The 'Creative Factory'

An Innovation Systems Model Using a Systems Thinking Approach

by

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Abstract

The author has designed, developed and applied, employing a system dynamics approach, a new innovation system concept – the Creative Factory – in order to communicate innovation theory to the different actors in the system using a common perspective and to reveal the complexity of innovation systems. Furthermore, the model aims to create a dynamic framework that can be used to analyse and assess the innovation activity of a firm against best practice and to illustrate, through simulation, the short and long-term influences of managers' decisions or external factors on innovation outcomes and between the different factors in the system.

The concept has at its centre the firm's knowledge creation, the new product design and development process and the competencies that separate successes from failures. These core elements are affected by other business activities of the firm such as the corporate strategy, the risk taking policy and the organisational structure. Additionally, it is influenced by the National Innovation Environment within which the firm operates. The creative factory model has been used in this project as an assessment tool in three different firms. Then, action-scenarios are simulated, which demonstrate how to improve and control the innovation activity of these three firms. Additionally, the author designed scenarios in order to demonstrate the effects of external influences on the innovation activity of the firms.

Studying the results of the creative factory's simulation, the interconnection between the elements of an innovation system is illustrated. The need for capital investment in research in parallel with organisational improvements is shown to be a key factor for the success of the innovation process. The importance of the early stages of the new product design and development process in the overall performance of a firm is demonstrated. Finally, the influence of the national innovation environment on the innovation process and on the related business activities is identified.

To my Parents

Declaration

I declare that except where referenced this thesis is the result of my own work. I also declare that this thesis has not been submitted for a degree in another university.

Acknowledgement

I am grateful to my supervisor Dr. Kevin Neailey for comments, suggestions and support. This thesis has benefited from suggestions and discussions with Dr. Baback Yazdani who suppervised the first two years of this project and Stuart Passey who participated in the supervision during the third year.

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List of Abbreviations

AoS: Appreciation of the Situation

CCM: Communicated Conceptual Model

FM: Formal Model

NIE: National Innovation Environment

NPDD: New Product Design and Development

OECD: Organisation for Economic Co-operation and Development

PioR: Policy Insights or Recommendations

SIN: System Integration and Networking

SODA: Strategic Options Development and Analysis

SSM: Soft Systems Methodology

1 Introduction

The term innovation has been used in the literature to describe both the process that uses new knowledge, technologies and processes to generate new products as well as the new or improved products themselves (Porter, 1990). Innovation is distinguished from the term invention as innovation also involves the factor of commercialisation. Porter identifies innovation as (1990: p 780): '*a new way of doing things (termed an invention by some authors) that is commercialised*'. Freeman and Soete mention (1997: p 6): '*an innovation in the economic sense is accomplished only with the first commercial transaction involving the new product, process system or device, although the word is used also to describe the whole process. Of course, further inventions often take place during the innovation process and still more inventions and innovations may be made during the diffusion process*'.

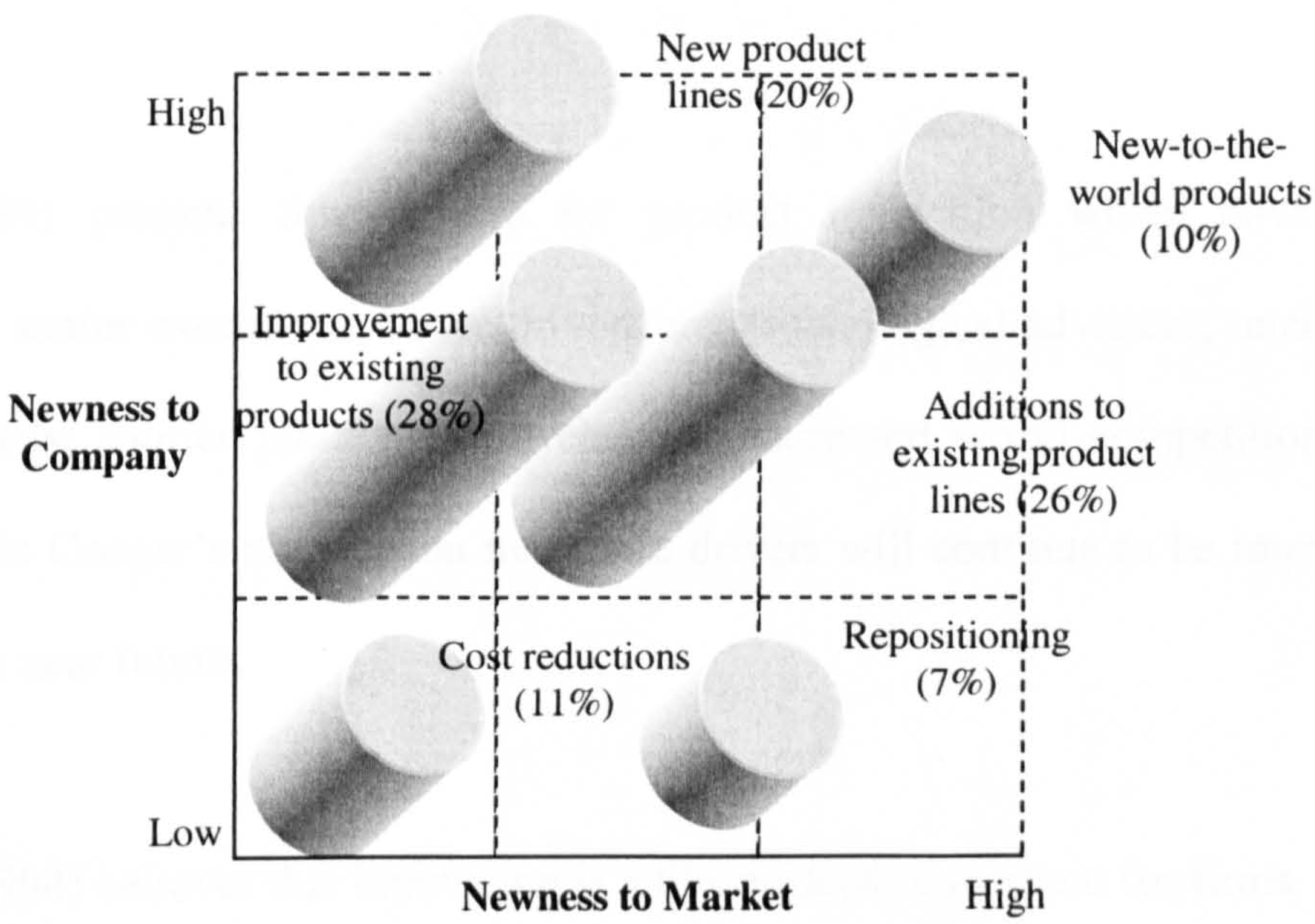
Edquist (1997b: p 9) quotes Schumpeter's definition for innovation identifying it as one of the broadest definitions in the literature: '*the setting up of a new production function. This covers the case of a new commodity as well as those of a new form of organisation such as a merger, of the opening up of new markets and so on. Recalling that production in the economic sense is nothing but combining productive services, we may express the same thing by saying that innovation combines factors in a new way, or that it consists in carrying out New Combinations*'. Edquist mentions that Schumpeter uses the term '*new commodities*' for what we could call new technologies or product innovations, adding that within the term '*the setting up of a new* *production function*' Schumpeter considers new organisational and technological processes as well as innovations. Moreover, he observes that the term innovation is used additionally for a new use or a '*new combination*' of existing factors, meaning the use of existing technologies or knowledge in a way that they have not been used before. This latter observation is supported by Nelson and Rosenberg (1993) who argue that often an invention is successfully commercialised by a different firm from the inventor and it may happen a long time after the invention first occurred. Thus, the successful diffusion of the new product or process is required in order for it to be characterised as an innovation.

Innovation is defined for this project as the creation of new products, knowledge or services by using new or existing scientific or technological knowledge, which provide a degree of novelty either to the developer, the industrial sector, the nation or the world and succeed in the marketplace.

1.1 Categories of Product Innovation

Tidd and his colleagues (1997) categorise product innovation according to the level of its novelty or newness, running from minor and incremental improvements to radical changes. Radical innovations may create discontinuity with the past, or in Schumpeter's terms 'creative destruction', that affect the whole structure of knowledge flow and may result in temporary dominance of the innovator in the marketplace (Utterback, 1994). Cooper (1999) defines 'newness' of products in two dimensions: New to the Company and New to the Market.

Within these two dimensions of newness, six different types of new products (Figure 1) have been identified (Booz-Allen and Hamilton, 1982 as found in Cooper, 1999): new to the world products; new product lines; additions to existing product lines; improvements and revisions to existing products; repositioning and cost reductions.



Index: (20%): Proportion of the type of new product launches of each category under study

Figure 1. Categories of New Products

Source Cooper, 1999 p23

Most companies have a mixed portfolio of new products although they often avoid involving themselves in projects that lead to highly innovative types of products because they feel that these involve higher risk and uncertainty. Cooper (1993) however, mentions that new to the world highly innovative products may not be quite so risky. This argument is based on the observation that these products tend to have significantly higher competitive advantage. The first two categories, which represent the highest novelty, even though they constitute only 30 percent of all new product launches, represent 60 percent of products viewed as successful and more innovative (Booz-Allen and Hamilton, 1982). Furthermore, they are recognised by the managers and the project teams as challenging projects that attract attention during development and they trigger willingness to make a 'better job' (Cooper, 1993).

1.2 Drivers of Innovation

Cooper (1999) presents four drivers for product innovation which have been identified by senior executives. These drivers are: technological advances; intensified customer needs; shorter product life cycles and increased world competition. The author accepts Cooper's observation that these drivers will continue to be important, at least in the near future.

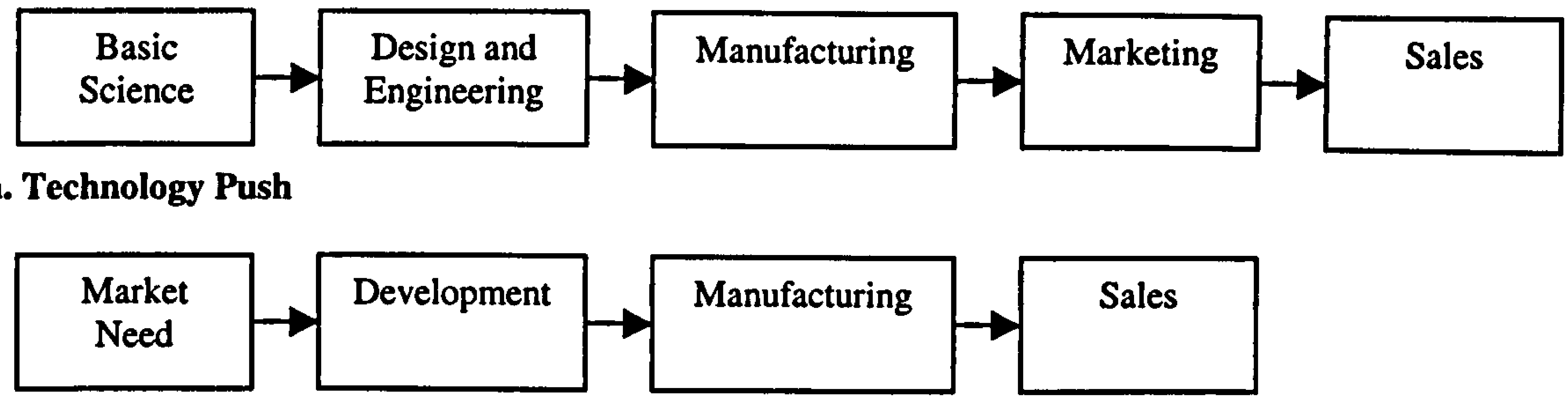
Utterback (1994) believes that innovation is a life-or-death ingredient for firms. Firms need to create incremental innovations in order to meet today's market demands, but also need to ensure their long-term survival by preparing radical innovation that reinvents their business and market. If they do not do so, Utterback argues, another company will, and will take their place in the marketplace. This view argues against shareholders who are interested in short term profits and who resist high-risk investment in a yet unproven technology. Tidd and his colleagues (1997) add to this argument, that even the largest firms face the fate of disappearing if they do not prepare radical innovations for the next generation of products and markets. They observe that almost 40% of the firms that made the Fortune Top 500 in the 1980s have disappeared, whilst of the 1970s list, 60% have been acquired or gone under. The destiny of small firms may be even worse as they lack the protection that a large firm, with a large resource base (capital) can offer.

