportunity.

Stage 2. Proposed theory and design concept.

Stage 3. Verification of theory and design concept.

Stage 4. Laboratory demonstration of the applicability of the concept.

Stage 5. Alternative versions of the concept are evaluated and developed to be defined as a full-scale approach.

Stage 6. The commercial introduction or initial operational use of the innovation.

Stage 7. The widespread adoption of the innovation.

Stage 8. Proliferation.

Martin seems to have confused inventions with innovations. A bulk of innovations relates to well established and fully developed existing products in order to extend the life cycle of those products. Therefore, in most cases, the stages proposed by Martin would not be applicable.

Padmore, et. al., introduced several types of innovation processes. Their paper showed that innovation processes should have the following characteristics: flexible enough to be useful in understanding the structure of different sectors, in different places and times, simple enough to be useful for discussions among policy makers and their expert analysts and advisors and quantifiable for testing purposes and robust as well. The paper mentioned three types of innovation processes such as: the linear model, the chain link model and the cycle model. The linear model was simple and straightforward. The cycle model incorporated the linear model of innovation, and was richer and more sophisticated than the chain link model. The cycle model was more symmetrical, however, that made it somewhat easier to generalize or specialize and, just as important, more intelligible to policy makers.

Golder, [41] suggested an innovation process as shown in Fig. 2.2 below.

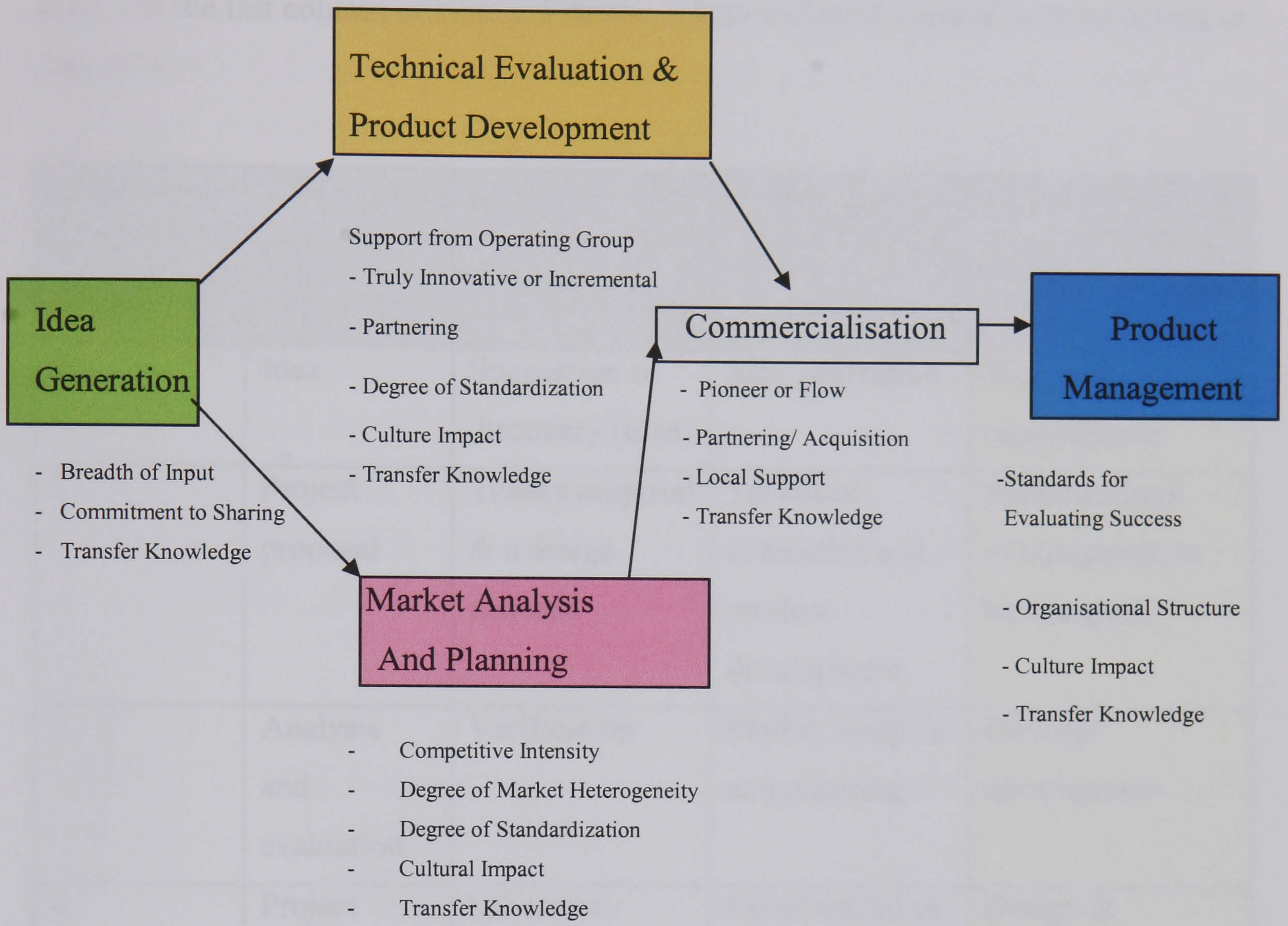


Fig. 2.2 The Golder innovation process

The innovation process is the heart of innovations. This process must happen fast enough to enable the customer to enjoy the benefits of that innovation (product) at an affordable price, while allowing the organisation responsible for the innovation to make a profit before the innovation becomes obsolete. The innovation process has to be logical, smooth, well integrated, and jointly produced by the R&D department and the production department. The process should have some feedback loops, for coordination, modification and verification. Table 2.2 below shows a comparison between the suggested innovation process and the processes introduced by Twiss [5], Martin [37], Golder [41]. They did not mention some intermediate stages and did not have feedback loops. All the innovation processes mentioned were workable but they were general and lacked several intermediate steps. In addition, they were not exactly relevant to innovations in engineering industries For Engineering industries the innovation process should start with the generation of an idea and should end with a product in the marketplace. The author would like to suggest an innovation process as shown in the last column of table 2.3 below, which will be discussed in more details in chapter 4.

Process / Stages	TWISS	MARTIN	Golder	Suggested
1	Idea	Suggestion or discovery (Idea)	Idea generation	Idea & user requirements
2	Project proposal	Theory proposal & a design concept	Technical evaluation and product development	Specifications of equipment to be designed
3	Analysis and evaluation	Verification	Market analysis and planning	Concept development
4	Project execution	Laboratory demonstration	Commercialisation	Design & simulation
5	Product	Alternative concepts	Product management	Prototyping
6		Commercial introduction		Testing and evaluation
7		Wide spread of innovation		Pre-production model
8		Proliferation		Production model

Table 2.3 Comparison between suggested innovation processes

2.6 APPROACHES TO MANAGING INNOVATIONS.

Roberts, R., [51] stated that since early 1980s the ability to manage innovation strategically had been presented as a fundamental feature of company planning by many innovation management theorists. Rothwell [52] emphasized that: placing innovation issues at the leading edge of corporate strategy was an indispensable task for top management. During the 1990s, managers ignore this message at their peril Rothwell [52]. Ohmae [53] & Porter [54] stressed the importance of attention to current international innovation management strategies. Ohmae in particular described prevalent strategies by which companies used management of technology to gain control of the customer, supplier and other firms. Studies like Foster's work on Japanese penetration of US information technology industries outlined how innovation management strategies were used successfully to gain advantage in the global markets, Foster [55].

Martinish [56] stated in his paper that economic growth depended on the successful commercialisation and management of innovations and the retention and reinvestment of profit from innovations. The ability to produce different kinds of innovations, commercialise them and manage various phases of innovations provided a sustained competitive advantage. Mature firms had the resources to fund research and product introduction, but often failed to capitalise on innovations because the fear of risks involved. Entrepreneurial firms were able to get an innovation to market, but often failed to develop the capabilities needed to compete in a mature product environment.

Innovations, according to Guil & Quinn [1] were reached by trial and error as a management technique. Twiss [5] believed that there was a managerial gap, which should be bridged if technology was to make a really effective contribution to the business. He stated that this was a gap of understanding, attitudes and motivations. To close the gap, he suggested that the businessperson must know more about the process of technological innovation, and the technologist should influence and be influenced by corporate considerations. Twiss discussed the process of technological innovation, the strategies for R&D, creativity and problem solving, project selection and evaluation, and R&D programme planning & control as an approach for the management of technological innovations.

Tidd et. al., [11] saw that the management of innovation was inherently difficult and risky, and indeed most of the new technologies failed to be translated into products and services. According to Rothwell [11], there were five generations of innovation models as shown in (Table 2.3):

Generation	Key Features
First	Simple linear model (linear sequence of functional activities).
Second	Technology pull model (market signals need for something new, which then drew through new solutions to the problem) & technology push model (new opportunities arising out of R&D gave rise to applications found their way to the marketplace).
Third	Coupling model (recognising interaction between different elements and feedback loops between them).
Fourth	Parallel model (integration within the firm, upstream with key suppliers and down stream with demanding and active customers, emphasis on linkages and alliances).
Fifth	System integration and extensive networking model (flexible and customized response, continuous innovation).

Table 2.3Generations of innovation models

Tidd et. al. also stated that the management of innovation was inherently interdisciplinary and multifunctional, and most management texts tended to emphasize a single dimension. They concluded that there were four components of the innovation process, which must be managed. These components were: taking a strategic approach to innovation and its management, developing and using effective implementation mechanisms and structures, developing and extending a supporting organisational context for innovation and building and maintaining effective external linkages.

Brunner, Gordon [10], found that innovation was all about making things that people wanted to buy, not about patents, or new technical developments. In addition, the R&D organisation needed to be constantly tuned to market shifts and needs, intimately involved with customers. This was the way to make the critical connection between what was needed and what was produced. In addition, the organisation needed to identify superior technologies, which were a mainline success. The paper also stated that the third important factor was an internal climate and culture that supported innovations, plus it was essential to have a Chief Executive Officer (CEO), who demanded innovation and participated personally in making the necessary choices and decisions. Talking from experience, the paper mentioned three fundamental factors to the success of innovations. These factors were: staying close to your customers, identifying superior technology, which was the mainline for success, and creating a supportive environment for innovation. This paper had addressed some of the main factors related to the management of the innovative environment but some of the ideas presented were controversial.

It should be clear that Roberts, Rothwell, Ohmae and Forester concentrated on the importance of innovations and their management, but did not discuss the problems related to the management of innovations in itself. Martinich emphasised specially the commercialisation of innovations and the management of innovations without getting into the details of both issues. Twiss focussed on the process of technological innovations ignoring other principal components such as the innovative environment and the innovators. Tidd et. al., Brunner & Gordon described an approach to the management of innovations without giving any details of how to achieve it. The author of this thesis concludes that the previous work reviewed took a general and superficial look on the management of innovations and did not discuss its principal components such as the innovative environment, the innovators and the innovation process in sufficient depth. Neither were the correlation between these components considered or established.

2.7 MODELLING INNOVATIONS.

Lal, et. al., [59] proposed a framework, which could take into account the effect of time lag between the knowledge of an innovation and its actual adoption. This delay feature had been captured in the models by employing a distributed time lag approach in which the contributions of time delay were expressed as a weighted response over a finite interval of past time through appropriately chosen memory kernels. This suggested framework looked at the time taken from the proposal of an idea till its actual implementation, but it was a kind of general knowledge that two out of ten ideas got the chance to be implemented and the adoption and implementation depended on several factors such as: their technical and commercial viability, feasibility, importance to the organisation and other factors.

Windrum, Paul [39] stated that, the use of modelling and simulation techniques in studies of technological innovation goes back to the Nelson and Winter's book written in 1982. In addition, he stated that a key driver in construction of computer simulations had been the desire to develop theoretical models capable of dealing with complex phenomena characteristics of technological innovation. The article mentioned that no single model captured all of the dimensions of innovation.

Tan, Christensen [2] defined the concept of product innovation and presented a conceptual model that could be used for evaluating innovation and for setting goals for innovation processes. Several views on product innovation were presented. Furthermore, a working language was developed that defined the terms innovation, innovating and innovative. The evaluation model for product innovation was conceptual based only on theoretical studies and on interviews with companies. Therefore, it was meant only to be a tool to obtain a better understanding of what product innovation was; it did not provide suitable evaluation of the innovation. Their thesis did not discuss the management of innovations or how to control innovations; it also did not discuss elements related to the innovative environment in any detail.

Repenning [3] synthesized a model that described the process through which participants in an organisation-developed commitment to using a newly adopted innovation. He then translated that framework into a formal model and analysed it using computer simulation. The analysis suggested three new aspects - reversion, regeneration and the motivation threshold characterizing the dynamics of implementation. He then stated that these aspects together provided an internally consistent theory of how seemingly rational decision rules could create the apparent paradox of innovations that generated early results but failed to produce sustained benefit. Repenning concluded that the failure of innovations could be attributed to an inappropriate implementation. Therefore, he concentrated in his paper, on analysing and modelling the implementation phase of the innovation.

Tan & Christensen presented a conceptual model to evaluate innovations and to set goals for the innovation process. Repenning synthesized a model, and then translated it to a formal model. Lal, et. al., proposed a framework, which considered the effect of time lag between the knowledge of an innovation and its actual adoption. Previous researchers did not succeed in developing a model capable of analysing the innovative environment, the innovators and the innovation process in an engineering company in order to use it as a tool for the management of innovations. The author of this thesis did not come across any computer model capable of conducting risk analysis for innovative engineering projects in order to identify the sources of risk and evaluate such risks with a view to preparing a risk response and exercise risk management.

2.8 SUMMARY OF MAIN OBSERVATIONS.

Most of the papers that have been reviewed did not make a distinction between innovations and inventions. Furthermore, they were very general and did consider the specific problems of managing innovations in engineering industries.

In chapter 1, it was suggested that innovations in engineering industries consisted of three principal components, namely: the innovative environment, the innovation process and the innovators. Managing innovations would require the management of these components. Earlier researchers did not appear to have identified these components and their sub-components. In addition, the influence of the main and sub-components on the success of innovations had not been analysed.

The research papers that have been reviewed did not show any evidence of the use of computers to deal with the multidimensional problems of managing innovations efficiently or analysing risks involved in their implementation. Nevertheless, the work of Amabile [15] was significant as it showed a methodology for carrying out research based on questionnaire type surveys.

In view of the aforementioned observations of earlier studies, it was felt that the research reported in this thesis was timely; moreover its aims as outlined in chapter 1 would be well justified.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 INTRODUCTION.

In chapter 1 the concept of innovation and their importance for engineering industries was discussed. As a consequence of continuing advances in all branches of science and technology, inventions in engineering industries, are becoming increasingly difficult to conceive, but in contrast, innovations are the lifeline of engineering industries. This is because the purpose of innovations is to extend the lifecycle of engineer products thereby spreading the heavy cost of tooling over a number of years. Innovations must have clearly defined aims such as improving performance, simplifying manufacturing processes, using alternative materials without impairing structural integrity, reducing costs, improving reliability or aesthetic appeal, to name just a few. They must be well managed and controlled in order to achieve the desired results with due regard for the time and the budgetary constraints.

Well-targeted and continuous research is needed to achieve these objectives. The role of management is: (a) to have a policy for on going applied research; (b) to create an environment that is conducive to a regular flow of innovative ideas; (c) to guide innovators to focus their innovative talent towards areas of interest or relevance to their company's business; and (d) to minimise the risks involved in adopting innovations by the application of reliable risk analysis techniques.

The literature review presented in the previous chapter has shown that, despite its importance, the management of innovations in engineering industries has not been given the attention that it deserves. Consequently there is a scarcity of published research papers that deal with managing all aspects innovations, particularly in engineering industries. Papers which have been cited in the published literature seem to have concentrated on general aspects of management and have not addressed the more specific issues such as methods for creating an innovative environment, problem-solving related to the innovative processes and encouraging the designers and the development engineers to steer their intellectual talents to creating a regular flow of innovative ideas. The minimisation of risks involved in adopting innovative ideas with the help of analytical techniques for risk analysis also does not appeared to have been covered adequately.

It should be noted that innovators are often over enthusiastic about their innovative ideas; consequently they cannot see flaws in their own innovations. Hence, giving the innovators the responsibility for converting their own ideas into products, processes or services may not produce satisfactory results. A great deal of tact and care is needed when handing over the task of implementing innovative ideas to a competent development team without causing an adverse effect on either the innovators or the innovative environment.

Managing innovations in engineering industries is a complex, multidisciplinary, and multifunctional task. To study this field in a meaningful manner will require a clear and scientific method. The purpose of this chapter is to propose a scientific method for carrying out this study to meet the research aims and also to ensure that management derives maximum benefit from the latest developments related to this important field.

3.2 RESEARCH METHOD.

Before deciding on the methodology to be used for carrying out this research, it would be pertinent to consider briefly different characteristics of research. There are three quite distinct but interrelated characteristic of quality research which distinguish this activity from others such as intelligence gathering, data collection, decision making and so on, which are often erroneously regarded as research.

Research has traditionally been classified into two types: fundamental, sometimes called pure research and applied research. This distinction should not be understood to imply that pure research supplies the theories, often with the help of simplifying assumptions, and applied research uses and tests those theories out in the real world. These definitions are too rigid to characterise what really happens in most disciplines, where, for example, applicable research may generate its own theories and may not just use theories developed from pure research. In view of these limitation of the classical definitions, the following threefold classification would perhaps be more appropriate:

(1) Exploratory Research;

(2) Testing-out Research;
(3) Problem Solving Research.

The distinctive nature of these three categories is described briefly in the following section:

Exploratory Research. This type of research would be involved in tackling a new topic, issue or a problem about which little is known. Therefore the research idea cannot be formulated at the beginning into a hypothesis. The problem may come from any part of a single discipline or it may be multi disciplinary. It may be a theoretical research puzzle or it may have empirical basis. The researcher will need to examine what theories or concepts might be appropriate, develop new ones if necessary, and study if the existing methodologies cane be used for tackling this problem. Complex real life problems cannot be tackled without properly formulated methodologies.

Testing-out Research. In this type of research it is necessary to find the limits of generalisations proposed previously by other researchers. This is a basic research activity which aims at testing the applicability of the generalisations to different situations than those from which those generalisations were originally developed. Usually the amount of testing to be done is large and continuous, because only by testing we are able to improve, by specifying, and clarifying, the important but often intricate generalisations, which form the basis for the development of all scientific disciplines.

Problem-solving Research. This type of research starts from a particular real-life problem, and brings the available intellectual resources together to bear on the solution. The problem must be defined in order to discover a correct method that can provide a solution. The researcher may have to create and identify original solution to the problem, often every step of the way. This usually involves a variety of theories and methodologies, often stretching across more than one discipline. This is because real-life problems are often messy and not amenable to solution within the narrow confines of a single academic discipline.

The problems of managing innovations in engineering industries are complex, but it should be noted right from the outset that research methods used for tackling these problems do not need to be specific only to engineering industries. Research methods that have been developed for other fields of study might be adopted to suit the needs of the engineering industries and applied successfully to manage innovations.

Industrial research is often understood to be concerned with problem solving. However, it should be noted that research is not simply limited to finding solutions to difficult problems; its scope extends far beyond the boundaries of problem solving as discussed earlier. It describes systematic procedures, collectively known as *research methodology,* for scientific investigations. These procedures may be divided into several steps as follows:

The first step is to understand clearly the background of the proposed research and to develop the wider socio-economic, scientific or technological justification for pursuing the proposed research. This study is necessary to identify and define the research problem. A precise problem definition is a prerequisite for tackling that problem.

The second step is to carry out a critical review of the relevant literature. The purpose of the literature study is to determine:

(a) Whether the problem has been studied previously and to assess the strengths and the weaknesses of that study;

(b) To ascertain the main conclusions drawn from the previous work and to assess their relevance to the proposed plan of work.

(c) A critical examination of the evidence on which the conclusions were based.

(d) Any shortcomings of the previous work that might invalidate either some or all of the conclusions.

(e) Any pitfalls in previous work that might be avoided in the proposed plan of work.

The critical review of the previous work is followed by a summary of the main observations. The aims of the proposed research programme must then be justified clearly in full view of these observations.

The third step is to identify those factors that influence both the problem and its solution, and then to analyse those factors to highlight the manner in which they influence the management of innovations. This is an important step for preparing the groundwork for finding a balanced solution to the problem.

The fourth step is to propose a solution for the problem. The problems of managing innovations may be seen from two distinctly different points of view as described below:

(i) Managing innovations in respect of products (i.e. novelty of design, use of novel materials, new manufacturing processes etc.) in order to shorten lead time while still working within the time and budgetary constraints.

(ii) Managing companies to be innovative in order to have a regular flow of ideas and to maintain a position ahead of the competition. This is necessary for engineering companies to win and to hold on to their share of the market in highly competitive markets.

The research reported in this thesis dealt with the second category and concentrated on developing tools to aid management in assessing the performance of their companies with respect to innovation. Hence, a set of two Computer Aided Management (*CAM*) analysis techniques was developed: (i) to assess engineering organisations for their innovativeness; and (ii) to evaluate the risk embedded in adopting and implementing an innovative concept. These must be validated by means of a number of case studies in order to ensure their general applicability. The first technique is based on a questionnaire. Every precaution has been taken in designing the questionnaire to ensure that it does not produce biased results. Furthermore, the results of case studies produced by the questionnaire must be tested against the results obtained by alternative and more reliable means. Four actual engineering companies/organisations were taken from different part of the world, with different management strategies to check the reliability of the questionnaire.

The fifth step is to record the results obtained from the case studies in order to discuss them and to draw conclusions. This step is of great importance since it is the final step of the research and it should provide a clear answer for the problems identified in chapter 1, and also it should point out the areas where future research might be conducted.

The author expected to encounter the following problems in the course of the research reported in this thesis:

(i). Lack of relevant research papers. There has been a scarcity in published research papers in the field of managing innovations in engineering industries. Papers which have been cited by and large deal with the general aspects of management and do not address the more specific issues such as methods for creating an innovative environment, problem-solving in the management of innovators, ensuring that 'innovative thought' is harnessed and steered towards the interests of the company and finally minimising the risk involved with the help of a number of analytical techniques. This problem will be overcome by relying on the practical experience and expertise of several active industrialists and on the outcome of some actual case studies.

(ii). Dealing with intangible factors such as encouragement, motivation, and leadership, which cannot be quantified in the usual sense. This problem will be solved by selecting and using a well understood factor and out of these as a unit factor, based on experience and consultations with several experts in industry and its management. The author hopes to assess the rest of the identifiable factors in terms of units relevant to the selected unit factor and use these values for computational purposes.

(iii). Validating the computer analysis techniques developed during the course of this research. Usually validation can be achieved by comparing the results obtained from more than one verification method. This was not the case in the research reported in this thesis because such verification methods were not available.

Therefore, the responses to the questionnaires were validated by comparing the results obtained from the case studies with results gathered by direct observations and from personal knowledge of the recent performance of the selected companies and/or projects.

The sequence of steps that was followed to carry out this research is shown in the diagrammatically in Fig, 3.1.

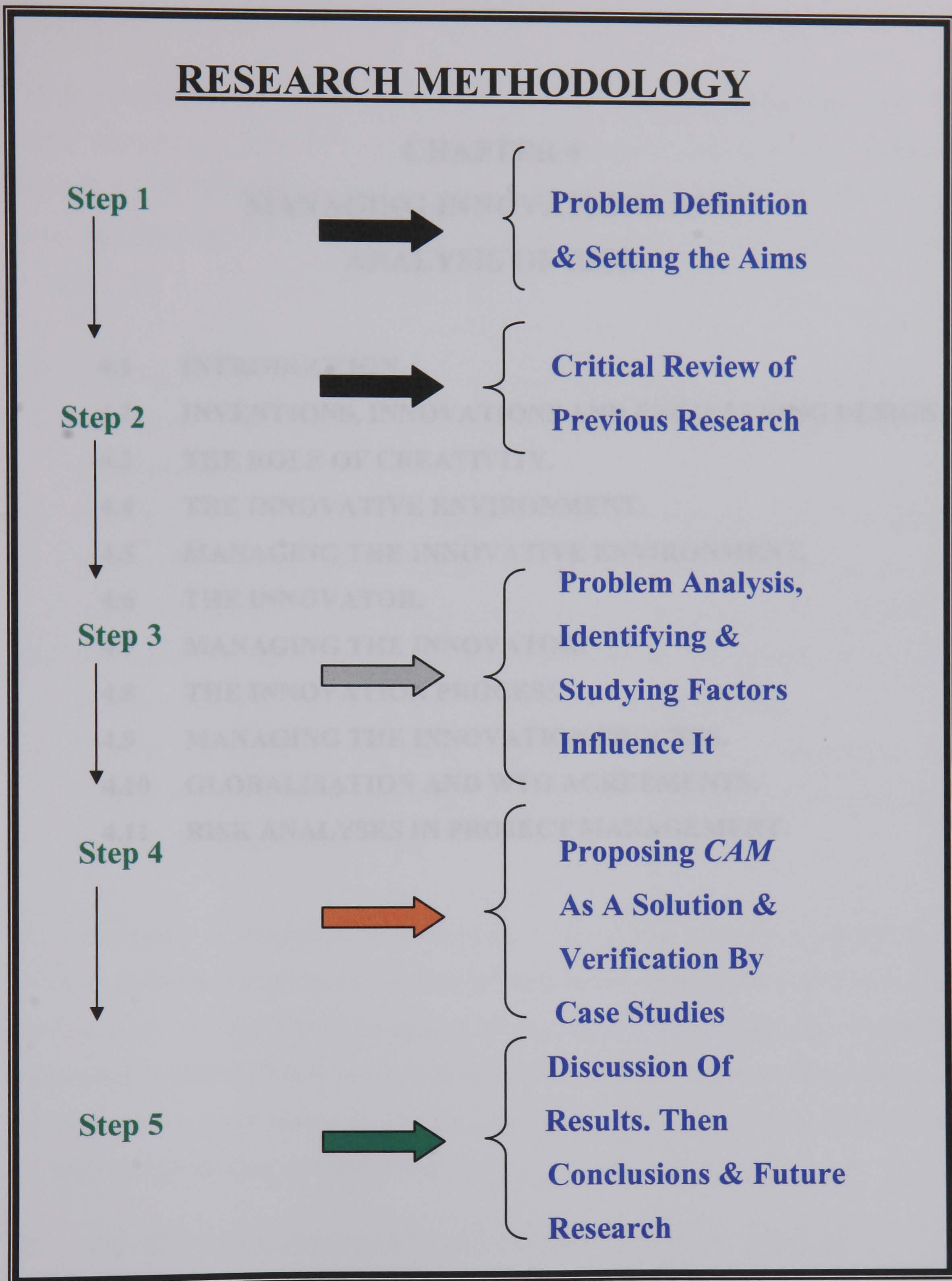


Fig. 3.1 Research methodology

CHAPTER 4

MANAGING INNOVATIONS AND ANALYSIS OF RISK

4.1 INTRODUCTION.

4.2 INVENTIONS, INNOVATIONS AND ENGINEERING DESIGN.

4.3 THE ROLE OF CREATIVITY.

4.4 THE INNOVATIVE ENVIRONMENT.

4.5 MANAGING THE INNOVATIVE ENVIRONMENT.

4.6 THE INNOVATOR.

4.7 MANAGING THE INNOVATOR.

4.8 THE INNOVATION PROCESS.

4.9 MANAGING THE INNOVATION PROCESS.

4.10 GLOBALISATION AND WTO AGREEMENTS.

4.11 RISK ANALYSES IN PROJECT MANAGEMENT.

4.1 INTRODUCTION

The general scenario of managing innovation was presented in previous chapters. The task of managing is complex because of its multidisciplinary nature and very important because of its significance for the engineering industries. In order to deal with this task systematically, the management task may be divided into the following four components:

(i). Creating and maintaining proper environment to ensure a continuous flow of innovative ideas relevant to the fields of interest of the employing engineering organisation;

(ii). Inspiring and leading staff, particularly in research and design areas, to develop a proper understanding of the designs of products, scope of innovations that would enhance the lifecycle of those products and target areas for innovations;

(iii). Managing the details of the processes involved in the acceptance and the implementation of innovative ideas or innovative design concepts;

(iv). Critical evaluation of the risks surrounding a particular innovation and formulating plans for minimising the impact of those risks on its success in meeting the declared objectives.

The importance of *inventions* and *innovations* in general terms was discussed in previous chapters. However, in the field of engineering these terms and *design* have specific meaning; they should be defined more precisely and in accordance with the engineering practice. Therefore, precise definitions of these terms for the purpose of this research are given below. In addition, the role of creativity has been identified as the source of generating innovative ideas.

4.2 INVENTIONS, INNOVATIONS AND ENGINEERING DESIGN.

Inventions represent tangible new products, contrivances, devices or new processes. Because of rapid growth of scientific and technological knowledge, it is becoming increasingly difficult to come up with entirely new ideas, which may lead to either new products, or to the introduction of new processes; consequently inventions tend to be rare. Examples of some important inventions in different areas are rotary fuel pump for diesel engines, the fuel cell for direct conversion of fuel to electricity, golf ball and daisywheel type print heads for electrical typewriters, etc.

The purpose of innovations, on the other hand, is to introduce improvements in either the designs of usually existing products or in current industrial processes; often because of continuous development. The purpose of innovations is to prolong the marketability of products and enhance competitiveness by reducing production costs using either economical manufacturing materials, without impairing the structural integrity of products, or through improved manufacturing processes. Hence, innovations are the lifeline of engineering industries and maintaining a continuous flow of technically and commercially viable innovations is of paramount importance for ensuring a sustainable growth rate of manufacturing companies.

Engineering design is very simply the process of converting both the inventive and innovative ideas into designs of products that can be manufactured economically as well as conveniently and sold at a handsome profit. Hence, engineering design is fundamental to, not an alternative of, inventions and innovations. The market success of engineering products depends on the excellence of engineering design. It should be remembered that engineering design is not limited only to drafting; the checklist of the complete process of good engineering design consists of at least eight steps as listed below:

(1) Understanding or perceiving customer's need, defining the design objectives and preparing design specifications;
(2) Preparing conceptual designs (this is the ideas stage);
(3) Defining the criteria for selecting a concept;
(4) Analytical design (designing to meet customer specifications);
(5) Structural design (to ensure structural integrity);
(6) Machine design (preparing General Arrangement drawing and component drawings.
(7) Design value analysis (to meet budgetary targets);

(8) Design for manufacture (to ensure that the design is appropriate to the available skills, manufacturing machines and materials).

Referring again to innovations it should be noted that as the list of products produced by using engineering principles and manufacturing processes is very large, for economic reasons engineering companies tend to specialize in producing carefully selected products or product lines. For example, a company, which specialises in manufacturing automobiles, will stand clear of producing white goods such as refrigerators, freezers, washing machines, etc. Large corporations often manufacture a wide range of products such as machine tools, ships, motor cars, computers, white goods, etc. However, different product lines would invariably be manufactured in different companies; all being parts of a single multinational corporation.

In view of this scenario, engineering companies prefer to concentrate their resources on only those innovations, which can contribute to the development of new models of their existing products, in some cases annually, within their chosen product lines. It is very important for the survival of companies to manage innovations to be relevant to their own interests. However, the need for this type of selectivity must be explained properly to innovators otherwise they would feel offended and could get disheartened.

There are three basic principles, from the management point of view, which must be followed:

(i). To create and maintain an environment that is conducive to innovations.

(ii). To ensure the relevance of innovations and to assess their technical and economic viability before accepting them.

(iii). To plan the implementations of selected innovations while maintaining high level of encouragement and at the same time adhering to the stringent time and money constraints.

In order to follow these principles, it is necessary to understand all aspects of innovations, i.e. their origin, role of creativity in fostering innovations, the type of environment that is necessary to stimulates creative thinking, etc.

Innovations pass through three main phases, the formation phase (the birth and evaluation of the idea), the implementation phase (from design to prototypes and to production) and the marketing phase. The failure of innovations may be due to either any one phase or collectively all three phases. This study concentrated only on all aspects of the first two phases.

4.2.1 Scope for Innovation. Innovative ideas may be applied in all departments of the organisation such as research, design, production, marketing and maintenance and at all stages. There are at least seven areas of innovations: (i) product innovation; (ii) process innovation; (iii) organisational innovation; (iv) management innovation; (v) production innovation; (vi) commercial and marketing innovation; (vii) service innovation.

There are also three types of innovations in terms of continuity and discontinuity:

(i). Radical, discontinuous, breakthrough, disruptive or revolutionary innovation: This refers to radically new products that involve dramatic leaps in terms of customer familiarity and use. Frequently these types of products involve the development and application of significant new technologies. Aeroplanes, automobiles, personal computers, and televisions were all discontinuous innovations when they were first introduced. Veryzer [42]. Doughery & Hardy [62] and Nadler & Tushman [63] stressed the importance of management support to discontinuous innovations.

    As stated earlier, here again these researchers have confused innovations with inventions. However, these products have experienced continuous and remarkably fast changes to improve their performance and reduce manufacturing costs through innovations.

(ii). Incremental, continuous or evolutionary innovation: This kind of innovation focuses on product improvements, upgrades, and life extensions Veryzer [42].

(iii). Continuum and a combination of incremental and radical innovation: This is a leap process followed by subsequent incremental steps. Tushman and Nelson, [44]. However, the argument has been made that only through a balanced portfolio approach to innovation, i.e. by pursuing both incremental and discontinuous projects, can a firm continue to prosper in the long term Morone, [60] and Tushman et al., [61]. While incremental innovation can maintain a company's lead in the short term, it is the projects at the discontinuous end of the spectrum that put firms in the lead in the first place.

The differences between the first two types of innovations are shown in Table 4.1:

Radical/ Discontinuous/ Breakthrough/ Disruptive/ Revolutionary innovation	Incremental/ Continuous/ Evolutionary innovation
Based on new technologies and aimed at a market that is unfamiliar with the product	Based on small contribution to existing technologies aimed at a market that is familiar with the product.
High degree of technological and market uncertainty	Lower degree of technological and market uncertainty
Intensive technology development	Less technology development
Advanced technological capability	Ordinary technological capability
Really new product	Improved existing product
High risk	Lower risk
Less time involved	More time involved
More expected profit	Less expected profit
More creativity	Less creativity
More managerial skills are required	Less managerial skills are required
More constraints	Less constraints
More challenges	Less challenges
More technology push	More technology pull

Table 4.1 The differences between radical and incremental innovations

The references quoted above and some of the references cited in the literature review, Chapter 2, argue on the definitions of innovations and their importance; definitions are general and not specifically for engineering industries, Moreover, the more important issue of the objectives of innovations do not appear to have been given much attention. In view of the fact that in industry a large majority of innovations are directed towards prolonging the life cycle of existing products, the main objectives of innovations may be stated as follows:

(i) To lower cost and achieve higher profitability by using alternative materials and simplifying the manufacturing process.

(ii) To improve the quality in terms of reliability, durability, performance and maintainability.

(iii) To improve competitiveness and protect market share.

(iv) To comply with legislation.

(v) To attract and retain higher calibre staff or to retain staff by offering interesting and challenging work.

(vi) To attract alliance partners through good reputation of the company for being innovative.

4.2.2 The Innovative Organisation. Successful organisations pay considerable attention to both internal and external sources of ideas that may be conducive to innovations, and they are responsive to market needs. Organisations have to achieve a certain level of innovativeness in order to stay competitive in a global marketplace. The innovative ideas may relate to products, processes, management or general administration. The integration of these components is necessary to achieve a high degree of overall innovativeness.

(i). ***Product Innovation***. Innovative organisations strive constantly to improve their existing products or provide new products. Many questions such as: how to provide new product, how can the product be made more cost effective, easier to produce, better in quality, easier to use, more reliable, more durable, easier to maintain etc. should always be asked. It is not always the case that innovation implies introducing a new line of products; as there will always be a scope to build new features in existing products such as by using different scientific principles. A very good example of this was the washing machine mentioned earlier which used ultrasonic technique instead of a detergent to clean clothes and electrolysis to clean used water for re-cycling.

(ii). ***Process Innovation***. Processes are also subject to continuous improvements to make them more efficient, easier to use, faster, less expensive, more accurate and yield higher productivity. The introduction of new materials, the development of new technologies and the use of new manufacturing machines lead to new and advanced processes. Hence, it is very important for manufacturing companies to stay focused on improving their processes. A very good example is the replacement of the classical chassis in modern motor cars by a thick single sheet metal stamping which was a remarkable process innovation for labour saving and cost cutting.

(iii). ***Management or Administrative Innovation***. Innovative products and innovative processes require innovative administrative system and management in order to turn innovative ideas into successful products or processes. Innovative ideas related to administration should lead to an administrative atmosphere that is efficient, less bureaucratic, transparent, creative, challenging, more stimulating for innovations, and more adaptable. Innovative organisations should endeavour persistently to improve their administrative system in order to lay the grounds for innovative processes and products to flow smoothly. It is the role of management to remove administration obstacles and clear the way for innovations. It is very important to be sure that innovations are free of any likely infringement of existing patents and provide patent protection whenever it is necessary.

The needs of each category of innovation are different, therefore to prescribe a unique approach for either achieving or encouraging innovations would be difficult but some general steps, which may help to achieve a high level of innovativeness, are listed in the following section

(i). Create a corporate-wide innovative culture.

(ii). Restructure the organisation to create a separate innovations department or function, e.g. Department of Unconventional Engines at VW of Germany.

(iii). Motivate key personnel for the success of the innovative function, and provide incentives for creative individuals.

(iv). Look for knowledge gaps and identify core skills.

(v). Recruit highly innovative individuals and provide them with the necessary support.

(vi). Develop managers' creativity and innovative skills.

(vii). Provide high priority to product and process innovation activities.

(viii). Borrow, buy and adopt new ideas.

(ix). Develop and maintain internal innovation programmes.

(x). Entwine the innovative function with innovative corporation.

(xi). Maintain an effective ideas management.

(xii). Take control of the innovation process.

4.2.3 Integration between Principal Components of the Innovation Process.

Managing complex innovations requires a staggering amount of integration between the principal components of the innovation process stretching from the ideas stage to high quality products, which can be offered to the market at competitive prices for the end user. Maim components of the innovative process are given below and are shown diagrammatically in Fig. 4.1:

(i) Creating and maintaining the innovative environment;

(ii) Inspiring and encouraging staff to be innovative;

(iii) Ensuring that innovations would be technically and commercially successful;

(iv) Taking necessary step and making provisions for marketing innovation. This component was considered to be outside the scope of the declared aims for this research.

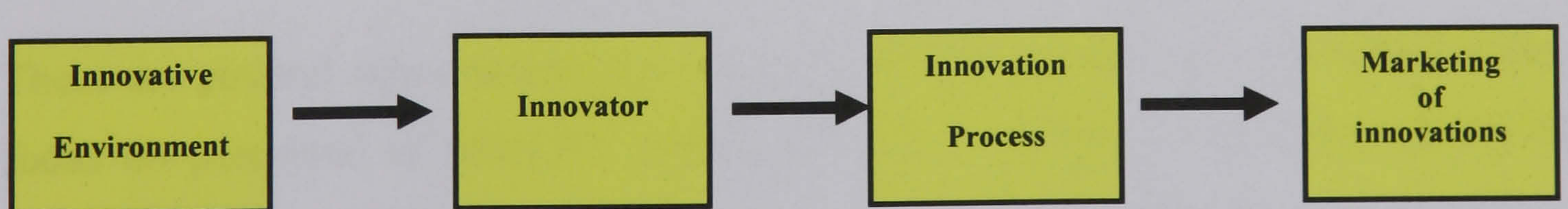


Fig. 4.1 The principal components of management of innovations

Tidd et al. [11] (p.48) have touched on organisations' need to integrate simple functions such as planning, managing projects and understanding customer needs with broader abilities behaviour, work ethics, commitment, etc. which can be taken together to make up an organisation's core activities for managing innovations. These core activities are listed below:

(a) Searching for ideas to initiate innovations.
(b) Making sure that, the new ideas are in harmony with organisational objectives.
(c) Acquiring technologies to support the new ideas or innovations through internal efforts such as Research & Design or external linkages involving subcontractors, networks, strategic alliance, consortia, joint ventures, licensing, universities and external R&D organisations.
(d) Executing the development process of the project from idea to product.
(e) Introduction of changes to the organisation, as reflected by the innovation.
(f) Evaluation of the innovation process for improvements reflected by the innovation.
(g) Developing the management and organisation structure to reflect lessons learnt.

4.2.4 Factors Influencing the Success of Innovations. In general, successful innovations would be based on the systematic analysis of sources of new opportunities, proper assessment of what may go wrong and a critical evaluation of the ensuing risks. In addition, innovations must be kept well focused on the expected benefits and they must stay within the time and budgetary constraints.

There are several other factors that contribute to the success of innovations such as: focus on perceived or predicted customers' needs, collecting and, when appropriate, sharing market intelligence, relevance to organisation's objectives, receptivity to innovations and constant lookout for sources of innovative ideas, absolute commitment from both the innovators and the management, rapid implementation of innovations, maintenance of healthy innovative environment, willingness to apply new technologies, effective programme selection procedures, developing partnerships and alliances, charismatic programme management coupled with leadership and guidance, the corporate desire to move the organisation forward and confidentiality of all aspects of the innovation to protect good lead time thus avoid early competition.

4.2.5 Guidelines for the Management of Innovations. Most of what happens in successful innovations is not the flash of genius or the happy coincidence; it is the result of systematic and persistent efforts of a well-disciplined management team. This team knows where and how to look for innovations and follow them through to successful implementation. It is not enough to have a great idea; for innovative ideas to pay off there must be a strategy that would bring the ideas to the market ahead of the competition. Innovation success is based on a combination of technological, marketing and organisational competences plus a good timing and an overall policy. There are several actions, including those due to Guile & Quinn [1], which may be taken to manage innovations successfully; they are:

(i) Developing a clear vision of the technological need.

(ii) Maintaining a close interactive relationship between innovators and marketing staff who can provide industrial intelligence based on their close contacts with end users or customers.

(iii) Designing for superior quality and better performance and higher productivity.

(iv) Utilizing multiple approaches, or parallel development, to improve the quality of technological solutions, team motivation, and the probability of ultimate success.

(v) Keeping innovative teams small, of flat management structure and open to new ideas with a supportive innovative environment.

(vi) Developing a high degree of internal technical expertise, to participate in and evaluate potential solutions.

(vii) Creating strong external linkages, to both domestic and foreign sources such as professional institutions, research laboratories and universities for relevant technological expertise.