Other researchers have found a broader driver for innovation, the socio-economic driver for growth. Starting from different perspectives Lundvall (1992), Porter (1990), Freeman and Soete (1997), and Stoneman (1995) found that innovation is a major contributor to growth in economic welfare over time. Sundbo (1998) goes a step further and theorises that major innovations are the reason for the world's economic cycles (Kondratiev waves). Thus, it is not surprising that governments try to promote innovation in order to solve the economic and social problems of their countries, such as productivity and unemployment rates, even though these attempts are not always successful (see for example the Green Paper on Innovation by EU commission, 1995 and National Innovation Systems by OECD, 1997).

1.3 Theories about the Innovation Process

Several theories have been developed in order to analyse and understand the nature of innovation and how it occurs. Each of these focuses on different areas that were dominant during the period that the theories were developed. Rothwell (1994a) has grouped these theories into five historical generations of theories about how the innovation process occurs:

1. **The Technology Push Theory** (Figure 2a), which was dominant in 1950s, is a simple linear process where the scientific and technological advances push a new product into the market.
2. **The Market Pull Theory** (Figure 2b), which was dominant in 1960s is also a linear process where the market needs pull a new product into the market.



a. Technology Push

b. Market Pull

Figure 2. The First Two Generations of Innovation Process Theory
Source: Rothwell, 1994b p41

3. **The Coupling Innovation Process Theory** (Figure 3), which was dominant during the 1970s and early 1980s and recognised that a push-pull theory comes closer to reality (Cooper, 1984b; Rothwell and Zegveld, 1985). According to this theory, the process is sequential but not necessarily continuous. The innovation process can be divided into a series of interdependent stages and feedbacks to the previous stage. The intra-organisational and external connections and influences create a complex net, linking together the different functions of the firm, the technological and scientific community and the marketplace (Rothwell and Zegveld, 1985).

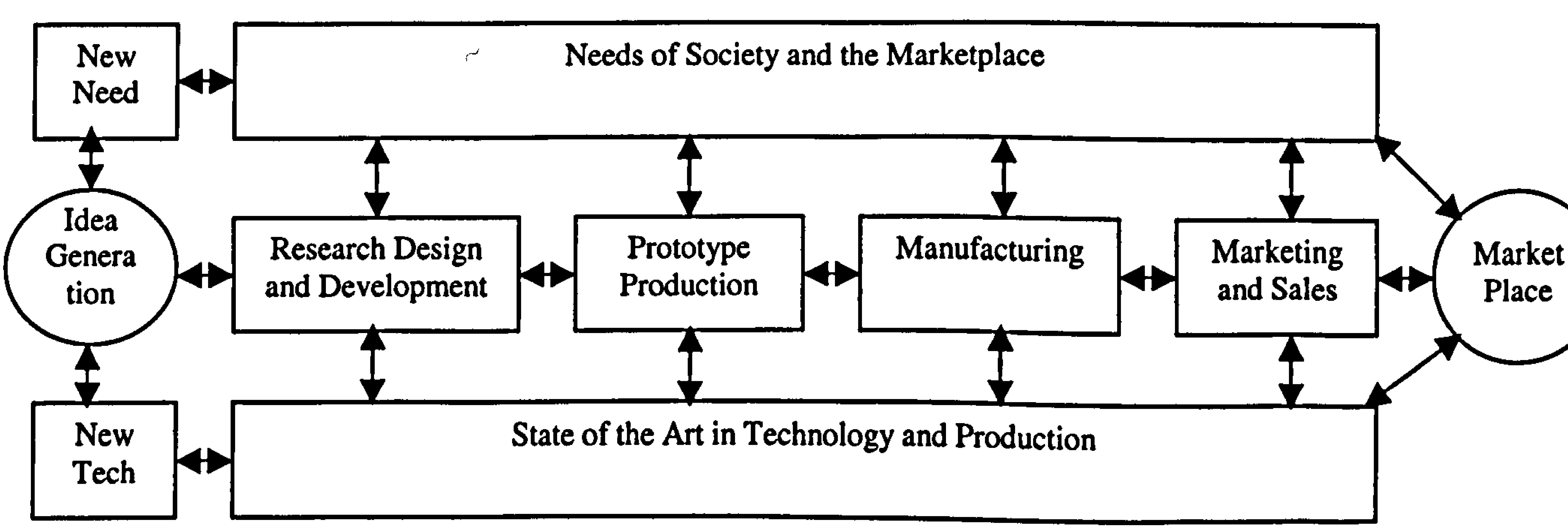


Figure 3. Coupling Model (Third Generation)
Source: Rothwell, 1994b p41

4. **The Functional Integration Innovation Process Theory** (Figure 4), which developed from observations of the methods that are used especially by the Japanese automobile and electronics industries. Here, industries involve the different functions of the firm that are responsible for the new product design and development process in a parallel, instead of a sequential mode. The core feature of this parallel approach is functional integration around a project in order to combine the expertise of the different specialists; to reduce the completion time and to reduce the rework needed at later stages (manufacturing and marketing) of the process (Imai et al., 1985).

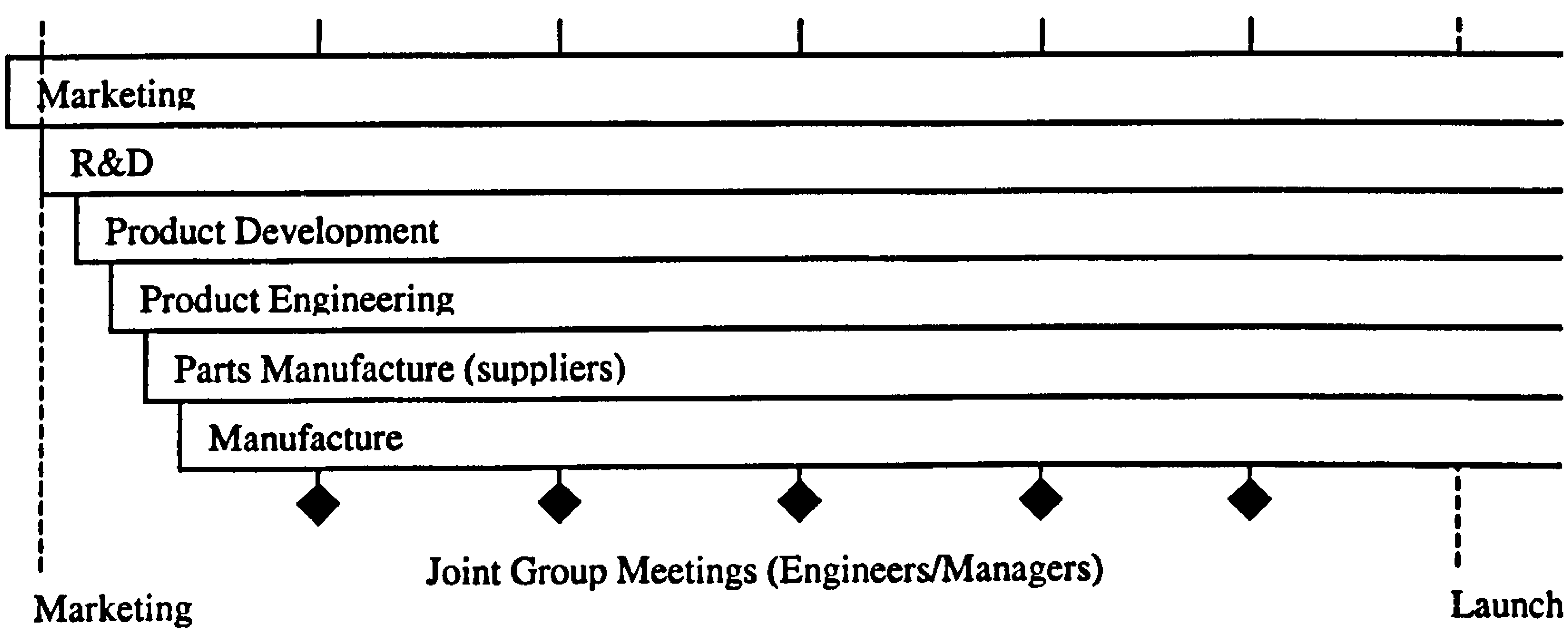


Figure 4. Example of the Integrated Innovation Process (Fourth Generation)

Source: Rothwell, 1994b p42
Note: This representation of 4G focuses essentially on the two primary internal features of the process, i.e. its parallel and integrated nature. Around this in practice is the web of external interactions represented in the 3G process (Figure 3).

5. **The Systems Integration and Networking Innovation Process Theory,** which is based on the fourth generation process but highlights the need for continuous change. The innovation process involves new electronic tools such as simulation, CAD/CAM and rapid prototyping, to aid the design and development stages. In addition, a network of suppliers, customers and other firms is developed in order to take advantage of the merging of technologies and to resolve the problem of the higher complexity of new products. Efficiency and speed are derived mainly

from the information efficiency of the process and from continuous communication across the innovation network. Table 1 summarises the strategic elements that are involved in the fifth generation theory of the innovation process.

Table 1. The fifth generation innovation process: Systems Integration and Networking (SIN)

Underling Strategy elements
➢ Time-based strategy (faster, more efficient product development)
➢ Development focus on quality and other non-price factors
➢ Emphasis on corporate flexibility and responsiveness
➢ Customer focus at the forefront of strategy
➢ Strategic integration with primary suppliers
➢ Strategies for horizontal technological collaboration
➢ Electronic data processing strategies
➢ Policy of total quality control

Source: Rothwell, 1994b p49

In the late 1980s and the 1990s however, a new generation has been developed; the 'systems of innovation' theory. This theory relates the policy of innovation players to the ability of firms to innovate which in turn affects the wealth of a nation (Sundbo, 1998; Edquist. 1997b). The theory also tries to identify the social and economic effects of the process that creates innovation and the actors that affect this process across a nation.

The literature of national systems of innovation focuses on the flow of knowledge at a personal, regional or national level. This knowledge flow includes institutional interaction between the actors of the system such as, firms, universities, research institutes, governments and their staff; political support from governments in areas such as, legislation, finance and infrastructure development; market characteristics, for example, size and sophistication and, enterprise activities, such as, investment in new technology, in-house research and new product design and development processes (Edquist, 1997b; OECD, 1997a; OECD, 1999; Lundvall, 1992; Nelson, 1993).

OECD has undertaken several national innovation system surveys for its member states. To make these surveys comparable and describe their findings under a standard methodology, OECD has created a general concept (Figure 5), named the innovation policy terrain.

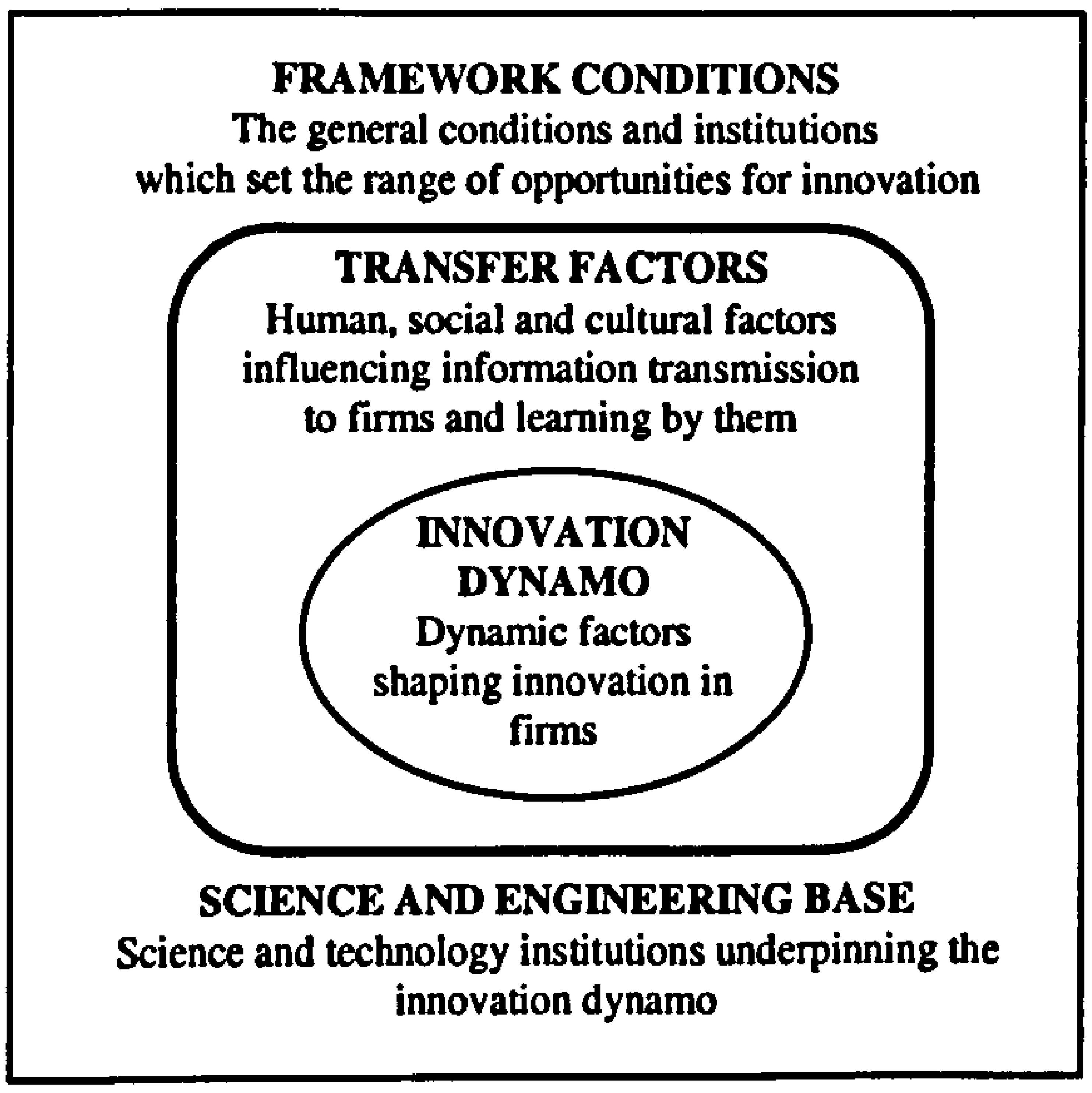


Figure 5. The innovation policy terrain
Source: OECD, 1997b p32

This concept has four general domains (OECD, 1997):

- **Framework conditions:** the institutional environment in which firms exist and operate. This framework includes: the education system; the infrastructure; the financial system; legislation, regulations and the macroeconomic conditions; the market accessibility, competitiveness and depth of the sector.
- **Science and Engineering base:** the scientific and technological knowledge which is generated by public sector research institutes and universities.

- **Transfer factors:** human, social and cultural factors that are responsible for transferring knowledge at the 'firm' level.
- **Innovation dynamo:** the system of factors shaping innovation at the firm level. These factors include the strategy and risk policy of a firm; the research and development (R&D) activities and the technological capabilities of a firm. The firm is the centre of innovation systems because it is the agent that uses existing knowledge or inventions in order to generate new products – knowledge, technologies or processes.

Another theoretical framework that is used broadly in the literature is the 'National Diamond' (Figure 6) that has been proposed by Porter (1990). This model groups the elements that form a national innovation system to four broad attributes (Porter, 1990: p71):

1. *'**Factor Conditions.** The nation's position in factors of production, such as skilled labour or infrastructure, necessary to compete in a given industry.*
2. ***Demand Conditions.** The nature of home demand for the industry's product or service.*
3. ***Related and Supporting industries.** The presence or absence in the nation of supplier industries and related industries that are internationally competitive.*
4. ***Firm Strategy, Structure, and Rivalry.** The conditions in the nation governing how companies are created, organised, and managed, and the nature of domestic rivalry.'*

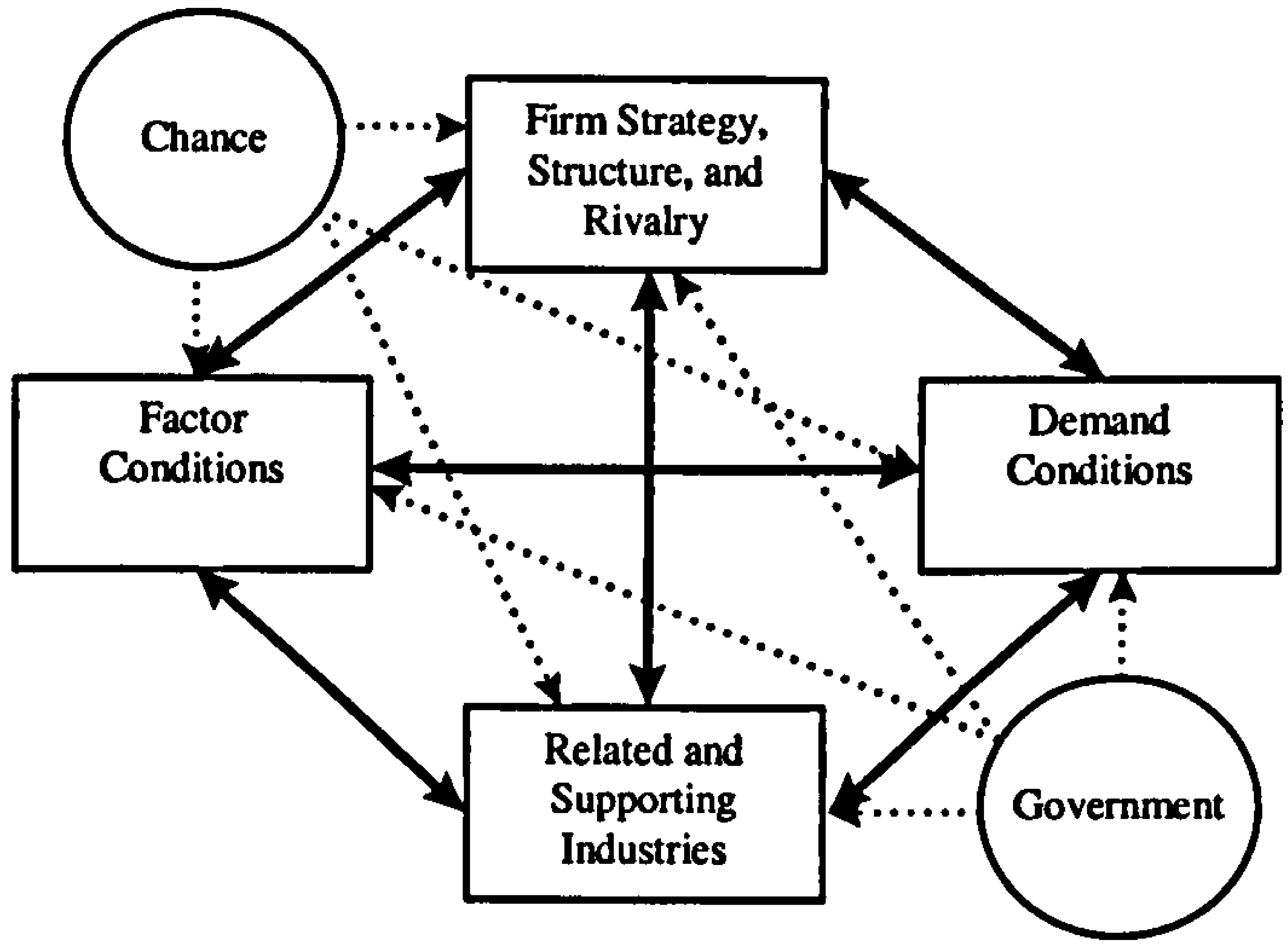


Figure 6. The National Diamond

Source: Porter, 1990 p127

Porter adds to these four main attributes two more factors – government and chance – which can influence these attributes in one way or another. For example, government can support an industrial sector through regulation, education policy or financial policy. Chance events on the other hand, are outside the direct control of firms or governments (for example physical disasters or shortages of physical resources). These chance events may appear as opportunities for a nation according to how they are used and to what extent they are prepared to react in a positive manner.

1.4 Identification of Research Need

The five generations of innovation theories, (Rothwell, 1994b), try to communicate to managers how innovation occurs in a firm and which factors affect the outcome of this process. This aims to enhance innovation activity by turning managers' attention to these elements and by considering their decisions according to the innovation outcome. The factors that are relevant to innovation, as they are presented in the literature, however, create a complex net. This complexity often makes managers take a decision, the outcome of which contradicts their original aims because changes on one side of this net are often difficult to correlate with effects in another area. Innovation system theories create an even broader framework of considerations; those of the industrial sector and the national environment. These new aspects turn the attention of firms to factors external to the firm. Additionally, they trigger the interest of policy-making bodies about innovation, as innovation systems theorise that the firm's innovation outcome can provide solutions to social and economic problems.

These theories however come from different perspectives that either focus on management, economic or social sciences. The author observes that frequently managers or policy-makers may deem one or the other approach irrelevant to their decisions. Thus, they often ignore it and cannot recognise the influence of their actions on the interests of the other actors in an innovation system.

Other theories about innovation offer a framework under which firms can assess their processes according to best practices (see for example, McGrath, 1996; Matheson and Matheson, 1998; Cooper, 1993). These assessment tools provide managers with a snapshot of their firm. This is an initial stage from which they can design their future decisions and strategy. These tools however, because they do not illustrate the effect of changes in the different business areas over time, make it difficult for managers to understand the long-term influence of their decisions. Additionally, managers and policy makers seek decisions that bring short-term results because these are directly visible to their shareholders or to public opinion. Solutions with short-term results however may reduce innovation activity in the longer-term and increase the problems that originally, they were trying to solve. For example, it is often observed that managers decide to cut research costs by reducing the number of employees and research spending, in order to improve short-term financial results. This decision however may result in long-term losses of market share and the inability to react to technological progress, which will effectively worsen the financial results of the firm (Hamel and Prahalad, 1994).