(viii) Empowering champions, or championing teams, to drive the innovation process.

(ix) Maintaining continuity, balance, and enthusiasm of the team of innovators.

(x) Providing a patient and long-term support that technological innovations require.

4.2.6 Innovation and Globalisation. In the current international political and commercial environment, organisations are competing against each other globally with following implications:

(a) The whole globe is the marketplace, and organisations must fulfil market needs but it is very difficult to understand market needs because the specifications, quality and the pricing structure of the product is usually different for different countries across the globe.

(b) The ability to compete globally is essential for survival and growth but the competition is not always fair.

(c) Radical and incremental innovation is also an essential requirement.

(d) To be successful, it is necessary for an organisation to be sensitive to market and technological trends, be responsive to opportunities and threats worldwide, and be able to exploit new ideas and products efficiently across the globe.

(e) Because of the exponential growth of transport and communication systems, chances of acquiring technologies appear to have increased tremendously, however, it should be remembered that new technologies are invariably confidential; they cannot be transferred; they must by acquired through concerted effort and self reliance.

In view of the present global scenario, it should be obvious that innovations have to be well managed in order to allow organisations to survive and grow in the face of intense competition. Technological superiority is the key to the success of engineering innovations.

4.3 THE ROLE OF CREATIVITY.

The traditional view of creativity is that it is product of subconscious processes with the solution suddenly coming to mind when the problem solver least expects it, Austin [9]. According to Wallas, there are four stages of the creative thinking:

(i). Preparation. This stage involves active work on the problem, such as determining facts and finding out what is already known.

(ii). Incubation. This stage does not involve active work on the problem, as if it is a period being used to solve the problem at a level beyond conscious awareness.

(iii). Illumination. This is the stage when the idea suggests itself unexpectedly.

(iv). Verification. A stage involves a deliberate attempt to elaborate and confirm a solution.

Current views of creative thinking are that it involves only two stages rather than four as suggested by Wallas. Those two stages are:

(i) Generation and selection of creative ideas;

(ii) Discovery and verification.

Creativity is also defined as the generation of a new idea, or a new way of doing things. The creative person is one who generates such new ideas, while the creative process is how these new ideas, solutions, and inventions are produced. Twiss [5].

Ideas appear spontaneously; they are not subject to planning. Since successful innovations originate from creative ideas, it is important that organisations receive creative ideas with an open mind. Creative solutions should be encouraged within on-going projects, and release the creative potential of staff by maintaining a receptive climate for creative ideas.

There appears to be no simple recipes for building a creative organisation, but it may be possible to identify some of its ingredients, for example, the organisational creativity is a combination of creative process, creative product, creative individuals and creative situations, Woodman et al. [30].

Several factors may help to enhance creativity and problem solving ability such as:

(i). Personal characteristics including self-motivation, special cognitive abilities, risk orientation, diverse experience, expertise in the area of interest, social skills, brilliance, naiveté, personal commitment, personal objectives and technological awareness.

(ii). Social environment factors such as freedom, good project management, sufficient resources, need for encouragement, pressure, recognition, sufficient time, challenge and special organisational characteristics.

(iii). Group characteristics for example leadership, cohesiveness, group longevity, group composition, group structure (organic or not), and communication patterns.

Another important issue is the "group creativity", which is not the sum of the creativity of individuals within the group. Instead, creative behaviour is mediated through the group and it is influenced by the composition of the group, characteristics and processes, as well as the context of the larger organisation. Rickards, [28].

The notion of creativity that it is product of subconscious processes with the solution suddenly coming to mind when the problem solver least expects it, Austin [9], may be true in some other fields such as fine arts, philosophical studies and literature (poetry & drama) but engineering and other applied sciences could not advance or even survive by following this notion. In support of this view, it would be pertinent to refer to the following two examples. During the early part of the Second World War, the British Royal Air Force did not have a fighter aircraft that could outperform the aircraft of the German Air Force. Spitfire was designed, tested, manufactured in great number and flew very successfully to meet the challenge. The aircraft was an embodiment of several creative ideas but the designer of Spitfire could not just sit around and wait for creativity to come in its own time; the war was on and he had to respond to a pressing need. The second example was that of landing on the Moon. Late President John F Kennedy publicly announced a date when an American astronaut would land on the moon. NASA's scientists and engineers accepted the challenge and made the vision of their President a reality. Again, this project had many problems for which creative solutions were needed. Creativity could not just be left to chance; it had to be made available at command. Applied scientists, in particular engineers, have to be creative at will when they are under pressure to meet certain targets.

In conclusion, for managing and influencing the organisational creativity positively, management has to (a) select suitable employees, who have demonstrable creative ability and other personal characteristics such as adequate technological competence, self-motivation, self-reliance, commitment, etc. and (b) their personal objectives are in line with the organisational objectives. Other factors, which may enhance or inhibit creativity, are exhibited freedom, good project management, sufficient resources, need for encouragement, organisational characteristics, recognition, sufficient time challenge, etc. They depend on the organisation and should not be left to chance; instead, they should be planned and managed properly.

4.4 THE INNOVATIVE ENVIRONMENT.

Progressive organisations would make a special effort to provide innovation intense environment, IIE for short, Roberts [45], to enable innovators to maintain a regular flow of innovative ideas. In order to increase their share of the market innovative organisations strive to increase the rate of innovation. This in turn leads to the proliferation of new high technology industries. However, it is paramount for innovative organisations to stay focused on the following activities:

(i) Clearly defining a strategic focus to channel innovative efforts in such a manner that they will pay off in global markets.
(ii) Collaboration. Because innovation, particularly in engineering industries, is a group process creating and sustaining a corporate environment is essential.
(iii) Structuring the organisation to ensure innovative ideas to rise and flourish.
(iv) Creativity and going after good ideas without bureaucratic delays.
(v) Leadership. Since leaders can envision a bright future, they can identify opportunities that can pave the path to success.
(vi) Culture, (the playing field).
(vii) Communication. Open communication of information, ideas and feelings is the blood of innovation.

In order to succeed in being innovative all organisations need to have two systems, one to run the day to day business and one to develop innovative ideas for new products and processes. A very good example of this is at Volkswagen of Germany where the company has a complete department dedicated to develop unconventional engines. To differentiate between the needs for running the business and for fostering the creative activities, the following key inputs are required:

(i) A leader or a champion who believes in encouraging good ideas and pushing them ahead (the entrepreneur);

(ii) A top management person of the organisation to sponsor and marshal resources;

(iii) A team with creative minds and experienced operators to marry what is needed with what is possible.

(iv) A short chain of command (flat organisation) which allows good ideas to move quickly through the system.

The innovative environment may be maintained and enhanced by putting the following ideas into practice:

(i) Freedom to work on areas of greatest interest.

(ii) Recognition and appreciation.

(iii) Contacts with stimulating colleagues.

(iv) Support for innovators to pursue management's interests by providing them with the necessary time and resources.

(v) Maintain good organisational environment to ensure that groups do not become stagnant and resistant to new ideas.

(vi) Stay in constant touch with outside technical and market developments.

(vii) Ensure management interaction with staff through an efficient communication programme.

(viii) As innovations involve risks encourage staff to take calculated risks.

(ix) Encouragement for individuals to own, and develop new ideas in spite of the fact they work as a part of a team.

(x) Tolerance of non- conformity.

(xi) Reduction of bureaucracy because bureaucracy has been generally known for resisting and squashing innovation.

(xii) Motivate and provide incentives for innovative individuals. It has been found that the reward system reinforces the view that challenging work is the most important intrinsic motivator and the centrepiece of the reward system. Also the reward system has to encourage rare and outstanding technical contributors to remain at the bench to invent and innovate, Brunner, Gordon, [10]. Some people are so motivated that they will overcome great personal handicaps to follow their innovative ideas to achieve impressive success. Watts & Humphrey [33].

(xiii) Development of the most promising members of staff through a technical resources programme.

(xiv) Confidentiality of all aspects of the innovation to avoid early competition.

(xv) Provision of interactive learning and creativity training programmes.

(xvi) Management should strike a balance between:

- Allowing freedom to creative individuals and maintaining team spirit.
- Toleration of non-conformity in an industrial setting and the culture stress on conformity.
- The mismatch between personal objectives and organisational objectives.

Since experts in management of innovations insist on small flat organisations, the reader might ask how do large organisations become and stay innovative. Often large organisations cooperate with small organisation to benefit from their innovative potential but they can also build their own potential by adopting the following:

(i) Creating an autonomous Innovations Department.

(ii) Keeping project teams small.

(iii) Emulate small company practices, by using groups that function in a skunk works style i.e. making small, informal teams of engineers, technicians, designers and model makers responsible for innovations and giving them considerable freedom from the constraints normal to the rest of the organisation. These teams should be charged with the task of developing a new product from idea to prototype and commercial stages without any intervening organisational barriers.

(iv) Appreciation of innovations by the higher management and inspiring staff taking keen interest in their innovative ideas.

(v) Market orientation i.e. having a vision for the practical realities of the marketplace.

4.5 MANAGING THE INNOVATIVE ENVIRONMENT.

From the previous discussions, several factors have been identified which relate to the innovative environment. These factors contribute in different amounts to the success of innovations. The influence of each factor on the management of the innovative environment is also different. These factors are:

- Clear vision to technological needs.
- Constant focus on customers predicted needs (market orientation).
- Maintenance of objectives.
- Sources of innovative ideas.
- Receptive to innovations. Open to creative ideas and participation in wide, continuous improvement activities.
- Willingness to apply new technologies.
- Effective programme selection.
- Commitment. (From management to both innovators and customers).
- Management guidance.
- Charismatic programme management.
- Desire to move the organisation forward.
- Interactive relationship between innovators and customers.
- Utilizing multiple approaches or parallel development to improve the quality of technological solutions, team motivation, and the probability of ultimate success.
- Flat structure. Suitable organisational structure, which enables creativity, interaction and minimizes bureaucracy.
- Internal technical expertise to participate in and evaluate potential solutions.
- Confidentiality of the innovation to avoid early competition.

- Strong external linkages to both domestic and foreign sources of technological expertise such as suppliers and universities.
- Empowering champions or championing teams to drive the innovation's process.
- Maintaining continuity, balance, and enthusiasm of the innovators.
- Providing the patient, long-term support that technological innovations require.
- Collaboration in a corporate environment.
- Permit innovative ideas to rise.
- Channelling innovative efforts, in ways that will pay off in the market.
- Creativity and going after good ideas at full speed.
- A sponsoring management to marshal resources (people, materials and time).
- A mix of creative minds and experienced operators.
- Freedom to work on areas of greatest interest.
- Recognition and appreciation.
- Freedom to broad contacts with stimulating colleagues.
- Encouragement to take risks.
- Encouragement of individuals, to own and develop new ideas, rather than having a team as a whole to do so.
- Tolerance of non- conformity.
- Reduction of bureaucracy.
- Motivate and provide incentives for innovative individuals.
- Interactive learning and creativity training programmes.
- Management should strike a balance between:

  (i) Provision for freedom to creative individuals, and maintenance of team spirit.
  (ii) Toleration of non-conformity in an industrial setting, and the culture stress on conformity.
  (iii) The mismatch between personal objectives and organisational objectives.

- Structuring shoot-outs among competing approaches.
- Emulate small company practices; by using groups that function in a skunk works style.

- Communication. Lack of communications between R&D and other departments, such as marketing and production can lead to inappropriate designs, (over or under design), which either may be uneconomical to produce or may fail to meet customer needs.
- Creative climate. Positive approach to innovative ideas.
- Leadership. It is a key linkage between individual creativity and organisational innovative potential.
- Challenge.
- Removal of inhibitors to innovation.
- External and internal social environment.
- Legislation.
- Economical and political environment.

The innovative environment is a dynamic and a complex entity and managing it requires mixing all the previous factors, which govern it in correct proportions to come up with a balanced recipe in order to provide a healthy atmosphere/environment for the birth, rise and continuous flow of innovations.

4.6 THE INNOVATOR.

The innovator is a highly committed person who places the success of the innovation above all other considerations and is prepared to risk both his/her career as well as personal interests to push his/her ideas against all odds. This individual is creative, action oriented, highly motivated, courageous and risk taker. Good innovators tend to have a better understanding of customer needs, pay attention to marketing processes, perform the development work more efficiently, and make use of outside technology as and when necessary, Twiss [5].

4.7 MANAGING THE INNOVATOR.

The innovator is at the centre of the innovation process, which is the core component of the innovation as a whole. The task for the management is to integrate the innovator's highly motivated and creative potential with the organisation's objectives. Several factors may influence the performance of the innovator. The task for the management is to have a proper understanding of those factors in order to facilitate and foster innovativeness. Those factors are listed below:

- **Creativity**. The innovator should be encouraged to remain creative and his/her creativity should be guided, not controlled, and channelled to coincide with the objectives of the organisation.
- **Commitment**. Commitment is essential for a sustained action in the face of difficulties but it should be focussed on satisfying market needs and it should also be in line with the organisational objectives. The unenviable task for the management is to the channel the high level of commitment of the innovator towards this goal.
- **Customer orientation**. The innovator should always have perception of market needs and should maintain a close contact with the marketing team
- **Alignment of objectives**. Clash between the innovator's and organisation's interests can seriously damage the interests of both therefore, it should be avoided.
- **Risk taking**. The innovator is usually driven by his innovative idea and is likely to ignore the risks. It is very important to encourage him to calculate all possible risks to the successful realisation of the innovation before reaching the implementation stage.
- **Technological awareness**. This element is extremely important but innovators are often so excited by their ideas that they tend to ignore even basic laws of physics and risk ultimate failure. Technological awareness can be achieved through interactive learning and the maintenance of strong external linkages with both domestic and foreign sources of technological expertise such as professional institutions, research laboratories, universities, etc.
- **Individualism and team spirit**. The innovator is creative by nature, but usually prefers to work alone. For the benefit of his organisation, he should also have leadership qualities. It is important for the management to encourage innovators to play leading roles, cultivate team spirit and be part of small innovative groups.

- **Highly motivated**. Usually innovators are highly motivated by nature, and it is in the best interest of the organisation to maintain an inspiring environment that is conducive to spreading high degree of self-motivation.

In general innovators like to work in a relatively free environment; therefore they should be managed discretely; neither in a patronising manner nor in a restrictive bureaucratic style.

4.8 THE INNOVATION PROCESS.

It was discussed earlier that innovation plays a very important part firstly in prolonging the marketability of existing products and secondly in bringing out new products. The first part makes by far the largest contribution to economic well being of engineering companies. This is because engineering companies are always strive to spread the cost of research, design, tooling, etc of products over as long a period as possible in order to keep the manufacturing costs down and stay competitive. In this case, attention would be focussed on producing new models of existing products at regular intervals of time by means of such steps as introducing new features, improving performance, reducing energy consumption, lowering prices by using alternative materials, processes or manufacturing techniques, etc.

It should be noted that in the case of new innovative products, they might be designed either for the consumer market or under a contract from a specific customer, e.g. designing a ship, a tanker, a civil airliner, military hardware for specific orders, etc.

New products for the consumer market will normally be designed on the basis of either perceived or predicted needs of the consumer market. This is because manufacturing companies cannot afford to carry out meaningful surveys of consumer opinions as the consumer market stretches across the world. In contrast, the designer for contracted equipment cannot afford to ignore the wishes of the customer because he is under a binding contract to meet customer specifications. The innovator or the designer has little freedom to follow his/her own innovative ideas without a prior written agreement with the customer.

Innovation process in each case would be different; consequently, the procedure to adopt that process would also be different. Therefore, it would be futile to describe a unique process for all cases listed in the preceding paragraphs. Nevertheless, there are those aspects of the innovation process, which are generic in nature and may be applied in all cases. In the case of new products a typical innovation process, common probably in defence related engineering industries, passes through a number of stages as given below:

- **Idea/Market need/User requirement**. The innovation process starts with an idea, which originates from specific needs of customers as identified by the marketing staff, or engineers in the R&D department. To insure continuous flow of new ideas from both sources, marketing department and R&D department, it is necessary to remove all communication barriers. After the formation of the idea, it should be recorded and carefully studied for technical feasibility and commercial viability as shown in appendix B. The innovative organisation has to get in touch with the end user/customer through the marketing department to understand the exact requirements, for example target performance and project objectives, constraints plus functional and logistical requirements. Environment analysis has to be conducted, and in the case of defence type innovation, threat analysis and mission analysis have to be carried out.
- **Specifications.** The R&D department or the innovation team translates the user or the customer requirements to technical specifications in order to start the design process. These specifications include confirmation of target performance, physical interfaces and logistical specifications. Functional analysis and functional allocation should also be conducted.
- **Concept development and design.** Based on the generated technical specifications, the innovator or innovation team in the R&D department starts to develop several concepts that may satisfy the user requirements in order to allow the customer to select a concept, which meets his preferences. Concept analysis and concept selection are conducted and the data pack generation starts during this stage. Based on the selected concept the R&D department starts the designing process. Then, the complete design is tested and evaluated, often by

computer simulation, prior to moving into metal cutting phase on the shop floor. Computer simulation helps to achieve the main objective, i.e. error free design or design for zero development. A model can also be built during this stage.

- **Prototyping.** Based on the designs from the previous stage, the production department, supported by on going consultation with the R&D department, starts to manufacture several prototypes in order to conduct various test and achieve a mature prototype. Some of the prototype are:
    - Experimental Development Model (XDM), a model used for laboratory testing to prove functionality.
    - Advanced Development Model (ADM), a model used for subsystem testing and evaluation.
    - Engineering Development Model (EDM), a model used for qualification and verification. The influence of logistics should be reflected on the designs and the prototypes. The data pack has also to be updated according to the changes and enhancements made. Subsystem testing, cost estimate, test and evaluation procedures and support plan are done at this stage.
- **Pre–Production Model (PPM).** Going through several prototypes leads to a pre-production model, and on this model or during this stage, the following steps are executed: (i) product process design; (ii) product process verification; (iii) user evaluation and approval; (iv) product specification; (v) preparation of jigs, fixtures and special tools; and (vi) data pack update.
- **Production Model.** Based on the pre–production model, the production department starts producing the production model. This model is that the customer will receive as a fulfilment of the idea or the user requirement as stated in the first stage of innovation process. Production planning, production personnel training and operational qualification is also conducted at this stage; customer response or reaction should be observed in order to keep the improvements and the innovation cycle in continuous motion.

The innovation process should be supported by a computer based Product Data Management (PDM) system, in order to reduce the time and cost of completing the production model. The innovation process is shown diagrammatically in Fig. 4.2, and a conventional flowchart for the innovation process is shown in Fig. 4.2A.

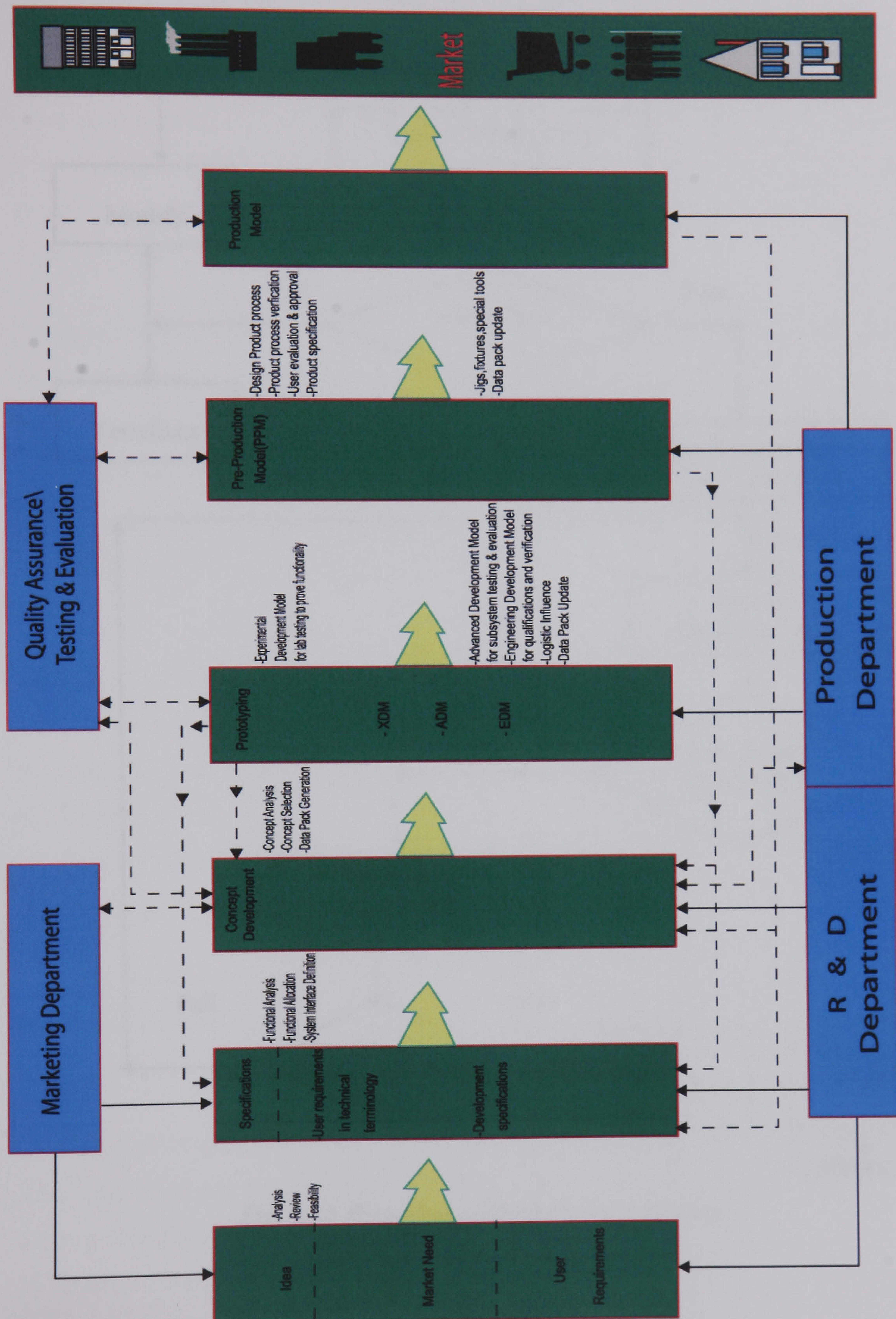


Fig. 4.2 The Innovation Process

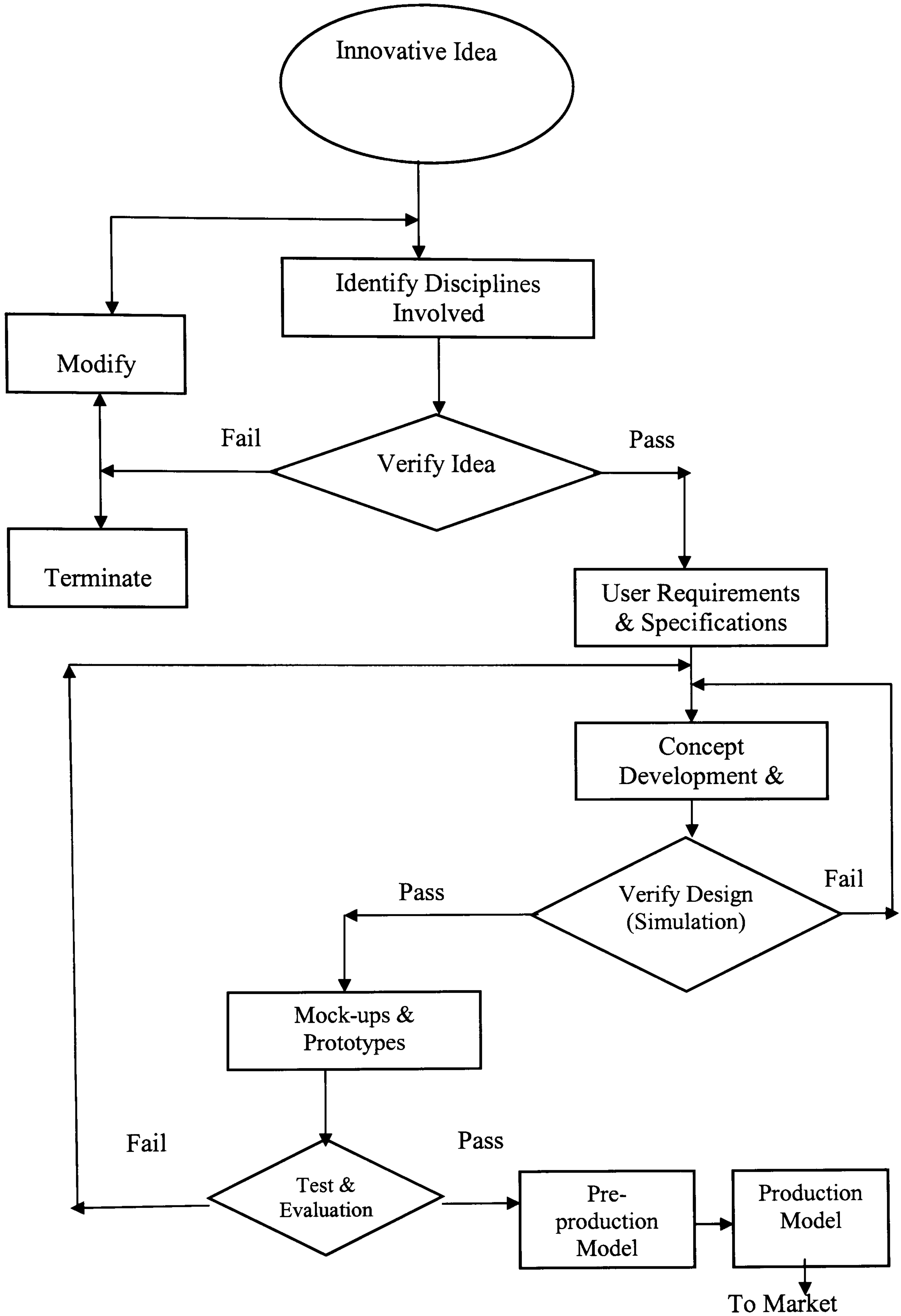


Fig. 4.2A Flowchart of the innovative process

4.9 MANAGING THE INNOVATION PROCESS.

Innovations in engineering industries may relate to products, processes or services. There is ample scope for innovations in all three areas. The starting point for all innovations is the birth of an idea, which, in the case of product related innovations, must be translated into the design of a marketable product that can be manufactured conveniently within the framework of budgetary and time constraints. Hence, engineering design plays a key role in the successful implementation of innovative ideas.

Management of the innovation process must cover; (i) creating and maintaining an environment that is conducive to generating innovative ideas; (ii) providing the necessary infrastructure capable of taking innovations from the ideas stage to the stage of successful and marketable products. A well-equipped engineering design office, research and development laboratories, workshops, etc. are vital elements of that infrastructure. The life cycle of engineering products may be divided into the following stages:

(a). Appreciation of need. The source of the idea;
(b). Converting the idea to product design (specifications);
(c). Manufacturing (mock up and prototype);
(d). Testing (design targets)
(e). Development (development targets)
(f). Release of shop drawings for production.

It is very important to note that engineering design is far more than drafting; drafting is a part of engineering design but not the complete design. The design checklist includes:

(a). Understanding the design objectives and defining achievable design specifications;
(b). Preparing conceptual designs and stating criteria for selecting the right design;
(c). Analytical design (designing to meet performance specifications);
(d). Structural design (designing for structural integrity);
(e). Aesthetical design (designing for visual appeal);

(f). Machine design (preparing general arrangement drawing and shop drawings);

(g). Design for manufacture (cost effective design that can be produced conveniently by using, as far as possible, the available skills, machine tools and other manufacturing facilities).

It is very important for engineering organisations to carry on with the incremental innovation and in parallel conduct rapid and radical innovations in response to either perceived or predicted market needs. It should be kept in mind that risk is proportional to the speed of change, which implies that rapid radical innovations carry relatively high risk but in return, they offer a handsome profit. Figure 4.3 below shows qualitatively typical trends of risk and profit related to innovations as functions of time. The shaded area on the graph, designated as *Area of Maximum Interest,* represents the area or period of maximum interest where companies should concentrate on maximising profit at the same time be more competitive through higher productivity, better quality, superior design, etc.

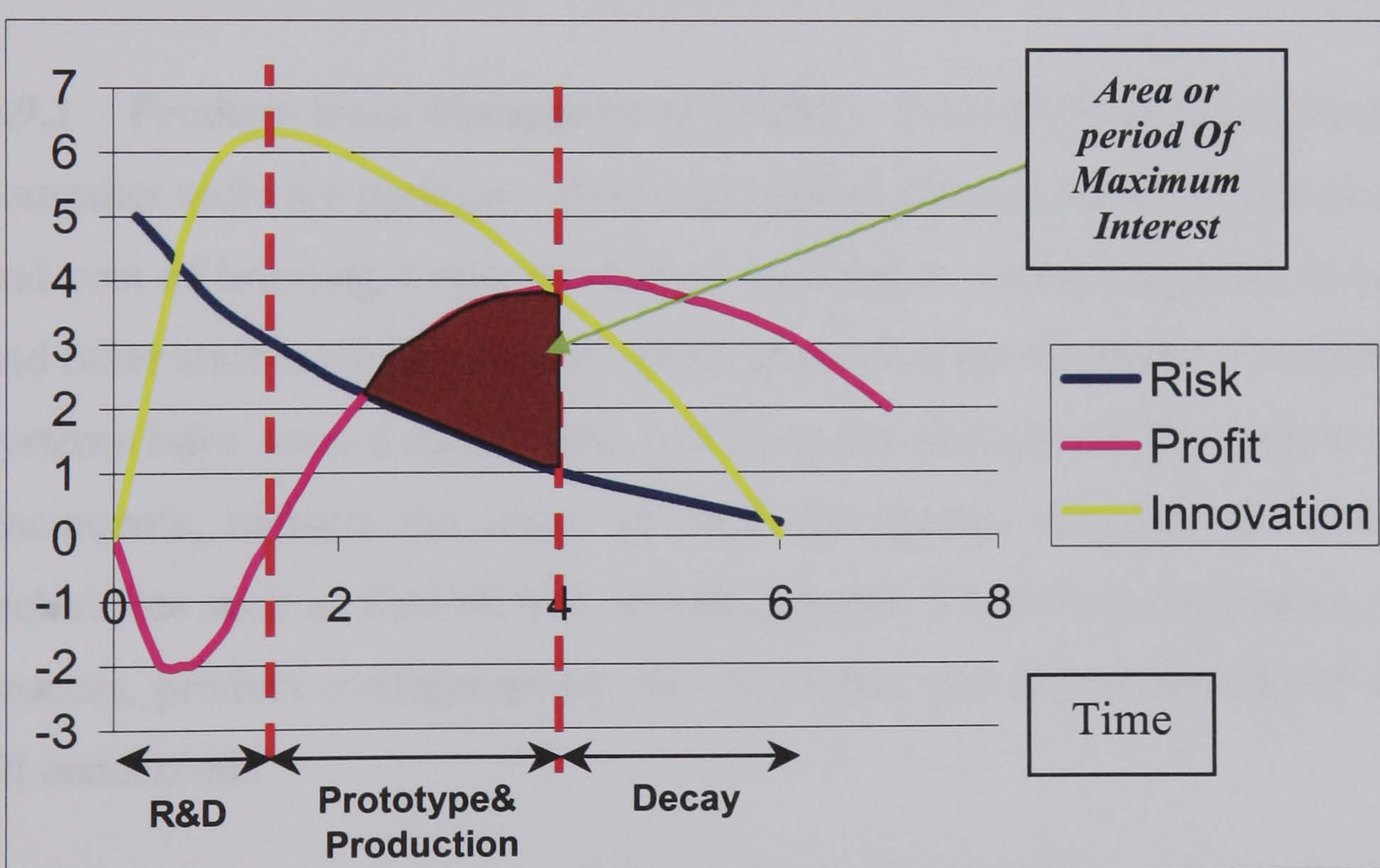


Fig. 4.3 Risk, innovation and profit verses time

As mentioned earlier, the innovation process is the heart of innovation, and should be well managed. Several factors with conflicting requirements influence the operation of the innovation process; those factors are:

1. Freedom and control.
2. Creativity and convention.
3. Individualism and teamwork.
4. Communication (R&D, Production, marketing and customer).
5. Feedback between the various stages of the innovation process.
6. The logical flow of the innovation process.
7. The participation of production engineers in the development process.
8. Customer participation in the innovation process.
9. The compatibility and diversity of the innovative team.
10. Reliability and accuracy of testing and production equipment.
11. The availability of good quality production materials.

Complex innovations tend to generate masses of data, which must be managed and used efficiently during the implementation process. Hence, the management of these data is an important part of the innovation process. Product data management, discussed hereunder, is a tool for speedy and reliable management of data.

4.9.1 Product Data Management (PDM). Product Data Management (PDM) is a computer software package, which can handle, process and control bulk to reduce time and cost of bringing a new product to the market, Armstrong [38]. It helps engineers, and other staff managing data to speed up product development. Computer based PDM systems have several capabilities including the storage and the control of all forms of documents, manage the usage of such documents, integrate all sorts of tools and techniques such as CAD/CAM, imaging, paper documents, catalogues, manufacturing process, product configurations, etc, efficiently and allows sharing of information by all concerned.

PMD systems have several functions, which could be user functions, such as: data management, workflow management, product structure management, parts or inventory management and project management or utility functions such as: communication control, data distribution, documents viewing and system administration. It is important to recognise that successful PDM systems require full support from the higher management.

4.10 GLOBALISATION AND WTO AGREEMENTS.

Managing innovations to face globalisation and WTO regulation is a major challenge which engineering companies, particularly those located in emerging countries, have to face in addition to competing against multinationals. Therefore, innovativeness for them is all the more important. However, it should be noted that managing innovation in such circumstances is complex and inherently non-linear as shown in Fig. 4.4 Hence, the task of managing must be looked at as a continuous process and not as a single event. Tidd et. al., [11].

Managing innovation in worldwide organisations is two-fold, Micheal et. al., [34], first, management must enhance efficiency and effectiveness of different innovation processes and second, it must create conditions that allow innovations to go through all stages simultaneously without any discontinuity or hindrance. These recommendations should be reserved for large worldwide organisations only; they can followed by small companies also which concentrate on select niche markets.

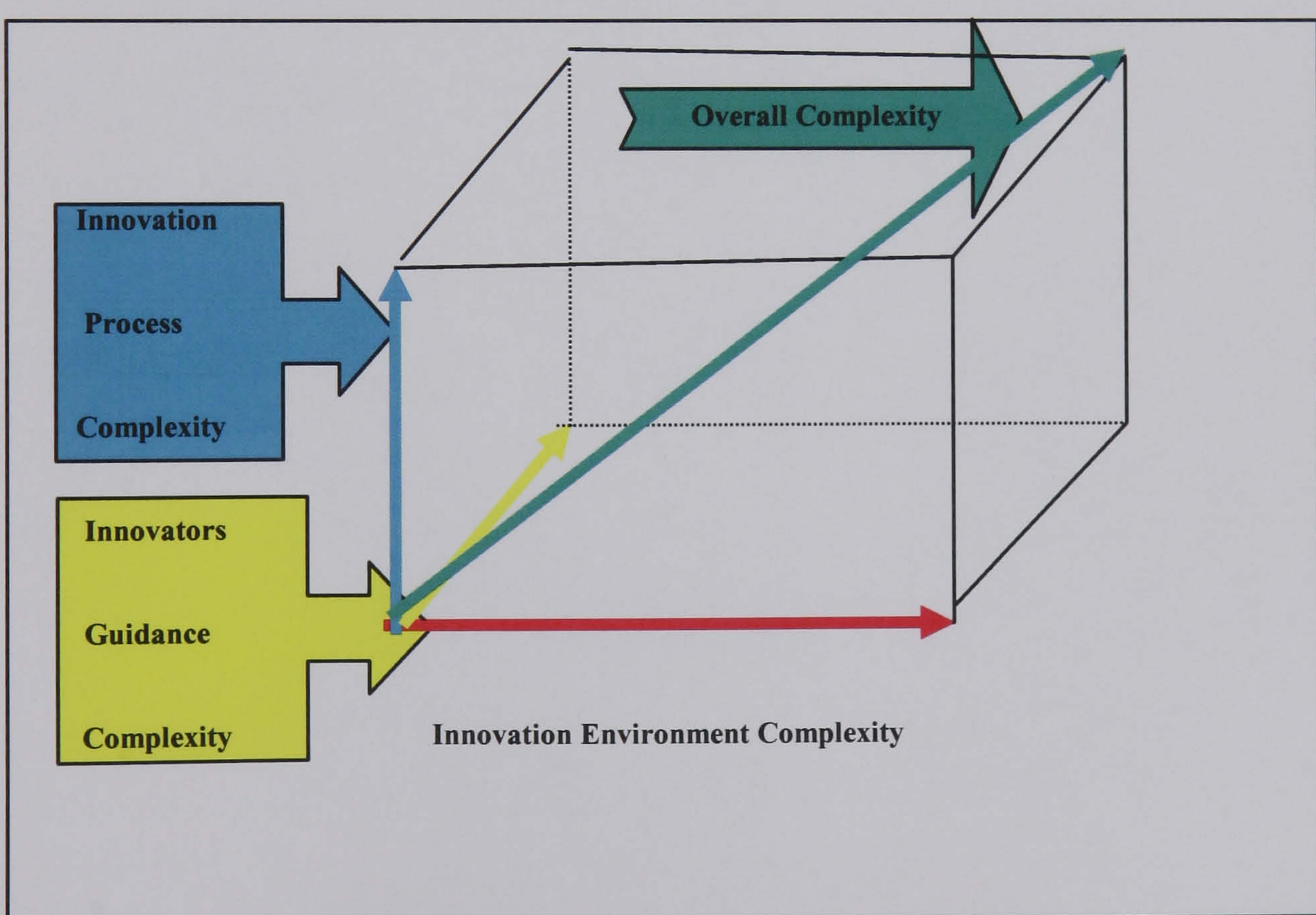


Fig. 4.4 Managing innovation's complexity

The difficulty in managing innovations is in satisfying conflicting requirements or tensions. Two major tensions are: first the tension between encouraging new ideas and the need for choosing only those which are inline with the company's objectives, and the second between encouraging individuals to generate good innovative and then share them with other members of the innovation team. Sharing is necessary for general dissemination and for rapid evaluation and development.

During prototyping and the production phase there are also two major tensions: first is to prevent unauthorized changes or modifications and asking the team to solve unforeseen problems, and second is keeping manufacturing engineers engaged in less interesting, but necessary, tasks such as documentation and at the same time involving them in more challenging work such as process improvements or problem solving

Figure 4.5.shows pictorially all the facets of managing innovation in engineering industries that have discussed in this chapter.

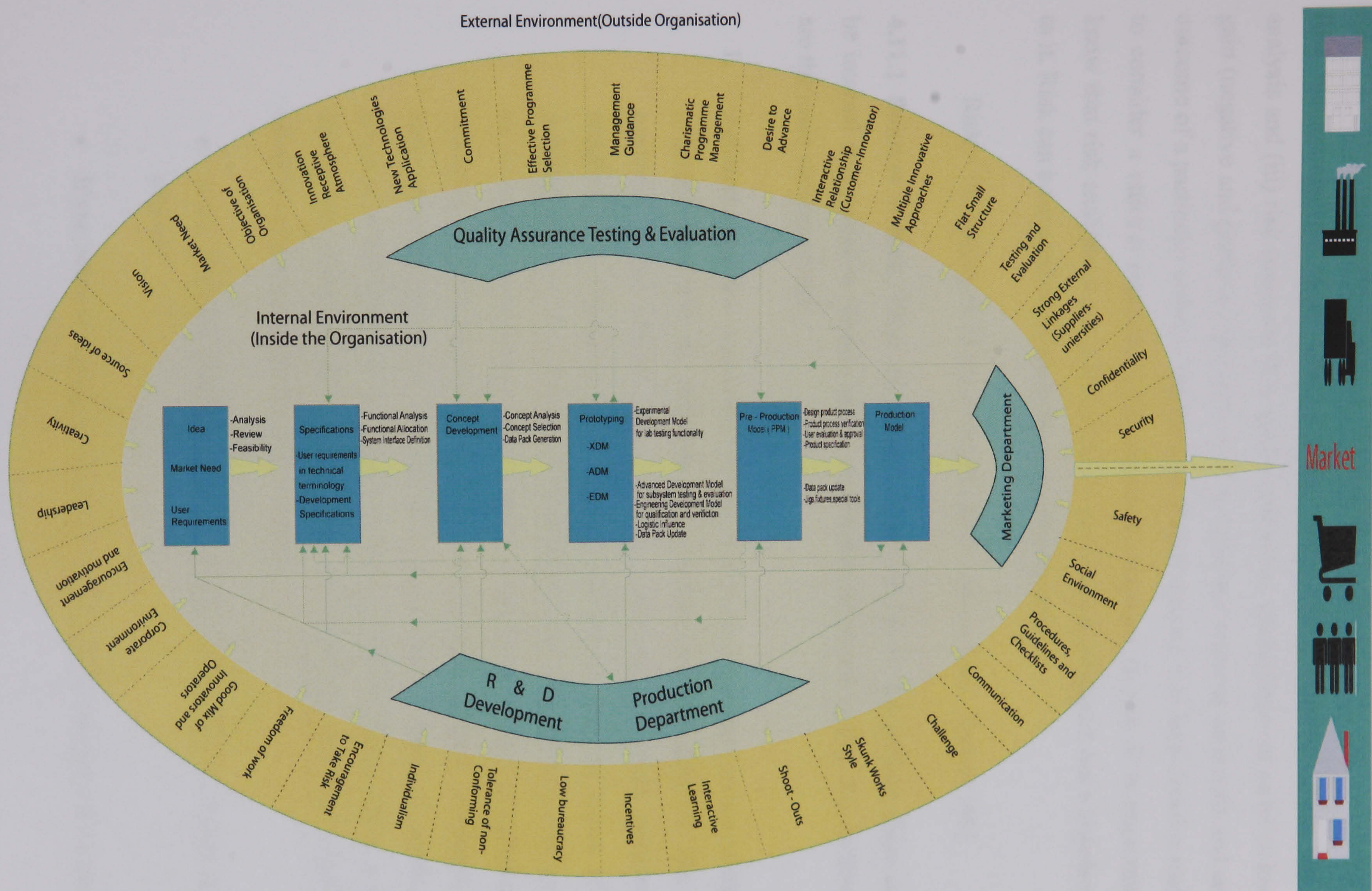


Fig.4.5 Innovation as Result of a Complex Management

4.11 RISK ANALYSIS IN PROJECT MANAGEMENT.

Risk management has three main elements, namely: (i) risk identification; (ii) risk analysis and (iii) risk response. Risk can be defined as the exposure to possible loss or gain (negative and positive risk) because of a difference between estimated and actual outcome of a particular activity. The purpose of risk analysis is to help decision makers to consider a rational response to the degree of exposure to risk. It is important to know that risk analysis is not a substitute for professional judgment but a supplement to it. Risk can be quantified by using the following equation:

Risk = Probability of Event x Magnitude of Loss or Gain   Raftery [46].