1.5 Research Objectives

The current project has emerged from the above observations. Its objective is to design a dynamic innovation systems model. This model aims to communicate innovation theory to the different actors in the system under a common perspective and to reveal the complexity of innovation systems. Furthermore, the model aims to create a framework that can be used to analyse and assess the innovation activity of a firm against best practice and to illustrate the short and long-term influences of managers' decisions or external factors on innovation outcomes and between the different factors in the system. In effect this framework provides a management tool that can give control of the innovation process to managers and help to improve decision making by analysing the processes and improving how the system works.

From the definition of innovation and the study of the theories that have been presented in the previous sections the author believes that a dynamic innovation systems model should be constituted by five main subsystems: Knowledge Creation; New Product Design and Development (NPDD); Product Success in the marketplace; the Internal Factors that influence a firm's core innovation process and the National

Innovation Environment. The core innovation process is constructed by the first three subsystems. The five subsystems operate in parallel and influence each other. The author has named this abstract concept the Creative Factory concept (Figure 7) because its purpose is to provide a tool – the 'factory' – that will improve innovation activity – the 'creativity' – of a firm.

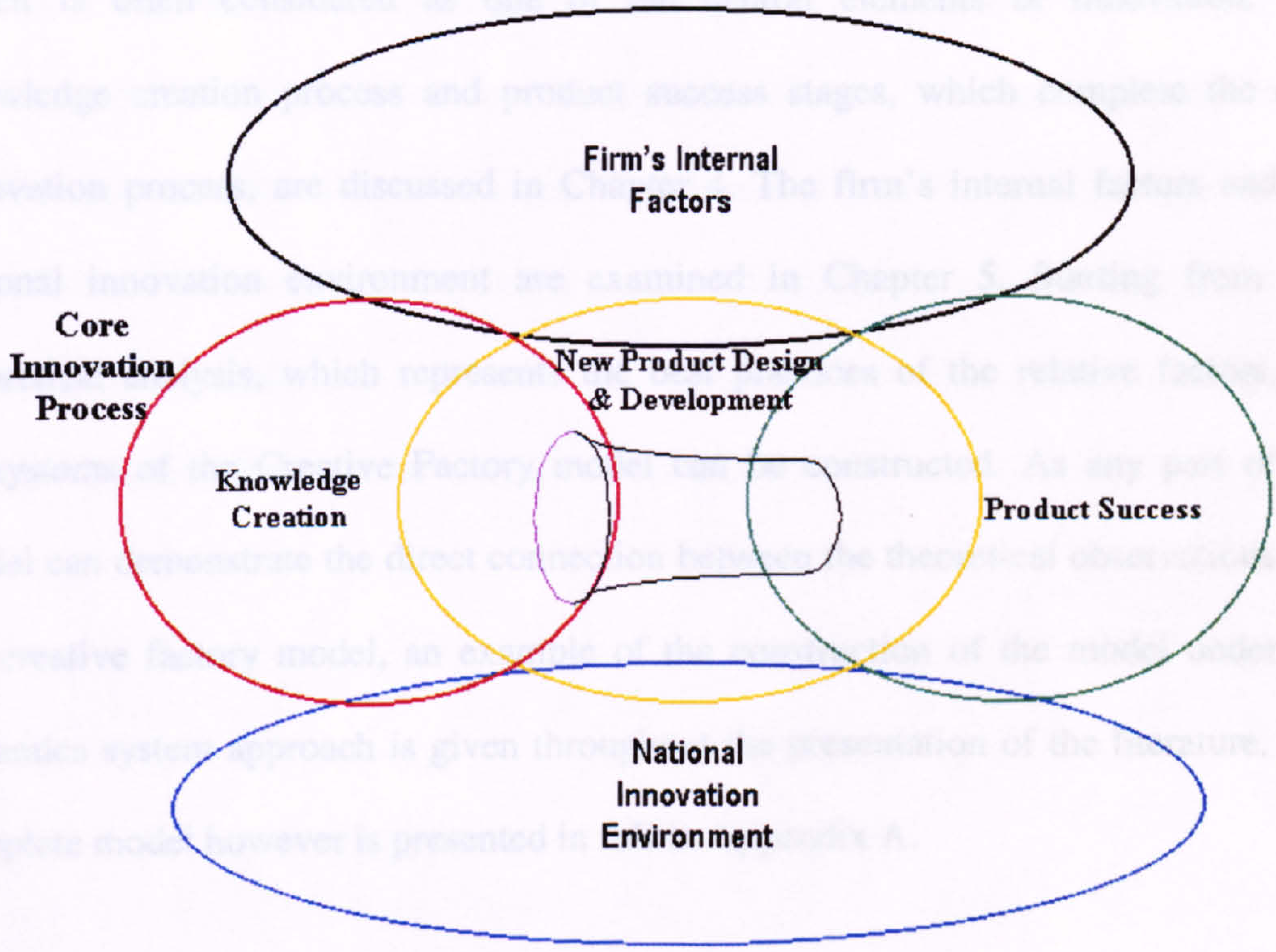


Figure 7. The Creative Factory Concept

1.6 Construction, Testing and Use of the Creative Factory Model

To construct and analyse the relationships of such a complex system as the Creative Factory, a dynamics systems methodology has been applied using the ithink[1]

[1] Software from High Performance Systems, Inc. www.hps-inc.com

business-modelling package, which is capable of designing and simulating the model. The logic of this methodology and the basic elements of the business-modelling package are described in Chapter 2. The relevant literature about the factors that make up the Creative Factory model is presented in Chapters 3, 4 and 5. Chapter 3 studies the new product design and development component of the core innovation process, which is often considered as one of the central elements of innovation. The knowledge creation process and product success stages, which complete the core innovation process, are discussed in Chapter 4. The firm's internal factors and the national innovation environment are examined in Chapter 5. Starting from this theoretical analysis, which represents the best practices of the relative factors, the subsystems of the Creative Factory model can be constructed. As any part of the model can demonstrate the direct connection between the theoretical observations and the creative factory model, an example of the construction of the model under the dynamics system approach is given throughout the presentation of the literature. The complete model however is presented in full in Appendix A.

Based on an extended questionnaire (Appendix B), structured interviews with different firms, from different sectors and nations, have been conducted in order to test the Creative Factory model. The test concerns the ability of the model to produce a realistic evaluation of a firm's innovation process, and the relevant internal and external factors (Chapter 6). This test, if successful, can be used to carry out an assessment of the firm. The analysis of the firm's assessment can show which areas are in need of improvement in order to enhance innovation activity. Then, by simulating different action-scenarios that affect these elements the Creative Factory model can illustrate the degree of influence of different business areas on the innovation activity. These results can be used to control the innovation process and persuade managers or shareholders of the effects of their decisions on the firm's overall performance. Additionally, the Creative Factory model can be used by policy-making bodies to identify how the national innovation environment affects firms' innovation activity as well as which areas they should improve in order to reduce barriers to innovation. The uses of the Creative Factory model to assess a firm, to simulate action-scenarios and to identify the effect of the national innovation environment are presented in Chapter 7. Chapter 8 provides a discussion of this project where limitations of the model are identified; further possibilities for the use of the model are described and further research into innovation systems is proposed. Finally, Chapter 9 presents the conclusions of this project.

2 Methodology

This chapter presents the methodology that has been used to design and implement the Creative Factory concept. Section one discusses the use of modelling in business systems. Section two describes the dynamic systems methodology of modelling and its use to design the Creative Factory model. The use of logic diagrams and their translation to the business-modelling package that are used for the simulation of the model are explained. Additionally, the user interface of the model is described. The validation approach for the Creative Factory model is discussed in section three.

2.1 Models in Business Systems

The factors that construct the Creative Factory concept create a complicated net of interrelations. One way for a firm to test the effect of a decision on one side of this net, according to its effect on the innovation outcome, is by experimenting in the real world. This however may be very expensive, time consuming or even dangerous if the decision is proved wrong. Models can be used by managers to assist them in the logical analysis of a simulation in order to take a decision and in controlling business processes by identifying, up front, the consequences of an action. The author adopts the definition of a model given by Pidd (1996: p15): "*a model is an external and explicit representation of parts of reality as seen by the people who wish to use that model to understand, to change, to manage and to control that part of reality*".

The technological advances in information technology today allow the use of computer based business-modelling packages, in which managers can create a model of their business and design their decisions based on results that can be generated by the simulation of this model in only a few minutes (Coyle, 1996). Compared to real experimentation, modelling has the following advantages (Pidd, 1998):

- **Lower Cost,** especially if something goes wrong with real experimentation.
- **Time saving** by simulating months or years of physical time in few seconds of computer time.
- **Replication** of the same conditions in order to repeat the simulation with any combination of decisions.
- **Minimum Safety concerns** when they simulate catastrophic events or the experimentation goes wrong
- **Legal compatibility** in the case of studying legislation changes or regulation scenarios, which have not yet been implemented.

2.1.1 Models as Appropriate Representations of Reality

A model has limitations, as it is a simplification or an approximation of reality. This simplification however is partly what makes it useful compared with reality (Senge, 1990). Pidd (1996) claims that good models are simple, concrete and fully-defined compared with the reality that they describe, which may be complex, subtle and ill-defined. Nevertheless, in using the technique of modelling, it is important that users test the degree to which their models are valid within the framework of the scenario which is being examined.

2.1.1.1 The Modelling Approach

Rosenhead (1989) suggests that from the late 1970s the approach of analysis and study of business factors has moved from a traditional mathematical modelling – 'hard systems' – approach, to a new 'soft systems' one. Several modelling approaches have been developed, with characteristics which apply to the soft systems style of modelling, such as[2]: Cognitive mapping and Strategic Options Development and Analysis (SODA); Soft Systems Methodology (SSM); Strategic choice; System Dynamics; Metagames and Hypergames.

Pidd (1996) identifies the differences between 'hard' and 'soft' approaches. Hard approaches describe a problem as a structured puzzle with a unique definition and solution. A model in a hard approach is a simplification but a valid representation of part of the real world. Additionally, organisations are just 'human machines' where people are organised according to their functions and geared to some unique objective (Checkland and Scholes, 1990). Soft approaches, on the other hand, perceive a problem as a set of circumstances with extreme ambiguity and sometimes disagreement about its definition between the people who are involved and who do not always operate in a predictable manner. The model is constructed step by step and aims, through the insights from the debates that take place, to make explicit the aspects of reality that are being studied and to create an understanding of why reality reacts in such a way (Pidd, 1996). Thus, the full definition of a problem may only

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[2] The reader can refer to Pidd, 1996; Pidd, 1998; Rosenhead, 1989; Coyle, 1996; Roberts et al, 1983; Gharajedaghi,1999; Checkland, 1993; Senge, 1990 for details of these approaches

emerge during the modelling process. The question of model validation however, is problematic and instead a level of confidence in the model takes its place (see Section 2.1.1.2). The tangible outcome or recommendation emerges from the cyclical and on going process of learning through the modelling process (Langley et al, 1995).

Some soft methodologies have a structured type of decision making or problem handling. Others, such as the SODA, SSM, Strategic Choice and System Dynamics make fewer assumptions. Independent of the method however, the focus is on helping to improve decision making by analysing the processes through which decisions emerge and by improving how the system works. There is no general idea of the level of complexity of a model that is proper for each case. Pidd (1996) suggests that if two models seem to be equally plausible then it is better to use the simpler one. Whether an element of a model is necessary depends on the user's intended purpose for the model. Thus, several layers of complexity can be created according to the nature of the problem and the audience that the model addresses (Coyle, 1996).

2.1.1.2 Model Validation

Zeigler and his colleagues (2000) analyse in detail the question of validation and verification of a model – especially referring to computer based simulation models. They distinguish the following elements (Figure 8):

- **The real system,** which is the source of observable data. This data consists of input:output relations that may not be simple to construct. Even if we do not understand the real system we can still observe its behaviour or treat it as a black box and observe its outputs.

- **An experimental frame,** which sets the assumptions and limitations under which the real system is to be observed or experimented with.
- **The base model,** which is defined as a hypothetical model which would account for all the input:output relations of the real system. In the case that a real system does not exist yet, then the base model needs to be imagined.
- **A lumped model,** which is an explicit and simplified version of the base model and is the one that will be used in the simulation.
- **A computer programme,** in which the lumped model is implemented and can generate the input:output relations of the lumped model.

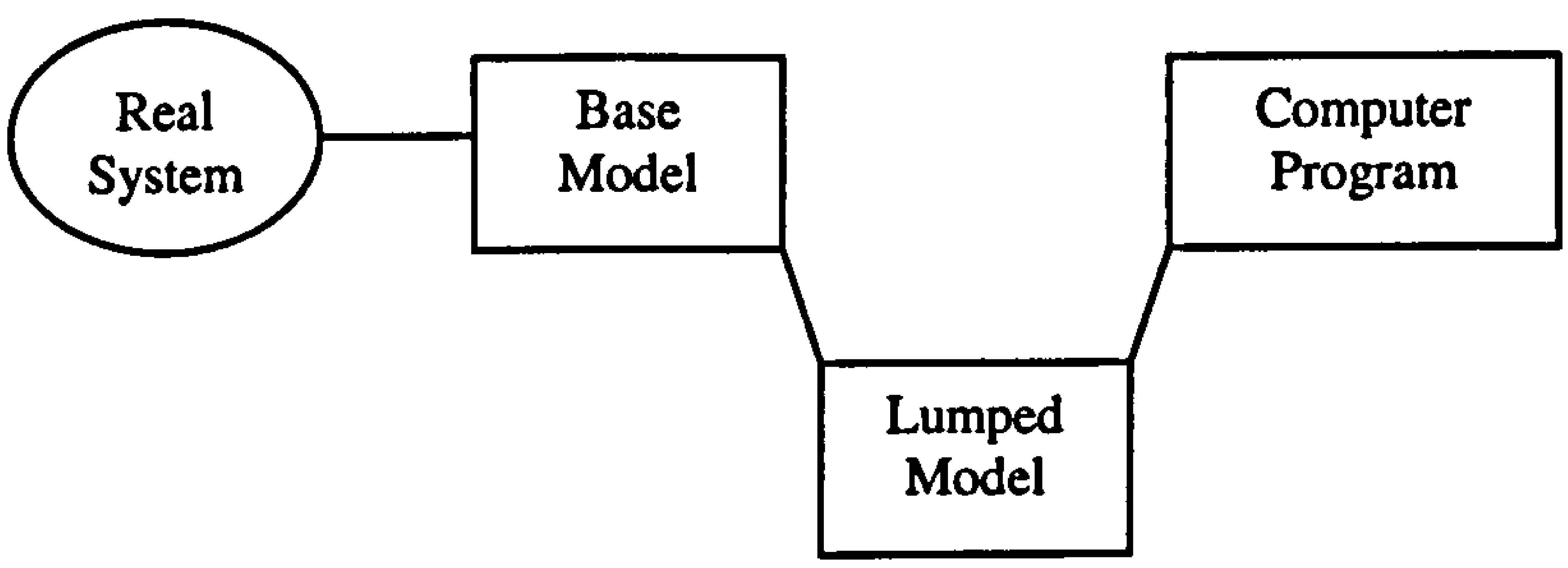

Figure 8. Zeigler's view of modelling
Source: Pidd, 1996 p322

Thus, in Zeigler's et al (2000) terms validation assesses the degree to which the lumped model's input:output relations match the real system ('open-box' validation), or if the relations are not known, have a close fit between the output of the two systems when they are triggered by the same inputs ('black-box' validation). Verification on the other hand means that the lumped model is properly realised in the computer program. Validation subsumes verification and a valid model cannot be unverified. A verified model however might be invalid if it is constructed correctly but for the wrong purpose.

Pidd (1996) identifies three main difficulties in the validation of business models:

- First, the models are often built to help investigate how something works or might work. In this case, the model is a theory about the operation of its reference system and so there is no understood reference to which the model can be compared.
- Second, models may be built under known conditions but their use is to study how to improve these conditions. Thus the original reference system is not valid any more.
- Third, models are often used to predict the future. The future however is uncertain and unknown, that is why it is modelled in the first place. Therefore, the future is the reference system.

The above difficulties do not undermine either the usefulness of modelling or its validation. Coyle and Exelby (2000) suggest that in business modelling it is better to refer to the level of confidence that can be placed in the conclusions that can be drawn from the output of a model rather than its validity. A number of proper tests, depending on the modelling technique, should be applied to and be passed by a model. The more tests that are passed the higher the confidence that the model is technically and logically correct in terms of its purpose and assumptions.

2.2 The Modelling Approach to the Creative Factory Concept

A soft systems modelling approach – the system dynamics – has been selected by the author in order to model the creative factory concept. Coyle (1996) after discussing previous definitions of System Dynamics, offers a complete definition (Coyle, 1996: p10):

"System dynamics deals with the time-dependent behaviour of managed systems with the aim of describing the system and understanding, through qualitative and quantitative models, how information feedback governs its behaviour, and designing robust information feedback structures and control policies through simulation and optimisation."

The selection was made on the basis of the ability of the methodology to handle both quantitative and qualitative variables, the level of development of existing supportive computer based modelling packages[3] and the proximity of the roots of the system dynamics to an engineering way of thinking, i.e. control systems engineering. Although the methodology has its roots in engineering, which can be traced to the work of Tustin (1953) and Forester (1961), it is commonly used in business administration and public policy analysis (Pidd, 1998). Pidd (1998) has showed how such an approach could be used to understand, control and develop these kinds of systems. Systems dynamics concentrates on the study of the connections between the different elements as well as the behaviour of the whole (Roberts et al, 1983). The feedback structures and the system's short- and long-term response to them determine how the policies of change are designed and in which direction, to satisfy targets that are set (Pidd, 1996).

Thus, the author believes that this methodology can be used to analyse and communicate innovation theory and the factors that affect innovation using a

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[3] Five software packages are available to model system dynamics, with similar performance that have been derived from system dynamics software programs in the 1970s and 1980s at the MIT: the DYNAMO by Pugh-Roberts Associates, which was the first computer language developed to simulate system dynamics; the STELLA and ithink from High Performance systems Inc; the Vensim from Ventana Systems Inc; the Mictroworld Creator and S^4 by Microworlds Inc and the Powersim from Powersim Corporation

commonly understood methodology. The ithink business-modelling package was selected to develop and simulate the model because it provided an advanced and easy to use interface for designing the model, writing the equations and presenting the results.

2.2.1 Building a System Dynamics Model

Coyle (1996) suggests a five-stage approach, which is used in System Dynamics to understand, control and improve a system (Figure 9):

1. **Problem Definition.** The first stage is to recognise and define the problem. It is also important to identify which people care about the problem and their reasons.
2. **System Description.** This is the first stage that is specific to System Dynamics. The problem is described with the use of influence diagrams (often called causal loop diagrams), which were first suggested by Maruyama (1963). These diagrams represent the forces that occur in a system and between its parts.
3. **Qualitative Analysis.** A close study of the influence diagrams of the system aims to understand the problem. The problem some times is solved at this stage by identifying the relationships that cause the problem or by finding missing components to control the situation. However, often the problem needs to be redefined after the understanding stage and the process returns to stage one.
4. **Simulation Modelling.** If qualitative analysis does not produce enough insight to solve the problem, the process proceeds to the construction of a simulation model by using special modelling packages. The influence diagrams and the simulation model are two versions of the same model, however the computer version, gives some advantages to the analyst: calculations and influences can be processed

faster; the model is easier to expand and to modify; the transformation of the model forces the analyst to think about and understand the problem. This stage also includes the verification and 'validation' of the model.

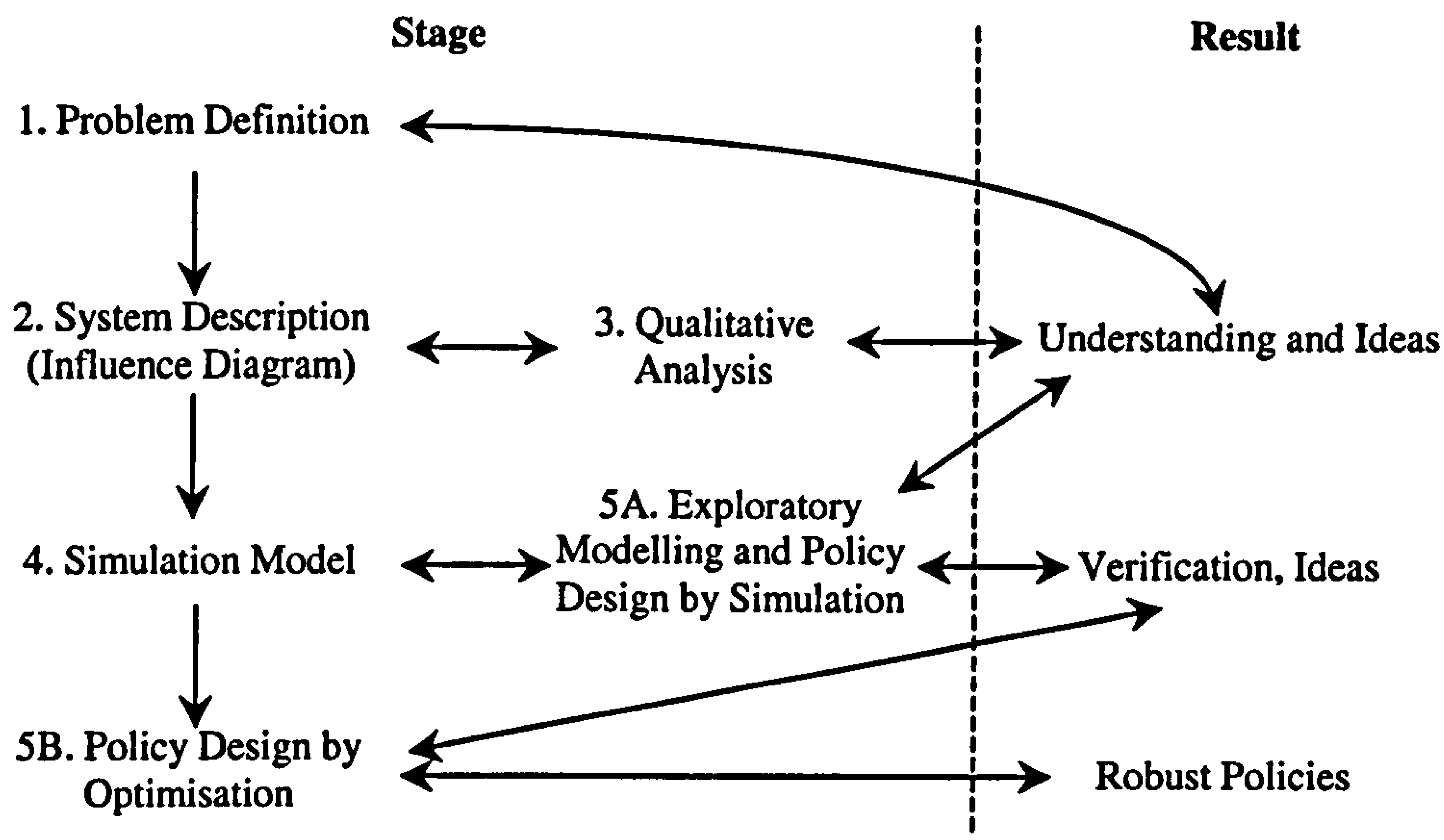


Figure 9. The Process of System Dynamics
Source: Coyle, 1996 p14 (with modifications)

5. **Policy Testing and Design.** Starting from the understanding of the situation from qualitative analysis, the analysts design and test different ideas and changes in the simulation model. By experimenting with different scenarios and studying the results of these proposals they try to understand the behaviour of the system and the feedback structures. When these are understood they can propose policies by using optimisation algorithms that can be run on the simulation model in a few minutes.