4.11.1 Sources of Risk. There are several sources of risk for any project; these could be internal or external in relation to the organisation as shown in Fig. 4.6. Following are the main sources of risk:

1. **Political situation.** An external source, which can be a major source of risk to projects, especially in countries with various political disputes like the countries of the Middle East. Political situations can reflect positive or negative risks depending on the type of the project and the nature of the political dispute. For example, an unstable political situation in a country can be a source of negative risk in terms of profit, time and availability of resources such as materials and labour for a certain project. However, the same situation could be a source of positive risk in terms of profit, for projects, which produce equipment or items to be utilized to serve a need during that particular political situation. The following questions might be asked in order to evaluate the risk involved:

    - Is the political situation likely to change during the execution of the project?

    - If yes, when is it going to happen in relation to the project time scale?

- What risks are expected: financial, restrictions on availability of time, materials, equipment, personnel, and market shift, change in customer requirements, etc.?
- Is it going to be a positive or a negative risk or both?
- What is the magnitude of the risk involved?
- What is the required response?

2. **Economical situation.** This is also an external source of risk. Unstable economical conditions can be a major cause of uncertainty of the success and the management of projects. This situation also could be a source of positive or negative risk depending on the type of the project and the nature of the economical problems. The following questions need to be answered to evaluate the risk to be encountered in this case:

- Is the economical situation likely to change during project life cycle?
- If yes, when is it going to happen in relation to the project time scale?
- What are the expected risks: financial, restrictions on availability of time, materials, equipment, personnel, and market shift, change to customer requirements, etc.?
- Is it going to be a positive or a negative risk or both?
- What is the size of risk involved?
- What is the required response?

3. **Market conditions.** This is an external source of risk for project management. Emerging markets or market shifts lead to changing customer needs or requirements, which can be a major source of risk for projects that require long time to introduce a product to the market. Changing market conditions can also puzzle the planer especially when the direction and speed of change is difficult to predict. Therefore many questions need to be considered with respect to market conditions such as:

- Is there a present market need?
- Or, is it a predicted market need?

- Have the user requirements been considered?
- Is the targeted customer an organisation or a general consumer?
- Is the marketing department in continuous touch with the targeted customer in order to sense changes and shifts in requirements?
- Are the marketing resources to sell the product adequate and available?

4. **Technical and Commercial Viability.** Successful projects are usually built around good ideas, which are technically and commercially viable; otherwise, a big source of risk exists right at the starting point, which most probably will decide the fate of the project. Before starting a project, the following questions should be asked to evaluate the risk and to decide the way forward:

   - Is the idea technically sound and will turn into a good marketable product that is commercially viable?
   - Will the outcome, product or service, be cost effective?
   - Is the innovative idea in the organisation's area of interest?

5. **Project Management.** Project management includes planning, organising, directing and controlling all activities related to a project and motivating the personnel concerned. It is about the management of a process of change and is considered as a main source of risk for the success of any project. The following questions may be considered to assure the fulfilment of the main aspects of project management:

   - Has a competent project manager been appointed, the necessary team skills identified and project team selected?
   - Has a detailed project plan been prepared?
   - Have project resources been organised?
   - Have the various project activities been directed towards the achievement of the project objective (s)?
   - Have the various project activities been controlled to fit within the limits set for them in the project?

- Does the management provide the required motivation to all personnel involved in the project?

6. **Project planning.** Project planning involves deciding what has to be done, when and by whom, i.e. identifying activities, determining their logical sequence, estimating times and resource requirements. Insufficient project planning is a main threat to the success of any project. Good planning allows wise use of time and resources and also helps in avoiding unpleasant surprises. The following questions could be asked while discussing this point:

   - Have the project activities been identified?
   - Has the logical sequence of the project activities been determined?
   - Has the time for each activity been correctly estimated?
   - Have the resources been estimated?
   - Has the project plan been prepared and presented in a readily intelligible format?
   - Has the plan been approved by the management?
   - Has the plan been communicated to and comprehended by all personnel concerned depending on their level of responsibility and involvement?

7. **Definition of the project.** Project definition determines the scope and nature of the project. The development of the project's definition is vital to its success. A comprehensive definition should state its purpose, ownership, technology, cost, schedule, duration, financing, sale and marketing, and resources requirement. Project definition can be achieved by setting the objectives, defining the scope through a milestone plan, setting the functional strategies and assessing technical risk, managing the design process and managing resources. The lack of clear and complete definition and the frequent change in the scope of the project can be a major source of risk. The following questions should be asked in the form of a check list in this regard:

   - Have the aims and objectives of the projects been identified?

- Has the scope of work for the project been specified?
- Are there any changes expected in the scope of the project?
- If yes, when? What would be the impact of the changes on the project?

8. **Availability of resources (equipment, materials, personnel, funds).** The uncertainty in the availability of equipment, materials, personnel or funds needed for the timely execution of the project can be a cause of failure of any project. The following questions need to be answered in the process of deciding the nature and size of the risk involved:

   - Is the availability of resources required for the project likely to change during the project cycle?
   - If yes, what are the resources, which, might be affected and when?
   - Will there be sufficient funds spread over the project period? If no, how much is the shortage? What is the impact on the project? What is the required response?
   - Will there be sufficient materials during the project period? If no, how much is the shortage? What is the impact on the project? What is the required response?
   - Is the necessary equipment for the project for manufacturing and testing available? If no, what is the extent of the shortage? What impact this may have on the project? What is the required response?
   - Will there be sufficient personnel (project team and a project leader) to support and execute the project on time? Do the available personnel have the required skills? Is the project team diverse in skills and compatible in behaviour? If no, what may be the impact of this incompatibility on the project? What is the required response?

9. **Time.** Shortage of time is a major and a vital source of risk from the management point of view. It is important for the organisations to introduce their products or services at the right time to be able to compete in the

marketplace. Being late could result in loosing the market to the competitor. The following questions need to be answered in order to evaluate the risk involved from time point of view:

- Is the allocated time adequate for this project or idea?
- Is there enough time for the organisation to execute the project and achieve the set objectives? Will the outcome product or service have adequate lead-time?
- Are the means available to manage the project time?

10. Project size. Inaccurate estimate of the size of the project is also an important source of risk. The bigger the project size the greater the risk especially when resources are limited. The worst case is when there is a large size project with less resources (funds, materials, equipment, and personnel), weak management, weak project team and lack of time. The following questions might be asked when discussing this point:

- Is the size of the project considered large in relation to the available resources, other facilities and the size of the organisation?
- Is the size of the project considered large in relation to the skills of the management?
- Is the size of the project considered large in relation to the skills of the project team?
- Is the size of the project considered large in relation to the size of markets?

11. Commitment. Commitment is an attribute to sustain action in the face of difficulties. The management and the project team should be committed to the success of the project. Lack of commitment is a major source of risk. The following questions may be asked to assess the level of commitment in the form of a check list:

- Is the management truly committed to the success of the project?
- Does the management provide suitable environment and facilities for successful completion of the project?
- Does the management provide the required resources for the project on time?
- Is the project team truly committed to the success of the project?

12. **Confidentiality.** Confidentiality of innovative ideas is very important in order to gain maximum lead-time and avoid early competition. Lack of confidentiality could mean failure of innovations or of innovative projects. The following questions may be asked in this regard:

    - Are all members of the management complying with confidentiality requirements?
    - Is the project team complying with confidentiality requirement?
    - Have all personnel concerned been educated about the subject of confidentiality and the consequences of lack of confidentiality?
    - Has the organisation taken the necessary measures to ensure confidentiality?

13. **Competition.** Competition can be a prime driver of innovations and high quality products and services; it also can be a source of risk. The following is required to face competition: (i) strict time schedules; (ii) high confidentiality; (iii) more marketing efforts and resources and (vi) competitive products and services in terms of prices and quality.

The following questions can be asked in this regard:

- Is there a competitor for the product or service in question?
- If yes, how serious and how critical is it?
- Is the product in question competitive in terms of price and quality?
- Did the organisation take the necessary measures to stay competitive?
- Does the organisation have an adequate market share?
- Does the organisation have alternative potential markets?
- Does the outcome product have a limited shelf life

14. **Laws and regulations.** None commercially oriented laws and regulations and their instability in a country can be a serious source of risk for the success of any project, because project planning can start on the basis of certain laws and regulations and half way through the project they are changed; consequently new taxes and new governmental limitations come into force. They can jeopardize the success of that project. The following questions should be asked to safeguard against such changes and to evaluate the size and nature of risk that might be encountered: A real life example of the effect of sudden changes in laws that set permissible pollution levels can be seen in the automobile industry

- Are laws and regulations likely to change during the project life cycle?
- If yes, when is the change likely to become effective?
- Will the change of laws and regulations have a positive or a negative impact on the project?
- What is the size of the expected impact?
- What is the required response?

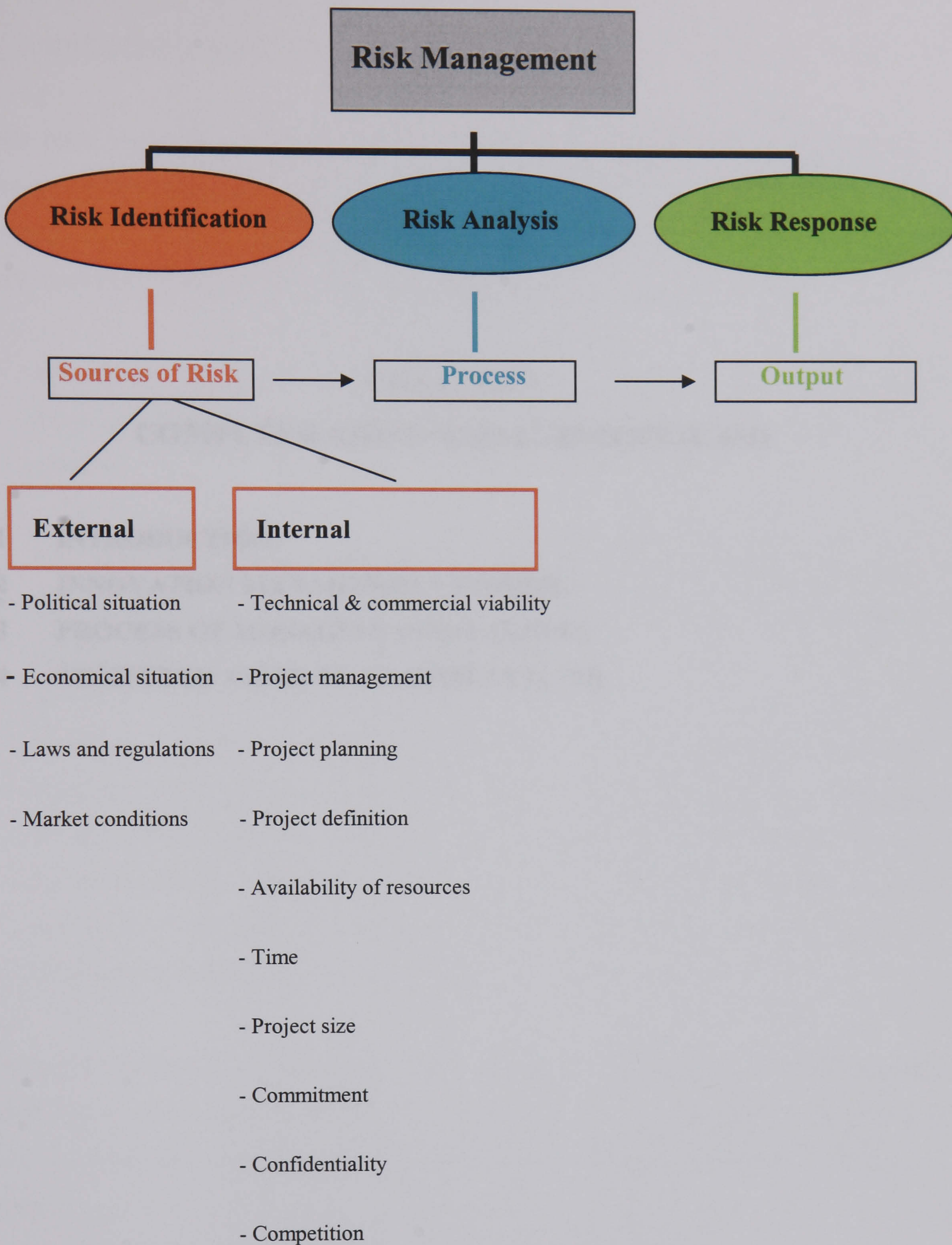


Fig. 4.6 Risk management and sources of risk

CHAPTER 5

COMPUTER AIDED MANAGEMENT (*CAM*)

5.1 INTRODUCTION.

5.2 INNOVATION MANAGEMENT SYSTEM.

5.3 PROCESS OF MANAGING INNOVATIONS.

5.4 COMPUTER AIDED-MANAGEMENT (*CAM*).

5.1 INTRODUCTION.

It has been discussed in previous chapters that managing innovations in engineering industries is a multidisciplinary task involving a large number of intangible variables; consequently it is not amenable to the standard analytical solutions. Other observations or conclusions form the earlier studies are summarised hereunder:

(a) Innovations in engineering products and processes are a necessity for achieving higher profitability and enhancing competitiveness in terms of price and quality of products.

(b) Innovations are essential for the survival and growth of engineering industries. They cannot be left to chance; they require an innovative intense environment (IIE) and should be planned and managed efficiently.

(c) Managing innovations in a highly competitive global marketing environment is a complex task that requires some means for fast assessment of the innovativeness of engineering companies. Innovativeness must be measured in terms of: (i) innovation intense environment, (ii) the innovators, (iii) the innovation process and (iv) a reliable method for estimating the risks involved in accepting innovative ideas and approving their implementation.

In view of this scenario, it was felt that developing computer applications for managing innovations in engineering industries efficiently would be both important as well as timely. It would be a step forward to move management from the arts to the science domain.

Managing innovations would be eased significantly if modern computational techniques were used to speed up the assessment of the innovativeness of engineering companies and the analysis of the impending risks that surround either the acceptance of innovative ideas or the authorisation of the implementation of innovative projects. A prerequisite for developing such computerised analyses is to identify all the variables that may have some influence on: (a) the environment that would be conducive to innovations; (b) the innovators or other personnel who may contribute to the generation of innovative ideas; and (c) the processes necessary for successful implementation of innovations. In order to develop computer applications, it would be helpful to treat the management of innovations as a system comprising the necessary variable that defines the operation of the system. The same approach may be used to analyse the risks embedded in the execution of innovative projects. In this chapter the aim is to understand and analyse the influence of factors or variables identified in chapter 4 and to introduce two computer applications to manage innovations in engineering companies.

5.2 INNOVATION MANAGEMENT SYSTEM.

Management of innovations in engineering industries may be treated as a system, which is influenced by a large number of intangible variable or factors. For efficient management, the system may be divided into three subsystems, namely: innovative environment; the innovators and the innovation processes. It is important to understand the nature of these variables and how do they influence innovations. Only then can one attempt to exercise the necessary controls to achieve an efficient management system. Variables that influence each component of the system are discussed below.

5.2.1 Factors that Influence the Innovative Environment.

The creation and the maintenance of the innovative environment depend on several factors or system variables. The influence of these variables is described hereunder.

1. ***Creativity***. Creativity is about the generation of new ideas, or new ways of doing things. In fact, the whole process of innovation is built around creativity; therefore, it is the core requirement for innovativeness. A creative individual can generate new ideas, new solutions, new ways of doing things, shortcuts, spontaneous response, etc., but creative organisations are built around creative individuals, creative solutions, creative processes, creative products and creative situations. It will be impossible to have an innovative organisation without the presence of creative individuals surrounded by a

creative atmosphere or environment. Organisations are expected to provide and reflect a creative environment by the following steps:

(a) Enhancing employee's personal characteristics such as: self-motivation, risk orientation, social skills, and technological awareness.

(b) Reflecting social environment factors such as: freedom, challenge, encouragement, recognition, etc.

(c) Promoting group characteristics such as: leadership, cohesiveness, group longevity, group composition, group structure, communication patterns, etc.

(d) Employing creative individuals to start with and enhancing their creativity.

2. ***Sources of ideas***. Innovative organisations should welcome good ideas and keep the door open for them. The classical view is that ideas can come from members of staff, partner companies, consultants, suppliers, internet, media, books, magazines, newspapers, exhibitions, customers, marketplace, etc. Therefore innovative organisations should make most or all of the aforementioned sources of ideas within the reach of all their employees in order to gain and give ideas. *However, the current view is that, in order to hold on to a cutting edge position in the technological sense, ideas must be made available at will; they must be generated. As innovative ideas come in response to a need, a comprehensive understanding of and a burning desire to satisfy that need are the prerequisites for generating new ideas.*

3. ***Vision and projection of objectives***. The vision of an organisation will set out how the organisation intends to position itself in the future and contributes to making that future become reality. The management should formulate a long-term vision with clear objectives and tangible goals. Proper planning is then necessary to ensure that short-term work is a seamless part of the long-term objectives. Also little can be done until clear objectives have been set. It is essential to make sure that all employees understand fully the vision and objectives of their organisation in order to align their personal objectives with the organisational objectives. Organisations must make their employees aware of their vision and objectives by the following actions:

(a) Holding seminars to explain the vision and objectives of the organisation to employees until they are fully understood.
(b) Regularly reminding them the organisational vision and objectives.
(c) Using banners and stickers showing organisational vision and objectives in order to exhibit them in various places in the organisation.
(d) Stating the organisational vision and objectives in manuals, brochures and. other publicity material.

4. ***Receptive atmosphere***. Receptive atmosphere for innovations is necessary to welcome all new ideas that may lead to improved, enhanced or new products, better processes, efficient procedures, latest management skills, better quality, skilful marketing, competitiveness in terms of quality and price, etc. The following steps may be helpful in creating the receptive atmosphere:

(a) Encouraging managers, supervisors and team leaders to have courage backed by professional judgement for welcoming new ideas.
(b) Providing incentives to attract good ideas.
(c) Providing suggestion boxes in different locations in the organisation.
(d) Maintaining a register for innovative ideas.
(e) Forming a joint team of technical and commercial staff to study, analyse, and evaluate new ideas for technical and commercial viability.
(f) Naming some of the projects or product models after the providers of the ideas, which lead to those projects or products.

5. ***Commitment.*** Innovative organisations would normally reflect an atmosphere of care and responsibility. They should maintain a genuine and visible commitment to innovations and designs, and ensure that both are exploited to their full potential. They should also maintain a commitment to quality and reliability, the success projects and to customer satisfaction. Lack of commitment creates an atmosphere of selfishness and leads to breakdown of trust. That in turn can jeopardize the chances of success of any innovative organisation. Therefore it is in the best interest of every one on the staff of an innovative organisation to have an atmosphere of commitment and shared responsibility. The following steps can help to ensue the existence of this atmosphere of commitment in an organisation:

(a) Reflecting a sense of shared responsibility.
(b) Showing care for employees, customers and suppliers.
(c) Sharing good and bad times with employees.
(d) Spreading an atmosphere of pride and friendship.
(e) Expressing the disadvantages of lack of commitment.
(f) Using the term commitment as part of the organisational slogans.

6. *Market needs.* The purpose of innovations is to stay ahead of the competition by introducing new models of popular existing products which satisfy market needs. Since popularity of product depends on customer satisfaction, therefore to understand what features of products would guarantee customer satisfaction is of a great importance. Some of the ways that may help to keep innovators aware of and in touch with market needs are: given below:

(a) Allowing innovators to make frequent visits to the marketplace to develop a feeling for its needs.
(b) Tasking the marketing department to provide periodical reports about market needs and circulate these reports to all departments.
(c) Inviting customer participation in a forum of user requirements prior to the design stage.
(d) Allowing customer participation in prototypes testing and evaluation (This would be applicable only to those products which are designed against specific contracts, e.g. defence hardware)
(e) Activating market intelligence.
(g) Enhancing means of communication.

7. *Effective programme selection.* Innovators are often over enthusiastic about their ideas; consequently they miss to spot flaws and weaknesses in them. Engineering companies can loose large sums of money by careless pursuit of innovative ideas which are unsound either technically or commercially. Therefore, a sound programme selection criterion is a perquisite for the success of innovative ideas or projects. Although it is rare that a company has many innovative ideas or projects to choose from; but sometimes it can happen. In such situations organisations must prioritise the acceptance of these ideas or the execution of innovative projects. Efficient programme selection may be achieved by the following steps:

(a) Forming a programme selection committee that includes senior staff members from marketing, production and R&D departments.

(b) Conducting a risk analysis study for the identified programmes.

(c) Conducting programme feasibility studies for technical and commercial viability prior to programme selection.

(d) Checking the coherence of programme objectives with the organisational objectives.

(e) Selecting marketable programmes.

(f) Ensuring the availability of adequate resources for programmes to minimise the risk of failure.

8. *Application of new technologies*. Use of new technologies is necessary to raise productivity levels, lower material costs, improve quality by using modern instrumentation and measurement for metrology, experimentation and quality assurance, maintain a competitive edge through a continuous flow of innovative ideas, etc. The innovative organisation should keep abreast by adopting new technologies either used or in development elsewhere. Procedures should be in place to seek out useful technologies. The following steps may be helpful in this regard:

(a) Forming an R&D department by employing experienced researches and encouraging them to be innovative in their work.

(b) Maintaining a close contact with research institutes, universities and other sources of knowledge.

(c) Enhancing communications network.

(d) Promoting organisational creativity.

(e) Subscribing to relevant professional journals and magazines.

(f) Enhancing in-house technology development through seminars, training courses and programmes of continuing education.

9. ***Management guidance***. For individuals to be innovative and creative, they must have discretely managed freedom of work avoiding tension between freedom and control. Hence it is suggested that *management guidance* instead of *control* should be used. Management should foster creativity and innovativeness as well as meet organisational objectives. Management guidance can be exercised through regular contact with employees to stay in touch and spread a sense of shared responsibility. Continuous reminding of organisational vision and objectives will help to keep innovators on the right track.

10. ***Charismatic programme management***. Project management includes planning, organising, directing, motivating and controlling activities of project teams. The motivation part of it is directed mainly towards the project team, which requires a good leader to inspire them and get the best out of them. Therefore, efforts should be focused on a responsive programme management with leadership being central in it. This may be achieved by selecting suitable programme/project managers who can work closely with their project teams to execute their projects efficiently. It is the duty of the project manager to educate and motivate his project team to become active participants and contribute to the successful completion of the project within the budget and time constraints.

11. ***Desire to advance***. Management of innovative organisations should have the ambition for advancement in the organisational environment in order to lead and stay competitive. This ambition can be fulfilled by the following actions:

(a) Expressing and reflecting the desire to advance.

(b) Employing innovative staff.

(c) Promoting general awareness of company's progress among employees.

(d) When ever possible within financial constraints utilizing new techniques, latest equipment and instruments to improve working efficiency.

12. ***Interactive relationship***. Innovative organisations should have a policy to maintain interactive relationship with the innovators, the customers, suppliers and the partner companies. This kind of relationship is beneficial for all participants, it helps in interactive learning, developing and sharing knowledge, knowing market needs and rapid response to market shifts.

13. ***Multiple or parallel innovative approaches***. In order to save time innovative companies should use different methods of achieving the goals of a certain programme by using them in parallel, and then select the one, which scores higher than others to meet the acceptance criteria. Innovative organisations would be well advised to adopt this approach even though it may require more resources at the beginning.

14. ***Shoot-outs between parallel approaches.*** This is the last action to be taken when adopting multiple innovative approaches in parallel. It has been said: that by adopting multiple approaches, companies can study different parallel approaches to achieve programme objectives. Selecting one of these approaches requires a shoot-out, a competition or some evaluation method. The selection may be assisted by using carefully defined criteria.

15. ***Maintaining small flat organisations***. Large organisations in general are more likely to suffer from problems such as stereotype management, more bureaucracy, lack of communications and poor social interaction. Creative individuals and innovators require close attention in order to keep them stimulated for generating new ideas. Moreover, it is relatively difficult to communicate and share ideas in

multi layer hierarchical organisations Therefore, in large organisations, it would be advisable to have small and flat innovative groups or departments.

16. ***Testing, evaluation and quality assurance***. One of the main objectives of innovations is to achieve competitiveness in terms of superior quality improved functionality and new features while maintaining the same or lower end-user price of products. Therefore, innovative organisations should take all necessary measures to meet these goals in all processes, products and services. The following measures may be taken to embed quality into the innovative environment:

(a) Setting up and following a quality policy as one of the organisational objectives.
(b) Generating general awareness among employees to work coherently to the set organisational quality standards.
(c) Providing the necessary tools for checking the quality of products.
(d) Employing fitness for use strategy to satisfy market needs.
(e) Taking the necessary measures to ensure continuous improvements.

17. ***External linkages***. External linkages are a main source of up to date knowledge for the innovative organisations. Those linkages can be universities, research institutes, data banks, partner companies and in some cases suppliers as well as competitors. External linkages can lighten the burden of financial investment for in-house work to acquire the same knowledge, help to attract funding, speed up processing of innovations, surmount barriers, etc. External linkages can be created through the following:

(a) Setting up joint ventures with other companies.
(b) Funding research in universities and research institutes.
(d) Encouraging employees to create links with external professional resources through conferences, seminars and exhibitions.
(e) Utilizing means of communications such as Internet to access and contact external linkages.

18. *Confidentiality*. Some times it takes a long time to convert an idea into a product or develop into a process. Since there are competitors with their active market intelligence looking for ideas, it is extremely important to keep innovative ideas confidential in order to avoid early competition. Innovative organisations should take suitable measures to protect the confidentiality of their innovative ideas for projects, products and processes. Some of the following measures may be taken to ensure confidentiality:

(a) Educating project teams on the importance of confidentiality.

(b) Making project teams aware of the competitors.

(c) Shortening the time taken to convert an idea to a product by using modelling and simulation at the design stage, rapid prototyping, and practicing confidentiality without blocking free communication.

(d) Putting all design documents on closed computer nets.

(e) Taking the necessary security measures during testing such adding confidentiality clause in contracts of employment.

19. *Job security of employees*. It is very difficult for employees to be innovative if they feel insecure in their place of work. Job insecurity can lead to a significant drop in creativity, hence in innovations. Therefore, innovative organisations must treat their staff as he most valuable asset and must adopt a policy of *Investing in People*. Friendly working environment and inspiring nature of work are the two most important attractions that a company can offer to innovators. In addition, the following measures may be taken to create the sense of job security:

(a) Provide good remuneration and fringe benefits such as medical insurance and contributory pension scheme.

(b) Showing commitment towards employees.

(c) Introducing profit sharing scheme in order to create a sense of belonging.

(d) Creating clubs and fostering social activities.

20. *Safety.* It is important to ensure that innovations do not violate safety standards. For example, an innovative tyre produced by Firestone resulted in several fatal accidents which costed Ford Motor Company millions of dollars in *out of court* settlements; that was followed by a drawn out dispute between Ford and Firestone. Safety of employees and equipment including materials, machines and premises is also important for avoiding accidents, damages to property or loss of materials of innovative organisations. Although safety at work does not play any part directly in the management of innovations; lack of safety can lead to loss of time and work. Consequently long delays occur in executing innovative projects. Innovative organisations should also take all necessary measures to ensure safety at work.

21. *Healthy internal social environment* All measures should be taken to ensure the existence of good interactive and healthy social environment in the innovative organisation. Such organisations should become like home and treat employees as a family. This healthy atmosphere will enhance creativity and innovativeness. The following measures could be taken to create an internal healthy environment:

(a) Planning and executing social functions for employees and their families.

(b) Promoting friendship among employees through company sponsored clubs.

(c) Encouraging and supporting the formation of social committees for employees.

(d) Establishing a funds box for social activities.

22. *Procedures, guidelines and checklists.* There should be some documented regulations, instructions, guidelines, checklists to avoid such conflicts as infringement of already existing patents. As settling legal dispute can be very costly, most companies keep patents attorneys on their staff. Innovative organisations must, as a matter of policy, check all innovative ideas for likely infringements of patents that they may cause. It would be a good practice also for innovators to guard against the likelihood of such infringements.

23. ***Communications.*** As a result of globalisation, innovative organisation has to compete internationally. This requires strong external linkages, which in turn will call for good communication networks. Internal communications are also important, in order to share ideas, exchange information and seek advice. The organisation should use the advances in information technology to speed up and expand the potential for more effective communications throughout the enterprise. The following steps may be taken in this regard:

(a) Establishing strong internal and external communication networks.

(b) Removing organisational communication barriers.

(c) Making sure that all departments of the organisation are close to each other geographically.

(d) Exercise less restrictions on communications provided confidentiality measures are met.

24. ***Challenging atmosphere.*** Technologically challenging atmosphere is a very good source of motivation but it is necessary to safeguard against its misuse. In every organisation, there would be some employees who prefer to engage themselves in challenging work and shirk mundane work for others to do. If this type of selective working is allowed by the management, it can create internal rivalries and destroy the harmony which is necessary for working as teams. The following steps may be taken to create the challenging atmosphere:

(a) Creating a competitive atmosphere for innovators.

(b) Naming some incentives for certain achievements.

(c) Creating an honours list for the innovators of the year at the organisational level.

(d) Investing in educating and training innovators in the form of a reward, for the mutual benefit of both the innovator and the organisation.

25. ***Skunk work style.*** It is relatively easy to guide, motivate and activate smaller groups of people rather than a larger group. Therefore, it is advisable for innovative organisations to structure their innovators or project teams to work in small informal well-integrated groups, which include all the required skills and expertise. Those groups should be given considerable autonomy and freedom from constraints that are normal for the rest of the organisation. These groups should be placed together with no intervening organisational barriers, for developing new products from the ideas stage to marketable products. The adoption of this style of work requires:

(a) More skilled manpower.
(b) More leadership qualities.
(c) More resources.
(d) Higher management attention.

26. *Interactive Learning.* In order to keep abreast with the scientific and technological advances, innovators must read, research reports, professional journals, advanced textbooks, etc. Interactive leaving technique is the most cost effective method of acquiring knowledge, albeit theoretical and usually cursory. For examples, one can gather enough knowledge of the science of the fuel cell by interactive learning but little can be found in published texts that may be helpful in mastering the technology of manufacturing even the simplest fuel cell. The benefits that may accrue from interactive learning depend on the channels used or the standard of participants in the discussion group.

27. *Incentives.* The incentives offered should be compatible with the value of the contribution for which the incentive is being offered and, at the time, be coherent with the needs of the individual. Financial rewards, training courses, achievement certificates, recognition, promotions, etc. are some examples of the incentives which may be offered. Giving incentives that are not appropriate may not serve any purpose, therefore, organisations must establish incentive schemes based on some form of correlation between incentives and in return, the benefits.

28. *Bureaucracy.* Rapid conveyance and execution of ideas is of tremendous importance for success of innovations. Cumbersome bureaucracy can be the main source of hindrance for pursuing innovative ideas and delay in the execution of innovative projects. Bureaucracy can also destroy the spirit of creativity and innovativeness. The following measures may be adopted to minimise bureaucracy:

(a) Keeping the organisational structure small and flat.
(b) Minimising and simplifying the paperwork.
(c) Shortening the chain of management by delegation of authority.
(d) Establishing efficient communication network.
(e) Encouraging and giving preference to verbal communications, whenever new ideas are involved.

29. *Tolerance to non-conformity.* Innovativeness is about new ideas to improve products, services, provide solutions for problems or provide new applications for existing scientific principles. Generally speaking, only two out of ten ideas are implemented even though all ten ideas are analysed, evaluated and verified. When it comes to ideas, innovative organisations should be tolerant to non-conformity. Innovators should be given the chance to try different things in order to shape up their ideas. This should not be understood as an acceptance to tolerance of non-conformity in products, on the contrary, when it comes to finished products, the organisation should aim for zero tolerance to poor quality, lower reliability, etc.

30. *Individualism.* Ideas are the fruits of an individual's creativity. It gives individuals great happiness and satisfaction to say, "This is my idea" or "I was the first one to think about it". Therefore, when it comes to providing ideas, individualism should be encouraged, but teamwork and team spirit should prevail when implementing such ideas. The following steps may be taken to encourage individualism:

(a) Paying close attention to all innovators as independent individuals.
(b) Allocating incentives for viable ideas.
(c) Naming some products after the persons who gave the ideas for those particular products.

(d) Maintaining an honours list for the innovators and selecting the innovator of the year at organisational level.

(e) Allowing some prestige for the innovators.

31. ***Risk taking.*** Innovative ideas lead to designs of new or improved products or services However, such ideas may not be accepted by the employer because they fall outside his/her interest. Freelance innovators can enjoy the luxury of generating innovative ideas without any restriction. An engineering company cannot afford to pursue innovative ideas, which fall outside its area of their interest. Risk taking is not meant to extend to such cases. All innovative ideas or projects carry certain amount of risk; it is within the scope of managing innovations in engineering industries to take those risks based on well-considered risk responses. Risk taking may be encouraged and aided by:

(a) Holding seminars on risk analysis and risk response.

(b) Tolerating certain degree of non-conformity providing the innovative ideas do not go outside the organisation's interest.

(c) Encouraging innovators to explore unknown domains.

32. ***Freedom of work.*** It is generally accepted that creativity requires freedom of thought as well as work but innovators working in engineering companies are obliged to follow standards, codes of practice, manufacturing restrictions, etc. They must learn to work also within the confines of their employers' interests. In spite of these limitations, management should endeavour to minimise restrictive practices and take such measures as flexible working hours to create a sense of freedom of work.

33. ***Mix of innovators and operators.*** It is important for the innovative organisation to remove the barriers between R&D and production or between innovators and marketing. Working together or as teams comprising staff from different areas is the most effective method for achieving:

(a) More mature and workable ideas.

(b) Advancement towards "design for zero development", or towards, "doing it right first time".

(c) Shortening the time required for testing the viability of ideas.

(d) Wider staff participation in projects.

34. ***Corporate environment.*** The innovation process starts with an idea or a question from an individual hence; at the beginning one person is involved but after that it is teamwork or group work. Therefore, the existence and the maintenance of the corporate environment is a vital need for the creative environment. Innovations should be promoted through teamwork to expand opportunities and increase overall benefits. The organisation should encourage internal and external networking. Lack of corporate environment will lead to lack of achievement and lower quality standards. The following may be taken to establish and enhance the corporate environment:

(a) Encouraging teamwork and team spirit.

(b) Encouraging social relations and social activities in the organisation.

(c) Holding seminars on the importance of corporate efforts and the corporate spirit in innovative organisations.

35. ***Encouragement and motivation.*** All staff involved should be encouraged and motivated whilst understanding fully their capabilities and limitation. The innovative atmosphere should be a stimulant to the innovators to generate ideas and to keep the innovation process in continuous motion. The fresh and optimistic atmosphere is essential for creativity. This can be a difficult task because what encourages and motivate a certain person does not necessarily encourage and motivate another. Nevertheless, general measures that would be applicable to most of the targeted innovators may be taken. In addition there are some special measures, which can be relevant to some individuals~~,~~ case-by-case. Some of those measures are given below:

(a) Creating a corporate atmosphere.
(b) Providing a comfortable working environment.
(c) Expressing the importance of the continuous flow of viable ideas.
(d) Appreciating and adopting good ideas.
(e) Providing rewards and incentives attractive to innovators.
(f) Linking the provision of good ideas and creativity to the promotion system in the organisation.

36. *Leadership.* The management of innovations has two parts; one is mechanistic administration and the other is leadership; the latter requires a charismatic approach to inspire staff to get the best out of them in order to maximise returns from the invested human, technical and financial resources, or the ability to obtain results from staff through personal example In innovative organisation the second part, i.e. leadership, is of paramount importance; but there is a role for both therefore project managers and team leaders should possess both administrative and leadership qualities. The following measure may be taken to provide a fertile environment for leadership:

(a) Enhancing and encouraging the leadership side of innovative management.
(b) Holding seminars and training courses on leadership.
(c) Encouraging risk taking and decision making.
(d) Encouraging management and employees to be active rather than reactive (take initiative).

37. *Empowering champions for the innovation process*. Project champion should be appointed and the management of innovative organisations should lay the ground and prepare a healthy atmosphere for innovations. The champions then should be given the responsibility to lead their projects. Champions are more of leaders than managers; they strive and maintain a dynamic atmosphere for the projects they are leading. The following steps may be taken for empowering champions:

(a) Provide the champions with guidelines only and leave the details for them to sort out.

(b) Establish a good pool of champions and train them as leaders.
(c) Make champions responsible and hold them accountable for their projects.

38. ***Enthusiasm of innovators.*** Innovators should have and maintain strong warmth and a feeling of keen interest in being creative constantly. Management should do all what it can to provide the necessary conditions to keep the innovators enthusiastic .The higher the level of enthusiasm, better will be the level of creativity. Some of the following steps may be taken to create and enhance innovators enthusiasm:

(a) Providing incentives.
(b) Letting innovators feel the taste of success.
(c) Providing freedom of work for the innovators.
(d) Providing and maintaining a challenging atmosphere to innovators.
(e) Shaping up innovators leadership.

39. ***Marshalling organisational resources.*** Provision of plentiful but scattered resources is just as bad as lack of them. Limited but well marshalled resources encourage innovative thinking. Therefore, good management of resources is essential for reducing risk and improving the chances of success for innovative project. The following measure may be taken to marshal organisational resources:

(a) Identifying resources.
(b) Making priorities for projects.
(c) Allocating resources to projects.
(d) Managing project resources through project managers and their teams.
(e) Providing support for project teams, in respect of the availability of resources.

40. ***Recognition and appreciation***. Part of reflecting a good healthy innovative environment is to provide an atmosphere of recognition and appreciation for staff, especially innovators. The greater the recognition and appreciation expressed for their ideas, the bigger the achievements in creativity and innovativeness. The following

measures may be taken to create an atmosphere of recognition and appreciation in an organisation:

(a) Showing respect for innovators.
(b) Providing incentives.
(c) Naming some of the innovations after their innovators.
(d) Making an honour list for innovators.

41. ***External environment.*** The management of an organisation is responsible for providing a healthy internal creative environment for the innovators, but there is also an external environment such as the political situation, economical situation, laws, regulations and market conditions that has an impact on the innovators as well as on the internal environment. Obviously, the management does not have control over the external environment, however, organisations should do their best with the help of other organisations to improve the external environment and treat it as uncertainties when doing the risk analysis for innovative projects. The following measures may be taken to minimise the risk due to adverse effect of the external environment:

(a) Conducting risk analysis for all innovative projects, bearing in mind the risk arising from external environment.
(b) Working with other organisation to improve the external environment.
(c) Avoiding projects, which require long time for execution because of the likelihood of changes in the external environment.
(d) Taking out some kind of insurance on innovative projects.

5.2.2 Factors That Influence the Innovators. The innovativeness of an engineering company depends on the innovators who are the source of innovations. The following section considers the factors which affect the innovators:

1. ***Innovators individual creativity.*** In the preceding section, creativity was considered from the environment point of view; in this section, creativity will be discussed from innovators' prospective. The innovator, who is a creative individual, generates new ideas or new methods of doing things. The question is: Are innovators talented from birth or they develop creative thinking through rigorous education? Since innovativeness depends on creativity, it would be helpful to understand how to develop creative thinking.

It is better to start with a person who has creativity in his/her genes, then educate and train such person to activate and enhance his/her creativity, but this dose not mean that creativity and innovativeness can not be taught. The following steps may help to establish and enhance individual creativity from the innovators prospective:

(a) Learning and practicing self-motivation, risk taking and social skills.

(b) Practicing different games, which activate creative thinking and problem solving.

(c) Attending seminars and training courses that enhance and raise the technological awareness of innovators.

(d) Feeling and showing strong personal commitment towards the organisation, the project and the customer.

(e) Taking the necessary measures to go through diverse experiences by working in diverse conditions in different subjects and fields.

(f) Aligning personal objectives with the organisational objectives.

2. ***Innovators group creativity.*** Group creativity is not the sum of individual's creativity, but it is a resultant creativity, which depends on the creative behaviour meditated through the group as influenced by the group's composition. The following measure may help to enhance group creativity:

(a) Joining a diverse but compatible innovative group.

(b) Strengthening the social ties with other members of the innovative group.

(c) Joining a group of creative individuals with similar personal objectives.

(d) Understanding and adopting organisational objectives.

3. ***Innovator's personal commitment.*** Innovators should feel committed to the project, to the organisation and to the customer. Lack of commitment means less commercially viable ideas. The commitment required could be established and enhanced by the following steps::

(a) Helping the organisation to providing a comfortable working atmosphere for fellow innovators.
(b) Understanding and believing in the organisational objectives.
(c) Coming closer to the customer and his needs.
(d) Feeling committed to the success of ideas.

4. ***Innovator's alignment of objectives.*** It is essential to align the objectives of the innovators with organisational objectives; otherwise a situation of conflict of interests will exist. The innovators should try from their side to align their own objectives with organisational objectives or at least do their best not to make their objectives in conflict with the organisational objectives. The following steps may be taken to align the objectives of the innovators:

(a) Understanding organisational objectives.
(b) To believe in and follow the organisational objectives.
(c) To align personal objectives with organisational objectives.

5. ***Innovator's risk orientation***. New or innovative ideas would invariably involve certain amount of risk. Therefore, innovators should expect and accept risk taking in the course of doing their work. Being risk oriented is necessary for trying new ideas. The following actions may help to enhance innovators' risk orientation:

(a) Understanding the concept of calculated risk and its adoption.
(b) Practicing and exercising on computer models instead of trials on actual prototypes "Computers Simulation"
(c) Conducting risk analysis before applying new ideas.
(d) Understanding and applying risk management measures.

6. ***Innovator's individualism***. Individualism is essential for creativity and innovativeness. Individualism puts a personal touch over new ideas and encourages continuous flow of new ideas. However, it is necessary to ensure that individualism does not or hinder interfere with teamwork or team sprit. The following steps may be taken to encourage individualism:

(a) Taking the necessary measures to enhance self-pride.
(b) Understanding the need for individualism as well as team sprit and where they apply.

7. ***Innovator's self-motivation***. Innovators should be self-motivated in order to ensure continuous flow of new ideas. The following steps may help to encourage self-motivation:

(a) Aligning own objectives with organisational objectives.
(b) Getting the right incentives.
(c) Feeling and living a continuous competition.
(d) Feeling and knowing customer needs.

8. ***Innovator's freedom of work***. Creativity requires the innovators to have freedom of work. This freedom comes from the comfortable innovative atmosphere provided by the organisation. The following actions may be helpful for enhancing the freedom of work for innovators:

(a) Reducing the interference from bureaucratic rules and regulations which may limit innovator's freedom of work.
(b) Establishing a friendly relationship with all colleagues.

9. ***Innovator's understanding of users' needs***. Innovations are about ideas that can be exploited commercially, and to be commercially successful requires user approval and acceptance. This implies innovators understanding of customers needs. The

following measures may be adopted to enhance innovators' understanding of user needs:

(a) Keeping closer observations of market needs.
(b) Developing innovative products to suit the prevailing economic state of markets

10. ***Use of outside technology and advice***. Innovators must have access to all available sources of ideas and awareness of high technology to ensure continuous flow of innovative ideas. The following steps may be taken in this regard:

(a) Communicating with external linkages such as universities, research institutes and colleagues in partner companies in order to gain fresh ideas.
(b) Socializing with innovators from other organisations and institutions.
(c) Staying in touch with the latest technology through the Internet, research papers, books and magazines.

11. ***Innovator's technological awareness***. Ideas for new competitive products require awareness of high technology. Therefore, innovators should be aware of the latest technologies in order to enrich their own knowledge. The following action may be taken to enhance innovators' technological awareness:

(a) Reading research reports and papers, scientific magazines and books.
(b) Attending specialist seminars and training courses.
(c) Interacting with scientists, researchers and innovators from other organisations.

12. ***Attentions to marketing*** .*The fruits of innovative ideas are* new products, which must be technically and commercially viable. Commercial viability of a product can be seen only through successful marketability. It is therefore important for innovators to

understand marketing issues in order to provide ideas coherent with market needs and marketing requirements. The following steps may be helpful in this regard::

(a) Studying the targeted market for proper appreciation of market needs.
(b) Having some marketing knowledge and skills.

5.2.3. Factors That Influence the Innovation Process. The innovation process is the third element, which determines the success of innovations or innovative projects. Therefore it is an important variable and it makes a significant contribution to the innovativeness of an organisation. The innovation process, in turn, depends on several factors described hereunder:

1. ***Studying and analysing innovative ideas***. Any project originates from an idea; this idea can come from customer need through the marketing department (market pull), or from the innovators in the R&D department (technology push). Then the idea gives birth to a project. This implies that this idea should be studied thoroughly and deeply to assess its feasibility and its technical and commercial viability. The analysis of the idea has to be done by a team of technical and commercial experts using an "innovative ideas investigation request" as shown in appendix B. The following steps may be taken to ensure feasibility of the idea:

(a) Ensuring that the idea is coherent with the political, economical and strategic factors.
(b) Making sure of the technical viability of the idea.
(c) Ensuring idea's commercial viability and its coherence with the market conditions.
(d) Ensuring the availability of resources for implementing the idea.
(e) Studying commercial, economical and technical risk embedded in implementation of ideas.

2. ***Technical viability***. All ideas should be analysed and studied for technical viability. This analysis is to check if the designs based on the innovative ideas can be transformed into hardware with the available personnel, skills, equipment and technical know how. It should be remembered that technical viability is a function of time and place, what is not viable today may be viable in the future because of the development of knowledge and expertise. In addition, what is not viable in an undeveloped country can be viable in an industrial country. The following steps may be taken to examine the technical viability of ideas:

(a) Testing of new ideas for technical viability as standard operating procedures.
(b) Employing expert personnel for testing and analysing new ideas.
(c) Using the right tools for evaluating news ideas.

3. ***Commercial viability.*** New ideas should be studied and analysed to check for commercial viability. Commercial viability includes knowing if there is a potential market or a potential customer for the outcome of the new ideas. This factor is also a function of time and place; what may be accepted by a certain customer in a certain place is not necessarily acceptable by another customer in a different place. In addition, the products acceptable today might not be acceptable tomorrow because of continuing development of designs and/or improvements of performance. The following are the guidelines for evaluating the commercial viability of ideas:

(a) Considering the evaluation of new ideas for commercial viability as standard operating procedures.
(b) Selecting expert responsible personnel for the commercial evaluation of new ideas.
(c) Using the right tools for evaluating news ideas.

4. ***Project definition and understanding user preferences.*** Determining the scope and the nature of the project in the light of user preferences are of vital importance for the success and marketability of innovations. The following ideas may be helpful in this regard:

(a) Appreciating and understanding user preferences.

(b) Finalising specific project definition and avoiding continuous major changes.

(c) Taking the necessary measures to insure that project managers and their teams do understand fully the scope and the nature of their projects.

5. ***Project feasibility study***. A project feasibility study must be carried out before adopting any project. Failing to conduct such a study may become the source of a serious risk for the project.

6. ***Preparation of precise specifications***. An experienced R&D team should prepare the exact specifications based on the user requirements and preferences. The following actions may be helpful in the preparation of precise specifications:

(a) Taking account of detailed user requirements.

(b) Conducting analysis on the environment where the output of the innovative project will be used.

(c) Employing an experienced technical team to derive the specifications from the user requirements.

7. ***Concept development.*** The R&D team should be able to present several concepts that reflect the derived specifications and fulfil the perceived or predicted customer requirements. The following steps may help to ensure good development of concepts:

(a) Employing experienced R&D team.

(b) Providing several concepts that suit the environmental and user requirements.

(c) Using computer techniques such as solid modelling for preparing several concepts, all to satisfy customer requirements

8. ***Concept selection.*** R&D normally provides several design concepts for each innovative idea in order to offer the customer the chance to select one to satisfy his/her personal preferences. R&D may make certain recommendations, taking into

consideration the areas of strength and weakness of each concept, favouring certain design. The following guidelines may be followed in selecting the right design concept:

(a) Explaining each concept in details and making a comparison between all available concepts.

(b) Using computer simulation and modelling to introduce the concepts to the customer.

(c) Making sure that concept selection is done by a true customer or an authorised representative capable of doing so. (This procedure used only innovative projects are contracted projects).

(d) In the case of a perceived or predicted future need and when confidentiality is of high importance, the task of concept selection should be given to a group of experts who represent the customer and who adhere strictly to the confidentiality criteria.

9. ***Risk management.*** In order maximise the chances of success it is essential to take all necessary measures to minimise risk in project execution. Risk management includes risk identification, risk analysis and risk response. The following steps may be taken for proper risk management:

(a) Identifying all sources of risk (internal & external).

(b) Identifying all sources of risk and analysing them to assess their magnitude.

(c) Preparing a risk response plan to face and minimise the influence of risks.

(d) Understanding that risk analysis is not a substitute for professional judgment but a supplement to it.

10. ***Project planning.*** Good project planning is of paramount importance for the success of innovations. Planning should include identifying all activities, determining their logical sequence, estimating execution times and the required resources for each. The following steps may help to enhance project planning:

(a) Preparing and presenting the project plan in a readily intelligible format.
(b) Getting approval for the prepared plan.
(c) Making sure that all concerned fully understanding the project plan.

11. ***Availability of resources for R&D.*** R&D resources are research laboratories, instrumentation, calibration facilities, model-shops, designers, draftsmen, design references, computer design packages, simulation packages, design tools and other equipment. The availability of such resources is of great importance and the lack of it will reflect negatively on the quality of research & design. The following steps are necessary to ensure the availability of R&D resources:

(a) Recruiting competent and innovative design office staff.
(b) Providing an innovative working environment for designers.
(c) Running continuing education and training programmes for the design office staff on regular intervals.
(d) Making the necessary design tools and equipment available.
(e) Using the latest solid modelling, design and simulation packages together with rapid prototyping equipment.
(f) Having well equipped research laboratories, stock of electronic instruments, repair & calibration facilities, etc.
(g) Encouraging R&D staffs to maintain close external links with universities, research institutes and professional bodies.

12. ***Availability of finance related to time scale.*** Availability of funds can be a major source of risk for the success of innovative projects. Estimates of funds for project should be reliable and expenditure of those funds should be kept under strict control and should not be allowed to outstrip work progress.

13. ***Availability of production personnel.*** Manufacturing of prototypes requires adequate numbers of competent production engineers and technicians to meet production schedule on time. Lack of appropriate human resources will reflect negatively on the delivery dates and also on the quality of prototypes due to work being rushed through. The following steps may help to ensure the availability of competent production staff:

(a) Recruiting competent and skilled production engineers and technicians.
(b) Ensuring the availability of the required technical skills.
(c) Providing training on regular basis to enhance personnel competency.
(d) Practicing total quality management.

14. ***Design for zero development***. Innovations are necessary for continuous development of products to prolong their life cycle but development should not be used for rectifying design faults. AS the cost of this type of developments is invariably very high. For competitiveness products should be designed with *the first time right design philosophy;* the target should be to aim for zero development. The following steps may be taken to pursue the philosophy of designing for zero development:

(a) Employing experienced designers.
(b) Using software packages such as solid modelling, CAE, CAD, etc as design aids.
(c) Exercising teamwork and team spirit extensively during this stage.

15. ***Logistic influence on design.*** Logistics impose their own requirements of the design of equipment. Some of these requirements are: easy transportability, immunity to shock and vibrations during transient, equipment comprising the minimum number of components for ease of maintenance in operation, etc. The following could be done to ensure that the logistic influence on designs has been considered:

(a) Analysing design concepts for logistic criteria before starting equipment design.

(b) Reflecting the logistical aspects on the designed equipment.

16. ***Generation of data packs and updates.*** All technical information to procure or manufacture materials and all documents that include the deign specification; concepts, calculations, drawings and build procedures, called data pack, should be generated and updated as necessary during the innovation process. Data packs are essential for production and future reference for modifications. Lack of data packs may cause non-uniformity and no standardisation in products. The following steps may be helpful in the generation updating of data packs:

(a) Training experts in the R&D department to generate and update data packs.

(b) Employing suitable computer software for data pack generation.

(c) Starting data packs generation at an early stage of the innovation process.

(d) Updating data packs and regularly making computer backup of data packs.

17. ***Prototyping***. Designs of complex engineering products represent approximations of a multitude of unknown; hence, they are based on many simplifying assumptions. Hence, the designer is always anxious: (i) to gain insight of the areas which may not be visible on two-dimensional drawings; and (ii) to check the desired functionality before starting to produce final manufacturing drawings. Building mock-ups and prototypes is a practical approach to dealing with these important but unknown areas. Now days the mock-up and prototyping approach has been replaced by solid modelling and running simulation programs. In the absence of these modern techniques, the designer has to rely on physical mock-ups and prototyping. The building of prototypes should be done through full cooperation with R&D and production departments. The following steps may be helpful at the prototyping stage:

(a) Making sure that employees understand the objectives of making prototypes.
(b) Building the prototypes should be done with joint efforts between R&D and production departments.
(c) Testing and evaluating designs and production quality should be conducted on the prototypes.
(d) Prototyping stage duration should be optimised (long enough to ensure product maturity and short enough to avoid early competition).

18. ***User evaluation and approval.*** This applies only to innovations in projects or in the design of equipment which is being produced under contract from a specific user. The user or his representative should approve prototype after checking that it meets user requirements. The following steps may be helpful in obtaining user approval:

(a) Testing and evaluation should be done according to well-established procedures.
(b) A prototype trial report should be generated and filed.
(c) A written approval of prototypes should be requested from the customer.

19. ***Manufacturing safety procedures***. Safety of personnel, equipment, premises and materials are of high importance to the innovative organisation. Setting up safety procedures for manufacturing and practicing them, promoting general awareness of safety among employees, conducting safety training programmes, providing safety tools and clothing and providing first aid kits on the shop floor can enhance safety. Lack of safety procedures may jeopardize the chances of success of innovative projects. Adopting the following safety procedures in the manufacturing environment may help to maintain safety at work:

(a) Promoting general awareness of safety among employees.
(b) Adopting the necessary safety measures.
(c) Conducting safety training programmes.

(d) Providing safety tools and cloths for employees.

(e) Making first aid kits available at key locations throughout the working environment, i.e. a factory or an office.

20. ***Value added element in production.*** The value of any product is made up of three main components, namely: (i) cost of materials; (ii) manufacturing cost and operational cost; and (iii) the value added element. The added value comes from the innovativeness of design, skills used for manufacturing a product to specified standards of quality. The contribution that manufacturing industries make to the national economy depends on the added value in the price of manufactured goods. Innovation plays a very important part in increasing the value added element. Larger the added value as percentage of the total price of manufactured goods, greater will be the contribution of those products to national prosperity. The following measures may be adopted to increase the magnitude of the added value in the total price of manufactured goods:

(a) Adopting good ideas and employing experienced designers to convert those ideas into good designs.

(b) Employing highly skilled production personnel to maintain the highest quality standards of manufactured goods.

(c) Using high precision production tools and equipment.

(d) Adopting the latest computational tools to design innovative products economically.

21. ***Cost and time for development.*** Time and cost are two major sources of risk for any project. Since development work is labour intensive the cost of development is usually very high. For this reason innovative organisations should aim for zero or minimum development, i.e. *doing it right from the first time* approach. The following steps may help in minimising development cost and shortening development time:

(a) Using computer design and simulation packages for reducing time to produce reduce designs of high quality innovative products.

(b) Understanding and practicing total design philosophy.

22. ***Creativity team in the innovation process***. The involvement of a creative team in the innovative process is of great importance. Members of the team should be innovative, compatible and diverse in skills. The following could be done to ensure the availability of a creative team involved in the innovation process:

(a) Employing creative people for implementing the innovation process.

(b) Making sure that people involved in the innovation process are compatible with each other and diverse in skills.

(c) Paying close attention to individual creativity and group creativity of the innovative team.

23. ***Teamwork and team spirit.*** The project team is a temporary organisation of people. Implementation of innovations requires collaboration between skills and talents of all to progress through the innovation process. Teamwork and team sprit is extremely important in the implementation of innovations. It is noteworthy that the group output of the team as a whole would be greater than the sum of the outputs of the individuals in the group. The group decision-making is likely to be better because a project team usually has a greater range of options that can be considered. It is the job of the project manager to facilitate the team's work and make it enjoyable. This may be achieved by establishing teamwork and team sprit among the team responsible for implementing innovations. The following steps may prove to be helpful in this regard:

(a) Selecting a team of people who believe in and practice teamwork.

(b) Directing managers, supervisors, team leaders and project managers to encourage and take the necessary measures to adopt and practice teamwork.

(c) Holding seminars on teamwork and team spirit and their importance.

24. *Logical flow of the innovation process.* The innovation process should be smooth, simple and logical in order to speed up the implementation of innovations. All employees should be familiar with the various stages of the adopted innovation process. The following steps may be taken to ensure logical flow of the innovation process:

(a) Keeping the innovation process simple and logical.
(b) Explaining the innovation process to all employees taking part in it.
(c) Planning and implementing feedback between the various stages of the innovation process.
(d) Providing all necessary tools such as computers, software packages, advanced equipment, communication equipment, etc. to speed up the implementation of the innovation process.

25. *Communications during the innovation process.* Collaboration, teamwork, exchange of ideas, removing barriers between organisational departments taking part in the process, e.g. R&D, production and marketing, and speeding up the innovation process require good communications. The following measures may be taken to establish good communications network:

(a) Bringing all departments involved in the innovation process close to each other geographically.
(b) Encouraging staff engineers and technicians to communicate with each other horizontally and discuss problem areas, progress, etc.
(c) Providing communications tools such as telephones and internal computer network.
(d) Keeping the organisational structure small and flat.
(e) Minimising bureaucracy in the organisation.

26. *Participation of production engineers in the innovation process*. The innovation process includes the design process which comprises several stages, the final stage being *Design for Manufacture.* The purpose of this stage to ensure the final product can be produced by using the available machines, material and manufacturing skills. Hence it is very important to involve production department in the innovation process in order to avoid major design changes. Major changes in designs at latter stages may be time consuming and costly; hence they can be a significant source of risk for the success of any project. Participation of production engineers in the innovation process can be beneficial also for exchange of ideas, expertise and knowledge between designers and production engineers. The following steps may help to ensure participation of production engineers in the innovation process:

(a) Planning and implementing an exchange programme.

(b) Planning and conducting joint R&D and production review meetings at several stages of the innovation process.

(c) Establishing and enhancing communications.

(d) Encouraging and providing the necessary tools for horizontal communication and interaction.

27. ***Compatibility within innovative team.*** Compatibility between members is the basic requirement to ensure teamwork and to foster team spirit among engineers and technicians involved in the innovation process. The following steps may be taken to enhance compatibility among members of the innovation team:

(a) Making sure that the innovative team does not have extremists or fanatics in their religious or political beliefs or extreme interests in sports among the innovative team members.

(b) Encouraging social interaction among the innovative team.

(c) Solving problems or personal differences collectively if possible.

(d) Convincing the innovative team that in order to succeed they should work towards being compatible with each other, i.e. they should think alike.

28. ***Customer participation in the innovation process.*** Innovative organisations should be market oriented and should keep the perceived or predicted needs and preferences of their markets in mind at all times during the innovation process. Participation of preferred customers in the innovation process is one approach to becoming market oriented. Customer participation starts right at the beginning of the innovation process. However, it is very important to keep the issues of confidentiality and competition always in mind

If the innovation is likely to become a patentable product then open customer participation must be avoided at all costs until the idea and the concept for the innovation have been patented.

29. ***Feedback between various stages of the innovation process.*** Each stage of the innovation process includes several measures and decisions. Some of the decisions require changes and updates on previous steps or they require passing the informing on to certain departments in the organisation. Therefore, feedback between the various stages of the innovation process is a necessity. The following steps may be taken to achieve proper feedback.

(a) Planning and pointing out feedback channels on the schematic charts of the innovation process and planning the implementation of such feedbacks.

(b) Explaining the concept of feedback and its importance to all personnel involved in the innovation process.

(c) Recording all updates and changes in accordance with the feedbacks that have already been enacted.

30. ***Availability of good quality production materials.*** High quality products require high quality production materials. Using poor quality materials can be a major source of risk to the success of products. The following could be done in this regard:

(a) Ensuring that all employees understand and appreciate the importance of using good quality production materials and bought in components.

(b) Adopting tight acceptance test backed by quality control measures for materials and components coming into a manufacturing plant.

31. ***Accuracy of test instruments and production equipment***. In order to maintain high quality standards, innovative organisations should focus on maintaining the quality of machine tools and the precision of on all measuring and test instruments. The following procedures may be adopted to preserve quality:

(a) Using high precision test and measuring instruments as well as good quality machine tools and other production equipment.
(b) Maintaining and calibrating all testing and production equipment regularly.
(c) Upgrading machine tools and other shop equipment test and measuring instruments, etc as and when necessary.

32. ***Integration of the innovation process.*** The innovation process should have personnel who possess the various skills needed to complete the innovation project, suitable equipment, the necessary production materials, etc. They should all integrated together to form a continuous and well-managed innovation process. Lack of integration may result in either expensive duplication of some work or unnecessary halts, thus increasing the project risk from the time as well as overall cost point of view. The following steps may be taken to achieve proper integration of the innovation process:

(a) Preparing a detailed and workable project plan.
(b) Understanding and explaining the role of each individual and of the department as a whole related to the project.
(c) Ensuring continuous and smooth flow of work in order to avoid unnecessary halts or delays.

33. ***Following the skunk work style.*** The project team should consist of engineers, technicians, designers and model makers with necessary skills to take ownership of the project. They should all be committed to the success of the project and follow skunk work style, which has proved to be an efficient method for executing and managing innovative projects. The following actions may be helpful in this regard:

(a) Understanding the concept of skunk work style by all employees.

(b) Adopting the skunk work style by the management for executing innovative projects.

(c) Managing human resources efficiently. One of the methods for achieving this is to ensure that the project team includes selected individuals with particular skills from different departments and using them only as and when needed. Otherwise they stay in their respective departments.

34. ***Freedom and control in the innovation process***. The innovation process should be managed tactfully. Members of the innovation teams should have freedom of work but controls are necessary to ensure that good discipline is maintained and wasteful use of resources is not allowed. Misuse of freedom or bureaucratic controls could easily become a major source of risk to the successful implementation of innovation.

35. ***Product data management (PDM).*** Projects dealing with Innovations may produce large volumes of data. The use of modern computers equipped with PDM systems is necessary for efficient management of these data and rapid execution of innovative projects. The project manager would be responsible for following steps: may be taken to promote product data management:

(a) Understanding the product data management system and adopting it

(b) Ensuring availability of hardware, software and expertise needed for the adoption of product data management.

36. ***Project management.*** Efficient project management is essential for the success of any project, hence selecting a competent project manager is very important. The project manager should be made responsible for the following:

(a) Defining critical paths for all innovative projects.

(b) Ensuring that time for each project has been properly allocated; project teams keep to the allocated time and maintains their focus.

(c) Making use of all available project planning tools.

(d) Identifying slack time properly and reallocating it to projects.

(e) Identifying and marking critical milestones projects.

(f) Setting up management' review schedules.

(g) Confirming support systems for all projects.

(h) Ensuring that conditions for all remain the same as those when the projects were initially launched.

(i) Ensuring that the initial objectives of projects are still valid and attainable.

(j) Reviewing and validating all assumptions relating to the projects.

(k) Ensuring that scopes of project do not change as the work progresses.

(l) Ensuring that projects are not impacted by any outside influences that could negatively alter schedules, costs, or performance of projects.

(m) Ensuring that management does not alter without reasons the original priorities assigned to the projects.

(n) Making sure that project expectations are not changed since the projects were started.

5.3 PROCESS OF MANAGING INNOVATIONS.

The process of managing innovations in engineering industries comprises three main components, namely: (i) managing the innovative environment; (ii) managing the innovators; and (iii) managing the innovation process. Each component is influenced by a large number of intangible variables. Some of these variables are common to all three principal components but it should be noted that their influence on each component may not be the same.

At this juncture it would be pertinent to review briefly the available methods that have been used by other researchers to study similar problems which are characterised by a large number of intangible variables.

In general, problems for computer analyses may be classified into two categories, namely: numerical problems and non-numerical problems. Problems in the first category are encountered in the fields of natural sciences and applied sciences such as biology, physics or engineering; and those in the second category in such diverse fields as social sciences, management, law, history, languages, etc. The technique for writing and developing computer codes for solving non-numerical problems is to first reduce the relevant data into numerical form and then to use well-established algorithms for analysing the numerical data.

Most widely used method for dealing with non-numerical problems is to use questionnaires. The questionnaire for a particular problem may be designed for either:

(a) Multiple choice answers;
(b) Yes/No answers which may be influenced by the prejudices and preferences of the individual who provides responses to the questionnaire;
(c) Giving a mark out of a range, say ten, for each question after a careful consideration of the reliability and relevance of the responses.

The first is prone to produce results, which may be based on either chance, or guesswork, the second does not offer any scope for making a carefully considered assessment. The third method is more likely to produce realistic responses as the person completing the questionnaire has to exercise personal judgment to evaluate the answer to each question within the specified range.

5.3.1 Justification of the Analysis Procedure. In view of these considerations, it was justified to use the third method to analyse responses to questionnaires related to two most important management functions: (i) to assess the innovativeness of engineering companies; and (ii) to analyse the risks involved in accepting and executing innovative projects.

It would be pertinent at this juncture to mention also that computer jargon often refers to modelling and simulation without making a clear distinction between these two terms. It should be noted that these two terms are not synonymous; modelling usually refers to the representation of a physical system in a suitable analytical form which can be programmed, and simulation refers to running that program to reproduce the operating behaviour of the of that physical system.

In the research reported here modelling refers to the representation of the problem of managing innovation which is a function of large number of intangible variables; they cannot be assigned algebraic or numerical values. Therefore, two questionnaires have been used to obtain responses in numerical form for each variable. Both questionnaires were designed with due care to ensure that the analysis of the responses would not produce biased results.

5.4 COMPUTER AIDED-MANAGEMENT (*CAM*).

Management of innovations in engineering industries has been considered under three main activities, namely: (i) managing innovative environment; (ii) managing innovators; and (iii) managing the innovation process. Each activity is multidimensional involving a large number of intangible factors.

The task for the management is: (a) to assess the innovativeness of engineering companies with reference to the three aforementioned factors; and (b) to analyse the risk surrounding the execution of innovation. However, the management task is very complex and not amenable to standard analysis because of the intangible nature of the variable that characterise the management system.

With suitable software, computers may be used to deal with all aspects of management such as improving product quality, reducing manufacturing costs, lowering risk, shortening the duration of the innovation process, simplifying innovation complexities, etc. One of the aims of this research was to produce such software.

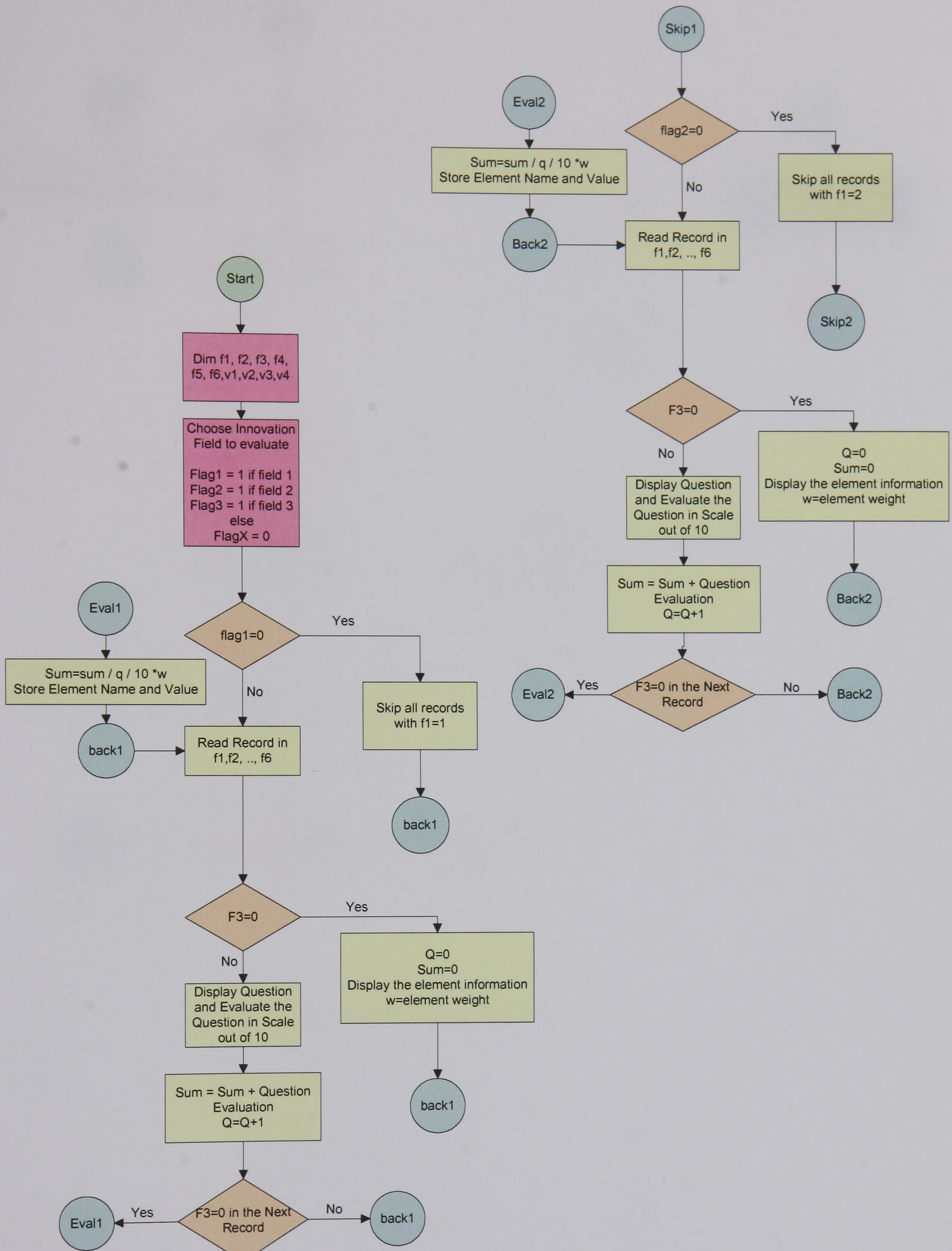
A suite of two analysis applications has been developed by the author to ease the task of managing innovations. Both applications are written in Visual Basic. They are interactive, based on carefully designed questionnaires, and may be used as a tool for computer-aided management (*CAM*) of the multidimensional problem as described earlier.

5.4.1 Application I – Innovativeness of Engineering Companies. The first application is used to assess innovativeness of organisations by evaluating their three principal components mentioned earlier. A flow diagram of the application is shown in Fig. 5.1. This application starts by asking the assessor to log in and enter certain identifying data such as the name and address of company or organisation that is being assessed. Then, the assessor is given the choice of assessing one of the three principal components, i.e. innovative environment, innovators and the innovation process. This is followed by the assessment process which starts with the relevant questionnaire. Assessing the innovative environment consists of 41 interrelated factors; evaluating the innovators involves 12 factors and assessing the innovation process considers 36 factors.

The assessment is carried out by taking each factor in turn; the analysis application then asks a series of questions, which the assessor must answer by assigning marks on a scale out of 10. The 89 factors and their definitions together with their unit values and the questions on each factor are given in appendix C; a sample of the information on each factor is shown in the following Table 5.1. Each factor is given a unit value based on the personal experience of the author. In addition, each factor is assessed as excellent, vary good, good, fair or poor.

Factor	Definitions of Factors and Questions	Unit Value	Principal Component
Creativity	Creativity is about generating new ideas, or new ways of doing things. In fact the whole innovation process is built around creativity, so it is the basic requirement for innovativeness. A creative individual can produce new ideas, new solutions, new ways, shortcuts, rapid spontaneous response, etc., but creative organisations rely on creative individuals, creative solutions, creative processes, creative products and creative situations.	6	Creative environment
	To what extent does the organisation enhance employee's personal characteristics such as: self-motivation, risk orientation, social skills, and technological competence?		
	To what extent does the organisation reflect social environment factors such as: freedom, challenge, encouragement, recognition, etc.?		
	To what extent does the organisation promote group characteristics such as: leadership, cohesiveness, group longevity, group composition, group structure, communication patterns, etc.?		
	To what extent does the organisation strive to adopt creative processes, creative solutions, creative products and creative situations?		

Table 5.1


Start
Dim f1, f2, f3, f4, f5, f6,v1,v2,v3,v4
Choose Innovation Field to evaluate
Flag1 = 1 if field 1
Flag2 = 1 if field 2
Flag3 = 1 if field 3
else
FlagX = 0
Eval1
Sum=sum / q / 10 *w
Store Element Name and Value
back1
flag1=0
Yes
No
Skip all records with f1=1
back1
Read Record in f1,f2, .., f6
F3=0
Yes
No
Q=0
Sum=0
Display the element information
w=element weight
back1
Display Question and Evaluate the Question in Scale out of 10
Sum = Sum + Question Evaluation
Q=Q+1
Eval1
Yes
F3=0 in the Next Record
No
back1
Skip1
Eval2
Sum=sum / q / 10 *w
Store Element Name and Value
Back2
flag2=0
Yes
No
Skip all records with f1=2
Skip2
Read Record in f1,f2, .., f6
F3=0
Yes
No
Q=0
Sum=0
Display the element information
w=element weight
Back2
Display Question and Evaluate the Question in Scale out of 10
Sum = Sum + Question Evaluation
Q=Q+1
Eval2
Yes
F3=0 in the Next Record
No
Back2

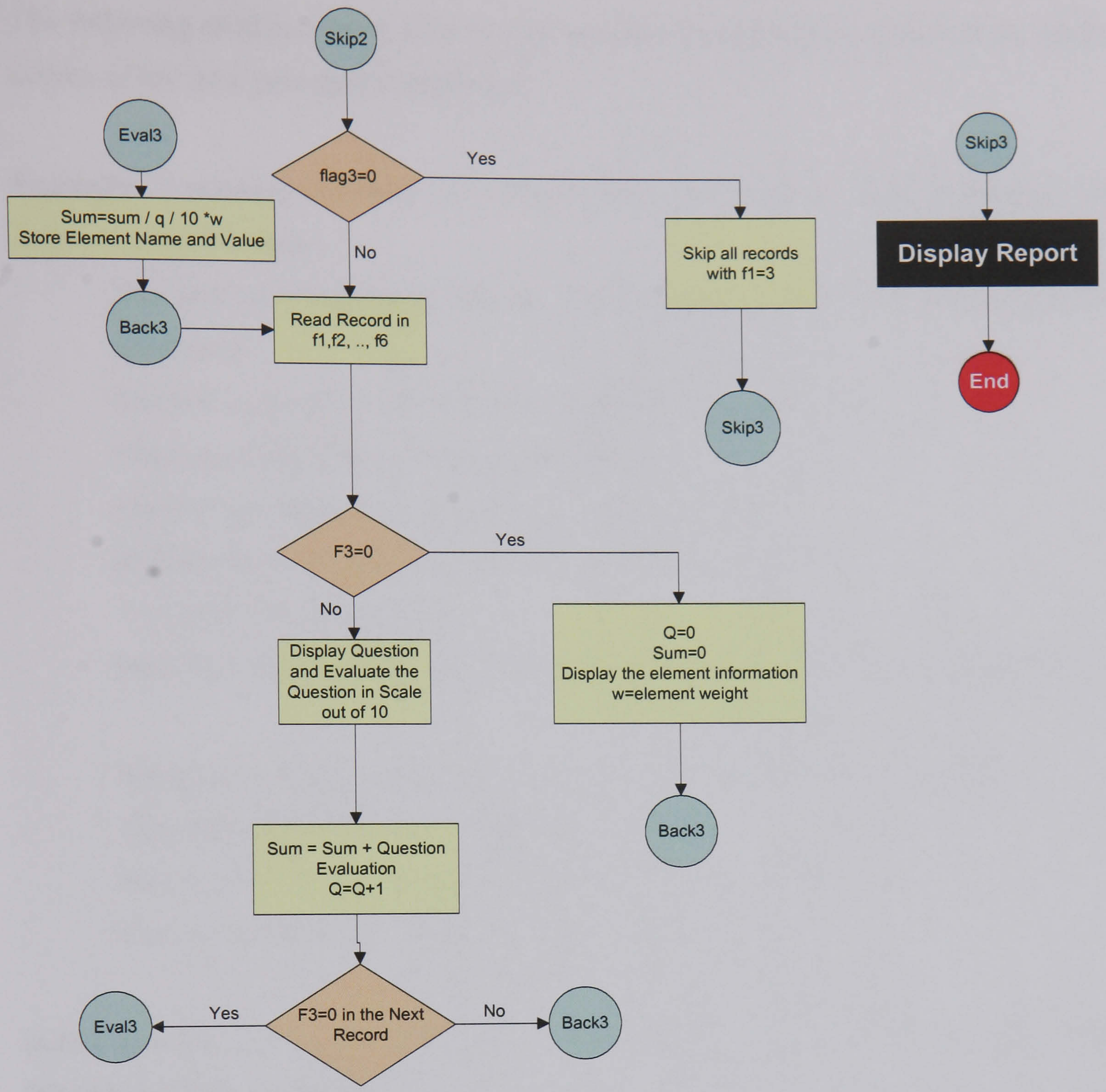


Fig. 5.1 Flowchart (Application I)

The following example shows how the assessment computation is carried out for all the factors of the three principal components.

Example: Assessing *creativity* as a factor that influences the management of the innovative environment.

- The maximum unit value that can be given to this factor is 6, as shown in the table above.
- Number of questions in the questionnaire on this factor are 4.
- Then each question is worth 6/4 unit value.
- The user evaluates each question on a scale out of 10.
- Assume the user has evaluated the 4 questions as follows:
  7/10, 9/10, 5/10 and 2/10.
- Then the user estimated value for creativity = (7/10 + 9/10 + 5/10 + 2/10) (6/4)
  = 3.45 unit value.
- Percentage estimated value for creativity = (3.45/6) x100%= 57.5 %.
- The evaluation criteria is as follows:
  Poor < 60%, Fair ≥60% and < 70%, Good ≥70% and < 80%
  Very Good ≥80% and < 90%, Finally, Excellent ≥ 90%.

In this example the *creativity* reflected by the innovative environment according to the following criteria, is <u>POOR.</u>

It was discussed earlier that the principal components and their sub components exercised a significant influence on the management of innovations in engineering companies. These influences are shown diagrammatically in Fig. 5.2.

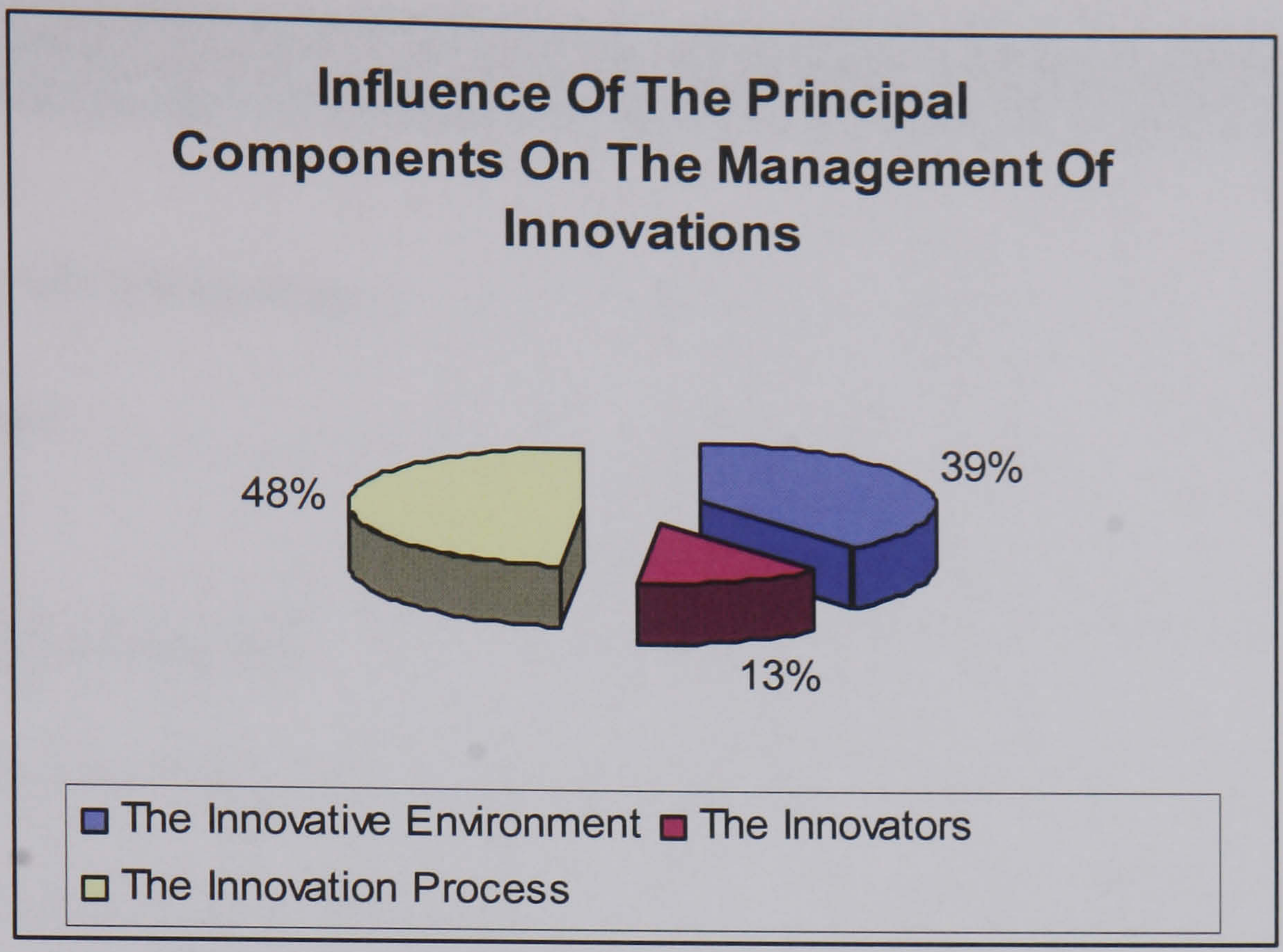


Fig. 5.2 The influence of the principal components.

The outcome of the complete assessment is presented in the form of a report; the format of the reports is shown in Fig. 5.3. Actual samples of these reports are shown in appendices E, F, G and H. The assessment of these organisations can also be shown in the form of curves as illustrated in Fig.5.4.