2.2.2 Influence Diagrams

The essential idea behind the influence diagrams is an information-action-consequences paradigm (Figure 10). In this paradigm the consequences are always physical in the sense that something flows in the system. The recognition of what flows in the system is the key element to a good model (Coyle, 1996). The action that is based on the information that has been collected creates consequences that may appear after some time (delay). These consequences generate further information and actions which may, in turn, continue the process.

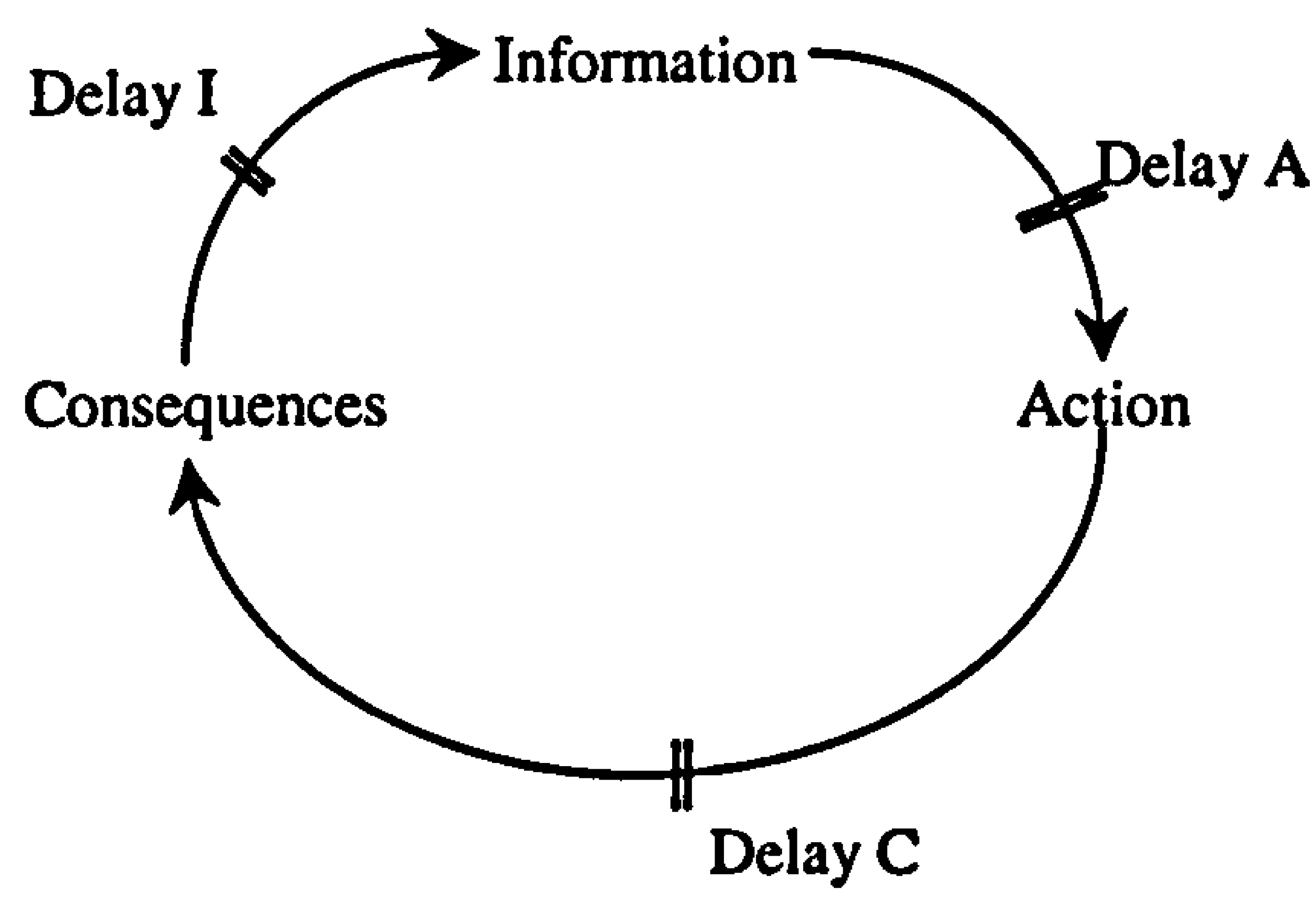


Figure 10. The Information/Action/Consequences Paradigm
Source: Coyle, 1996 p4

2.2.2.1 <u>Basic Influence Diagrams</u>

The dynamic behaviour of the information/action/consequences paradigm is the basis of any analysis. Four fundamental flows have been identified which, in combination, create the influence diagrams of any system (Senge, 1990):

1. **Reinforcing Loop.** This simple diagram (Figure 11) connects an action directly to its consequences that come after a period of time from the moment that the action takes place. The '+' sign means that, when a variable at the tail of the arrow

changes, the variable at the head always changes in the same direction. A '–' sign has the opposite effect. This is an open loop control system, where its output will continue to increase or decrease without a limit as long as the input (action) increases or decreases. A person or an organisation that is not aware of the delay may take more corrective action than needed, or give up because they cannot recognise that any progress has been made.

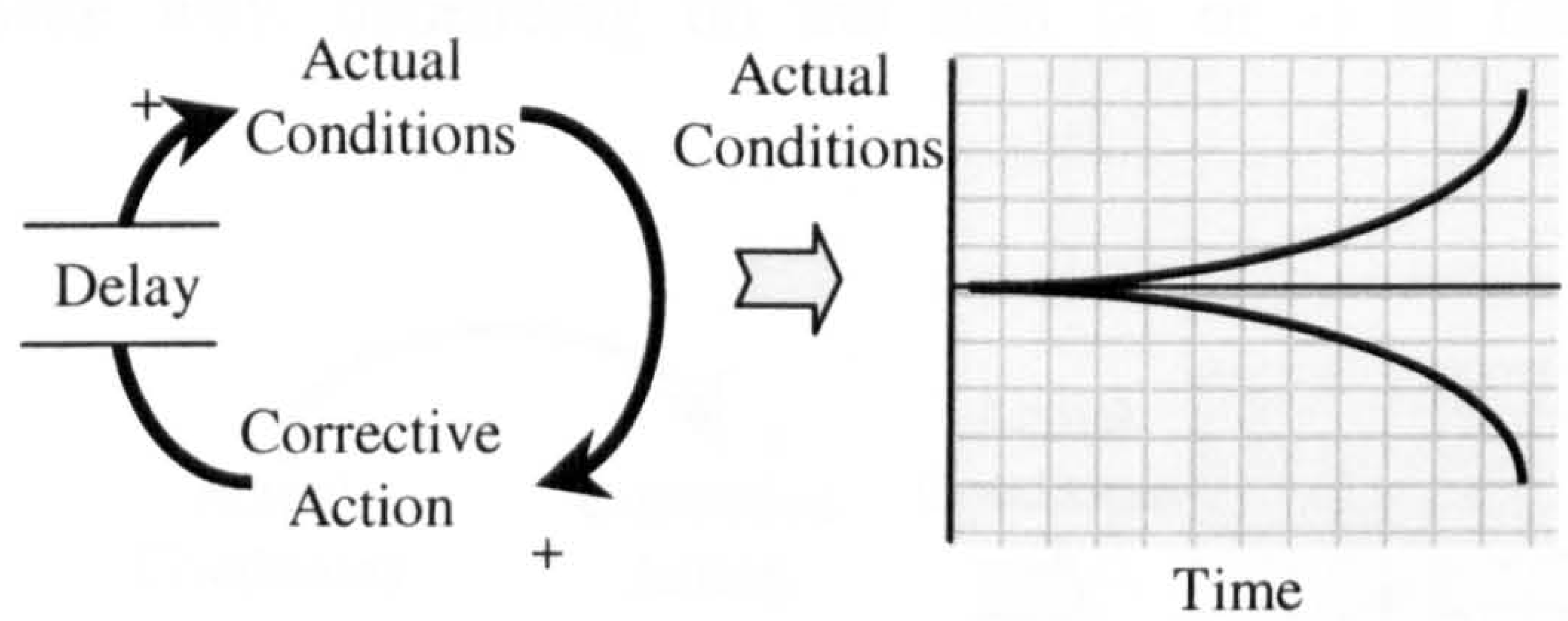


Figure 11. Reinforcing Loop

2. **Balancing Loop**. This diagram brings (Figure 12) one additional factor, which creates a target or a limitation which the final condition of the system can take. This target is compared to the actual state of the system, in order to provide information about the next action that its outcome will bring to the new status of the system's output. This diagram creates a closed loop control system where the feedback of the comparison of the target and the actual status controls the actions of the system. The delays in this system are critical factors for the ability of the system to be stabilised and should be considered in the design of each action.

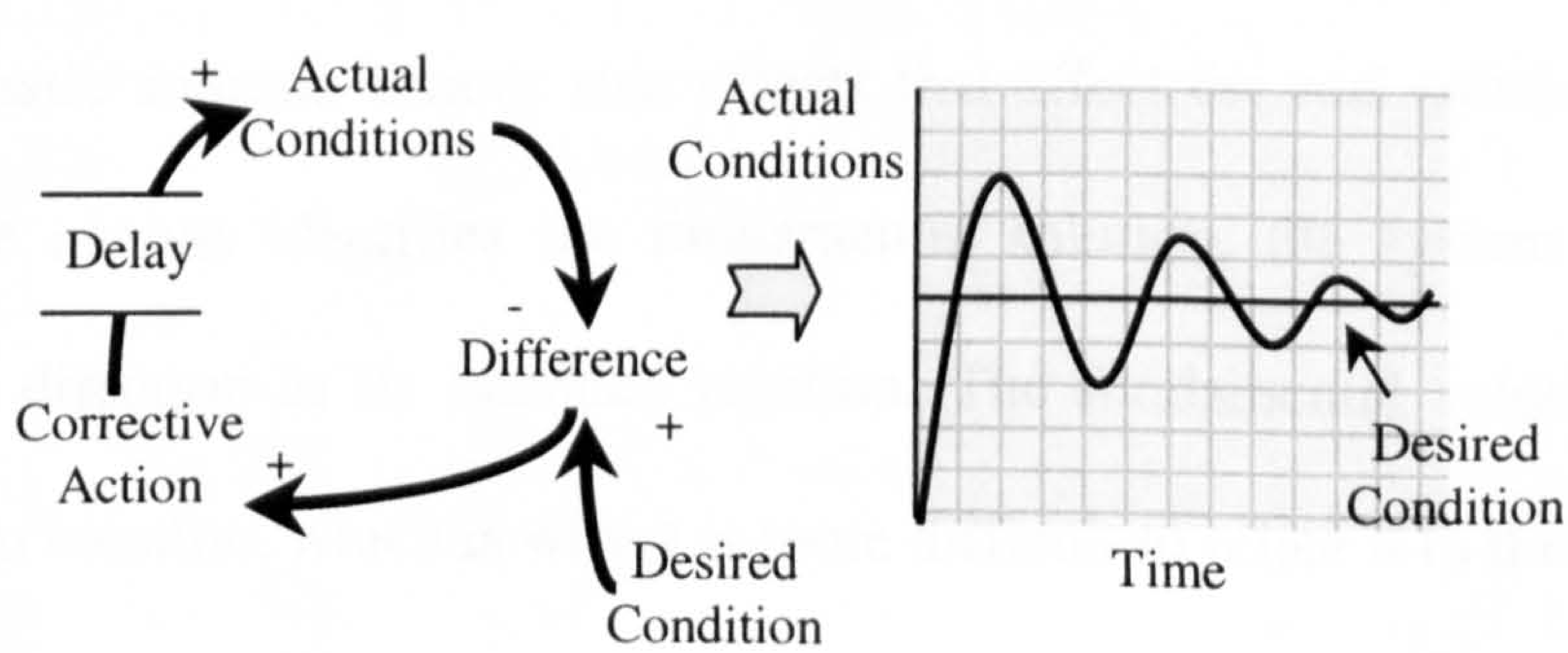


Figure 12. Balancing Loop

3. **Fixes that Fail**. It is often possible to observe a system that, although in the beginning behaved as a reinforcing type of system, after a period of time failed to reach the conditions that were intended by the actions. This happens because there is another 'hidden' loop, which influences output. This loop is hidden by the delay that is present before the response to the actions (Figure 13). The unintended consequences may accelerate the original action/consequence effect or direct it in the opposite way, depending on the sign (+ or -) of the action/consequence diagram.