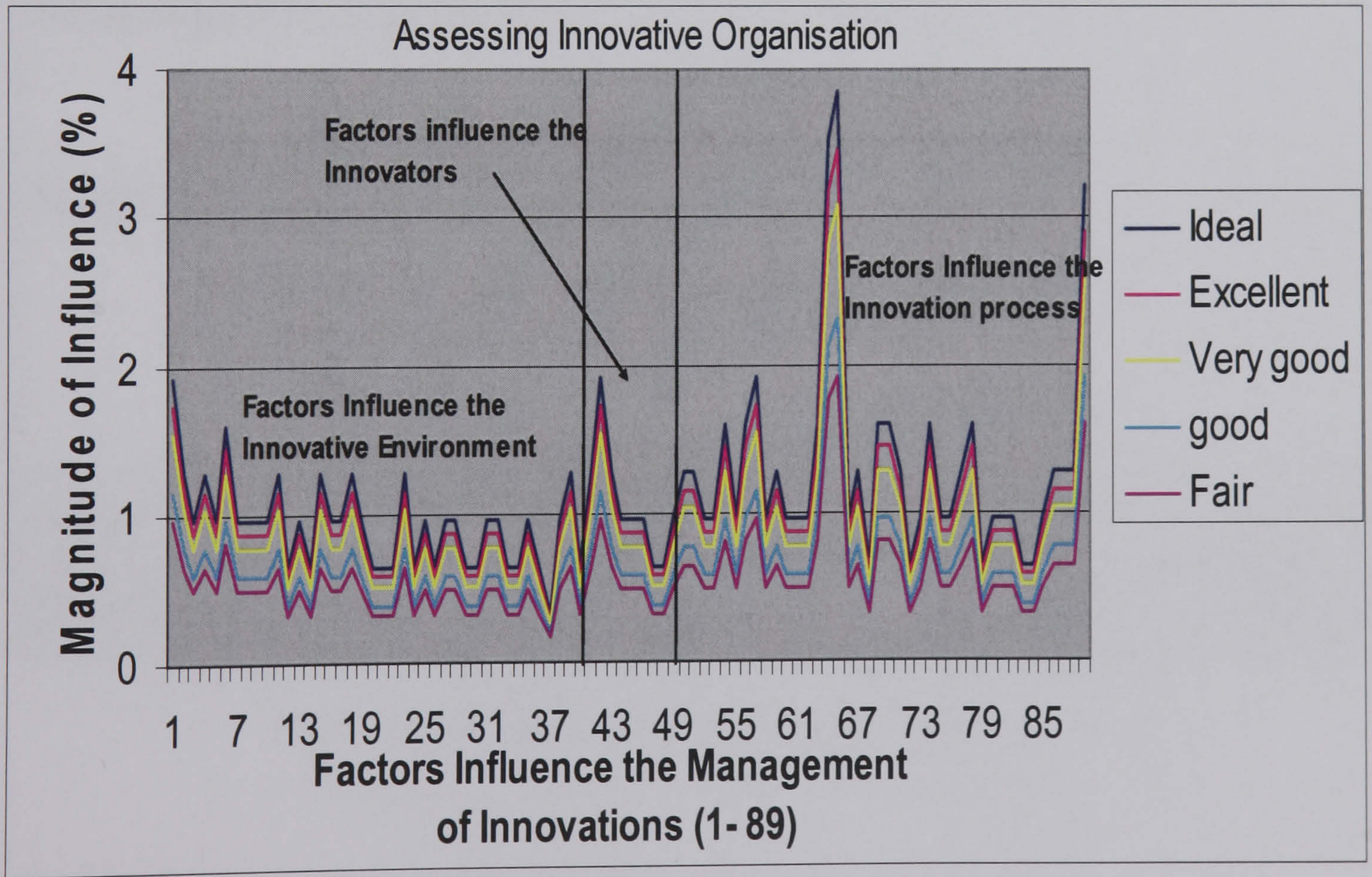


Fig. 5.4 Assessing innovative organisations

Innovative Organisation Evaluation Report

Name Of Organisation: ....

Address: ....

....

Executive Summary

* The innovative environment in the organisation is ....

* The innovators in the organisation is ....

* The innovation process in the organisation is ....

Evaluation of the innovative environment

Evaluation of the innovators

Evaluation of the innovation process

____________________________ __________________

Name and signature of the evaluator Date

Fig. 5.3. Innovative organisations evaluation report.

5.4.2 Application II – Risk Analysis in Project Management.

This application was designed to assess the risk that might be encountered during the execution of innovative projects. The aim was to help the management to choose a rational response to the degree of exposure to the risk during the execution of certain project. It is important to note that this application is used only as a tool and not as a substitute for professional judgment. The flow diagram of this application is shown in Fig. 5.5.

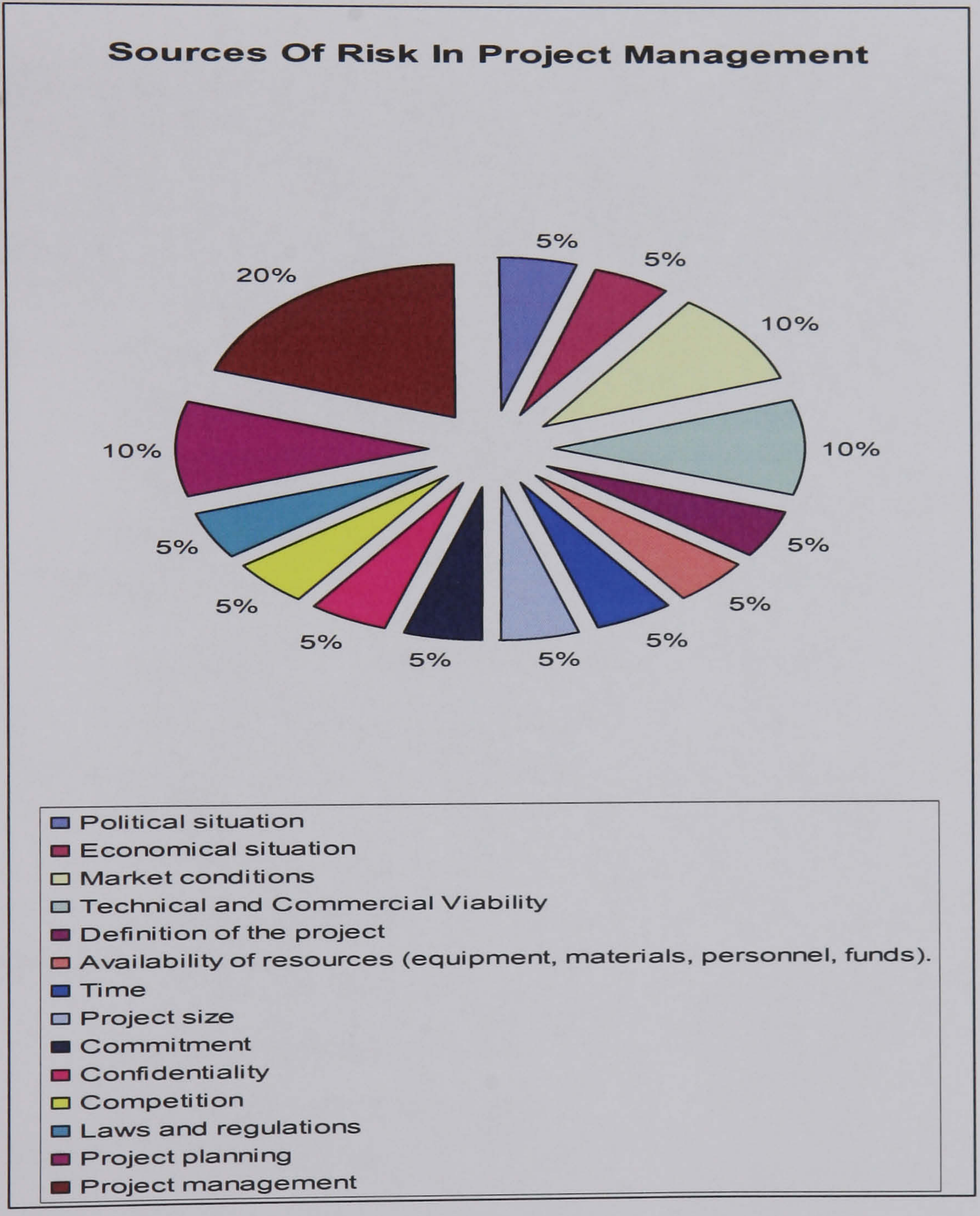


Fig.5.6 Sources of risk in project management

The Application starts by requesting the user to enter the company name, company address and project name. Then it introduces all sources of risk by defining each source and asking several questions on each of the sources of risk shown diagrammatically in Fig. 5.6. The evaluator answers each question on a scale out of 10, bearing in mind that the lower the risk the higher would be the mark on the scale and visa versa. The process continues until all the sources of possible risk are assessed. The sources of risk, their definition, the size of risk and related questions are in given in the database, Appendix D. A sample of the information taken from that database is shown Table 5.2 below.

Source of Risk	**Definition and Questions on Sources of Risk**	**Maximum Risk in Unit Value**
Technical and Commercial Viability	Successful projects are usually built around good ideas, which are technically and commercially viable; otherwise, a big source of risk exists right at the starting point, which most properly will decide the fate of the project.	10
	How much do you evaluate the efforts in considering the evaluating the project from technical and commercial viability?	
	How much do you evaluate the efforts in selecting expert responsible personnel for the technical and commercial evaluation of the project?	
	How much do you evaluate the efforts in using the right tools for evaluating the project from technical and commercial point view?	

Table 5.2

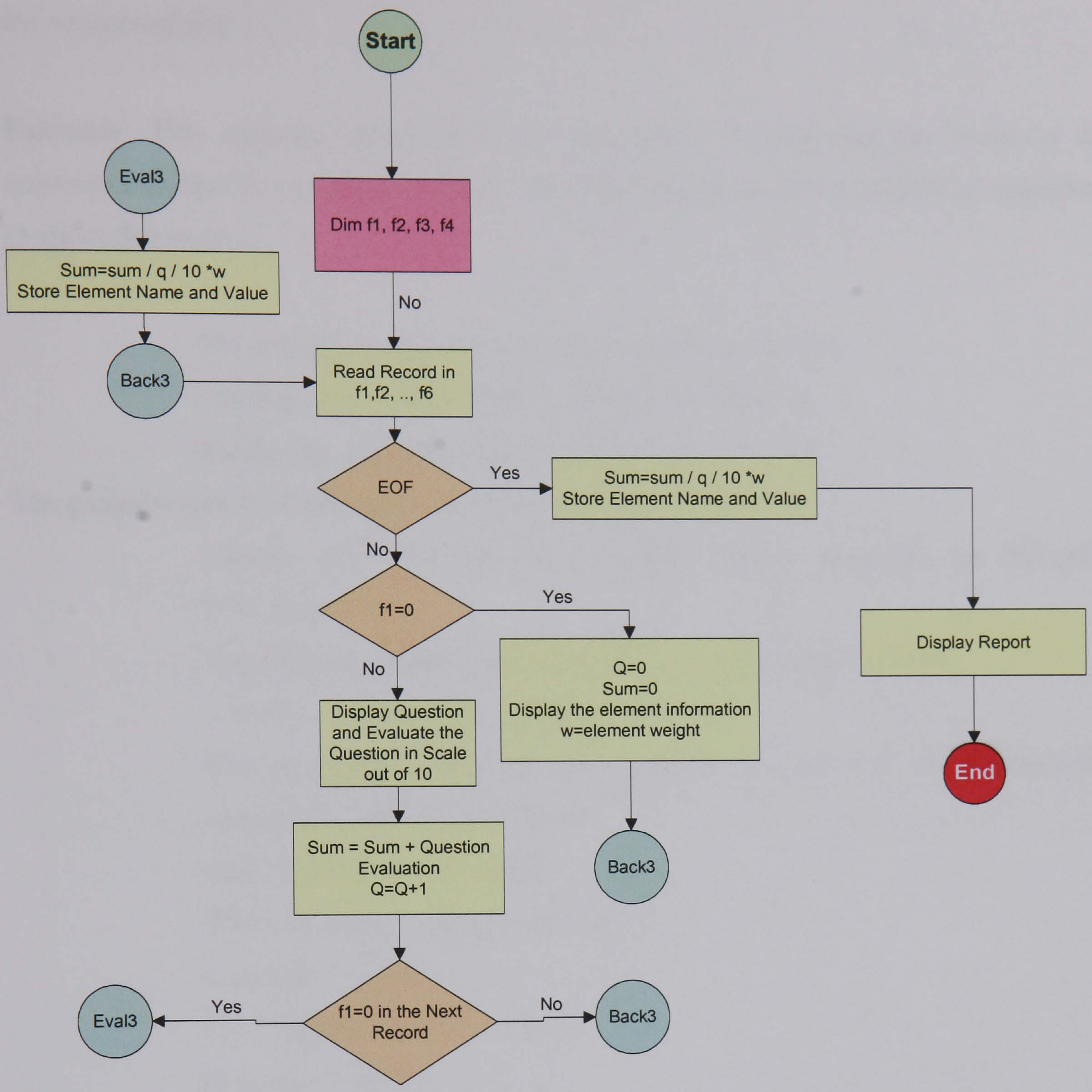


Fig.5.5 Flowchart (Application II)

The following example shows how the assessment computation is carried out for all of the sources of risk.

Example: This example demonstrates the procedure for assessing the *technical & commercial viability* as a source of risk. The following is the data available in appendix D about this source:

- The maximum unit value given to this factor is = 10.
- Number of questions on this source of risk are = 3.
- Hence, the unit value of each question is.... = 10/3.

The program user evaluates each question on a scale out of = 10.

- Assume that the user has evaluated the 3 questions as follows: 7/10, 9/10, 5/10.
- Then the user assessment for *technical & commercial viability* = (7/10 + 9/10 + 5/10) x 10/3 = 7 unit value.
- The percentage value of user assessed for *technical & commercial viability* = (7/10) x 100 = 70 %.
- Risk = 100% - 70% = 30%.
- The evaluation criteria is as follows:

  Low risk < = 15%

  15% < Medium risk < = 40%

  High risk > 40%

Then the risk in the *technical & commercial viability* of this project according to the evaluation criteria is <u>MEDIUM</u>.

The outcome of this analysis is presented in the form of a report, the format of which is shown in Fig. 5.7. Actual samples of these reports are given in appendices I and J.

RISK ANALYSIS IN PROJECT MANAGEMENT REPORT

Name Of Organisation:...

Address: ....

....

Project Description:...

Executive Summary

* Project risk = [? %]
* Project risk is [Low, Medium, High]

Evaluation of the project risk

____________________________ __________________

Name and signature of the evaluator Date

Fig. 5.7 Risk evaluation report for innovative projects.

CHAPTER 6
CASE STUDIES

6.1 INTRODUCTION.

6.2 ASSESSMENT OF INNOVATIVENESS - CASE STUDIES.

6.3 RISK ANALYSIS - CASE STUDIES.

6.1 INTRODUCTION.

Most significant part of this research is the development of two questionnaires based computer analysis procedures, which are the core of a software package for computer-aided management (*CAM*). The first procedure, the management model, deals with the assessment of the innovativeness of engineering companies and the second, the risk analysis model, which predicts the risks likely to be encountered in the acceptance or the execution of innovative ideas or innovative projects. Although adequate precautions were taken in designing the questionnaires to ensure that they would not produce unfair or biased results, it was still necessary to test both procedures for their reliability. The tests were carried out by means of real life case studies. This chapter presents the results of the case studies.

6.2 ASSESSMENT OF INNOVATIVENESS - CASE STUDIES.

Four engineering organisations were chosen from different geographical regions around the globe: two from Asia, one from Africa and one from Europe. The details of how the surveys were carried out and the results are given below.

6.2.1. Case Study I - Company A – Jordan.

Company A is an agency of the Jordanian Government, which was established officially by Royal Decree on 24th August 1999. The company is an independent organisation managed by a steering committee reporting directly to His Majesty the King of Jordan. The long-term goal of the organisation is to develop an indigenous, self-sufficient and financially self-supporting engineering research and design facility to support the development of sound manufacturing capability for producing engineering equipment of high quality at competitive prices for both national as well as international markets. The organisation has been structured, both in terms of staff and facilities, to achieve its goals. The operational structure includes two main groups: the Engineering Group and the Business Development Group; the latter comprises Market Intelligence Team, Marketing and Sales Team, Marketing Support and Commercial Operations Team. The scope of work of the Engineering Group covers the full spectrum of research, design and development, starting with user requirement definition, through conceptual design and continuous development of products to the identification and acquisition of enabling technologies. This process is then followed by prototyping, evaluation trials, optimisation and finally the commercialisation of products which includes the preparation of manufacturing data packs.

Company Mission

The company mission is to create the conditions for the establishment of an independent and sustainable industrial base within Jordan.

Staff Profile. The company has 206 employees. Twenty-eight are professionally qualified and experienced engineers, 26 of these are mechanical engineers and 2 are electronic engineers. Twenty-one are project managers; two are about to complete their research programmes for PhD degrees of a reputable university in the United Kingdom through part studies. The company retains the services of three consultant engineers, one of whom acts as Science and Technology Advisor to the Steering Committee. The Design Office is staffed by 7. Bachelors degree holders and one PhD. General administration and support staff includes 6 sales and marketing personnel with Bachelor degrees, 2 lawyers handling contracts, 8 fully qualified accountants, 5 IT data processing personnel, 4 office managers with Bachelor degrees, 4 clerk typists, 5 technical clerks, 20 electricians, 29 mechanics, 2 carpenters, 31 welders, 21 machinists, 2 store keepers, 4 drivers, and a number of cleaning, security and services personnel.

A major weakness of the company is that engineering staff, although well qualified, most of them did not undergo practical training and they lack the all important industrial experience. The obvious consequence of this weakness is that they do not have a feel for innovative ideas; consequently, they cannot contribute to the development of innovations. Appreciation of real life industrial problems is a prerequisite for innovative ideas. However, it should be noted that this weakness is not peculiar to engineering companies in Jordan only; companies in almost all developing countries face the same problem.

Achievements. In the three years since its establishment, the company has been fully engaged in 28 projects, six of which have been completed or are approaching the completion stage. Each project has a designated project manager who heads the project team. The projects range, to mention a few, includes the Black Iris, a cost-effective, light weight and affordable utility vehicle suitable for a number of uses in the sandy terrain and dusty climate of the Middle East, a multi-purpose tactical intervention vehicle optimised for service in the Middle East and, in conjunction with Rokon, a Desert Ranger dual-wheel drive motorcycle for Middle East applications. Some advanced projects including research and design of a 60 kW direct-drive turbo-alternator running at the design speed of 60,000 rev/min for emergency use are being studied in collaboration with a premier university in the UK. Other projects, for example a solar powered car, are in the early stages of development. The company has taken part in a number of well-recognised national and international exhibitions, conferences and seminars.

<u>Discussion of the Results of Assessment</u>

(a) The results of the assessment showed that company A was below average as an innovative organisation. In view of the enviable social status of the company and its staff profile, the below average rating in terms of innovativeness is indeed disturbing and deserves some explanation. The attributes normally required for innovations are: good understanding of the present status of the product, which has to be remodelled (i.e. is the subject of innovation) in order to: (a) extend its life cycle, improve its performance, upgrade its design, etc. The company is pre-occupied by the numbers of projects it is handling; consequently, technical staff does not get any opportunity to think about innovations. It would be a mistake to rate mundane developments as innovations because this would inevitably give a false sense of achievement to technical staff.

(b) The innovative environment was found to be below average with one area of strength i.e. the conveyance and execution of ideas and work. But this was offset by the following areas of weakness: vision and objectives projection, provision of innovative receptive atmosphere, reflection of market needs, programme selection, application of multiple innovative or parallel approaches, application of shoot-outs between parallel approaches, evaluation and quality assurance standards and procedures, organisational internal social environment, usage of procedures, guidelines and checklists, challenge in the innovative environment, adoption of interactive learning, acceptance to individualism when it comes to the provision of ideas, reflection of risk taking, reflection of corporate environment, leadership in the organisation, empowerment of champions to drive the innovation process, the atmosphere of enthusiasm for the innovators and the atmosphere of recognition and appreciation.

(c) The innovation process also was assessed as average with following strengths and weaknesses:

(i) Areas of strength were: the availability of finance related to time scale, data pack generation and update, user evaluation and approval of prototypes, customer participation in the innovation process and the integration of the innovation process.

(ii) Areas of weakness were: lack of innovative ideas and poor assessment of the technical and commercial viability of those few which were presented, the assessment of project feasibility, risk management, the reflection of logistic influence on design, teamwork and team spirit, the feedback between stages of the innovation process and product data management (PDM).

(d) The innovators in the organisation were assessed to be below average with no areas of strength and the following areas of weaknesses: the innovator's individual creativity, risk orientation and attention to marketing. Most serious problem was their out of date scientific and professional knowledge which is the key to innovations.

(d) The computer analysis was used by the Deputy Director General to evaluate company A; it was able to identify 6 specific areas of strength and 28 specific areas of weakness.

The results of the assessment seemed to be reliable but were disturbing indeed. However, the computer analysis could be considered to have proved to be a useful management tool.

Summary of Results

- The innovative environment at company A was found to lie between fair and below average range.
- The innovators in company A were also assessed as fair to below average.
- The innovation process at company A was evaluated and found to be average to good.

The detailed evaluation report is shown in appendix E.

6.2.2. Case Study II - Company B - Jordan.

This company established in 1972 as a semi government scientific organisation, is responsible for carrying out research and advanced studies. The whole organisation is structured around several Divisions; the assessment was limited only to the operation of one Division of the organisation, hereafter called the company.

Company Mission

The mission of the company is to conduct applied research and provide specialised training in computer technology and industrial studies. In addition, the company is responsible also for software development for a range of administrative scientific and industrial applications, and developing computer systems for institutions in both the public and the private sectors.

Staff Profile. This company has 11 senior system analysts, 4 system analysts, 2 assistant system analysts, 5 senior programmers, 21 programmers, 9 information scientists, 1 industrial engineer, 13 economists, 5 maintenance engineers, 5 operators, 11 technicians and 7 administrators. In terms of academic qualifications, the company has a staff compliment of 2 PhDs, 10 M.A. / M.Sc., 47 B.A. / B.Sc., 20 holders of Diplomas and 25 others.

Achievements. The company has provided consultancies, carried out technical studies, and undertaken software development projects for scientific applications in engineering designs and statistical analyses and provided information services to more than 150 local and international institutions.

The company is a well-established centre for IT training and has conducted over 500 specialized short courses attended by more than 6000 individuals.

Discussion of the Results of Assessment

(a) The results of the assessment showed that on overall rating for innovations, company B was average. In view of the fact that the primary function of this company is research in the broad field of Information Technology, its record of innovations is disappointing. IT is a new industry, therefore it offers ample scope for innovations in software development for specialist applications such as engineering, telecommunications, biomedical, digital control, to name a few. Lack of innovations should be a matter of serious concern for the company and efforts should be made to explore, bearing in mind the high level of academic qualifications of its staff, the reasons for a poor record of innovations.

(b) The innovative environment was also found to be average with the following strengths and weaknesses:

(i) Areas of strength were: creative environment, vision and objectives projection, commitment reflected by the innovative environment, reflection of market needs, management guidance, reflection of desire to advance, application of multiple or parallel innovative approaches, evaluation and quality assurance standards and procedures, centre external linkages, job security of employees, safety measures in the centre, communication facilities and system, adoption of interactive learning, conveyance and execution of ideas and work, marshalling of the company resources and the atmosphere of recognition and appreciation.

(ii) Areas of weakness were: the provision of innovations receptive atmosphere and the acceptance of individualism in generating ideas.

(c) The innovation process was assessed and found to be average with the following areas of strengths and weaknesses:

(i) Areas of strength were: project definition and understanding of user requirements, assessment of project feasibility, concept development, project planning, availability of production personnel, data pack generation and update, user evaluation and approval of prototypes, value added element in products, creativity of the team involved in the innovation process, teamwork and team spirit, communications during the innovation process, customer participation in the innovation process, feedback between stages of the innovation process, availability of good quality production materials, good integration of the innovation process, application of the skunk work style, balance of freedom and control through the innovation process, product data management (PDM) and project management.

(ii) Areas of weakness were: the assessment of the technical and commercial viability of ideas, risk management, availability of R&D resources, adoption and application of design for zero development and the reflection of logistic influence on design.

(iii)The innovators in the centre were assessed to be average without any areas of strength but the following weaknesses: innovators risk orientation, individualism as related to creativity, self-motivation, technology awareness and attention to marketing.

The computer analysis was used by the Director of the company B to evaluate its innovativeness; the computer analysis was able to identify 35 specific areas of strength and 13 specific areas of weakness.

Summary of Results

- The innovative environment at company B was assessed and found to be good to average.
- The innovators at company B were also evaluated and found to be good to average.
- The innovation process adopted at company B was assessed and also was found to be around average to good.

The detailed evaluation report is shown in appendix F.

6.2.3. Case Study III - Company C - South Africa.

This privately owned company was founded in 1997. It has sourced personnel from the South African Military and Engineering Development Industry. The company specialises in automotive and related development and it is currently engaged in approved international contracts in this field. The company has no product affiliations but it is an accredited automotive design authority for MAN (SA) & Land Rover (SA).

Company Mission

The company's primary function is the application of internal and networked infrastructure, creativity in conceptualisation, design skills, development techniques and mature product technology. The aim is to enable the low to medium volume delivery of competent and integrated product systems of appropriate complexity within a suitable financial and project structure, for operational deployment and financial exploitation by the user or the client.

Staff Profile. A core team of 15 people is employed full time comprising 4 professional engineers, 7 technicians, 2 industrial designers, and 2 administrative personnel. In addition the company makes extensive use of networking and subcontracting of specialists.

Achievements. This company has developed a unique technology for light, commercial armouring and product hardening; it is currently engaged in MRI in the development of technology required for call centre management and EMS deployment. The company has also developed a procedure for risk management associated with Full Maintenance Leasing (FML) of Specialist equipment.

Discussion of the Results of Assessment

(a) The results of the evaluation showed that this company also was average from the point of view innovativeness. As the function of this company was essentially advanced design and development, its average rating in respect of innovativeness was unexpected. Perhaps it would be pertinent to mention that in general consulting companies in engineering industries tend to be conservative and prefer to use well established ideas, material and products. They like to avoid risks involved in innovations.

(b) The innovative environment was found to be average with the following strengths and weaknesses:

(i) Areas of strength were: creative environment, commitment reflected by the innovative environment, reflection of market needs, management guidance, charismatic programme management, reflection of desire to advance, organisational interactive relationship, application of shoot-outs between parallel approaches, size and organisational structure, evaluation and quality assurance standards and procedures, job security of employees, safety measures in the organisation, organisational internal social environment, usage of procedures, guidelines and checklists, application of the skunk work style, provision of incentives, conveyance and execution of ideas and work, organisational tolerance to non-conformity, reflection of risk taking, reflection of freedom of work, reflection of corporate environment, reflection of encouragement and motivation, empowerment of champions to drive the innovation process, atmosphere of enthusiasm for the innovators and marshalling of organisational resources.

(ii) Areas of weakness were: the sources of ideas, the provision innovative receptive atmosphere, programme selection, the application of new technologies and the external environment.

(c) The innovation process as well was assessed to be average with the following strengths and weaknesses:

(i) Areas of strength were: the project definition and understanding of use requirements, concept development, concept selection, availability of finance related to time scale, reflection of logistic influence on design, data pack generation and update, prototyping process, user evaluation and approval of prototypes, development cost and time, creativity of the team involved in the innovation process, teamwork and team spirit, compatibility of the innovative team, customer participation in the innovation process, integration of the innovation process, application of the skunk work style, balance of freedom and control through the innovation process and product data management (PDM).

(ii) Areas of weakness were: Studying the commercial viability of ideas, the availability of production personnel, manufacturing safety procedures, value added in products, participation of production engineers in the innovation process and suitability and accuracy of testing tools and production equipment.

(d) The innovators in the organisation were found to be average with the following Strengths and weaknesses:

(i) Areas of strength were: innovators group creativity, innovators personal commitment, innovators alignment of objectives, innovators individualism as related to creativity, innovators self-motivation, innovators freedom of work and innovators understanding of customer needs.

(ii) Areas of weakness were: the innovators effective use of outside technology and advice and innovators technology awareness.

The General Manager of Company used the computer analysis to make the assessment. He was able to identify 48 specific areas of strength and 14 specific areas of weakness.

Summary of Results

- The innovative environment at company C was evaluated and assessed to be good to average.
- The innovators in company C were also evaluated and assessed to be good to average.
- The innovation process adopted and applied at company C was closely evaluated and assessed to be good to average also.

The detailed evaluation report is shown in appendix G.

6.2.4 Case Study IV - Company D - United Kingdom.

This company was founded in 1914 and since its formation has grown s internationally now embracing 14 wholly owned sales companies and 42 exclusive industrial distributors worldwide. It has become a leading manufacturer of power tools and automation equipment.

Company Mission

Company's mission is to become the undisputed global leader for industrial assembly tools to light assembly for aerospace, MVI components and the automotive after-sales industries by offering tools that combine high productivity, cost efficiency and the best price/performance index.

Staff Profile. The company has a staff compliment of 1 Development Manager with an engineering degree, 1 Technology Manager (mechanical), 1 Project Engineering

Manager and 6 Mechanical Products Design Engineers (2 with engineering degrees); total establishment of 9.

Achievements. Inclusion of ergonomic features in the grip designs of pneumatic hand tools. Design and manufacture of electric DC powered small screwdrivers to meet CE, UL and CSA approval standards. Design and manufacture tools in a modular manner, to allow for quick and easy servicing by customers. The modular concept also allows customers to change purchased tools to suit changing requirement, for example, the output speed or the output drive, etc.

Discussion of the Results of Assessment

(a) The results of the evaluation showed that company D was also an average company in terms its innovativeness rating. As this company claimed to hold a leading position in the field of assembly tools, it should have scored higher than average rating in respect of innovativeness. An average rating was unexpected.

(b) The innovative environment was also assessed as average with the following strengths and weaknesses:

(i) Areas of strength were: creative environment, vision and objectives projection, reflection of market needs, provision of charismatic programme management, reflection of desire to advance, organisational interactive relationship, application of multiple innovative parallel approaches, organisational size and structure, evaluation and quality assurance standards and procedures, confidentiality standards, safety measures in the organisation, adoption of the skunk work style, conveyance and execution of ideas and work and mix of innovators and operators (R&D and production).

(ii) Areas of weakness were: the provision of innovative receptive atmosphere, organisational external linkages, organisational internal social environment, challenge in the innovative environment, provision of incentives, acceptance to individualism when it comes to the provision of ideas, reflection of risk taking, reflection of freedom of work, reflection of encouragement and motivation, leadership in the organisation, empowerment of champions to drive the innovation process, atmosphere of enthusiasm for the innovators and atmosphere of recognition and appreciation.

(c) The innovation process was assessed to be above average to very good with the following strengths and weaknesses:

(i) Areas of strength were: study and analysis of idea, assessment of the technical and commercial viability of ideas, project definition and understanding of user requirements, assessment of project feasibility study, concept development, project planning, availability of finance related to time scale, adoption and application of design for zero development, prototyping process, user evaluation and approval of prototypes, manufacturing safety procedures, value added in products, creativity of the team involved in the innovation process, teamwork and team spirit, logical flow of the innovation process, participation of production engineers in the innovation process, customer participation in the innovation process, feedback between stages of the innovation process, availability of good quality production materials, suitability and accuracy of testing tools and production equipment, application of the skunk work style and product data management (PDM).

(ii) Areas of weakness were: development cost and time, and the compatibility of the innovative team.

(d) The innovators in the organisation were assessed to be below average with the following strength and weaknesses:

(i) Areas of strength were: innovators alignment of objectives, innovators individualism as related to creativity and their attention to marketing.

(ii) Areas of weakness were: innovators risk orientation, understanding of customer needs, effective use of outside technology and advice and technology awareness.

The Technology Manager used the computer analysis to assess the company and he was able to identify 40 specific areas of strength and 19 specific areas of weakness.

Summary of Results

- Thee innovative environment at company D was assessed and found to be good to average.
- The innovators at company D were also evaluated and found to be fair to below average.
- The innovation process adopted at company D was assessed and also was found to be above average to very good.

The detailed evaluation report is shown in appendix H.

6.3 RISK ANALYSIS – CASE STUDIES.

The analysis of risk involved in following innovative ideas is one of the most important but difficult areas in the field of managing innovations in engineering industries. However, before analysing the risks, it is necessary to identify and understand the various categories of risks, devise techniques for their measurement, state the boundaries of acceptable risks and describe steps that should be taken to minimise the impact of risks on the success of the project.

Engineering related risks may be classified as follows:

1. ***Total failure***: The project may fail to meet the design or performance specification. This is the most serious of all risks and it is usually the result of following half-baked designs. It should be accepted that inherent design faults cannot be put right through any amount of development.

2. ***Partial failure of first kind***: Performance may falls short of the target marginally and the project may not allow necessary development because of the budgetary or time constraints.

3. ***Partial failure of second kind***: The project may reach the specified performance targets but the budgetary and time limit would be exceeded to complete the remaining work. The project may become a case of being too late and too expensive.

In accepting innovative concepts of final designs of engineering products, management runs also business related risks, e.g. the product may be a flop from the marketing stand point.

In order to avoid marketing related risks, first it is necessary to have proper appreciation of the principles of marketing. Marketing is a highly specialised area therefore only very basic ideas can be considered in this thesis.

There can be two approaches to manufacture marketable products: (i) to determine market needs and produce goods to satisfy those needs; (ii) to manufacture goods on the basis of the perceived market need for certain goods and then to use advanced marking techniques to popularise those goods. The first is, of course, the classical or textbook approach; it depends on a properly conducted market research before even considering the design of a product.

The results of risk analysis are often quoted in terms of percentage values. These values represent the ratio of (chance of failure/absolute certainty of failure) x 100%. A computer procedure that was written for carrying out risk analysis was used to asses risk involved in the execution of two project of company A. The results of have been presented as percentage values.

6.3.1 Case Study V. Project AB3 –Black Iris.

Project Description. Project AB3, known as The Black Iris, was initiated to meet the Jordanian requirement. The Black Iris is a cost effective, lightweight and affordable utility vehicle, designed to rally car principles, to achieve good *off the road* performance and handling ability. It offers a large load area capable of carrying up to six passengers plus their personal luggage to a maximum total capacity of 700 kg. The design and manufacture of the AB3 was carried out by company A of Jordan in conjunction with a British company. A photograph of the vehicle is shown below in Fig. 6.1.

Fig. 6.1 Project AB3 – The 4X4 Black Iris.

Project Assessment. The project manager of the AB3 used the risk analysis procedure, referred to earlier, to assess the risks involved. The results showed that the risk expected in adopting and executing this project was around 14.10%. Hence the project was considered to be of low risk category. The program identified eleven areas of low risk such as the political situation, economical situation, market conditions, the technical and commercial viability of the project, project definition, availability of resources, project duration, project size, commitment to the project, confidentiality matters and the existing laws and regulations. The analysis also identified three areas of medium risk such as competition, project planning and project management.

Summary of Results

- The risk expected in the adoption and the execution of the project was assessed to be only 14%.
- This was considered a low risk project.

The detailed evaluation report is shown in appendix I.

6.3.2 Case Study VI. Project AB10, A Light Hovercaft.

Project Description. Project AB10, A Light Hovercraft, was launched to meet the need of the Jordanian Coast Guard. The AB10 was a cost effective, lightweight and affordable hovercraft, designed to guard the Jordanian shores of the Red Sea against smugglers and infiltrators. Hence, it was specified that the craft should be capable of working on both seawater and land, i.e. amphibious operation. The craft is capable of carrying up to eight passengers plus their personal luggage to a maximum total capacity of 1000 kg. The design and manufacture of the AB10 was carried out by company A of Jordan. A photograph of the craft is shown in Fig. 6.2.

Project Assessment. The project manager of the AB10 used the risk analysis procedure referred to earlier in this chapter. The results of the analysis showed that the risk expected in adopting and executing this project was around 38.14%. This assessment put the project in to a medium to near high risk category. The analysis also identified three areas of low risk such as the political situation, confidentiality matters and the risk related to the existing laws and regulations. Seven areas of medium risk were identified such as the economical situation, project definition, availability of resources, project duration, project size, the degree of commitment and risk related to project management. The program has identified four areas of high risk such as market conditions, the technical and commercial viability of the project, competition and risk related to project planning.

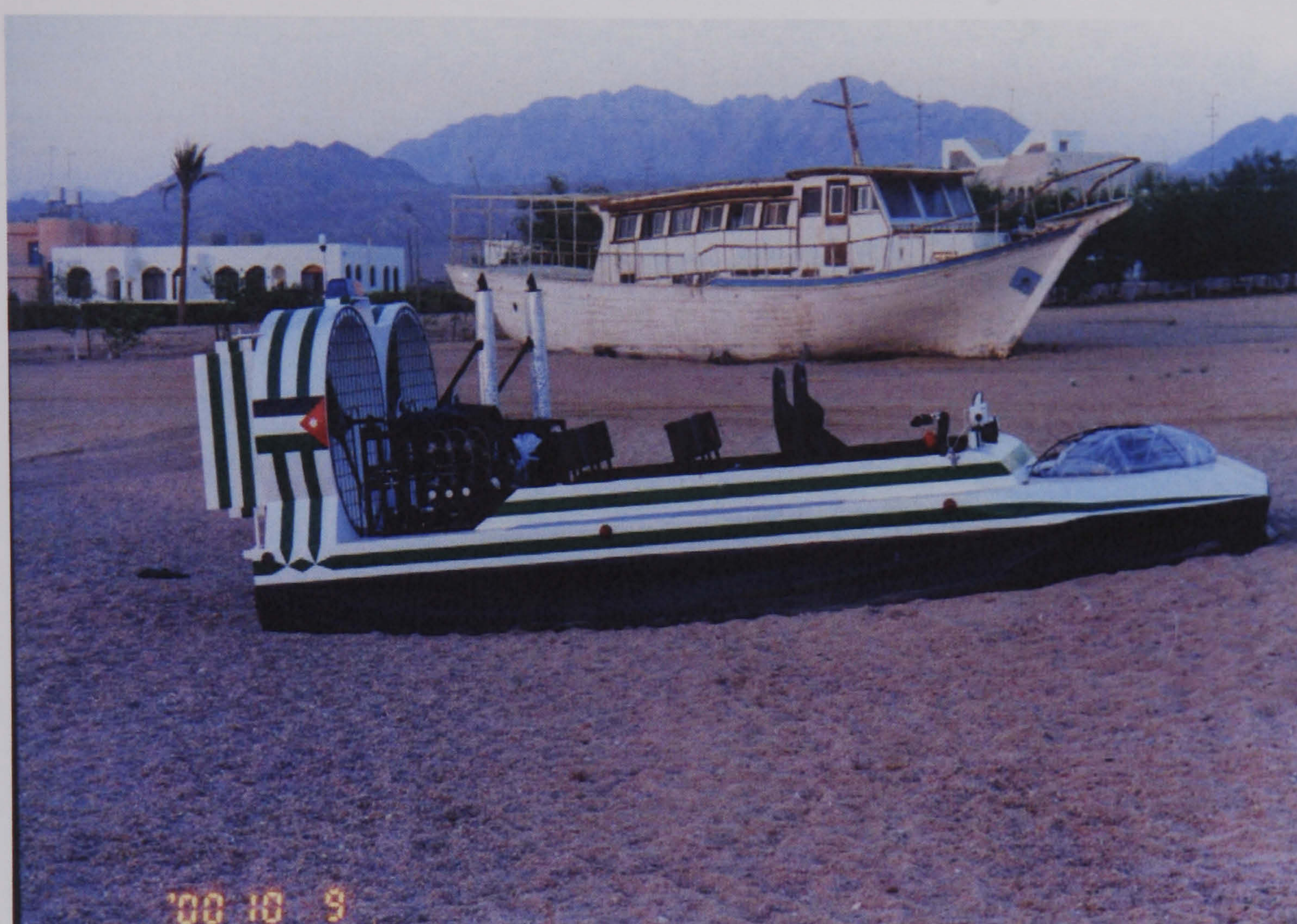


Fig. 6.2 Project AB10 – The Light Hovercraft

Summary of Results

- The risk expected in the adoption and the execution of the project was assessed to be 38.14%.
- The predicted risk for the adoption and execution of this project was considered to be of medium category.

The detailed evaluation report is shown in appendix J.

CHAPTER 7
DISCUSSION RESULTS

7.1 INTRODUCTION.

Competition between organisations, one of the principal challenges facing the present day engineering industries, is increasing sharply as more and more emerging countries enter into the engineering manufacturing arena, and industrial production outstrips the demand for manufactured goods. WTO agreements, free trade and globalisation have further exasperated the situation, particularly for emerging countries, to market manufactured goods. In the face of free trade agreements, it is no longer possible for engineering companies to feel safe even within their own home markets. In order to face this new world order, engineering companies globally have only two options: (i) to get out of the marketing arena and perish (ii) to learn to face the international competition that is dominating the market for manufactured goods.

Invariably engineering companies have to compete simultaneously on four fronts:

(i) Price of manufactured goods for the end-user;
(ii) Quality of goods;
(iii) Delivery dates;
(iv) Attractive terms they can offer to dealers to promote sales.

A continuous flow of innovative ideas is an important tool for enhancing competitiveness by introducing novel changes on any one or all of these four fronts. Hence, the primary aim of the innovative ideas has to be either to improve the quality, functionality, aesthetic appeal of manufactured products or to introduce new engineering materials and simpler production techniques to lower the manufacturing cost. This is indeed a tall order and, in order to meet this challenge, engineering companies must consider the management of innovation as a dire necessity and not simply a bureaucratic interference for hard pressed engineering, production and planning staff.

In spite of the fact that the importance of managing innovations in engineering industries has long been recognised, as seen in the brief but critical review of the available research papers, publications directly relevant to the specific needs of these industries is scarce. Nevertheless, from the reviewed publications around twenty factors that may influence the management processes have been identified. But neither the innovation process nor innovative environment including its component elements have been considered in sufficient detail by the previous investigators. Moreover, the innovators, who are at the very heart of the innovation process, their needs, in particular the environment, for producing good innovative ideas which are relevant to their company's interests, the methods for stimulating them to become more creative, etc. have not been given adequate attention. Such advanced issues as establishing theoretical or empirical correlations between the innovative environment, the innovation process and the innovators also have not been established. The major shortcoming in the previous work appears to be that the management of innovations has been considered solely from a general management perspective and not from an engineering point of view. It would not be incorrect to remark that the subject of managing innovations in engineering industries has been treated as if it was the domain of engineering-orientated managers and not that of management-oriented engineers.

The research reported in this thesis attempted to look at the problem form engineering perspective and to draw attention to some of the problems of managing innovations confronting engineering industries. It has been proposed that management attention should be focused on the problems in three main areas: (i) creating the innovative environment; (ii) understanding the processes which lead to generating innovative ideas; and (iii) encouraging and nurturing engineering and production staff in general and innovators among them in particular to be creative. The acceptance and implementation of innovative projects or ideas always involves certain amount of risk, therefore a reliable method for calculating the risks embedded in innovations has also been developed as a part this study.

Eighty-nine interrelated factors have been identified which seem to influence innovations and their management in engineering industries. Hence, in analytical terms the management of innovations in engineering industries may be described as an equation with eighty-nine interrelated variables. Most of these variables, such as leadership, challenge, encouragement, motivation, etc., are intangible therefore not amenable to either analysis or quantification and control. A Computer Aided Management (*CAM*) procedure has been developed to overcome this problem. The development of these two analysis techniques may be claimed to be timely, significant and novel. These techniques should help firstly to speed up the assessment of companies in terms the three aforementioned factors and secondly to calculate the imbedded risks in adopting innovative ideas or executing innovative projects. Both computer analysis procedures, which use questionnaires to assess the claims of engineering organisations to innovativeness, were validated with the help of a number of real life case studies of selected companies from different parts of the world.

7.2 DISCUSSION OF RESULTS – ANALYSIS I.

The results of the case studies were presented in chapter 6. The aim here is to discuss and, where necessary, explain those results with logical reasoning.

7.2.1 Cass Study I - Company A. This case study assessed Company A, a Jordanian engineering organisation, for its innovativeness or innovative capabilities by using Application 1 of the *CAM* package. The computer analysis showed that the overall assessment of this company for its innovativeness was below average. The reasons for this overall assessment are explained as follows.

Innovative Environment. The innovative environment in company A was assessed as poor especially in areas such as: vision and objective projection, provision of receptive atmosphere for innovative ideas or innovations, appreciation of market needs, programme selection, application of multiple or parallel approaches, application of shoot-outs between parallel approaches, evaluation and quality assurance, existence and usage of quality standards and quality control procedures, internal social environment, guidelines and checklists, existence of challenging atmosphere, interactive learning, encouragement of individualism, reflection of risk taking, reflection of corporate environment, leadership, atmosphere of enthusiasm, recognition and appreciation by superiors.

The weaknesses in the innovative environment of the company were the result of the following reasons:

(i) Being a newly established organisation it had no tradition of research, design or innovations;
(ii) Being a part of a non-industrial country, it did not have access to professional bodies such as industrial associations, professional institutions, etc;
(iii) Local staff unable to compete internationally due to inexperienced;
(iv) Other influences such as non-industrial culture in the whole of Middle East region which includes Jordan.

It is suggested that the innovative environment of this company may be improved by adopting the following measures:

(a) Always explain the vision and objectives of the organisation to new employees; hold seminars to explain and clarify organisational vision and objectives; use banners and stickers showing organisational vision and objectives and ensure the existence of organisational vision and objectives on brochures and manuals.
(b) Encourage managers, supervisors and team leaders to welcome good ideas; provide suggestion boxes in different locations in the organisation; maintain a record of good ideas; form an experienced and specialised team to study and develop ideas and name some of the ideas after their providers.
(c) Allow innovators to make frequent visits to the marketplace to assess its needs; task the marketing department to provide periodical reports about market needs and circulate these reports to all departments; invite customer participation when preparing user requirements prior to the design stage; allow customer participation in prototypes, testing and evaluation; gathering information though active market intelligence; bringing the marketing department closer to the customer and enhancing the means of communication.

(d) Form a programme selection committee to include marketing, production and R&D experts; conduct a risk analysis study on candidate programmes; conduct a feasibility study prior to programme selection; check the coherence of programme objectives with organisational objectives; select programmes, which satisfy customers' needs taking into consideration the availability of resources to avoid the risk of failure.

(e) Adopt the multiple or parallel approach criteria between programmes and conducting shoot-outs between them.

(f) Set a quality statement to suit the organisational environment; provide the necessary tools for checking the quality of products; employing fitness-for-use strategy to satisfy market needs; take the necessary measures to ensure continuous improvements and promote general awareness of products among employees.

(g) Plan and execute some social functions for employees and their families; stem out rivalries and encourage friendship among employees; encourage and support the formation of employee social committees and establish a funds box for social activities.

(h) Prepare a written management plan and standard operating procedures; prepare standard forms and establish a procedure for updating all related documents periodically to keep them inline with current practices.

(i) Create a competitive atmosphere for the innovators; provide incentives for certain achievements; create an honours list for the innovator of the year at the organisational level; and invest in educating and training the innovators in the form of a reward, for the mutual benefit of both the innovators and the organisation.

(j) Treat all innovators as independent individuals; allocate incentives for viable ideas; name some products after the individuals who gave the idea for that particular product to give the innovators sense of achievement and prestige.

(k) Conduct seminars on risk taking and highlight the importance of calculated risk taking, creativity; tolerance of non-conformity in the field of creativity and innovativeness and encourage innovators to be unpredictable and non-classical.

(l) Enhance and encourage the leadership side of management; hold seminars and provide training courses on leadership; encourage risk taking and encourage management as well as employees to be active, taking the initiative rather than being reactive.

Finally, it should be noted that in practice good innovative ideas and innovations in engineering cannot be conceived without a sound understanding of the relevant scientific principles and a good grasp of the associated technologies. This understanding and grasp are subject to a very rapid obsolescence. It is now generally accepted that due to very rapid advances that are taking place in modern times, the half-life of the scientific knowledge and engineering potential is only approximately three years. Therefore, no engineer can have a lasting claim to his/her scientific knowledge that was acquired during his/her education. Expertise without basic knowledge is like a tool that needs sharpening very badly. Management should be aware of this phenomenon and recognize that in order to count on the expertise of its staff; a company must take steps to update the scientific knowledge through a well-tailored programme of continuing education. Any engineering organisation, which does not encourage its technical staff to publish regularly in reputable professional journals and participate actively in international conferences, cannot stay in the forefront of knowledge that is a prerequisite for generating innovative ideas or originating cutting edge innovations.

Innovators. The innovators in company A were also evaluated; they too were assessed as below average as they were weak in several areas including technological competence, individual creativity, group creativity, understanding of customer needs, attention to marketing, the use of outside technology, etc.

It is suggested that the performance of innovators in this company may be improved by introducing the following measures:

(i) Guide the innovators to cultivate and practice self-motivation, develop courage for calculated risk taking and acquire social skills. Encourage them to practice different games that activate creative thinking and problem solving; hold seminars and training courses that may contribute to the enhancement of technological competence; encourage them to feel and show strong personal commitment towards the organisation, their projects and customers; take necessary steps to encourage diverse experiences by working on various subjects and motivate them to align their personal objectives with those of their organisation.

(ii) Study the targeted market and be aware of market shifts; come closer to the customer, understand his/her financial situation to provide affordable products and keep customers needs in mind at all times.

(iii) Encourage innovators to read reports, research papers, scientific magazines and books; attend seminars and training courses and interact with scientists, researchers and innovators from other organisations by taking active part in national and international conferences.

7.2.2 Case Study III - Company C. This was a South African engineering organisation the managing director of this company, who had a good knowledge of its mission, took the responsibility for using the computer analysis procedure. He was astonished to see that his company too was assessed by the computer analysis for innovativeness as an average organisation.

Innovative Environment. The innovative environment in company C was assessed as average to good in general. It had some areas of strength but the management of the sources of ideas was particularly poor. Welcoming good ideas and keeping the door open for them might help to improve this area. Sources of ideas could be individuals, partner companies, consultants, suppliers, the internet, radio & television, books, magazines, newspapers, exhibitions, customers, the marketplace, etc. Hence, it was suggested that company C should keep most or all these sources of ideas within the reach of all its innovators and other employees so that they may interact with these channels to acquire as well as give ideas.

Innovators. The innovators in company C were assessed by the computer analysis procedure as weak in two areas: (i) the effective use of outside technologies; and (ii) in technology awareness. These weaknesses may be overcome by taking the following corrective measures:

(a) Communicating with external linkages such as universities, research institutes, colleagues in partner companies and suppliers in order to gain fresh ideas. Socialising with innovators from other organisations and institutions also may in this regard.

(b) Reading reports, research papers, scientific magazines and books, attending various seminars and training courses, supporting staff to attend continuing education programmes and interacting with scientists, researchers and innovators from other organisations.

The author has considered these two case studies for discussion in order to show that the questionnaires developed for this purpose, i.e. Procedure I, has produced meaningful results; it may be used successfully as a tool to assess innovativeness of organisations to highlight their strength and weakness. The questionnaires were given intentionally to individuals from the assessed organisations who had no previous knowledge of either their scope or structure. This approach was necessary to establish that the procedure was user friendly.

It should be noted that case studies (II and IV) produced similar results; therefore, they have not been discussed here in order to avoid unnecessary repetition. Since the aim of this study was to validate the computerised analysis procedure rather than to assess all the organisations selected for this study, further discussion was considered unnecessary.

Those who took part in completing the Analysis Procedure I confirmed that: (a) it yielded unbiased results as they were not able to influence the outcome of the assessment; (b) the analysis procedure was very user-friendly; they were able to complete the questionnaires within the specified time without any support from the author. Furthermore, they felt that knowing the areas of weakness and strengths in their companies was very significant for planning remedial actions. Appendix K shows comments of six experts on the computer analysis I.

7.2.3. Comparison of Results – Analysis I. Table 7.1 below shows the comparison between selected sub-components of all companies selected for the purpose of case studies. The aim of the comparison was to show that the Computer Analysis I produced reliable results in assessing supposedly innovative engineering companies taken from different parts of the world, Asia, Africa and Europe, with only one common denominator, and that they were all actively involved in the design and development of engineering products.

Principal Component	Sub-Components	Case Study I	Case Study II	Case Study III	Case Study IV
The Innovative Environment	Environment Creativity	Good	Very Good	Excellent	Excellent
	Sources Of Ideas	Good	Good	Poor	Good
	Reflection Of Market Needs	Poor	Very Good	Very Good	Very Good
	Organisational Size And Structure	Good	Good	Excellent	Excellent
	Marshalling Of Organisational Resources	Good	Very Good	Excellent	Good
	External Environment	Fair	Good	Fair	Good
The Innovators	Individual Creativity	Poor	Good	Good	Good
	Group Creativity	Fair	Good	Very Good	Good
	Understanding Of Customer Needs	Fair	Good	Very Good	Poor
	Technology Awareness	Fair	Poor	Poor	Poor
The Innovation Process	Study And Analysis Of Idea	Good	Good	Good	Excellent
	Project Definition	Good	Very Good	Very Good	Excellent
	Risk Management	Poor	Fair	Good	Very Good
	Project Planning	Good	Very Good	Good	Excellent
	Availability Of R & D Resources	Good	Poor	Good	Good
	Design For Zero Development	Good	Fair	Good	Excellent
	Application Of The Skunk Work Style	Good	Very Good	Very Good	Excellent
	Product Data Management	Poor	Very Good	Very Good	Excellent
	Project Management	Good	Very Good	Good	Very Good

Table 7.1 Comparison of assessment results of selected engineering companies

7.3. DISCUSSION OF RESULTS – ANALYSIS II.

The second Analysis was developed for predicting the risks embedded in adopting innovative ideas or executing innovation projects. As in the case Analysis I, this analysis also was tested by carrying out case studies of selected engineering projects instead of companies. The results of the case studies were presented in chapter 6. The discussion of those results is presented in the following section to have some idea of the usefulness and the reliability of the Risk Analysis procedure.

7.3.1 Case Study V - Project AB3 (Black Iris). The manager for project AB3 carried out the analysis to assess the risk embedded in developing this project. The Assessment indicated that the risk involved was 14.1%, a borderline case between low and medium risks, thus it necessitated a risk response. The risk response required the identification of dominant sources of risk in order to implement the necessary measures for risk control. The Analysis identified three dominant areas of medium risk. The aim of risk response was to minimise risk by reducing medium risks to low risks. These sources of risk were: stiff competition, insufficient care in project planning and project management.

Recommended Risk Response. The recommended risk response for project AB3 is given below:

1. Response to the risk of competition:
   (a) Identify both competitors and competitive products to the Black Iris.
   (b) Evaluate criticality and seriousness of the existing competition.
   (c) Ensure competitiveness of the Black Iris in terms of quality and price. Higher productivity is generally the best means of reducing manufacturing costs and increasing competitiveness.
   (d) Look for alternative potential markets.

2. Response to the risk of improper project planning:
   (a) Identify and breakdown project activities; determine their logical order and estimate the time required for each activity through time and motion study.
   (b) Estimate project resources requirements and investigate sources of economy.
   (c) Prepare project plan, get it approved and make sure that it is understood by all concerned with the project.
3. Response to project management risk:
   (a) Prepare a clear and detailed project plan.
   (b) Select an experienced project manager and competent project team qualified in automotive engineering; ensure team unity by creating high team spirit and safeguard against hidden individual agendas.
   (c) Ensure completion of all project assignments on time.
   (d) Ensure that project scope does not change and will not be impacted by outside influences.
   (e) Before starting, ensure the validity and the attainability of initial project objective

7.3.2 Case Study VI - Project AB10 (Hovercraft). The project manager for AB10 project has carried out the risk analysis study to assess the risk involved in developing this project. The risk was assessed to be 38.14%, a borderline line case between the medium and the upper limits and closer to the high risk region. The risk analysis procedure identified four sources of high risk namely, market potential, the technical and commercial viability of the project, competition and project planning.

<u>Recommended Risk Response</u>. The recommended risk response for this project is as follows:

1. Response to market conditions risk:
   (a) Evaluate coherence of the AB10 with the user requirements and study the possible future changes on such requirements.
   (b) Evaluate the marketing resources available for selling the AB10.
   (c) Take all necessary steps to achieve higher productivity.

2. Response to risk related to the technical and commercial viability requires assess a team with relevant expertise; this experience was not available

3. Response to the risk of stiff competition:

   (a) Identify competitive products to the Hovercraft and the competitors.

   (b) Evaluate criticality and seriousness of the existing competition.

   (c) Ensure competitiveness of AB10 in terms of quality and price and functionality features.

   (d) Look for alternative potential markets.

4. Response to project planning risk:

   (a) Identify project activities; determine their logical order and estimate time required for each activity.

   (b) Estimate project resources requirement.

   (c) Prepare project plan, get it approved and make sure that it is understood by all those who are involved in this project.

7.3.3 Comparison of Results - Analysis II. Analysis of risks was carried out for two projects: case study V and cases study VI. The aim was: (i) to validate this application for analysing risks surrounding innovative projects; and (ii) to determine its suitability as a tool for computer aided Risk Analysis in Project Management. The discussion of the results of these case studies is given below.

Considering both case studies, together with the evaluation reports as presented in Appendices H & I, it should be apparent that the analysis was able to predict the risks involved reasonably well in numerical terms and assign values of 14.1% for case study V and 38.14% for case study VI. The analysis was also able to specify risk categories; i.e. low, medium or high for approximately fourteen expected sources of risk for each case study. This prediction pointed out the source or sources, which were responsible for increasing the risk this was very useful information for preparing the appropriate risk response.

These results, although based on limited amount of data, have shown that Analysis II /Application II may be used confidently to analyse risks surrounding the implementation of innovative projects.

It would also be pertinent to mention that in order to assess the reliability of the predictions, two projects or case studies were considered which had already been completed and their outcome was known. By working closely with the project managers and tracing back the history of their projects, it was possible to conduct risk analysis for those projects using Risk Analysis Procedure. The results predicted by the analysis could, therefore, be compared with already known data.

The predicted risk for case V was as low as 14.1% and it reflected the true state of project AB3. It should be noted that Black Iris is in production; it has a good market in Jordan and other Middle Eastern countries.

As for case study VI, AB10 project (Hovercraft), the predicted risk was 38.14%. This was a high risk project and in reality it did not succeed. The high risk was due to the fact that the project was not technically viable. The analysis was able to confirm this by indicating a high technical non-viability. The hovercraft failed the initial tests. Further development also was not successful. Hence, the project had become a budget drain; the Risk Analysis, Procedure II, was able to predict with reasonable reliability the risk involved in each project. Light heartedly, the hovercraft turned into an overdraft and company A decided to abandon this project.

It should be noted that hovercraft of various sizes are being used quite successfully both for civilian as well as military use. Therefore, in view of this evidence, it would be wrong to suggest that the hovercraft was not technically viable. The fact of matter in the case of AB 10 project was that it was handled in an amateurish manner consequently; it lacked a serious and systematic approach to an advanced design.

Risk predictions by using computer aided Risk Analysis Procedure provide a sound basis for preparing risk responses. The response for each project was discussed with the project managers responsible for projects AB3 and AB10. Both project managers confirmed the suitability of the risk responses generated by the analysis.

Table 7.2 summarises the results of case studies for the Black Iris Project, case study V, and the Hovercraft project, case study VI. It can be seen that the predicted overall risk for project AB3 is 14.1%. Most of the sources of risk have also been estimated as low risk. The success of this project may be taken as an evidence of the reliability of the prediction.

In the case of project AB10 the predicted risk was 38.14%. Most of the sources of risk were predicted to lie between high and medium, hence the project had no chance of success. Both these results demonstrate the usefulness of computerised Analysis procedure as a tool for analysing risks involved in innovative projects, but further test are needed to increase the confidence level in the reliability of predictions.

Finally, some remarks on the limitations of the risk analysis model would be pertinent. The model considers risk associated only with management and marketing. These are important areas but one must not overlook the fact that many engineering projects fail because of the professional weaknesses of the engineering staff responsible at the design stage. The main causes of failures, which arise from poor engineering capabilities of staff, are:

(a) Half-baked designs ending up with lengthy as well as costly development programmes.

(b) Poor quality because of inadequate appreciation of all the factors, which determine quality.

(c) Poor estimates of time needed to complete engineering projects, hence missing delivery dates and loosing the all important lead time;

(d) Poor estimating techniques for costing engineering projects, hence exceeding budgetary limits and loosing the competitive edge.

Risk Categories	**Sources Of Risk**	**Case Study V Project AB3**	**Case Study VI Project AB10**
External	Political Situation	Low	Low
	Economical Situation	Low	Medium
	Market Conditions	Low	High
Internal	Technical And Commercial Viability	Low	High
	Project Definition	Low	Medium
	Availability Of Resources	Low	Medium
	Project Duration	Low	Medium
	Project Size	Low	Medium
	Commitment	Low	Medium
	Confidentiality	Low	Low
	Competition	Medium	High
	Laws And Regulations	Low	Low
	Project Planning	Medium	High
	Project Management	Medium	Medium
Expected Risk		14.10%	38.14%

Table 7.2 Summary of the results of case studies V and VI.

There is ample scope for improving the reliability of the computerised Risk Analysis Procedure so that it may be used with high degree of confidence in computer aided management (*CAM*) and remove the drudgery of manual estimation of the risks involved in innovative engineering projects.

CHAPTER 8

CONCLUSIONS AND FURTHRE STUDY

8.1 PROJECT SUMMARY.

8.2 CONCLUSIONS.

8.3 SUGGSSIONS FOR FURTHER STUDY.

8.1 PROJECT SUMMARY.

The primary aim of this research was to provide a methodology for managing technological innovations in engineering industries. Innovations are the lifeline of engineering companies; they are necessary for (i) extending the life cycle of engineering products, (ii) enhancing competitiveness and (iii) increasing profitability of engineering companies. Therefore, the efficiency of managing innovations in engineering industries is of paramount importance. However, it has been argued that managing technological innovations is a complex and multidimensional task comprising a large number of intangible variables. Hence, it is not amenable to standard analyses.

Invariably, adopting innovative ideas or handling innovative projects involves a risk element. Understanding the sources of risk is necessary in order to plan and implement risk responses and managing innovations safely and efficiently. The risks that surround engineering innovations also depend on many intangible variables; therefore, analyses of risks, at best, can only be predicted estimates.

In view of the importance of innovations to the successful development of the engineering industries, research on managing them efficiently was considered to be significant as well as timely. This research was started with the aim of first unravelling the problems to understand its complexities and then developing a reliable analysis method in the form of computer aided management.

8.2 CONCLUSIONS.

(a) Innovations in engineering industries fall into two categories: (i) those leading to the designs of completely new products; and (ii) those covering the applications of well established principles to existing products. The second category makes by far the largest contribution to satisfy the needs of global markets.

(b) The primary purpose of innovations in the second category is to extend the life cycle of engineering products in order to spread the cost of research, design and tooling over longer periods thus help manufacturing companies to control end user prices and stay competitive. Hence, these innovations are the lifeline of engineering industries.

(c) Because of the importance of innovation, their management has been researched quite extensively; consequently, many papers have been published on this subject. A comprehensive study of the relevant published literature, reports and other publications revealed that while general aspects of managing innovations have been well researched, the complex problems of managing innovations in engineering industries have not given much attention.

(d) Authors of some papers appeared to have confused innovations with inventions. Due to almost exponential growth of the scientific and technological knowledge, it is becoming increasingly difficult to come-up with new inventions, but a continuous flow of innovative ideas is necessary for the survival of engineering industries. Hence a very progressive approach to managing innovations in engineering industries is of paramount importance.

(e) The importance of innovations for engineering industries has been emphasised amply in the research papers and other publication by previous researchers but none has suggested the areas where innovative ideas should be focused. In order to extend the life cycle of existing models of products, innovative ideas would normally be focussed on:

(i) improving aesthetic design to enhance customer appeal;
(ii) simplifying manufacturing processes to reduce cost;
(iii) adding additional features to improve functionality;
(iv) using alternative and recyclable materials to reduce weight without impairing structural integrity;
(v) achieving higher energy efficiency and lower impact on the environment such noise and pollution;

(f) Competence in engineering design is necessary to convert inventive and innovative ideas to successful products that can be manufactured economically and sold at a handsome profit. But design must not be limited only to drafting. Due care must be taken in staffing engineering design offices.

(g) The acceptance of innovative ideas and the execution of innovative projects would inevitably involve embed risks. Hence proper risk analysis is an indispensable part of managing innovations in engineering industries.

(h) The task of managing innovations may be divided into three main components, namely: (i) the creation and maintenance of innovative environment; (ii) inspiring and leading staff to be innovative and (iii) developing processes for the successful implementation of innovations. Each of these components depends on a large number of intangible variables.

(i) Managing innovations and predicting the risks embedded in accepting innovative ideas or executing innovative projects may be simplified by using computational techniques; however, the difficulty is that both problems are multidimensional comprising large numbers of intangible variables. Therefore, they are not amenable to the standard analytical solutions.

(j) Two questionnaire based computer analysis procedures have been developed as computer aided management, *CAM*, tools for assessing the innovativeness of engineering companies and predicting the risks involved in either approving innovative ideas or authorising the adoption of innovative projects.

(k) Six case studies were conducted to test the two computer analysis procedures for: (i) user friendliness of both applications and (ii) for the reliability of results. The results of this study, although based on limited amount of data, were very encouraging. Both applications were found by the users to be user friendly.

(l) The innovativeness of engineering companies depends on a sound understanding of the basic principles of physical sciences and competence in the use of relevant technologies. The management task is to take all necessary steps to safeguard against obsolescence of engineering knowledge. In academic circles it is acknowledged that, due to rapid advances in scientific and technological fields, the half-life of engineering knowledge has now dropped to approximately three years. Management should encourage active participation in national and international conferences, attending internal or external seminars, following training programmes; continuing education, etc are the best means of safeguarding against obsolescence of engineering knowledge.

(m) Although creativity plays a very important part in promoting both inventions and innovations, three most important elements that are required for the creation and sustenance of innovative organisations are: (i) the innovative environments; (ii) active innovators and; (iii) well-integrated innovative processes.

(n) Economic growth of engineering companies depends on good management and successful commercialisation of innovations. Innovations must be acknowledged as essential for engineering companies to establish and maintain a competitive edge but innovators must always be guided to be sensitive to the perceived or predicted needs of global markets.

8.2 SUGGESTIONS FOR FURTHER STUDY.

Before attempting to suggest further work in the important field of managing scientific and technological innovations, it would be pertinent to summarise the work covered in this thesis. Hence a summary of work is given below:

A continuous flow of innovative ideas and a systematic commercialisation of those ideas are vital for engineering companies to maintain a competitive edge in relation to performance, price and quality of their products.

A continuous flow of innovative ideas cannot take place of its own accord. A lively and inspiring approach to the management of innovative ideas is a prerequisite for this process. The research reported in this thesis first identified those factors which seemed to have a significant influence the creating the environment that may be conducive to generating scientific and technological innovations. A suite of two applications for computer aided management (*CAM*) have been developed: the first application deals with assessing the innovativeness of engineering companies and the second predicts the risk embedded in accepting innovative ideas or authorising the execution of innovative projects.

In order to determine the reliability of these applications, they were used in real life case studies involving carefully selected engineering companies. The case studies were based on sets of questionnaires which were specially designed to ensure that they would not produce biased responses. The results were encouraging as they agreed reasonably with the profiles of those companies gathered by the author over a period through personal observations.

It should be noted that the development of *CAM* applications is an attempt to move the management of innovations in engineering industries from the domain of arts to the domain of science, but further research is needed to test the reliability and usefulness of the *CAM* suite of analysis application by studying a large number of engineering companies.

Modelling of innovative ideas for assessing their technical and commercial viability and also for analysing the embedded risks is an important step in accepting or launching innovations. Simulation of innovative ideas based on reliable modelling of innovative ideas could serve as a valuable tool also for controlling and minimising the time required for their implementation. Further work in this area would be a valuable addition to this research.

This research has shown that technological innovations originate from and are influenced by a large number of factors. The task of managing all those factors may be simplified by showing their relative contributions to creating a suitable environment for innovative ideas to thrive. Further work that may lead to the development of influence coefficients would make a valuable contribution to the science of managing innovations in engineering industries.

The impact of external influences such as the prevailing political and economical situation, legislation, market conditions, etc. on the creation and maintenance of the innovative environment was not considered in the research reported in this thesis. However, these factors are important and they deserve some attention.

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APPENDICES

APPENDIX A
GLOSSARY

Science: A branch of study that is based on the scientific method; it involves experimentation, observation, measurement and reasoning true to scientific principles.

Technology: This word is often used as if it was a synonym of engineering or applied science. The word technology has the following meanings:

- Science of the indusial arts (The Concise Oxford Dictionary.
- Applied science [Merriam – Webster].
- A technical method of achieving a practical purpose [Merriam – Webster].
- The assembly of hardware and software means the tools used by human beings to achieve socio-economic goals. Levy [35].
- Technology refers to the ways in which people use discoveries to satisfy needs and desires and to alter the environment to improve their lives. ZCI Encyclopaedia (1994 edition).

In this thesis word *Technology* refers to the techniques used for conducting a technical task such designing, manufacturing, testing etc. or the skill of performing a certain process. It should be noted that science can be leaned through courses of study but invariably technological knowledge can be acquired only through training and practice.

Engineering: This term embraces science and technology; the science part is subject to obsolescence and, by atomic analogy, the *half life* of the scientific knowledge is now widely accepted to be only about three years. Hence, there is a very strong case for continuing education in order to up date the scientific knowledge

Design: The word design has several meanings [Merriam – Webster] such as:

- A sketch or plan for a future product.
- To conceive and plan out.

- To devise for specific function or end.
- To make a pattern or a sketch of.
- The arrangement of elements or details in a product or a work of art.

Since literary definitions fail to do justice to engineering design, the following is the author's attempt to give a comprehensive idea of the concept of design. Design is an integral and most important part of engineering entailing the conversion of concepts to drawings of marketable products, which can be manufactured conveniently and sold at a handsome profit. This definition implies that the designer should have an innovative mind and be fully conversant with the materials of construction, manufacturing process, economic factors to relate market price to product life and last but not least marketing aspects.

Management: In general Management is understood to mean the following:

- To handle or to control.
- To make and keep submissive.
- To achieve one's purpose

However, in industry management comprises administration and leadership. Invariably lack of leadership qualities leads to bureaucratic administration, which is often seen as an obstructive which tends to kill initiative, an important attribute for creativity and innovation.

Invention: This is the conversion of scientific or technical principles into tangible new artefact or processes. The invention is the base from which commercially viable new product can be developed.

Innovation: The word innovation is used in a variety of ways therefore it is prone to ambiguity. Even the British Standards do not give a precise definition or explain the purpose of innovations in engineering industries. Some of these definitions are given below:

- Transforming of an idea into a novel product, operational process or new service in industry or commerce, BS 7000-1:1999 [47].
- Successful exploitation of new ideas, BS 7000-1:1999 [47].
- The creation of change which introduces a significant element of "newness" in thought and action, BS 7000-1:1999 [47].
- Innovation is development of new, better and improved products to satisfy market needs, Tan, Christansen [2].

Since the aim of this research is to study the techniques of engineering innovations in order to manage them efficiently, it is necessary to understand innovations in terms of their objectives. The task then will be reduced to checking whether or not a particular innovation achieves its objectives.

Innovations are necessary in engineering products and processes to achieve higher profitability and enhanced competitiveness in terms of quality as well as price. Some of these areas, which are open for innovations, are given below:

(i) Using alternative materials to reduce cost for manufacturing a product without affecting its structural integrity.

(ii) Using different manufacturing techniques either to simplify the process or increase productivity.

(iii) Carrying out design modifications to reduce the number of parts to manufacture a product.

(iv) Achieving higher competitiveness by: improving performance, quality, reliability or aesthetic appeal..

(v) Producing a better user-friendly product / process.

(vi) Easier maintainability

APPENDIX B

IDEA INVESTIGATION REQUEST

Idea No:	
Idea Tag:	(This will become the project name if promotion is successful)
Business Opportunity File No:	(To be allocated upon promotion of the idea)
Idea's Initiator:	
Idea's Anchor:	
Idea's Brief Description:	
Idea's Initiation Date:	
Suggested Classification:	(Non / Secret / Top Secret)

Internal Circulation and Promotion

Manager Research & Development: **Or** **Manager Business Development:**	--- ---
Idea's Initiator:	---
Idea's Anchor:	---
Appointed Parties/ Partners:	---

Summary Overview Compiled by Initiator and/or Anchor **Background/Origin:**	
Summarised Overview:	
Executive Request/Instruction:	
Supporting Documentation: **Annexure 1** **Annexure 2** **Annexure 3** **Annexure 4** **Annexure 5** **Annexure 6** **Annexure 7** **Annexure 8** **Annexure 9**	Note: Where no documentation applies mark 'Not Applicable'

Internal Recommendation for Further Investigation

Audited and authorized by the Manager, Marketing/ Business Development or R&D

Anchor Recommendation

Having researched and reviewed an appropriate amount of information in support of this request my recommendation is that [Name of Organisation], and specifically the Marketing / Business Development department or R&D Department proceed by, …

(Delete the unwanted options)

Approving Further Investigation

Postponing Further Investigation Until (Date and/or Period)__________________

NOT Proceeding with any Further Investigation

(for the following reasons)

Strategic Input

(Provided by the Manager subsequent to consultation with external authorities)

Authorization

-------------------------------------- --

Manager: R&D or Marketing Manager Idea's Anchor

Signatures to be accompanied by full name, date and authoritative designation

IDEA REVIEW CRITERIA

Audited and authorized by technical & commercial assessment team prior to submission to management

Factors	Maximum Value %	Given Value %
Political, Economical & Strategic Factors	10%	
Technical Viability	20%	
Commercial Viability & Market Conditions	20%	
Availability Of Resources (Personnel, Budget, Materials & Equipment)	20%	
Commercial & Economic Risk	10%	
Technical Risk	10%	
Schedule & Programme Risk	10%	
Total	100%	
Recommended Decision	GO ☐	NO GO ☐
Assessment Team Signatures:		

Management Decision	GO ☐	NO GO ☐
CEO/ General Manager Signature:		

Innovative Ideas Record

Idea No.	Name of Initiator	Description of the Innovative Idea	Initiation Date

APPENDIX C

DATABASE – APPLICATION I / ANALYSIS I

Assessment of Innovativeness

Colour Code:

Serial	The Principal Component	Colour Code
1	The Innovative Environment	
2	The Innovators	
3	The Innovation Process	

Questionnaire Criteria:

Questionnaires in general are schedules designed to collect a mixture of factual and attitude data. They are not just lists of questions or forms to be filled out; they are a intended to serve as scientific instruments for measuring and collecting particular kinds of data, Oppenheim, A. N., [49]. The responses for the questionnaire given below are going to be answered on a scale out of ten and is designed to comply with the following criteria: questions used are clear and not be ambiguous, vague, offensive, biased, inconsistent, emotive, loading or leading. Distortion in response is allowed for by cross correlation of question response. The steps, which have been considered in questionnaire design, McColl, E. [48] are:

1. Specify information to be sought.
2. Determine type of questionnaire and method of administration.
3. Decide on question content.
4. Determine the appropriate form of response.
5. Determine question wording.
6. Determine question sequencing.
7. Determine the physical format and layout.
8. Pilot test and revise as required.

D	E	F	G
Creativity	Creativity is about the generation of new ideas, or new ways of doing things. In fact the whole innovation process is built around creativity, so it is the basic requirement for innovativeness. A creative individual means new ideas, new solutions, new ways, shortcuts, rapid spontaneous response, etc., but creative organisations mean creative individuals, creative solutions, creative processes, creative products and creative situations.	6	Creative environment
	To what extent does the organisation enhance employee's personal characteristics such as: self-motivation, risk orientation, social skills, and technological competency?		
	To what extent does the organisation reflect social environment factors such as: freedom, challenge, encouragement, recognition, etc.?		
	To what extent does the organisation promote group characteristics such as: leadership, cohesiveness, group longevity, group composition, group structure, communication patterns, etc.?		
	To what extent does the organisation strive to adopt creative processes, creative solutions, creative products and creative situations?		

Sources of ideas	Innovative organisations should welcome good ideas and keep the door open for them. Sources of ideas could be individuals, partner companies, consultants, suppliers, internet, radio & television, books, magazines, newspapers, exhibitions, customers, marketplace, etc. So innovative organisations should make most or all the mentioned sources of ideas in the reach of all their employees in order to gain and give ideas.	4	Sources of ideas
	To what extent does the organisation strive to make sources of ideas such as books, magazines, journals and newspapers in the reach of all their employees in order to gain and give ideas?		
	To what extent do you evaluate the number of ideas provided in relation to the number of innovators in the organisation?		
	To what extent do you evaluate the efforts of the innovators in making good use of the available sources of ideas?		
Vision and objectives projection	The vision of an organisation will set out how the organisation intends to position itself in the future and contributes to making that future becomes reality. The management should formulate a clear long-term vision with clear objectives and tangible goals then ensure that short-term work is a seamless part of the long-term continuum. Also little	3	Vision and objectives projection

	can be done until clear objectives have been set. It is essential to make sure that employees understand fully the vision and objectives of their organisation, in order to align personal and organisational objectives.		
	To what extent do you evaluate the efforts of the organisation in explaining the vision and objectives of the organisation to the new employees?		
	To what extent do you evaluate the efforts of the organisation in holding seminars to explain the vision and objectives of the organisations for the employees?		
	To what extent do you evaluate the efforts of the organisation in continuously reminding of its vision and objectives?		
	To what extent do you evaluate the efforts of the organisation in using banners and stickers in promoting its vision and objectives?		
	To what extent do you evaluate the efforts of the organisation in promoting its vision and objectives in brochures and manuals?		
Providing innovative receptive atmosphere	An innovative receptive atmosphere should be open and welcoming to all ideas that could lead to enhancing products, processes, procedures, management, quality, marketing, competitiveness, …etc.	4	Providing innovative receptive atmosphere

	To what extent do you evaluate the efforts of the organisation in encouraging managers, supervisors and team leaders to welcome good ideas?		
	To what extent do you evaluate the efforts of the organisation in providing incentives to attract good ideas?		
	To what extent do you evaluate the efforts of the organisation in providing suggestion boxes in different locations in the organisation?		
	To what extent do you evaluate the efforts of the organisation in providing a register for ideas?		
	To what extent do you evaluate the efforts of the organisation in forming a specialized team to study, analyse and develop ideas?		
	To what extent do you evaluate the efforts of the organisation in naming some of the ideas after their providers?		
Commitment	Innovative organisations are required to maintain a genuine and visible commitment to effective innovations and designs and ensure that innovations are exploited to their full potential, they should also maintain a commitment to quality and reliability. The commitment from the organisation's side should be extended towards employees, customers and suppliers, but also this atmosphere should encourage and motivate	3	Commitment reflected by the innovative environment

	employees to be committed to the organisation, to the success of their projects and to customer satisfaction. Lack of commitment leads to an atmosphere of selfishness and no trusts, which can jeopardize the chances of success of any innovative organisation.		
	To what extent do you evaluate the efforts of the organisation in reflecting the sense of shared responsibility?		
	To what extent do you evaluate the efforts of the organisation in showing care for employees, customers and suppliers?		
	To what extent do you evaluate the efforts of the organisation in sharing good and bad times with the employees?		
	To what extent do you evaluate the efforts of the organisation in spreading an atmosphere of commitment?		
	To what extent do you evaluate the efforts of the organisation in being committed to the quality and reliability of its products and services?		
	To what extent do you evaluate the efforts of the organisation in showing the disadvantages of lack of commitment?		
	To what extent do you evaluate the efforts of the organisation in using the term 'commitment' as part of the slogans of the organisation?		

Market needs	The main interest of any innovative organisation is to come up with a product, which is acceptable to customers and sold in the marketplace. So customer satisfaction is extremely important, which implies an organisational need to reflect market requirements, in order to get the innovators to think about customer satisfaction in a form of products or services that can be exploited. Innovators remoteness from market-needs lead to unmarketable products, simply because they do not fulfil customer requirements.	5	Reflection of market needs.
	To what extent do you evaluate the efforts of the organisation in allowing innovators to make frequent visits to the marketplace to assess market-needs?		
	To what extent do you evaluate the efforts of the organisation in tasking the marketing department to provide periodical reports about market needs and circulate these reports to all departments?		
	To what extent do you evaluate the efforts of the organisation in inviting customer-participation in the form of user-requirements prior to the design stage?		

	To what extent do you evaluate the efforts of the organisation in allowing customer participation in prototype testing and evaluation?		
	To what extent do you evaluate the efforts of the organisation in activating market intelligence?		
	To what extent do you evaluate the efforts of the organisation in bringing the marketing department closer to the customer?		
	To what extent do you evaluate the efforts of the organisation in enhancing communications with the marketplace?		
Effective programme selection	Innovations are about ideas that can be exploited commercially, so it is important to select ideas, which can be converted to marketable products and services. Once there are several viable ideas, then organisations must prioritise. Management should be able to select good ideas and convert them to innovative programmes.	3	Programme selection
	To what extent do you evaluate the efforts of the organisation in forming a programme selection committee, which includes marketing, production and R&D experts?		
	To what extent do you evaluate the efforts of the organisation in conducting a risk analysis study on any programme prior to selecting it for execution?		

	To what extent do you evaluate the efforts of the organisation in conducting a feasibility study on any programme before selecting it for execution?		
	To what extent do you evaluate the efforts of the organisation in checking the coherence of programme objectives with organisational objectives?		
	To what extent do you evaluate the efforts of the organisation in selecting programmes, which satisfy customer needs?		
	To what extent do you evaluate the efforts of the organisation in studying the availability of resources to reduce the risk of failure of selected programmes?		
New technologies application	Organisational survival, growth and maintaining a competitive edge require continuous flow of ideas, new applications of science and application of new technologies in order to provide new products or services. Old is past, new is present and future. Applying old technologies keep organisations behind, but applying new technologies put them in the lead. The innovative organisation should identify technologies used or in development elsewhere, then checking how it might apply them. Again procedures should be in place to seek out useful technologies.	3	Application of new technologies

	To what extent do you evaluate the efforts of the organisation in forming an R&D department from well-selected innovative individuals?		
	To what extent do you evaluate the efforts of the organisation in maintaining close contact with research institutes, universities and other sources of knowledge?		
	To what extent do you evaluate the efforts of the organisation in enhancing communications with the sources of knowledge?		
	To what extent do you evaluate the efforts of the organisation in enhancing organisational creativity?		
	To what extent do you evaluate the efforts of the organisation in prescribing to pertinent journals and magazines?		
	To what extent do you evaluate the efforts of the organisation in enhancing 'in-house' technology development?		
Management guidance.	Innovative and creative individuals require the freedom of work to remain creative, but this freedom has to be controlled without creating a tension between freedom and control, that is why the term management 'guidance' is used rather than 'control', therefore management should try to guide employees to achieve organisational objectives in order to maintain creativity and innovativeness.	3	Management guidance.

	Management guidance can be exercised through continuous contact between management and employees.		
	To what extent do you evaluate the efforts of management in striking a balance between freedom and control with respect to the innovators?		
	To what extent do you evaluate the efforts of the organisation in providing guidance to their innovative employees?		
Provision of charismatic programme management	Project management includes planning, organising, directing, motivating and controlling activities. The motivation part of it is directed mainly towards the project team whom require a good leader to inspire them and get the best out of them. So efforts should be focused on a responsive programme management with some leadership in it, which means selecting suitable programme/ project managers who are constantly and closely working with their project teams to execute their projects efficiently. It is the duty of the project manager to educate and motivate the project team to be active participant and contributor in the project.	3	Provision of charismatic programme management

	To what extent do you evaluate the efforts of the organisation in selecting excellent programme managers?		
	To what extent do you evaluate the ability of programme managers to inspire their project teams?		
Desire to advance	Management of innovative organisations needs to have, maintain and reflect the desire to advance in the organisational environment in order to remain creative and competitive.	4	Reflection of desire to advance
	To what extent do you evaluate the efforts of the organisation in expressing and reflecting the desire to advance?		
	To what extent do you evaluate the efforts of the organisation in employing innovative staff?		
	To what extent do you evaluate the efforts of the organisation in predicting future needs?		
	To what extent do you evaluate the efforts of the organisation in utilizing new techniques, advanced processes and the latest equipment and instruments?		
	To what extent do you evaluate the efforts of the organisation in applying new technologies?		
Interactive Relationship	Innovative organisations strive for an interactive relationship, the components of this relationship are: the management, the innovators, the customers, the suppliers and partner companies. This interactive	2	Organisational interactive relationship

	relationship is beneficial to all participants, it helps in interactive learning, assessing market needs, developing knowledge and rapid responses to market shifts.		
	To what extent do you evaluate the efforts of the organisation in promoting interactive relationships?		
	To what extent do you evaluate the efforts of the organisation in adopting a policy of interactive relationship?		
	To what extent do you evaluate the efforts of the organisation in improving communication means and skills in order to enhance interaction?		
Multiple innovative or parallel approaches	Companies tend to use different parallel ways to achieve an objective, then choosing the approach, which stands out. This policy is advantageous in terms of enhanced solutions, improved product quality, higher motivation and increased probability of success. Innovative organisations are advised to adopt this approach even though it requires more initial resources.	3	Application of multiple innovative or parallel approaches
	To what extent do you evaluate the efforts of the organisation in adopting multiple or parallel approaches?		