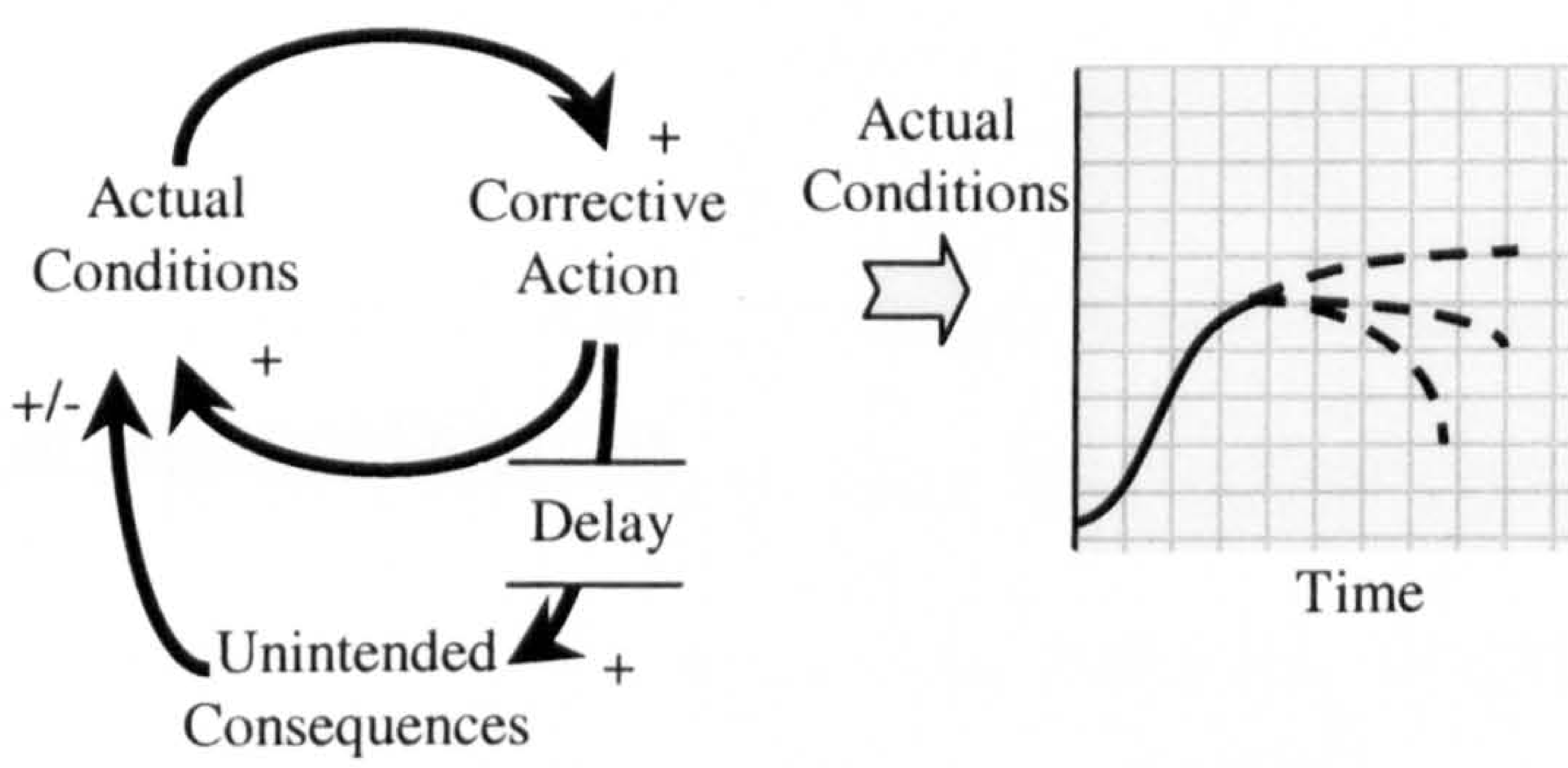


Figure 13. Fixes that Fail Loop

4. **Shifting Effect Loop**. This diagram (Figure 14) is based on the parallelism of symptomatic and fundamental solutions to a problem. Thus an action that is thought to bring about a solution to a problem, after a time, is proved to have no effect or even a negative effect. This happens because this solution attacks the symptoms of the problem and not the fundamental reasons. Additionally, the symptomatic solution creates side effects that affect the real solution negatively. Until the analyst identifies the fundamental solution, the system reacts in the opposite direction to its intended reaction. The fundamental solution often is a long-term solution, which is why it is more difficult to relate it to the problem.

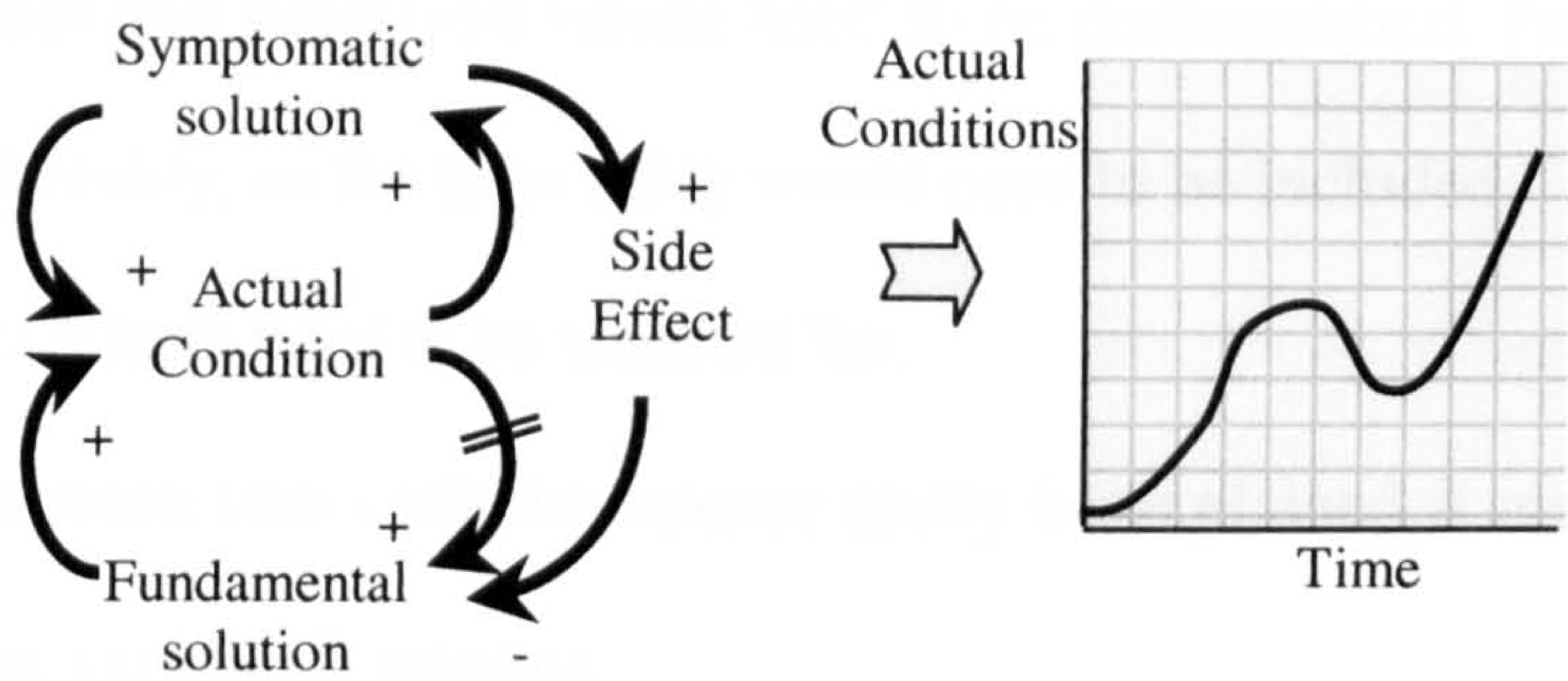


Figure 14. Shifting Effect Loop

The rest of the basic diagrams that Senge (1990) suggests are combinations of these four.

2.2.2.2 <u>Design of Influence Diagrams</u>

Coyle (1996) suggests some guidelines for the design of influence diagrams using the fundamental information/action/consequences idea:

- The purpose, for which the model is constructed, needs to be clear. The distinction between the top-level strategic view and more detailed problems should be identified. Additionally, who is the customer and what is his/her interest from the analysis needs to be clear.
- The differences between the information/action/consequences parts of the paradigm always need to be taken into consideration.
- The variables that are chosen need to be defined so that they can be measured and varied over time.
- Whenever a variable such as ‘actual value’ is seen, the ‘desired value’ relation needs to be identified and vice versa. Without the comparison of these, feedback does not exist and control cannot be achieved.

- Actual values and perceived values need to be distinguished. Perception actually lags behind reality, so the time delay would need to be included.
- Unintended effects need to be watched for.
- If a link between two variables cannot easily be explained it may be because an intermediate variable is missing.
- Above all, the diagrams need to be kept as simple as possible.

2.2.2.3 Level of Detail of Influence Diagrams

Influence diagrams can be drawn at different levels of detail according to the purpose for which they are to be used. Coyle (1996) identifies four levels of detail (Figure 15). The size of the ellipse suggests the amount of detail the diagram contains. This division is not an optimum or a 'recipe' for the level of detail that a diagram requires and often a mix of different levels of detail (diagonal ellipse) can be used, this latter being the approach taken to design the creative factory model.