Shoot-outs between parallel approaches	This is the final activity to be conducted when adopting multiple/ parallel innovative approaches. Companies should use different parallel ways of achieving an objective, then choosing one of these ways or approaches to emerge rapidly over others". Now choosing one of these ways or approaches to emerge over others requires a shoot-out, a competition or some kind of evaluation method to decide which approach to select. A careful, wise attitude and actions should be taken to avoid upsetting or discouraging the individuals have been working on the approaches, which have been dropped during the shoot-out.	2	Application of shoot-outs between parallel approaches
	To what extent do you evaluate the efforts of the organisation in conducting a fair, subjective and detailed comparison between alternative solution and concepts?		
Maintaining small flat organisations	Large organisations in general are more likely to suffer from several problems such as difficulties in management, extensive bureaucracy, and lack of communications and poor social interaction. Creative individuals and innovators require close attention in order to be stimulated to provide new ideas, which will be harder to achieve in large organisations. In addition to that, it will be relatively hard to communicate and share	4	Size and organisational structure

	ideas in a multi-layered hierarchy's organisational structure. So it is preferable to have small flat innovative organisations.		
	To what extent do you evaluate the efforts of the organisation in maintaining a small size organisation?		
	To what extent do you evaluate the efforts of the organisation in maintaining a flat structure?		
	To what extent do you evaluate the efforts of the organisation in maintaining close attention and touch with their staff and customers?		
Testing, evaluation and quality assurance	One of the main objectives of innovations is competitiveness in term of quality and price. So being competitive in quality is of paramount importance. Innovative organisations should take all necessary measures to ensure high quality. All ideas, products and services should be subject to continuous testing and evaluation, in fact quality should be built into the innovative environment.	3	Evaluation and quality assurance standards and procedures
	To what extent do you evaluate the efforts of the organisation in setting a quality statement to suit the organisational environment?		

	To what extent do you evaluate the efforts of the organisation in generating general awareness among employees to work coherently to the set organisational quality statement?		
	To what extent do you evaluate the efforts of the organisation in providing the necessary tools for checking the quality of products?		
	To what extent do you evaluate the efforts of the organisation in employing fitness-for-use strategy to satisfy its own market needs?		
	To what extent do you evaluate the efforts of the organisation in taking the necessary measures to build the quality into the environment?		
External linkages	External linkages are a main source of knowledge for the innovative organisations. Those linkages can be suppliers, universities, research institutes, data banks, partner companies and competitors. External linkages can lighten the burden of financial investment, attract funding, speed processing of innovations, surmount barriers and speed up entry to markets.	3	Organisational external linkages
	To what extent do you evaluate the efforts of the organisation in making joint ventures?		
	To what extent do you evaluate the efforts of the organisation in funding research in universities and research institutes?		

	To what extent do you evaluate the efforts of the organisation in creating and maintaining contact with various suppliers?		
	To what extent do you evaluate the efforts of the organisation in encouraging departments and staff to create links with external social resources through conferences, seminars and exhibitions?		
	To what extent do you evaluate the efforts of the organisation in utilizing means of communications such as Internet to access and contact external linkages?		
Confidentiality	Innovations are usually formed around simple ideas and some times, it takes a long time to convert an idea into a product or a process, and since there are competitors with their active market intelligence looking for ideas too, then it becomes extremely important to keep innovations confidential in order to avoid early competition. Innovative organisations are expected to take tough measures to ensure secrecy of their ideas, products and processes.	4	Confidentiality standards
	To what extent do you evaluate the efforts of the organisation in educating staff and project teams on the importance of confidentiality?		
	To what extent do you evaluate the efforts of the organisation in making project teams aware of the competitors?		

	To what extent do you evaluate the efforts of the organisation in shortening the time taken to convert an idea into a product by working overtime and utilizing rapid prototyping?		
	To what extent do you evaluate the efforts of the organisation in putting all design documents on closed computer net?		
	To what extent do you evaluate the efforts of the organisation in countering competitor's market intelligence?		
	To what extent do you evaluate the efforts of the organisation in taking the necessary security measures during testing and evaluating prototypes?		
Security of employees	It is not possible to innovate over the long-term if people do not feel secure in their jobs or can foresee a threat to their job security. It is of paramount importance for an organisation to reflect an atmosphere of security for employees in order to become more creative. Lack of security means less innovativeness.	3	Job security of employees
	To what extent do you evaluate the efforts of the organisation in ensuring job security?		
	To what extent do you evaluate the efforts of the organisation in providing good wages and pensions?		
	To what extent do you evaluate the efforts of the organisation in investing in developing the technical skills of employees?		

	To what extent do you evaluate the efforts of the organisation in showing commitment towards employees?		
Safety	Safety of employees, equipment, materials and premises are essential for prosperity of innovative organisations. Lack of safety could lead to the hindrance of innovations. Innovative organisations should take the necessary measures to ensure safety.	2	Safety measures in the organisation
	To what extent do you evaluate the efforts of the organisation in improving safety awareness among employees?		
	To what extent do you evaluate the efforts of the organisation in conducting safety-training courses?		
	To what extent do you evaluate the efforts of the organisation in providing safety tools clothing and equipment?		
	To what extent do you evaluate the efforts of the organisation in providing signs and banners to remind employees of certain aspects of various hazards?		
	To what extent do you evaluate the efforts of the organisation in providing efficient fire fighting systems?		
	To what extent do you evaluate the efforts of the organisation in providing sufficient first aid kits in workshops and buildings?		

Healthy internal social environment	Measures should be taken to ensure that good interactive and healthy social environment do exist in the innovative organisation. Such organisations should become like home and employees treated as family. This healthy atmosphere will enhance creativity and innovativeness.	2	Organisational internal social environment
	To what extent do you evaluate the efforts of the organisation in planning and executing some social functions for employees and their families?		
	To what extent do you evaluate the efforts of the organisation in promoting healthy relationships among employees?		
	To what extent do you evaluate the efforts of the organisation in encouraging and supporting the formation of social committees for employees?		
	To what extent do you evaluate the efforts of the organisation in establishing a funds box for social activities?		
Procedures, guidelines and checklists	There should be some documented regulations, instructions, guidelines, checklists and standard operating procedures in the organisation to guide and remind employees of the main things to look for when executing work. These procedures and guidelines should be subject to continuous update.	2	Usage of procedures, guidelines and checklists

	To what extent do you evaluate the efforts of the organisation in preparing a written management plan to be followed?		
	To what extent do you evaluate the efforts of the organisation in preparing and working according to written standard operating procedures?		
	To what extent do you evaluate the efforts of the organisation in preparing standard forms and preparing a flowchart for them?		
	To what extent do you evaluate the efforts of the organisation in updating instructions, forms and standard operating procedures periodically, as required?		
Communications	Under the present situations, an innovative organisation has to compete globally. This requires strong external linkages, which requires good communication nets. Internal communications are also as important in order to share ideas, exchange information and seek advice.	4	Communication facilities and system
	To what extent do you evaluate the efforts of the organisation in establishing strong internal and external communication nets?		
	To what extent do you evaluate the efforts of the organisation in removing organisational communications barriers?		

	To what extent do you evaluate the efforts of the organisation in making sure that all departments of the organisation are close to each other geographically?		
	To what extent do you evaluate the efforts of the organisation in putting fewer restrictions on communications providing that all confidentiality matters are met?		
Challenging atmosphere	Creating challenging atmosphere for the innovators means creating a substantial source of motivation and incentives in order to remain creative.	2	Challenge in the innovative environment
	To what extent do you evaluate the efforts of the organisation in creating a competitive atmosphere for the innovators?		
	To what extent do you evaluate the efforts of the organisation in putting a target number of ideas for innovators to achieve in a certain period of time and encouraging them to meet the set target?		
	To what extent do you evaluate the efforts of the organisation in creating an honour list for the best innovators and encouraging them to have their names on that list?		
	To what extent do you evaluate the efforts of the organisation in investing in educating and training the innovators as a form of a reward for achievement?		

Skunk work style	It is relatively easy to guide, motivate and activate smaller group of people rather than a larger group. So it is advisable for innovative organisations to structure their innovators or project teams to work in small informal well-integrated groups, which include all the required skills and experiences. Those groups should be given considerable freedom from constraints normal to the rest of the organisation. Those groups should be placed together with no intervening organisational barriers, to developing new products from ideas to production models, and this is what is known as the skunk work style.	3	Application of the skunk work style
	To what extent do you evaluate the efforts of the organisation in employing more skilled manpower for the adoption of the skunk work style?		
	To what extent do you evaluate the efforts of the organisation in enhancing leadership and management at the group level for the adoption of the skunk work style?		
	To what extent do you evaluate the efforts of the organisation in having more resources for the adoption of skunk work style?		
	To what extent do you evaluate the efforts of the higher management of the organisation in paying more attention to the work groups?		

Interactive learning	Interactive learning is an important technique in innovative organisations, because it can be executed 'in house', in addition to that, it can be focused on subjects of main concerns. Interactive learning can be achieved by using an internal computer net, and can also be done by discussions between a number of employees on certain chosen topics or problems. Innovative organisations should promote this type of learning to enhance innovativeness.	2	Adoption of interactive learning
	To what extent do you evaluate the efforts of the organisation in adopting interactive learning?		
	To what extent do you evaluate the efforts of the organisation in having the right tools for interactive learning such as intra net, audio video communication system and discussion rooms?		
Incentives	Types of incentives offered should be coherent and compatible with individuals needs. So, knowing the individuals and their needs suggests the type of incentives to be offered. Financial rewards, training courses, challenge, achievement certificates, recognition, promotions, … etc., are some examples of incentives, which can be offered. Giving the wrong type of incentives can backfire. Therefore, organisations are required to establish an incentive system	3	Provision of incentives

	where the type and size of incentives are studied carefully in order to be compatible with the innovators needs.		
	To what extent do you evaluate the efforts of the organisation in adopting a system for incentives?		
	To what extent do evaluate the efforts of the organisation in providing the right incentives for their employees?		
Bureaucracy	Bureaucracy can be a main source of harm to innovations and innovators. It is also a source of delay and hindrance to creativity and innovativeness. The rapid conveyance and execution of ideas is of tremendous importance	3	Conveyance and execution of ideas and work
	To what extent do you evaluate the efforts of the organisation in keeping the organisational structure small and flat?		
	To what extent do you evaluate the efforts of the organisation in minimising and simplifying the paperwork?		
	To what extent do you evaluate the efforts of the organisation in shortening the chain of management by delegation of authority?		
	To what extent do you evaluate the efforts of the organisation in establishing efficient communication net?		

	To what extent do you evaluate the efforts of the organisation in encouraging and giving preference to verbal communications, whenever new ideas are involved?		
Tolerance to non-conformity	There should be tolerance to non-conformity when it comes to ideas. Innovators should be given the chance to try different things in order to shape up their ideas. This should not be understood as an acceptance to tolerance of non-conformity in products, on the contrary, when it comes to finished products, the organisation should aim for zero tolerance.	2	Organisational tolerance to non-conformity
	To what extent do you evaluate the efforts of the organisation in accepting non-conformity when it comes to new ideas and their implementation?		
	To what extent do you evaluate the efforts of the organisation in rejecting non-viable ideas without discouraging innovators or hearting their feelings?		
Individualism	Ideas are the fruits of an individual's creativity. It gives individuals happiness and satisfaction to say, " this is my idea" or " I was the first one to think about it ". Therefore, it is important to encourage individualism when it comes to creativity and innovativeness, but when it comes to implementing those ideas then teamwork and team spirit should be encouraged.	2	Acceptance to individualism in the provision of ideas

	To what extent do you evaluate the efforts of the organisation in paying close attention to all innovators as independent individuals?		
	To what extent do you evaluate the efforts of the organisation in differentiating between individualism and teamwork?		
	To what extent do you evaluate the efforts of the organisation in encouraging individualism by allocating incentives for innovative individuals?		
	To what extent do you evaluate the efforts of the organisation in naming some products after the person who gave the idea for that particular product?		
	To what extent do you evaluate the efforts of the organisation in making an honour list for outstanding innovators and selecting an innovator of the year at organisational level?		
	To what extent do you evaluate the efforts of the organisation in giving innovative individuals some prestige?		
Risk taking	New ideas mean new or improved products or services, which did not exist before. Any prediction into the future implies risk taking. Therefore, in order to become an innovator one has to be a risk taker. The more newness in the idea, the more risk involved.	3	Reflection of risk taking
	To what extent do you evaluate the efforts of the organisation in conducting seminars about risk taking and highlighting its importance to creativity?		

	To what extent do you evaluate the efforts of the organisation in tolerating non-conformity in the field of creativity and innovativeness?		
	To what extent do you evaluate the efforts of the organisation in encouraging innovators to be unpredictable and non-classical?		
	To what extent do you evaluate the efforts of the organisation in educating innovators on calculated risk?		
Freedom of work	Being creative requires the freedom of doing work, trying new things and exploring new techniques. It would be extremely hard to become creative and provide workable ideas without the sense of freedom and the ability to take risk. The management should not apply certain restrictions on innovative employees in order to keep them focused and tuned on being creative.	3	Reflection of freedom of work
	To what extent do you evaluate the efforts of the organisation in making fewer restrictions on the working hours?		
	To what extent do you evaluate the efforts of the organisation in avoiding restricting the innovators to work in a limited working space?		
	To what extent do you evaluate the efforts of the organisation in showing tolerance and understanding?		

	To what extent do you evaluate the efforts of the organisation in avoiding restricting the innovators to work on one subject only?		
Mix of innovators and operators	It is important for the innovative organisation to remove the barriers between R & D and production or between innovators and production engineers.	2	Mix of innovators and operators (R & D and production)
	To what extent do you evaluate the efforts of the organisation in adopting the skunk work style (complete diverse integrated work groups)?		
	To what extent do you evaluate the efforts of the organisation in improving communications between R&D and production?		
	To what extent do you evaluate the efforts of the organisation in allowing the production department to work with R&D on testing the technical viability of ideas?		
	To what extent do you evaluate the efforts of the organisation in placing the R&D department close geographically to the production department?		
	To what extent do you evaluate the efforts of the organisation in rotating engineers between production and R&D?		

Corporate environment	The innovation process starts with an idea or a question from an individual, so at the beginning one person might be involved but after that it is group work and teamwork. Therefore, the existence and the maintenance of the corporate environment is a vital need for the innovative environment. Lack of a corporate environment will lead to lack of achievement and lower quality standards.	2	Reflection of corporate environment
	To what extent do you evaluate the efforts of the organisation in encouraging teamwork and team spirit during the implementation of ideas?		
	To what extent do you evaluate the efforts of the organisation in encouraging social activities and social relationships in the organisation?		
	To what extent do you evaluate the efforts of the organisation in conducting seminars about the importance of corporate efforts and corporate spirit in innovative organisations?		
Encouragement and motivation	The innovative atmosphere should be a stimulus to the innovators to give ideas and provide strong motives to keep the innovation process in continuous motion. This fresh optimistic atmosphere is an essential need for creativity. This task can be a difficult one because what encourages and motivates a certain person does not necessarily encourage and motivate another	3	Reflection of encouragement and motivation

	person. There are general measures, which, can be taken and are applicable to most of the targeted innovators, but there are some special measures, which are case-by-case and relevant to certain individuals.		
	To what extent do you evaluate the efforts of the organisation in creating a challenging atmosphere?		
	To what extent do you evaluate the efforts of the organisation in providing a comfortable working environment?		
	To what extent do you evaluate the efforts of the organisation in providing an atmosphere, which helps in allowing continuous flow of viable ideas?		
	To what extent do you evaluate the efforts of the organisation in appreciating and adopting good ideas as a mean of encouragement?		
	To what extent do you evaluate the efforts of the organisation in providing rewards and incentives as a mean of encouragement for the innovators?		
	To what extent do you evaluate the efforts of the organisation in linking the provision of good ideas and creativity to the promotion system in the organisation?		
Leadership	The management of innovations has two parts; one is pure administration and the other is leadership to inspire staff to	2	Leadership in the organisation

	maximise the returns from the invested human, technical and financial resources or the quality of obtaining results from staff and employees through personal influence. In such organisations the second part, "leadership" is of paramount importance in order to stimulate and motivate staff to give their extreme best. Whilst there is a role for both project managers and leaders, the term 'team management' or 'project management' will denote both management of tasks and leadership of people involved.		
	To what extent do you evaluate the efforts of the organisation in enhancing and encouraging the leadership side of innovative management?		
	To what extent do you evaluate the efforts of the organisation in providing seminars and training courses on leadership?		
	To what extent do you evaluate the efforts of the organisation in encouraging risk taking and decision making?		
	To what extent do you evaluate the efforts of the organisation in encouraging management and employees to be active rather than reactive (take initiative)?		

Empowering champions to drive the innovation process	The management of innovative organisations should lay the ground works and prepare a healthy atmosphere for innovations, but they ought to give the chance to project champions to lead on their project. Champions are more of leaders than managers; they strive to maintain a dynamic atmosphere for the project they are leading on.	1	Empowerment of champions to drive the innovation process
	To what extent do you evaluate the efforts of the management of the organisation in providing the champions with guidelines only and leave details to them?		
	To what extent do you evaluate the efforts of the organisation in preparing a good pool of champions and training them as leaders?		
	To what extent do you evaluate the efforts of the organisation in making champions responsible, and holding them accountable for their projects?		
Enthusiasm of innovators	Innovators should have and maintain strong warmth, of feeling a keen interest in being constantly creative. Management should do all that it can to create the necessary conditions to keep the innovators enthusiastic .The higher the level of enthusiasm, the higher the level of creativity.	3	Atmosphere of enthusiasm for the innovators
	To what extent do you evaluate the efforts of the organisation in letting innovators feel the taste of success?		

	To what extent do you evaluate the efforts of the organisation in providing freedom of work for the innovators as a stimulant for enthusiasm?		
	To what extent do you evaluate the efforts of the organisation in providing and maintaining a challenging atmosphere to innovators as a mean of enthusiasm?		
	To what extent do you evaluate the efforts of the organisation in shaping up innovators and champions leadership?		
Marshalling organisational resources	Large scattered resources are just as bad as lack of resources. A little well marshalled resources are a lot better than large badly spread resources. Therefore good management of resources is essential for reducing risk and improving the chances of success for innovative project.	4	Marshalling of organisational resources
	To what extent do you evaluate the efforts of the organisation in identifying resources?		
	To what extent do you evaluate the efforts of the organisation in setting up priorities for projects?		
	To what extent do you evaluate the efforts of the organisation in allocating resources to projects?		
	To what extent do you evaluate the efforts of the organisation in managing project resources through project managers and their teams?		

	To what extent do you evaluate the efforts of the organisation in providing support for project teams, with respect to the availability of resources?		
Recognition and appreciation	Part of reflecting a good healthy innovative atmosphere is to provide an atmosphere of recognition and appreciation for the staff, especially innovators whom need this to remain innovative. The greater the recognition and appreciation of the innovators, the more the creativity and innovativeness.	2	Atmosphere of recognition and appreciation
	To what extent do you evaluate the efforts of the organisation in showing respect to innovators?		
	To what extent do you evaluate the efforts of the organisation in providing incentives as a mean of recognition and appreciation?		
	To what extent do you evaluate the efforts of the organisation in naming some of the innovations after their innovators as a mean of recognition and appreciation?		
	To what extent do you evaluate the efforts of the organisation in making an honour list for outstanding innovators as a mean of appreciation?		

External environment	The external environment could have an impact on the innovators and on the internal creative environment. Obviously the organisation does not have control over the external environment such as the political situation, economical situation, laws, regulations and market conditions, but it should do its extreme best with the help of other organisations to improve the external environment and keep it's uncertainties in mind when performing risk analysis for their innovative projects.	4	External environment
	To what extent do you evaluate the efforts of the organisation in performing risk analysis for all innovative projects taking the external environment into considerations?		
	To what extent do you evaluate the efforts of the organisation in collaborating with other organisation to improve the external environment?		
	To what extent do you evaluate the efforts of the organisation in avoiding projects, which require a long time for execution?		
	To what extent do you evaluate the efforts of the organisation in setting up insurance on innovative projects?		

Innovators individual creativity	Creative organisations mean creative individuals, creative solutions, creative process, creative products and creative situations. Creativity can be looked at from an environment point of view, but in here, creativity will be looked at as it applies to innovators. The creative individual or the innovator is the one who generates new ideas or new ways of doing things.	6	Innovators individual creativity
	To what extent do you evaluate the efforts of the innovators in providing viable ideas?		
	To what extent do you evaluate the efforts of the innovators in understanding processes and products of the organisation?		
	To what extent do you evaluate the efforts of the innovators in taking the necessary measures to enhance creative thinking and problem solving?		
	To what extent do you evaluate the efforts of the innovators in attending seminars and training courses that enhance and raise their technological competence?		
	To what extent do you evaluate the efforts of the innovators in taking the necessary measures to go through diverse experiences by working in a multitude of conditions in different subjects and fields?		
	To what extent do you evaluate the efforts of the innovators in learning and practicing self-motivation and risk taking?		

Innovators group creativity	Group creativity is not the sum of the individual's creativity, but it is a resultant creativity, which depends on the creative behaviour meditated through the group as influenced by the group's composition.	4	Innovators group creativity
	To what extent do you evaluate the resultant creativity in relation to the number of innovators in the organisation?		
	To what extent do you evaluate the efforts of the team of innovators in understanding the processes and products of the organisation?		
	To what extent do you evaluate the compatibility and diversity of the innovative group?		
	To what extent do you evaluate the efforts of the innovators in becoming compatible with each other by strengthening their social ties?		
Innovator's personal commitment	The innovators should be committed to the project, to the organisation and to the customer. Lack of commitment means less viable ideas.	3	Innovators personal commitment
	To what extent do you evaluate the efforts of the innovators in understanding and believing in the vision and objectives of the organisation?		
	To what extent do you evaluate the efforts of the innovators in maintaining high efficiency?		

	To what extent do you evaluate the efforts of the innovators in getting closer to the customers in order to provide better services and products?		
	To what extent do you evaluate the efforts of the innovators in executing projects on time with both high quality and efficiency?		
Innovator's alignment of objectives	It is essential to align the objectives of the innovators themselves with the organisational objectives; otherwise a situation of incompatibility will exist. The innovators should try from their side to align their own objectives with organisational objectives or at least do their best to avoid conflict in objectives.	3	Innovators alignment of objectives
	To what extent do you evaluate the efforts of the innovators in knowing and understanding organisational objectives?		
	To what extent do you evaluate the efforts of the innovators in believing and meeting organisational objectives?		
	To what extent do you evaluate the efforts of the innovators in taking the necessary measures to align their own objectives with the organisational ones?		

Innovator's risk orientation	Creativity and innovativeness require trying new things and new ideas, which embed a certain amount of risk. Therefore, innovators should expect and accept risk taking in the course of doing their job. Being risk oriented is a necessity for trying new ideas.	3	Innovators risk orientation
	To what extent do you evaluate the efforts of the innovators in understanding calculated risk and the consequences of its adoption?		
	To what extent do you evaluate the efforts of the innovators in performing risk analysis before a doping or executing new projects?		
	To what extent do you evaluate the efforts of the innovators in understanding and utilising risk management measures or risk-response?		
	To what extent do you evaluate the efforts of the innovators in conducting trials and exercises on computer models "computer simulation" instead of trials on actual prototypes?		
	To what extent do you evaluate the efforts of the innovators in having and operating in an environment, which offers a freedom of work?		
Innovator's individualism	Individualism is essential for creativity and innovativeness. Individualism puts a personal touch over the new ideas and encourages the continuous flow of new ideas. Individualism should not prevent or hinder teamwork or team spirit.	2	Innovators individualism as related to creativity

	To what extent do you evaluate the efforts of the innovators in understanding the need for both individualism and team spirit and where they apply?		
	To what extent do you evaluate the efforts of the innovators in taking the necessary measures to practice individualism in providing ideas and teamwork when implementing them?		
Innovator's self-motivation	Innovators should be self-motivated in order to ensure continuous flow of new ideas.	2	Innovators self-motivation
	To what extent do you evaluate the ability of the innovators to work in discouraging conditions and overcome setbacks?		
	To what extent do you evaluate the ability of the innovators to enjoy their work regardless to management appreciation?		
	To what extent do you evaluate the efforts of the innovators in feeling and living a continuous competition?		
	To what extent do you evaluate the efforts of the innovators in taking initiative to feel and understand customer needs?		
Innovator's freedom of work	Creativity requires the innovator's feel and practicing of freedom of work. This freedom comes from the comfortable innovative atmosphere provided by the organisation.	3	Innovators freedom of work

	To what extent do you evaluate the ability of the innovators in providing and trying ideas freely without being discouraged by the probability of success or failure?		
	To what extent do you evaluate the level of trust and reliance between the innovators and their management?		
Innovator's understanding of user needs	Innovations are about ideas that can be exploited commercially, and to be commercially successful requires user approval and acceptance. This implies the innovator's understanding of customers needs.	4	Innovators understanding of customer needs
	To what extent do you evaluate the efforts of the innovators in coming closer to the customer?		
	To what extent do you evaluate the efforts of the innovators in understanding customer requirements and constraints in order to provide suitable and affordable products and services?		
	To what extent do you evaluate the ability of the innovators to predict customer future needs?		
Innovator's effective use of outside technology and advice	Innovators require various sources of ideas and high technological awareness to ensure continuous flow of ideas	4	Innovators effective use of outside technology and advice

	To what extent do you evaluate the efforts of the innovators in communicating with external linkages such as suppliers, universities, research institutes and colleagues in partner companies in order to gain fresh ideas?		
	To what extent do you evaluate the efforts of the innovators in socialising with innovators from other organisations and institutes?		
	To what extent do you evaluate the efforts of the innovators in staying in touch with the latest technologies through the Internet, research papers, books and magazines?		
Innovator's technology awareness	New competitive ideas require high technological awareness. Therefore, innovators should be aware of the latest technologies in order to enrich their own knowledge.	3	Innovators technology awareness
	To what extent do you evaluate the efforts of the innovators in reading reports, research papers, scientific magazines and books?		
	To what extent do you evaluate the efforts of the innovators in attending various seminars, workshops, exhibitions and training courses?		
	To what extent do you evaluate the efforts of the innovators in interacting with scientists, researchers and innovators from other organisations?		

Innovator's attention to marketing	It is known that, innovations are about ideas that can be exploited commercially. Therefore, it is beneficial for the innovators to understand marketing issues in order to provide ideas coherent with market needs and marketing requirements.	3	Innovators attention to marketing
	To what extent do you evaluate the efforts of the innovators in having some marketing knowledge and skills?		
	To what extent do you evaluate the efforts of the innovators in studying the targeted market?		
	To what extent do you evaluate the efforts of the innovators in staying close to the market in order to be aware of market needs and shifts?		
Study and analysis of idea	Any project originates from an idea; this idea can come from customer need through the marketing department (market pull), or from the innovators in the R&D department (technology push). Then the idea gives birth to a project. This implies that this idea should be analysed thoroughly and deeply to study its feasibility and its technical and commercial viability.	5	Study and analysis of idea
	To what extent do you evaluate the efforts in ensuring that the idea is coherent with the political, economical and strategic factors?		

	To what extent do you evaluate the research and studies done to ensure the technical viability of the idea?		
	How much do you evaluate the efforts in ensuring the idea's commercial viability and its coherence with the market conditions?		
	To what extent do you evaluate the efforts in ensuring the availability of resources for implementing the idea?		
	To what extent do you evaluate the efforts in studying the commercial, economical and technical risks embedded in implementing the idea?		
Technical Viability	All ideas should be analysed and studied for technical viability. This includes knowing if ideas can be achieved with the available personnel, skills, equipment and know-how. The technical viability is a function of time and place. What is not viable today could be viable in the future with the development of knowledge and expertise. Also what is not viable in undeveloped country is viable and within the capabilities of a developed one.	3	Assessment of the technical viability of ideas
	To what extent do you evaluate the efforts of the R&D department in considering testing of new ideas for technical viability as standard operating procedures?		

	To what extent do you evaluate the efforts of the organisation in selecting experts for testing and analysing new ideas for technical viability?		
	To what extent do you evaluate the efforts of the organisation in using the right tools for evaluating new ideas for technical viability?		
Commercial viability	New ideas should be studied and analysed to check for commercial viability. Commercial viability includes knowing if there is a potential market or a potential customer for the implementation of the new idea.	5	Commercial viability
	To what extent do you evaluate the efforts of the organisation in considering the evaluation of new ideas for commercial viability as a "standard operating procedures"?		
	How much do you evaluate the efforts of the organisation in selecting expert, responsible personnel for the commercial evaluation of new ideas?		
	To what extent do you evaluate the efforts of the organisation in using the right tools for evaluating new ideas for commercial viability?		
Project definition and understanding of user requirements	Defining the project by determining its scope and nature in the light of understanding the user requirements are of vital importance.	6	Project definition and understanding of user requirements

	To what extent do you evaluate the efforts of the organisation in understanding the precise user requirements?		
	To what extent do you evaluate the efforts of the organisation in setting a specific project definition and avoiding continuous major changes?		
	To what extent do you evaluate the efforts of the organisation in taking the necessary measures to ensure that the project manager and his team understand the scope and nature of the project fully?		
Project feasibility study	A project feasibility study should be conducted before the adoption of any project; failing to do so will constitute a source of risk for such a project.	3	Assessment of project feasibility study
	To what extent do you evaluate the efforts in doing an extensive project feasibility study before the adoption of the project?		
Derivation of specifications	An experienced R&D team should derive the exact specifications from the user requirements.	4	Derivation of specifications
	To what extent do you evaluate the efforts of the R&D department in taking detailed user requirements with the help of the user?		
	To what extent do you evaluate the efforts of the R&D department in conducting environmental analysis on the environment where the product of the project is going to be used?		

	To what extent do you evaluate the efforts of the organisation in employing experienced technical team to derive the specifications from the user requirements?		
Concept development	The R&D team should be able to present several concepts that reflect the derived specifications and fulfil customer requirements or the predicted requirements.	3	Concept development
	To what extent do you evaluate the efforts of the organisation in employing an experienced R&D team?		
	To what extent do you evaluate the efforts of the R&D department in providing several concepts that fit the user requirements and suit the user and his environment?		
	To what extent do you evaluate the efforts of the R&D department in using computer technology in providing different concepts?		
Concept selection	The R&D department has to provide several concepts, in order to allow the customer to make a selection. It is the duty of the R&D engineers to highlight the areas of strength and areas of weakness of each concept to the customer.	3	Concept selection
	To what extent do you evaluate the efforts of the R&D department in explaining the concepts provided in details and making a comparison between them to the customer?		

	To what extent do you evaluate the efforts in using computer simulation and modelling when introducing the concepts to the customer?		
	To what extent do you evaluate the efforts in ensuring that a true customer, capable and authorised in doing so, does concept selection?		
	To what extent do you evaluate the efforts in doing the concept selection by a group of experts, capable of representing the customer and maintain confidentiality at the same time (in the case of predicted future need when confidentiality is of high importance)?		
Risk Management	It is essential to take all the necessary measures to minimise risk embedded in project execution in order maximise the chances of success. Risk management includes risk identification, risk analysis and risk response.	3	Risk management
	To what extent do you evaluate the efforts in conducting risk analyses on projects using a team of experts in this field?		
	To what extent do you evaluate the efforts in identifying project sources of risk (internal & external)?		
	To what extent do you evaluate the efforts in analysing the identified sources of risk in order to find other embedded risks?		

	To what extent do you evaluate the efforts in preparing a risk response plan in order to counter predicted risks when they arise?		
	To what extent do you evaluate organisation understanding that risk analysis is not a substitute for professional judgment but a supplement to it?		
Project planning	Good project planning is of paramount importance to the success of any project. Planning includes identifying project activities, determining their logical sequence, estimating execution times and the required resources.	5	Project planning
	To what extent do you evaluate the efforts in identifying project activities?		
	To what extent do you evaluate the efforts in determining the logical order of project activities?		
	To what extent do you evaluate the efforts in estimating time required for the execution of each project activity?		
	To what extent do you evaluate the efforts in estimating project-required resources?		
	To what extent do you evaluate the efforts in preparing and presenting the project plan in a readily intelligible format?		
	To what extent do you evaluate the efforts in approving the project plan?		

	To what extent do you evaluate the efforts in understanding the project plan by all parties and individuals concerned?		
Availability of R&D resources	R & D resources are the designers, draftsmen, design references, computer design packages, simulation packages and design tools and equipment. The availability of such resources is of paramount importance and the lack of it will reflect negatively on the design quality.	11	Availability of R & D resources
	To what extent do you evaluate the efforts in recruiting skilled innovative designers and draftsmen?		
	To what extent do you evaluate the efforts in providing the designers with an innovative comfortable atmosphere?		
	To what extent do you evaluate the efforts in training and updating the designers and the draftsmen constantly?		
	To what extent do you evaluate the efforts in ensuring the availability of the required design tools and equipment?		
	To what extent do you evaluate the efforts in using advanced design and simulation packages?		
	How much do you evaluate the efforts in providing good and strong external linkages for the R&D staff such as links to universities, research institutes and suppliers?		

Availability of finance related to time scale	Innovative organisations tend to study and estimate the funds needed to support innovative projects. Funds and their availability could be a major source of risk to the success of any project. Project funds should be spent wisely as the project progresses.	12	Availability of finance related to time scale
	To what extent do you evaluate the efforts in evaluating the funds needed for any project before execution?		
	To what extent do you evaluate the efforts in ensuring the availability of project funds related to time scale?		
	To what extent do you evaluate the efforts in managing project funds and their expenditure?		
Availability of production personnel	Prototypes manufacturing requires sufficient competent production engineers and technicians. Lack of such resources will reflect negatively on the quality of prototypes.	3	Availability of production personnel
	To what extent do you evaluate the efforts in recruiting competent and skilled production engineers and technicians?		
	To what extent do you evaluate the efforts in ensuring the availability of the required technical skills?		
	To what extent do you evaluate the efforts in providing continuous training to enhance production personnel competencies?		

	To what extent do you evaluate the efforts in emphasising total quality management practices to the production personnel?		
Design for zero development	Designers should aim at "design for zero development" or "do it right the first time". Being careful and precise during the design stage saves high development costs at a later stage.	4	Adoption and application of design for zero development
	To what extent do you evaluate the efforts of the organisation in employing experienced creative designers?		
	To what extent do you evaluate the efforts of the organisation in using computer-aided design packages?		
	To what extent do you evaluate the efforts in adopting the idea of " design for zero development" or " do it right the first time"?		
	To what extent do you evaluate the efforts in applying teamwork and team spirit extensively during the design stage?		
Logistic influence on design	Logistics have a great influence on designs. The daily running of the designed equipment, its maintainability and its future support reflect significantly on designs. Ignoring the logistic influence on the designed equipment could constitute a major source of risk of failure.	2	Reflection of logistic influence on design
	To what extent do you evaluate the efforts in conducting environment analyses for the designed equipment prior to the start of design?		

	To what extent do you evaluate the efforts in studying the logistical factors and their influence on the designed equipment and taking that into consideration?		
	To what extent do you evaluate the efforts in reflecting the logistical aspects on the designed equipment?		
Data pack generation and update	All technical information to procure or manufacture materials or all documents that include the design specification; concepts, calculations, drawings and build procedures are called data pack, which should be generated and updated during the innovation process. Data packs are essential for mass production and future reference. Lack of data packs will result in lack of uniformity and standardisation.	5	Data pack generation and update
	To what extent do you evaluate the efforts in training experts in the R&D department to generate and update data packs?		
	To what extent do you evaluate the efforts in using suitable computer software for data pack generation?		

	To what extent do you evaluate the efforts in starting data packs generation at an early stage of the innovation process?		
	To what extent do you evaluate the efforts in data packs updating and performing constant computer backups?		
Prototyping	Building prototypes is a necessity to mature products. It is always better to detect design and production faults at an early stage before putting the product in the hands of the customer. Testing and evaluations are usually done on the prototypes. The build of prototypes should be done with joint cooperation between R&D and production departments.	5	Prototyping process
	To what extent do you evaluate the efforts in ensuring employees understanding of the needs of making prototypes?		
	To what extent do you evaluate the efforts in ensuring that the build of prototypes is done with joint efforts of R&D and production engineers?		

	To what extent do you evaluate the efforts in ensuring that testing and evaluating designs and production quality is conducted while building the prototypes?		
	To what extent do you evaluate the efforts in ensuring the optimisation of prototyping duration (long enough to ensure product maturity and short enough to avoid early competition)?		
User evaluation and approval	The user or his representative should evaluate a mature prototype to check for fulfilment and conformance with user requirements. The customer should also approve the prototype before moving into the production stage.	4	User evaluation and approval of prototypes
	To what extent do you evaluate the efforts in ensuring that testing and evaluation is done according to a well-documented procedures?		
	To what extent do you evaluate the efforts in ensuring that a trial report of the prototype is generated and disseminated?		
	To what extent do you evaluate the efforts in ensuring that prototypes are initially accepted by the producer and finally by the customer?		
	To what extent do you evaluate the efforts in ensuring that a written acceptance or approval of the prototype is requested from the customer?		

Manufacturing safety procedures	Safety of personnel, equipment, premises and materials are of paramount importance to the innovative organisation. Setting and practicing manufacturing safety procedures, promoting safety general awareness among employees, conducting safety training, providing safety tools and clothes and providing first aid kits on the shop floor, can enhance safety. Lack of safety procedures and measures could jeopardize the chances of success of innovative projects.	2	Manufacturing safety procedures
	To what extent do you evaluate the efforts in promoting safety general awareness among employees?		
	To what extent do you evaluate the efforts in taking the necessary safety measures?		
	To what extent do you evaluate the efforts in conducting safety-training programmes?		
	To what extent do you evaluate the efforts in providing safety tools and clothes for employees?		
	To what extent do you evaluate the efforts in providing first aids kits?		

Value added in production	The value of any product consists of the cost of materials, manufacturing cost and the added value. The added value comes from the value of the innovative idea; design and manufacturing skills used and the embedded quality. The more the added value there is, the higher the product quality and the more expected profit.	3	Value added in products
	To what extent do you evaluate the efforts in adopting good ideas?		
	To what extent do you evaluate the efforts in utilizing highly skilled production personnel?		
	To what extent do you evaluate the efforts in utilizing high precision production tools and equipment?		
	To what extent do you evaluate the efforts in employing experienced dedicated designers?		
	To what extent do you evaluate the efforts in utilizing powerful computer design packages?		
Development cost and time	Development cost and time are two major sources of risk for any project. Usually, development cost is relatively high, that is why innovative organisations should aim for "zero development" or "doing it right the first time". Development time should be long enough to ensure product maturity and short enough to avoid early competition.	5	Development cost and time

	To what extent do you evaluate the efforts in designing for zero development or for doing it right the first time?		
	To what extent do you evaluate the efforts in spending a long enough time to mature the product and a short enough time to avoid early competition?		
	To what extent do you evaluate the efforts in using computer design and simulation packages in designing and evaluating products?		
	To what extent do you evaluate the efforts in understanding the user requirements and reflecting them in the designed products?		
Creativity of the team involved in the innovation process	The existence of a creative team involved in the innovative process is of great importance. This team of people should be creative, compatible and diverse in skills.	3	Creativity of the team involved in the innovation process
	To what extent do you evaluate the efforts in employing creative people for implementing the innovation process?		
	To what extent do you evaluate the efforts in ensuring that the people involved in the innovation process are compatible and diverse in skills?		
	To what extent do you evaluate the efforts in paying close attention to individual and group creativity of the innovative team?		

Teamwork and team spirit	The project team is a temporary organisation of people. Implementation of innovations requires collaboration of all skills and talents to drive the innovation process from idea to product. Teamwork and team spirit is extremely important in the implementation of innovations. The group output of a team should be greater or equal to the sum of the outputs of the individuals. The group decision-making is likely to be better, since a project team usually has a greater range of options that can be considered. It is the job of the project manager to enhance teamwork and make it enjoyable.	3	Teamwork and team spirit
	To what extent do you evaluate the efforts in selecting a team of people who believe in teamwork and have the expertise to practice it?		
	To what extent do you evaluate the efforts in directing managers, supervisors, team leaders and project managers to encourage and take the necessary measures to adopt and practice teamwork?		
	To what extent do you evaluate the efforts in holding seminars on teamwork and team spirit and its importance?		

The logical flow of the innovation process	The innovation process should go through smooth and simple logical stages in order to speed up the innovation process. All personnel in the innovative organisation should know the innovation process from idea to product.	4	Logical flow of the innovation process
	To what extent do you evaluate the efforts in setting simple logical innovation process?		
	To what extent do you evaluate the efforts in explaining the innovation process to all employees involved in the process?		
	To what extent do you evaluate the efforts in taking all necessary measures to plan and implement feedback between stages of the innovation process?		
	To what extent do you evaluate the efforts in providing all necessary tools such as computers, software packages, and advanced equipment and communication equipment to speed up and shorten the innovation process duration?		
Communications during the innovation process	Collaboration, teamwork, exchange of ideas, removing barriers between organisational departments (R&D, production and marketing) and speeding up the innovation process requires good communications.	5	Communications during the innovation process

	To what extent do you evaluate the efforts in bringing departments involved in the innovation process closer to each other geographically?		
	To what extent do you evaluate the efforts in encouraging staff, engineers and technicians to communicate constantly with each other horizontally?		
	To what extent do you evaluate the efforts in providing communications tools such as telephones and internal computer nets?		
	To what extent do you evaluate the efforts of the organisation in keeping the organisational structure small and flat in order to enhance internal communications?		
	To what extent do you evaluate the efforts in minimising bureaucracy in the organisation?		
Participation of production engineers in the innovation process	Design to manufacture requires knowing the capabilities and skills of the production department, otherwise, the R&D department will come up with some designs which look good on papers but can not be produced with the existing equipment and skills, and this will call for design change. Changing designs at later stages will be time and effort consuming, which could become a significant source of risk to the success of the project. All this can be avoided by involving	2	Participation of production engineers in the innovation process

	production engineers at an early stage of design; this is also beneficial for the exchange of ideas, expertise and knowledge between design and production engineers.		
	To what extent do you evaluate the efforts of the organisation in planning and implementing an exchange programme between R&D and production engineers?		
	To what extent do you evaluate the efforts of the organisation in planning and conducting joint R&D and production meetings at several stages of the innovation process?		
	To what extent do you evaluate the efforts of the organisation in establishing and enhancing communications between R&D and production engineers?		
	To what extent do you evaluate the efforts of the organisation in encouraging and providing the necessary tools for horizontal communication and interaction between R&D and production engineers?		
Compatibility of the innovative team	Compatibility is a basic requirement to ensure teamwork and team spirit among engineers and technicians involved in the innovation process.	3	Compatibility of the innovative team

	To what extent do you evaluate the efforts of management in ensuring that the innovative team does not have extremists or fanatics in religion or politics or even in sports among the innovative team?		
	To what extent do you evaluate the efforts of management in encouraging social interaction among the innovative team?		
	To what extent do you evaluate the efforts of management in solving problems or personal differences that might arise among the innovative team?		
	To what extent do you evaluate the efforts in convincing the innovative team that success of their innovations and their organisation should take a high priority?		
Customer participation in the innovation process	Innovative organisations are market oriented. Customer needs should be kept in mind at all times during the innovation process, to do that, organisations should insure constant customer participation in order to address his exact needs and avoid deviation. Customer participation starts right at the beginning of the innovation process. Customer should participate in the formation of the idea, in putting the user requirements, in concept selection and in prototypes testing. In fact, R&D engineers should consult the customer whenever they are in doubt.	3	Customer participation in the innovation process

	The issue of confidentiality and competition should also be kept in mind. This is issue will reflect significantly on limiting customer participation in the innovation process. Knowing that customer participation is a must and in the case of the existence of sensitivity to open customer participation, then the organisation should refer to a controlled user committee, which provides true customer representation and reflects his needs without scarifying confidentiality in order to avoid early competition.		
	To what extent do you evaluate the efforts in making sure that the organisation is market oriented?		
	To what extent do you evaluate the efforts in keeping the R&D department in constant touch with the customer?		
	To what extent do you evaluate the efforts in ensuring customer participation in the formation of the innovative ideas?		
	How much do you evaluate the efforts in ensuring customer participation in identifying user requirements?		

	To what extent do you evaluate the efforts in ensuring customer participation in concept selection?		
	To what extent do you evaluate the efforts in ensuring customer participation in testing and evaluation of prototypes?		
Feedback between stages of the innovation process	Each stage of the innovation process includes several measures and decisions. Some of the decisions taken require changes and update on previous steps or require informing certain departments in the organisation. Therefore, feedback between the stages of innovation process is a necessity.	3	Feedback between stages of the innovation process
	To what extent do you evaluate the efforts in planning and pointing out feedback lines on the schematic charts of the innovation process and planning execution of such feedbacks on the ground?		
	To what extent do you evaluate the efforts in explaining the concept and the importance of feedback to all personnel involved in the innovation process?		
	To what extent do you evaluate the efforts in making the required updates and changes to conform to the feedbacks made?		

The availability of good quality production materials	Higher quality products require high quality raw materials or production materials. Using poor quality materials can be a major source of risk to the success of products.	2	Availability of good quality production materials
	To what extent do you evaluate the efforts in ensuring that all employees understand and appreciate the importance of using good quality raw and production materials?		
	To what extent do you evaluate the efforts in adopting tight supply quality control measures?		
Suitability and accuracy of testing tools and production equipment	The innovative organisation should be competitive in terms of quality of products and process, which implies suitable, high precision testing tools and production equipment.	2	Suitability and accuracy of testing tools and production equipment
	To what extent do you evaluate the efforts in using high precision testing tools and production equipment?		
	To what extent do you evaluate the efforts in maintaining and calibrating all testing and production equipment constantly?		
	To what extent do you evaluate the efforts in upgrading shop equipment and testing tools constantly to ensure accurate high quality products?		

Integration of the innovation process	The innovation process should have personnel from various needed skills, suitable equipment, the required raw materials and a good process, all integrated together to present a continuous, homogeneous, well-managed innovation process. Lack of integration will result in unnecessary halts and increasing project risk from a time point of view.	3	Integration of the innovation process
	To what extent do you evaluate the efforts in ensuring accurate and detailed project planning?		
	To what extent do you evaluate the efforts in explaining and understanding the role of each individual and department in the project?		
	To what extent do you evaluate the efforts in ensuring continuous and smooth flow of work through the project to avoid unnecessary halts or delays?		

The employment of skunk work style	The formation of a project team consisting of a small team of engineers, technicians, designers, model makers and all the necessary skills to take ownership of the project and become committed to its success is called a skunk work style which has proved to be efficient in executing and managing innovative project.	4	Application of the skunk work style
	To what extent do you evaluate the efforts in understanding the skunk work style concept by employees?		
	To what extent do you evaluate the efforts in adopting the skunk work style by the management as a style of work for executing innovative projects?		
	To what extent do you evaluate the efforts in managing manpower efficiently and avoid keeping redundant manpower (this can be achieved by identifying the individuals of the project team from the different departments and using those individuals when needed only, then sending them back to their own departments)?		
Freedom and control through the innovation process	The innovation process should be wisely managed. Freedom of work and comfort is necessary for people involved in the innovation process, but too much freedom could become a source of risk. The same thing applies for control, because the	4	Balance of freedom and control through the innovation process

	innovation process should be controlled, but too much control could also be a source of risk .So management should strike a balance between freedom and control in managing the innovation process.		
	To what extent do you evaluate the efforts in striking a balance between freedom and control in managing the innovation process?		
Product data management (PDM)	The innovative organisation should use a computer system capable of handling processes and controlling mass data in order to speed up the innovation process and reduce costs.	4	Product data management (PDM)
	To what extent do you evaluate the efforts in understanding the concept of product data management by management and employees?		
	To what extent do you evaluate the efforts in adopting the product data management concept?		
	To what extent do you evaluate the efforts in ensuring availability of hardware, software and expertise needed for the adoption and activation of product data management?		

Project management	Project management is essential for the success of projects. Selecting a competent project manager is of vital importance also. Poor project management can be a main source of risk to the degree of success or failure of any project.	10	Project management
	To what extent do you evaluate the efforts in identifying and listing all project activities?		
	To what extent do you evaluate the efforts in calculating the cycle time of each project activity?		
	To what extent do you evaluate the efforts in identifying the necessary project team skills?		
	To what extent do you evaluate the efforts in selecting the correct project team members?		
	To what extent do you evaluate the efforts in getting project teams working well as a unit?		
	To what extent do you evaluate the efforts in completing all project assignments on schedule?		
	To what extent do you evaluate the efforts in ensuring the effectiveness of project team's problem solving approach?		
	To what extent do you evaluate the efforts in ensuring that project critical decisions have been made on timely basis?	10	

	To what extent do you evaluate the efforts in checking if hidden agendas are arising?		
	To what extent do you evaluate the efforts in ensuring that project teams are maintaining focus?		
	To what extent do you evaluate the efforts in ensuring that project teams' time has been properly allocated to the projects?		
	To what extent do you evaluate the efforts in identifying the critical path?		
	To what extent do you evaluate the efforts in employing all project planning tools?		
	To what extent do you evaluate the efforts in identifying and reallocating all projects' slack time properly?		
	To what extent do you evaluate the efforts in identifying projects' critical milestones?		
	To what extent do you evaluate the efforts in setting management review schedules?		
	To what extent do you evaluate the efforts in confirming all support systems?		
	To what extent do you evaluate the efforts in ensuring that all conditions are the same as when the projects were launched?		
	To what extent do you evaluate the efforts in ensuring that the initial objectives of projects are still valid and attainable?		

	To what extent do you evaluate the efforts in reviewing and validating all projects' assumptions?		
	To what extent do you evaluate the efforts in ensuring that project scopes have not been changed?		
	To what extent do you evaluate the efforts in ensuring that projects are not impacted by any outside influences that could negatively alter projects schedules, costs, or performance?		
	To what extent do you evaluate the efforts in ensuring that management does not alter the original priorities assigned to the projects?		
	To what extent do you evaluate the efforts in ensuring that project expectations are not changed since the projects were started?		

APPENDIX D

DATABASE – APPLICATION II / ANALYSIS II

Risk Analysis in Project Management

Table Colour Code:

Description	Colour Code
External Sources of Risk	
Internal Sources of Risk	

Questionnaire criteria:

Questionnaires in general are formalised schedules used to collect a mixture of factual and attitude questions. A questionnaire is not just a list of questions or a form to be filled out. It is essentially a scientific instrument for measurement and for collection of particular kinds of data. Oppenheim, A. N., [49]. The questionnaire below is designed to comply with the following criteria: questions used are clear and not be ambiguous, vague, offensive, biased, inconsistent, emotive, loading or leading. Distortion in response is allowed for by cross correlation of question response.

C	D	E	F
Political situation	An external source of risk, which can be a major source of risk to projects, especially, in countries with various political disputes. Political situations can reflect positive or negative risks depending on the type of the project and the nature of the political dispute. For example, an unstable political situation in a country can be a source of negative risk in terms of profit, time and availability of resources such as materials	5	Political situation

	and labour for a certain project, but the same situation could be a source of positive risk in terms of profit, for projects which produce equipment or items to be utilised to serve a need during that particular political situation.		
	How do you evaluate the current political situation related to the advantage or disadvantage of the project in terms of finance, availability of time, availability of materials, availability of equipment, availability of personnel, market shift, change to customer requirements, etc.?		
	How do you evaluate the expected political situation during the project life cycle related to the advantage or disadvantage of the project in terms of finance, availability of time, availability of materials, availability of equipment, availability of personnel, market shift, change to customer requirements, etc.?		
Economical situation	An external source of risk. Unstable economical conditions can be a major source of uncertainty to the success and management of projects. This situation also could be a source of positive or negative risk depending on the type of the project and the nature of the economical problems.	5	Economical situation

	How do you evaluate the current economical situation related to the advantage or disadvantage of the project in terms of finance, availability of time, availability of materials, availability of equipment, availability of personnel, market shift, change to customer requirements, etc.?		
	How do you evaluate the expected economical situation during the project life cycle related to the advantage or disadvantage of the project in terms of finance, availability of time, availability of materials, availability of equipment, availability of personnel, market shift, change to customer requirements, etc.?		
Market conditions	An external source of risk to project management. Emerging markets or market shifts lead to change in customer needs or requirements, which, can be a major source of risk for projects that require long time to introduce a product to the market. Changing market conditions can also puzzle the planer especially when the direction and speed of change is hard to predict.	10	Market conditions
	How do you evaluate the present market need?		
	How do you evaluate the future predicted market need?		

	How do you evaluate the efforts in understanding and considering the user requirements?		
	How do you evaluate the efforts of the marketing and R&D departments in being in continuous touch with the targeted customer, in order to sense changes and shifts in requirements?		
	How do you evaluate the availability of the marketing resources to sell the project output?		
Technical and Commercial Viability	Successful projects are usually built around good ideas, which are technically and commercially viable, otherwise a big source of risk exists right at the starting point, which most properly will decide the fate of the project.	10	Technical and Commercial Viability
	How much do you evaluate the efforts in considering the evaluating the project from technical and commercial viability?		
	How much do you evaluate the efforts in selecting expert responsible personnel for the technical and commercial evaluation of the project?		
	How much do you evaluate the efforts in using the right tools for evaluating the project from technical and commercial point view?		

Definition of the project	Project definition is determining the scope and nature of the project. The development of the project's definition is vital to its success. A comprehensive definition should state its purpose, ownership, technology, cost, schedule, duration, financing, sale and marketing, and resources requirement. Project definition can be achieved by setting the objectives, defining the scope through a milestone plan, setting the functional strategies and assessing technical risk, managing the design process and managing resources. The lack of adequate definition and the frequent change in the project scope can be a vital source of risk.	5	Definition of the project
	How much do you evaluate the efforts in identifying the aims and objectives of the projects?		
	How much do you evaluate the efforts in specifying the project scope of work?		
	How much do you evaluate the probability of change in the project scope?		
	How much do you evaluate the efforts in considering and understanding the impact of change in project scope and preparing a suitable response for such change?		
Availability of resources (equipment, materials	The uncertainty in the availability of equipment, materials, personnel or funds needed for the timely execution of the project can be a cause of failure or success	5	Availability of resources (equipment, materials

personnel, funds).	to any project.		personnel, funds).
	How much do you evaluate the probability of change in the availability of resources required for the project during the project life cycle?		
	How much do you evaluate the availability of sufficient funds spread over the project life cycle?		
	How much do you evaluate the availability of sufficient production or row materials during the project life cycle?		
	How much do you evaluate the availability of sufficient manufacturing and testing equipment during the project life cycle?		
	How much do you evaluate the availability of sufficient personnel - with the required skills - to support and execute the project on time?		
Time	Time is a major and a vital source of risk from a management point of view. It is important for the organisations to introduce their products or services at the right time to achieve a break through or gain a competitive edge. Being late could mean loosing the market to the competitor.	5	Time
	How much do you evaluate the chances of success for the project, from time suitability point of view?		

	How much do you evaluate the availability of enough time for project execution and achievement of the set project objectives?		
	How much do you evaluate the availability of means to manage project time?		
Project size	Project size is also an important source of risk. The bigger the project size the greater the risk, especially when resources are limited. The worst case is when there is a large size project with less resources, weak management, weak project team and lack of time.	5	Project size
	How much do you evaluate the size of the project in relation to the availability of resources (give a high mark when resources are equal or greater to project need, lesser and lesser resources implies lower and lower marks)?		
	How much do you evaluate project size in relation to the size and capability of the organisation (give a high mark when the project size is within the capability of the organisation, lesser and lesser organisational capability in relation to project size implies lower and lower marks)?		
	How much do you evaluate project size in relation to the skills of the management (give a high mark when the project size is within the capability and skills of the management, lesser and lesser management		

	skills in relation to project size implies lower and lower marks)?		
	How much do you evaluate project size in relation to the skills of the project team (give a high mark when the project size is within the capability and skills of the project team, lesser and lesser project team skills in relation to project size implies lower and lower marks)?		
	How much do you evaluate project size in relation to markets availability (give a high mark when the project size is compatible with the market size, lesser and lesser market size in relation to project size implies lower and lower marks)?		
Commitment	Innovative organisations are required to reflect an atmosphere of care and responsibility, they should maintain a genuine and visible commitment to project, they should also maintain a commitment to quality and reliability. The commitment from the organisation's side should be extended towards the project team, the success of the project, the customers and suppliers, but also this should encourage and motivate the project team to be committed to the full success of the project too. Lack of commitment can jeopardize the chances of success of the project.	5	Commitment

	How much do you evaluate the willingness of organisation for showing the sense of shared responsibility?		
	How much do you evaluate the willingness of organisation for showing care for the project team, customers and suppliers?		
	How much do you evaluate the willingness of the organisation for sharing good and bad times with the project team?		
	How much do you evaluate the willingness of organisation for expressing the disadvantages of lack of commitment?		
	How much do you evaluate the willingness of project team for showing commitment toward the organisation and the success of the project?		
Confidentiality	Confidentiality is an absolute must especially in innovative projects in order to avoid early competition and to achieve remarkable breakthrough and maximum profit. Lack of confidentiality could mean the total failure and loss of the project.	5	Confidentiality
	How much do you evaluate the willingness of all members of the management to comply with confidentiality?		
	How much do you evaluate the willingness of the project team to comply with confidentiality?		
	How much do you evaluate the awareness of all personnel concerned about the issue of confidentiality and it's consequences?		

	How much do you evaluate the efforts of the organisation in taking the necessary measures to enforce confidentiality?		
Competition	Competition can be a prime driver behind innovation and high quality products and services; it also can be a source of risk. The existence of competition requires strict time schedules, high confidentiality, more marketing efforts and resources and competitive products and services in terms of prices and quality.	5	Competition
	How much do you evaluate the efforts in knowing the competitive products or services and the competitors?		
	How much do you evaluate the efforts in knowing and evaluating the seriousness and criticality of the competition?		
	How much do you evaluate the efforts in ensuring that the organisation is taking the necessary measures to produce a competitive product?		
	How much do you evaluate the efforts in ensuring that the organisation has an adequate market share and an alternative potential market?		
	How much do you evaluate the efforts in ensuring that the outcome product has a good shelf life?		

Laws and regulations	Non-commercial oriented laws and regulations and their instability in a certain country can be a source of risk for the success of any project. Project planning can start on certain laws and regulations, and half way through the new taxes and new governmental limitations come into existence, which can jeopardize the probability of success of that project.	5	Laws and regulations
	How much do you evaluate the efforts in finding out about the laws and regulations, if they are likely to change during the project life cycle?		
	How much do you evaluate the efforts in knowing the type and size of impact of change in laws and regulations on the project, and preparing the required response?		
Project planning	Project planning involves deciding what has to be done, when and by whom, which means identifying activities, determining their logical sequence, estimating times and resource requirements. Insufficient project planning is a main threat to the success of any project. Good planning allows the wise use of time and resources and also helps in avoiding unpleasant surprises.	10	Project planning
	How much do you evaluate the efforts in identifying project activities?		
	How much do you evaluate the efforts in determining the logical order of project		

	activates?		
	How much do you evaluate the efforts in estimating time required for each activity?		
	How much do you evaluate the efforts in estimating project resources requirement?		
	How much do you evaluate the efforts in preparing and presenting the project plan in a readily intelligible format?		
	How much do you evaluate the efforts in approving the project plan?		
	How much do you evaluate the efforts in understanding the project plan from all parties and individuals concerned?		
Project management	Project management includes planning, organising, directing and controlling activities in addition to motivating the concerned personnel. It is the management of a process of change and is considered as a main source of risk to the degree of success or failure of any project.	20	Project management
	How much do you evaluate the efforts going to be exerted in identifying and listing all project activities?		
	How much do you evaluate the efforts going to be exerted in calculating the cycle time of each project activity?		
	How much do you evaluate the efforts going to be exerted in identifying the necessary project team skills?		

	How much do you evaluate the efforts going to be exerted in selecting the correct project team members?		
	How much do you evaluate the efforts going to be exerted in getting project teams working well as a unit?		
	How much do you evaluate the efforts going to be exerted in completing all project assignments on schedule?		
	How much do you evaluate the efforts going to be exerted in ensuring the effectiveness of project team's problem solving approach?		
	How much do you evaluate the efforts going to be exerted in ensuring that project critical decisions are going to be made on timely basis?		
	How much do you evaluate the efforts going to be exerted in checking if hidden agendas are going to arise?		
	How much do you evaluate the efforts going to be exerted in ensuring that project team is going to maintain focus?		
	How much do you evaluate the efforts going to be exerted in ensuring that project time is going to be properly allocated to the projects?		
	How much do you evaluate the efforts going to be exerted in identifying the project's critical path?		

	How much do you evaluate the efforts going to be exerted in employing all project planning tools?		
	How much do you evaluate the efforts going to be exerted in identifying and reallocating the project's slack time properly?		
	How much do you evaluate the efforts going to be exerted in identifying the critical milestones?		
	How much do you evaluate the efforts going to be exerted in setting management review schedules?		
	How much do you evaluate the efforts going to be exerted in confirming all support systems?		
	How much do you evaluate the efforts going to be exerted in ensuring that all conditions are the same as when the project was launched?		
	How much do you evaluate the efforts going to be exerted in ensuring that the initial objectives of the project will still be valid and attainable?		
	How much do you evaluate the efforts going to be exerted in reviewing and validating project assumptions?		
	How much do you evaluate the efforts going to be exerted in ensuring that project scope will not been changed?		

	How much do you evaluate the efforts going to be exerted in ensuring that the project will not be impacted by any outside influences that could negatively alter project schedule, cost, or performance?		
	How much do you evaluate the efforts going to be exerted in ensuring that management does not alter the original priority assigned to the project?		
	How much do you evaluate the efforts going to be exerted in ensuring that project expectations will not change after the start of the project?		

APPENDIX E
EVALUATION REPORT - CASE STUDY I

Assessment of Innovativeness
Evaluation Report

Name of Organisation: Company A.

Address: Amman 11190, Jordan

Executive Summary

The organisational innovative environment is fair.

The innovators in the organisation are fair.

The innovation process in the organisation is good.

Evaluation Of The Innovative Environment

1. Good creative environment.
2. Good sources of ideas.
3. Poor vision and objectives projection.
4. Poor provision of innovative receptive atmosphere.
5. Fair commitment reflected by the innovative environment.
6. Poor reflection of market needs.
7. Poor programme selection.
8. Fair application of new technologies.
9. Good management guidance.
10. Good provision of charismatic programme management.
11. Good reflection of desire to advance.
12. Good organisational interactive relationship.

13. Poor application of multiple innovative or parallel approaches.
14. Poor application of shoot-outs between parallel approaches.
15. Good size and organisational structure.
16. Poor evaluation and quality assurance standards and procedures.
17. Good organisational external linkages.
18. Fair confidentiality standards.
19. Good job security of employees.
20. Fair safety measures in the organisation.
21. Poor organisational internal social environment.
22. Poor usage of procedures, guidelines and checklists.
23. Good communication facilities and system.
24. Poor challenge in the innovative environment.
25. Fair adoption of the skunk work style.
26. Poor adoption of interactive learning.
27. Fair provision of incentives.
28. Very good conveyance and execution of ideas and work.
29. Good organisational tolerance to non-conformity.
30. Poor acceptance to individualism in the provision of ideas.
31. Poor reflection of risk taking.
32. Good reflection of freedom of work.
33. Good mix of innovators and operators (R & D and production).
34. Poor reflection of corporate environment.
35. Fair reflection of encouragement and motivation.
36. Poor leadership in the organisation.
37. Poor empowerment of champions to drive the innovation process.
38. Poor atmosphere of enthusiasm for the innovators.
39. Good marshalling of organisational resources.
40. Poor atmosphere of recognition and appreciation.
41. Fair external environment.

Evaluation Of The Innovators

1. Poor innovators individual creativity.
2. Fair innovators group creativity.
3. Good innovators personal commitment.
4. Good innovators alignment of objectives.
5. Poor innovators risk orientation.
6. Good innovators individualism as related to creativity.
7. Good innovators self-motivation.
8. Good innovators freedom of work.
9. Fair innovators understanding of customer needs.
10. Fair innovators effective use of outside technology and advice.
11. Fair innovators technology awareness.
12. Poor innovators attention to marketing.

Evaluation Of The Innovative Process

1. Good study and analysis of idea.
2. Poor assessment of the technical viability of ideas.
3. Poor commercial viability.
4. Good project definition and understanding of user requirements.
5. Poor assessment of project feasibility study.
6. Good derivation of specifications.
7. Good concept development.
8. Good concept selection.
9. Poor risk management.
10. Good project planning.
11. Good availability of R & D resources.
12. Very good availability of finance related to time scale.
13. Good availability of production personnel.
14. Good adoption and application of design for zero development.
15. Poor reflection of logistic influence on design.

16. Very good data pack generation and update.
17. Good prototyping process.
18. Very good user evaluation and approval of prototypes.
19. Good manufacturing safety procedures.
20. Good value added in products.
21. Good development cost and time.
22. Good creativity of the team involved in the innovation process.
23. Poor teamwork and team spirit.
24. Fair logical flow of the innovation process.
25. Good communications during the innovation process.
26. Good participation of production engineers in the innovation process.
27. Good compatibility of the innovative team.
28. Very good customer participation in the innovation process.
29. Poor feedback between stages of the innovation process.
30. Good availability of good quality production materials.
31. Good suitability and accuracy of testing tools and production equipment.
32. Very good integration of the innovation process.
33. Good application of the skunk work style.
34. Good balance of freedom and control through the innovation process.
35. Poor product data management (PDM).
36. Good project management.

Name And Signature Of The Evaluator **Date**

3rd June 2002

Ghazi Khdairi

(Deputy Director General)

APPENDIX F
EVALUATION REPORT- CASE STUDY II

Assessment of Innovativeness
Evaluation Report

Name of Organisation: Company B.

Address: Amman, Jordan

Executive Summary

The organisational innovative environment is good.
The innovators in the organisation are good.
The innovation process in the organisation is good.

Evaluation Of The Innovative Environment

1. Very good creative environment.
2. Good sources of ideas.
3. Very good vision and objectives projection.
4. Fair provision of innovative receptive atmosphere.
5. Very good commitment reflected by the innovative environment.
6. Very good reflection of market needs.
7. Good programme selection.
8. Good application of new technologies.
9. Excellent management guidance.
10. Good provision of charismatic programme management.
11. Excellent reflection of desire to advance.
12. Good organisational interactive relationship.

13. Very good application of multiple innovative or parallel approaches.
14. Good application of shoot-outs between parallel approaches.
15. Good size and organisational structure.
16. Very good evaluation and quality assurance standards and procedures.
17. Very good organisational external linkages.
18. Good confidentiality standards.
19. Excellent job security of employees.
20. Very good safety measures in the organisation.
21. Good organisational internal social environment.
22. Good usage of procedures, guidelines and checklists.
23. Excellent communication facilities and system.
24. Good challenge in the innovative environment.
25. Good adoption of the skunk work style.
26. Very good adoption of interactive learning.
27. Good provision of incentives.
28. Very good conveyance and execution of ideas and work.
29. Good organisational tolerance to non-conformity.
30. Fair acceptance to individualism in the provision of ideas.
31. Good reflection of risk taking.
32. Good reflection of freedom of work.
33. Good mix of innovators and operators (R & D and production).
34. Good reflection of corporate environment.
35. Good reflection of encouragement and motivation.
36. Good leadership in the organisation.
37. Good empowerment of champions to drive the innovation process.
38. Good atmosphere of enthusiasm for the innovators.
39. Very good marshalling of organisational resources.
40. Very good atmosphere of recognition and appreciation.
41. Good external environment.

Evaluation Of The Innovators

1. Good innovators individual creativity.
2. Good innovators group creativity.
3. Good innovators personal commitment.
4. Good innovators alignment of objectives.
5. Fair innovators risk orientation.
6. Poor innovators individualism as related to creativity.
7. Fair innovators self-motivation.
8. Good innovators freedom of work.
9. Good innovators understanding of customer needs.
10. Good innovators effective use of outside technology and advice.
11. Poor innovators technology awareness.
12. Fair innovators attention to marketing.

Evaluation Of The Innovative Process

1. Good study and analysis of idea.
2. Poor assessment of the technical viability of ideas.
3. Poor commercial viability.
4. Very good project definition and understanding of user requirements.
5. Very good assessment of project feasibility study.
6. Good derivation of specifications.
7. Very good concept development.
8. Good concept selection.
9. Fair risk management.
10. Very good project planning.
11. Poor availability of R & D resources.
12. Good availability of finance related to time scale.
13. Very good availability of production personnel.
14. Fair adoption and application of design for zero development.
15. Fair reflection of logistic influence on design.

16. Excellent data pack generation and update.
17. Good prototyping process.
18. Very good user evaluation and approval of prototypes.
19. Good manufacturing safety procedures.
20. Very good value added in products.
21. Good development cost and time.
22. Very good creativity of the team involved in the innovation process.
23. Very good teamwork and team spirit.
24. Good logical flow of the innovation process.
25. Excellent communications during the innovation process.
26. Good participation of production engineers in the innovation process.
27. Good compatibility of the innovative team.
28. Very good customer participation in the innovation process.
29. Very good feedback between stages of the innovation process.
30. Excellent availability of good quality production materials.
31. Good suitability and accuracy of testing tools and production equipment.
32. Very good integration of the innovation process.
33. Very good application of the skunk work style.
34. Very good balance of freedom and control through the innovation process.
35. Very good product data management (PDM).
36. Very good project management.

Name And Signature Of The Evaluator **Date**

5th June 2002

Dr. Saqer Abdal Rahman

General Director

APPENDIX G
EVALUATION REPORT- CASE STUDY III

Assessment of Innovativeness
Evaluation Report

Name of Organisation: Company C.

Address: Pretoria, South Africa.

Executive Summary

The organisational innovative environment is good.

The innovators in the organisation are good.

The innovation process in the organisation is good.

Evaluation Of The Innovative Environment

1. Excellent creative environment.
2. Poor sources of ideas.
3. Good vision and objectives projection.
4. Fair provision of innovative receptive atmosphere.
5. Very good commitment reflected by the innovative environment.
6. Very good reflection of market needs.
7. Fair programme selection.
8. Fair application of new technologies.
9. Excellent management guidance.
10. Very good provision of charismatic programme management.
11. Very good reflection of desire to advance.
12. Very good organisational interactive relationship.

13. Good application of multiple innovative or parallel approaches.
14. Excellent application of shoot-outs between parallel approaches.
15. Excellent size and organisational structure.
16. Very good evaluation and quality assurance standards and procedures.
17. Good organisational external linkages.
18. Good confidentiality standards.
19. Very good job security of employees.
20. Very good safety measures in the organisation.
21. Excellent organisational internal social environment.
22. Very good usage of procedures, guidelines and checklists.
23. Good communication facilities and system.
24. Good challenge in the innovative environment.
25. Excellent adoption of the skunk work style.
26. Good adoption of interactive learning.
27. Excellent provision of incentives.
28. Excellent conveyance and execution of ideas and work.
29. Excellent organisational tolerance to non-conformity.
30. Good acceptance to individualism in the provision of ideas.
31. Excellent reflection of risk taking.
32. Very good reflection of freedom of work.
33. Fair mix of innovators and operators (R & D and production).
34. Very good reflection of corporate environment.
35. Very good reflection of encouragement and motivation.
36. Good leadership in the organisation.
37. Very good empowerment of champions to drive the innovation process.
38. Very good atmosphere of enthusiasm for the innovators.
39. Excellent marshalling of organisational resources.
40. Good atmosphere of recognition and appreciation.
41. Fair external environment.

Evaluation Of The Innovators

1. Good innovators individual creativity.
2. Very good innovators group creativity.
3. Excellent innovators personal commitment.
4. Very good innovators alignment of objectives.
5. Good innovators risk orientation.
6. Excellent innovators individualism as related to creativity.
7. Excellent innovators self-motivation.
8. Excellent innovators freedom of work.
9. Very good innovators understanding of customer needs.
10. Poor innovators effective use of outside technology and advice.
11. Poor innovators technology awareness.
12. Good innovators attention to marketing.

Evaluation Of The Innovative Process

1. Good study and analysis of idea.
2. Good assessment of the technical viability of ideas.
3. Fair commercial viability.
4. Very good project definition and understanding of user requirements.
5. Good assessment of project feasibility study.
6. Good derivation of specifications.
7. Very good concept development.
8. Very good concept selection.
9. Good risk management.
10. Good project planning.
11. Good availability of R & D resources.
12. Very good availability of finance related to time scale.
13. Fair availability of production personnel.
14. Good adoption and application of design for zero development.
15. Very good reflection of logistic influence on design.

16. Very good data pack generation and update.
17. Very good prototyping process.
18. Excellent user evaluation and approval of prototypes.
19. Fair manufacturing safety procedures.
20. Fair value added in products.
21. Very good development cost and time.
22. Very good creativity of the team involved in the innovation process.
23. Very good teamwork and team spirit.
24. Good logical flow of the innovation process.
25. Good communications during the innovation process.
26. Fair participation of production engineers in the innovation process.
27. Excellent compatibility of the innovative team.
28. Excellent customer participation in the innovation process.
29. Good feedback between stages of the innovation process.
30. Good availability of good quality production materials.
31. Fair suitability and accuracy of testing tools and production equipment.
32. Very good integration of the innovation process.
33. Very good application of the skunk work style.
34. Excellent balance of freedom and control through the innovation process.
35. Very good product data management (PDM).
36. Good project management.

Name & Signature Of The Evaluator **Date**

4th June 2002

Mr. Hennie Bouwers

APPENDIX H

EVALUATION REPORT - CASE STUDY IV

Assessment of Innovativeness

Evaluation Report

Name of Organisation: Company D.

Address: Hemel Hempstead, Herts, UK.

Executive Summary

The organisational innovative environment is good.

The innovators in the organisation are fair.

The innovation process in the organisation is very good.

Evaluation of the innovative environment

1. Excellent creative environment.
2. Good sources of ideas.
3. Very good vision and objectives projection.
4. Poor provision of innovative receptive atmosphere.
5. Good commitment reflected by the innovative environment.
6. Very good reflection of market needs.
7. Excellent programme selection.
8. Good application of new technologies.
9. Good management guidance.
10. Very good provision of charismatic programme management.
11. Excellent reflection of desire to advance.
12. Excellent organisational interactive relationship.
13. Very good application of multiple innovative or parallel approaches.
14. Good application of shoot-outs between parallel approaches.

15. Excellent size and organisational structure.
16. Very good evaluation and quality assurance standards and procedures.
17. Fair organisational external linkages.
18. Very good confidentiality standards.
19. Good job security of employees.
20. Excellent safety measures in the organisation.
21. Poor organisational internal social environment.
22. Good usage of procedures, guidelines and checklists.
23. Good communication facilities and system.
24. Poor challenge in the innovative environment.
25. Excellent adoption of the skunk work style.
26. Good adoption of interactive learning.
27. Poor provision of incentives.
28. Very good conveyance and execution of ideas and work.
29. Good organisational tolerance to non-conformity.
30. Poor acceptance to individualism when it comes to the provision of ideas.
31. Poor reflection of risk taking.
32. Poor reflection of freedom of work.
33. Very good mix of innovators and operators (R & D and production).
34. Poor reflection of corporate environment.
35. Fair reflection of encouragement and motivation.
36. Poor leadership in the organisation.
37. Poor empowerment of champions to drive the innovation process.
38. Poor atmosphere of enthusiasm for the innovators.
39. Good marshalling of organisational resources.
40. Poor atmosphere of recognition and appreciation.
41. Good external environment.

Evaluation of the innovators

1. Good innovators individual creativity.
2. Good innovators group creativity.
3. Good innovators personal commitment.
4. Very good innovators alignment of objectives.
5. Poor innovators risk orientation.
6. Very good innovators individualism as related to creativity.
7. Good innovators self-motivation.
8. Fair innovators freedom of work.
9. Poor innovators understanding of customer needs.
10. Poor innovators effective use of outside technology and advice.
11. Poor innovators technology awareness.
12. Very good innovators attention to marketing.

Evaluation of the innovation process

1. Excellent study and analysis of idea.
2. Excellent assessment of the technical viability of ideas.
3. Excellent commercial viability.
4. Excellent project definition and understanding of user requirements.
5. Excellent assessment of project feasibility study.
6. Good derivation of specifications.
7. Excellent concept development.
8. Very good concept selection.
9. Very good risk management.
10. Excellent project planning.
11. Good availability of R & D resources.
12. Excellent availability of finance related to time scale.
13. Good availability of production personnel.
14. Excellent adoption and application of design for zero development.
15. Very good reflection of logistic influence on design.

16. Very good data pack generation and update.
17. Excellent prototyping process.
18. Excellent user evaluation and approval of prototypes.
19. Excellent manufacturing safety procedures.
20. Excellent value added in products.
21. Fair development cost and time.
22. Excellent creativity of the team involved in the innovation process.
23. Excellent teamwork and team spirit.
24. Excellent logical flow of the innovation process.
25. Very good communications during the innovation process.
26. Excellent participation of production engineers in the innovation process.
27. Fair compatibility of the innovative team.
28. Excellent customer participation in the innovation process.
29. Excellent feedback between stages of the innovation process.
30. Excellent availability of good quality production materials.
31. Excellent suitability and accuracy of testing tools and production equipment.
32. Very good integration of the innovation process.
33. Excellent application of the skunk work style.
34. Very good balance of freedom and control through the innovation process.
35. Excellent product data management (PDM).
36. Very good project management.

Name and signature of the evaluator **Date**

4th July 2002

Roger Saunders

APPENDIX I
EVALUATION REPORT - CASE STUDY V

Risk Assessment Of Innovative Projects
Evaluation Report

Name of Organisation: Company A.

Address: Amman 11191, Jordan.

Project Name: Black Iris (AB3).

Executive Summary

The risk expected in the adoption and the execution of the assessed project =14.10%
The expected risk for the adoption and execution of this project is low.

Assessment Of Project Risk

1. Low risk imposed by the political situation.
2. Low risk reflected by the economical situation.
3. Low risk imposed by market conditions.
4. Low risk imposed because of the technical and commercial viability of the project.
5. Low risk expected because of the instability of project definition.
6. Low availability of resources (equipment, materials, personnel, funds).
7. Low risk expected because of project duration.
8. Low risk expected because of project size.
9. Low risk expected as related to the degree of commitment to the project.
10. Low risk expected because of confidentiality matters as related to the project.

11. Medium risk expected because of existing and expected competition.
12. Low risk imposed because of the existing laws and regulations.
13. Medium risk expected because of project planning.
14. Medium risk expected because of project management.

Name & Signature Of The Evaluator **Date**

18th June 2002

Erim Khalid

Project Manager

APPENDIX J
EVALUATION REPORT - CASE STUDY VI

Risk Assessment Of Innovative Projects
Evaluation Report

Name of Organisation: Company A.

Address: Amman 11191, Jordan.

Project Name: Hovercraft (AB 10).

Executive Summary

The risk expected in the adoption and the execution of the assessed project =38.14%
The expected risk for the adoption and execution of this project is medium.

Assessment Of Project Risk

1. Low risk imposed by the political situation.
2. Medium risk reflected by the economical situation.
3. High risk imposed by market conditions.
4. High risk imposed because of the technical and commercial viability of the project.
5. Medium risk expected because of the instability of project definition.
6. Medium availability of resources (equipment, materials, personnel, funds).
7. Medium risk expected because of project duration.
8. Medium risk expected because of project size.
9. Medium risk expected as related to the degree of commitment to the project.

10. Low risk expected because of confidentiality matters as related to the project.

11. High risk expected because of existing and expected competition.

12. Low risk imposed because of the existing laws and regulations.

13. High risk expected because of project planning.

14. Medium risk expected because of project management.

Name & Signature Of The Evaluator

Date

18th June 2002

Maher Assaf

Project Manager

APPENDIX K

COMMENTS ON COMPUTER ANALYSIS I (MANAGING INNOVATIVE ORGANISATIONS) FROM INDUSTRY

This appendix includes several letters from industrial experts belong to different industrial environments, whom have used computer analysis I (Managing Innovative Organisations) to assess certain known companies to them and have sent their comments on the program. These experts are:

Name	Appointment	Company	Country
Mr. Bassam Issa	Manager, Design & Development Department	King Abdullah II Design & Development Bureau	Jordan
Dr. Saqer Abdel- Rahim	Manager, Computer Technology Centre	Royal Scientific Society	Jordan
Mr. Hennie Bouwer	General Manager	Mechanology Design Bureau	South Africa
Mr. Roger Saunders	Technology Manager- Mechanical	Desoutter Limited	United Kingdom

بسم الله الرحمن الرحيم

KING ABDULLAH II DESIGN & DEVELOPMENT BUREAU

P.O.Box 927190 - Amman 11190 - Jordan

مــركز المــلك عبداللــه الثاني للتصميم والتطويــر

ص.ب ٩٢٧١٩٠ - عمان ١١١٩٠ - الأردن

KADDB/Research and Studies/2002/ 2533
Date: 18 July 2002

To : **Ghazi Khdairi**
King Abdullah II Design and Development Bureau (KADDB)
Amman, Jordan

From : **Bassam Issa**
Design and Development Department Manager
King Abdullah II Design and Development Bureau (KADDB)
Amman, Jordan

Dear Ghazi,

Feedback on Computer Program-Managing Innovative Organisations / Evaluation of Innovative Organisations

Many thanks for giving me the opportunity to use your computer program to evaluate our organisation. I would like to give you some feedback on the program.

1. I found the program finding to be user-friendly and extremely comprehensive.
2. The results predicted by the program were accurate and very close to reality.
3. The assessment report produced by the program was explicit and informative.
4. May I suggest we reuse your computer program in the future to reassess our organisation after undergoing extensive reorganization, as a tool to document our progress.

Yours sincerely,

Bassam Issa
KADDB Design and Development Department Manager

Tel: +962 (5) 3985622 Fax: +962 (2) 6256142 هاتف: ٣٩٨٥٦٢٢ (٥) ٩٦٢ + فاكس ٦٢٥٦١٤٢ (٢) ٩٦٢ +
E-mail: info@kaddb.com

RSS 5344806 07/18 '02 09:07 NO.515 01

بسم الله الرحمن الرحيم

The Royal Scientific Society — الجمعية العلمية الملكية

Center.: Computer Technology Centre — المركز:

Reference: (1) 194/12/1 / 14468 — الرقم:

Date: 17 / 7/ 2002 — التاريخ:

Amman 2002

Facsimile Message
5340520

S. A/Rahim

From: Dr. Saqer Abdel-Rahim
Computer Technology,
Training and Industrial
Studies Centre
Royal Scientific Society
E-mail : saqer@rss.gov.jo

To: Col. Ghazi Khdairi
Deputy Director General
King Abdullah II Design and
Development Bureau
Amman - Jordan
Fax: 02 6256142

Dear Mr. Khdairi

I refer to using your program to evaluate our centre at the RSS. I would like to thank for giving us the apportunity to use this useful program which indeed points out the performence of the centre.

However, the following comments have been noticed:

1- The program is user friendly, a modification to allow the user to go back for reviewing some answers is recommended .
2- Most of the questions required for the assesment are there.
3- Enough information were given by the program to identify the strength and weaknesses of our centre.
4- In general , the program is quite beneficial for evaluation of institutions. The results I got from the program correspond to a great extent to my own evaluation of my centre.

In addition, it provided me with a documented analysis of the points of evaluation specially the strength and weaknesses of the centre which will assest in improving the performance.

Many thanks

& Best wishes

S. A/Rahim

ص.ب: ١٤٣٨، الجبيهة ١١٩٤١ الأردن * تلفون: ٥٣٤٤٧٠١ (٦ ٩٦٢) * فاكسميلي ٥٣٤٤٨٠٦ * http://www.rss.gov.jo
P.O Box 1438, Al-Jubaiha 11941 Jordan * Tel. (962 6) 5344701* Fax. 5344806 * Email: rssinfo@rss.gov.jo

MDB

• MECHANOLOGY DESIGN BUREAU •

developing todays future

15 July 2002

Col. Ghazi Khdairi
King Abdullah II Design & Development Bureau
Amman
Jordan

Dear Col. Ghazi

COMPUTER PROGRAM

The use of your computer program on 5 June 2002 to evaluate MDB refers. I would like to comment as follows on the program:

- I found the program user friendly.
- The questionnaire appeared to be comprehensive regarding the subject.
- The program was found to be a useful tool to evaluate strengths and weaknesses of the environment, the innovators and the innovation process.
- It is my opinion that there is a fair correlation between my own assessment of our company and the response from the program.
- It is worthwhile to mention that there are numerous duplications in the questions. Although it is in different sections, it should be phrased differently to avoid same answers to evaluate different aspects.
- Further it is recommended that checks and balances be built into the program to ensure consistency.
- Graphic presentation of the results may also be considered.

I trust you will find the feedback constructive.

Kind regards,

Hennie Bouwer

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Mr. G. Khdairi
Deputy Director General
King Abdullah 11 Design & Development Bureau
Jordan

Dear Mr. Khdairi

I would like to take this opportunity in thanking you for including me and our company in evaluation of your computer aided management software programme on "Assessment of Innovative Organisations".

The programme was both informative and useful in identifying areas within our organisation, which could benefit from improvement. I believe the resultant evaluation report gave a fair reflection of the situation within the company

With regard its usage, I considered it to be very user friendly, easy to understand and straightforward operate.

I believe that it would be a useful tool for companies, which believe they need to promote and develop innovation within their particular environment.

If you feel I can be any further assistance please do not hesitate to contact me.

May I wish you every success for the future.

Yours Sincerely

Signed

Mr. Roger Saunders

Technology Manager - Mechanical