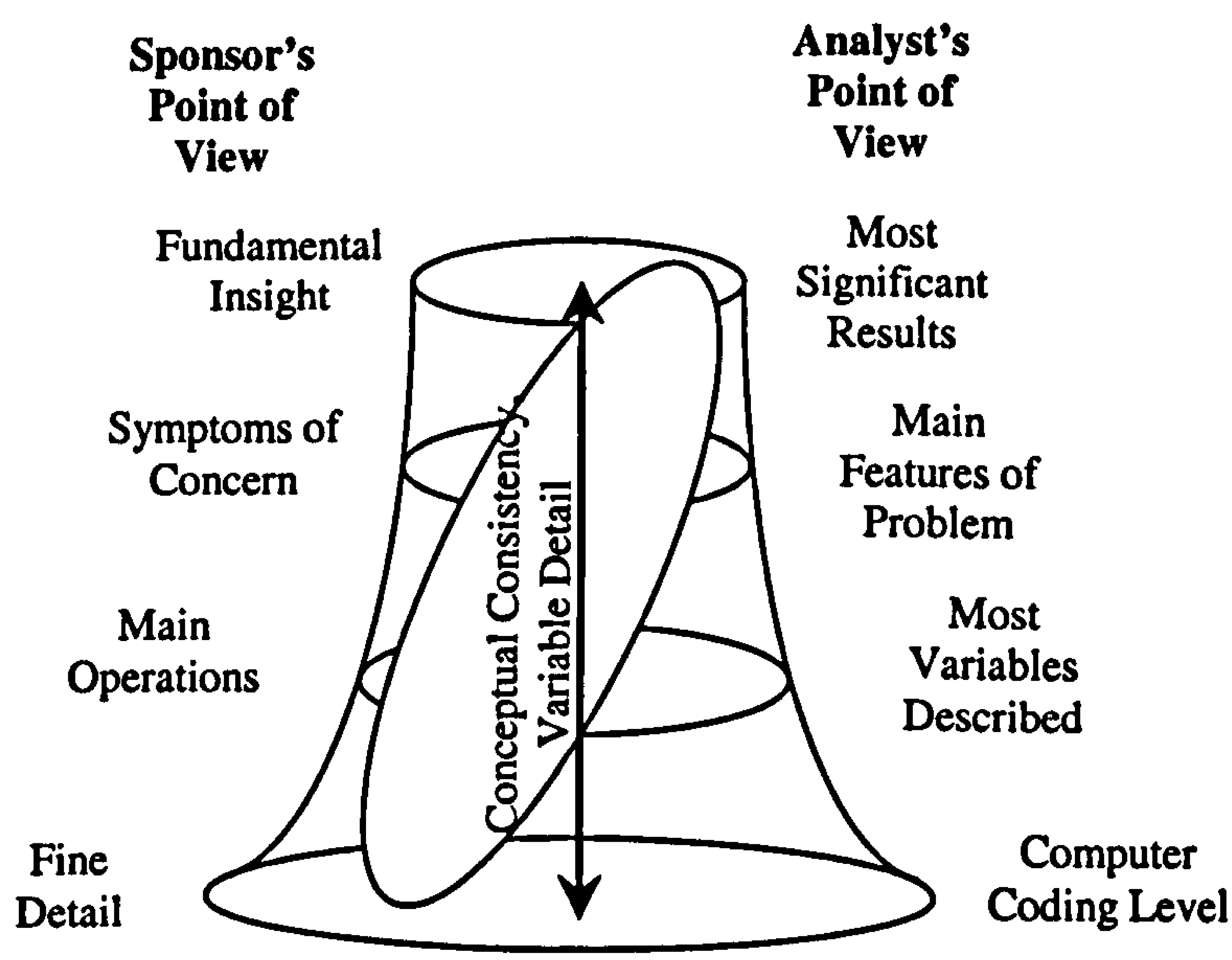


Figure 15. The 'cone' of Influence Diagrams
Source: Coyle, 1996: p44

Additionally, Figure 15 distinguishes between the users – sponsors and analysts – of the diagrams and the point of view that these users may take of the expected results from each level of detail.

Even the most highly detailed diagram however does not need to include every single detail of a system. This is because the fundamental idea of the use of a model is the simplification of the reality. Additionally, influence diagrams are used as a tool for communication, which does not require the knowledge of the simulation techniques of system dynamics. Thus, only information necessary to understand and illustrate the problems and operations of the system is needed. Table 2 suggests some criteria that can be used to recognise a good diagram. These criteria were considered by the author during the development of the creative factory model in order to design the influence diagrams.

Table 2 . Some Criteria for assessing influence diagrams

1. Have the purpose and the target audience for the diagram been carefully chosen? It would be no good using a level 4 diagram for a level 1 audience.
2. Are the factors which it includes consistent with the purpose?
3. The objective of system dynamics is policy analysis, so are the policies clearly shown in the diagram?
4. System dynamics also aim to produce policies which are robust against a range of circumstances, so are the exogenous factors which might present the system with setbacks or opportunities clearly identified?
5. Are the variables capable of being easily explained to the target audience, are they capable in principle of being measured and can they vary over time?
6. If it is a level 1 diagram, does it capture the most significant insights and was it drawn after careful analysis?
7. Can the diagram be redraw to be one level lower or higher without losing conceptual consistency?
8. Has the diagram been constrained by too slavish an adherence to the conventions? If it is too complicated it may fail to communicate. On the other hand, the conventions identify important aspects of a system.
9. Is the diagram neat and tidy, with a minimum number of lines crossing? Can feedback loops be clearly seen?
10. Do I understand the diagram myself before I try to explain it to someone else or to write about it?

Source: Coyle, 1996: p46

2.2.3 Fundamental Ideas of Simulation

When Forrester (1961) first developed the theory of system dynamics modelling, the idea was that the modeller would develop the system dynamics diagrams and use them for qualitative analysis and then s/he would write the equations which would be used to simulate the system for a quantitative analysis (Pidd, 1996). The ithink software can be used by a modeller to sketch the diagrams directly on a computer using a graphical interface and automatically it generates the fundamental equations to define the connections between the different elements.

2.2.3.1 System Dynamics Simulation

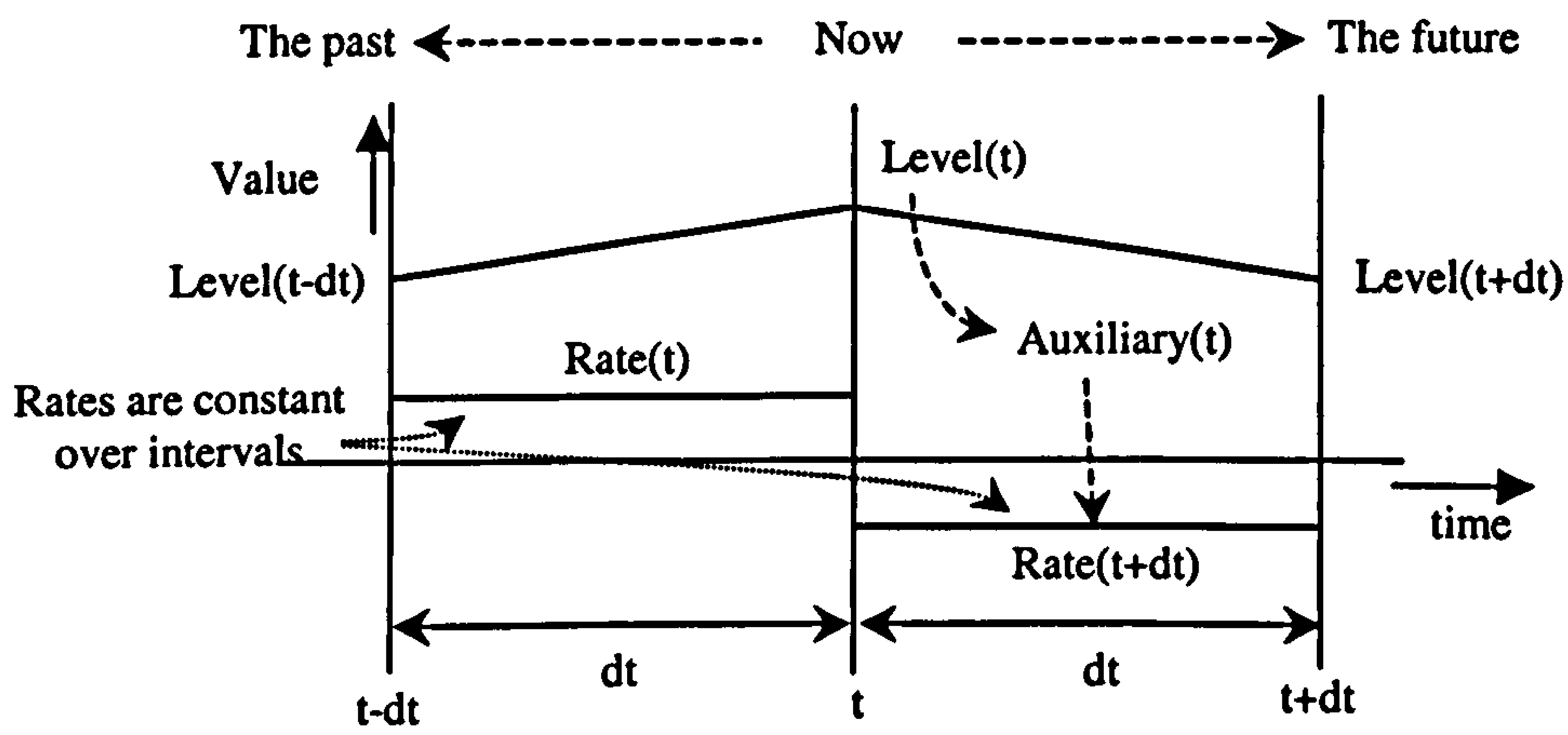
System dynamics are based on a 'time-step' simulation[4], the idea of which is that the model takes a number of steps (dt) along the time axis. The number of steps are as many as are necessary to simulate reasonably accurately the total period that the analyst wishes to investigate (Pidd, 1998). In the case of the creative factory the base time unit is 1year and the time-step has been set at 1month.

In a simulation model, at the end of each time-step, the variables which represent the state of the system, called 'stocks' or 'levels' in system dynamics, take the value that corresponds to the consequences which have been generated during the previous time-step. The dimensions or units of measurement of these variables are the same as the dimensions of the factors of the real system. The level variables can also be

[4] Other methodologies are based on 'event-based' simulation as described in textbooks (see for example Pidd, 1998).

considered as the 'memory' of the system, as, at each time point, they represent the status of the system that has been transformed from all the previous actions. Additionally, the variables that represent the flow of information or the rate of change, are calculated to generate the consequences in the system for the next step (Figure 16). The dimensions of the flow variables are the amount that flowed over time (value/time) where 'time' is the base time that is used in the real system (e.g. hours, weeks, months).

A third variable is necessary, in practice, in the system dynamics simulation, which is termed 'auxiliary'. It reflects intermediate stages and transforms the current levels into 'now' variables in order to calculate the next flow and its units ensure consistency between stocks and rates (Coyle, 1996).



<u>The Fundamental Equations:</u>
Level(t)=Level(t-dt)+dt*Rate(t)
Rate(t+dt)=f(Level(t),Auxiliary(t),Parameters)

Figure 16. The fundamental Variables and Equations of System Dynamics
Source: Coyle, 1996 p87

2.2.3.2 The Language of the ithink Modelling Package

The basic elements of the ithink interface are the 'Stocks', 'Flows', 'Converters' and 'Connectors' (Figure 17). Stocks represent accumulations. In manufacturing, for example, there are accumulations of raw materials, work in process inventories and finished goods. Stocks however can be used for intangible factors as well, such as, in human resources management, the frustration levels of employees or tiredness. Flows on the other side can refer to rates of deliveries, production, consumption of materials, expenses and learning. Stocks and flows are inevitably related. If there is an accumulation of something, this accumulation had to result from some activity, a controlled flow of something (ithink manual, 1997).

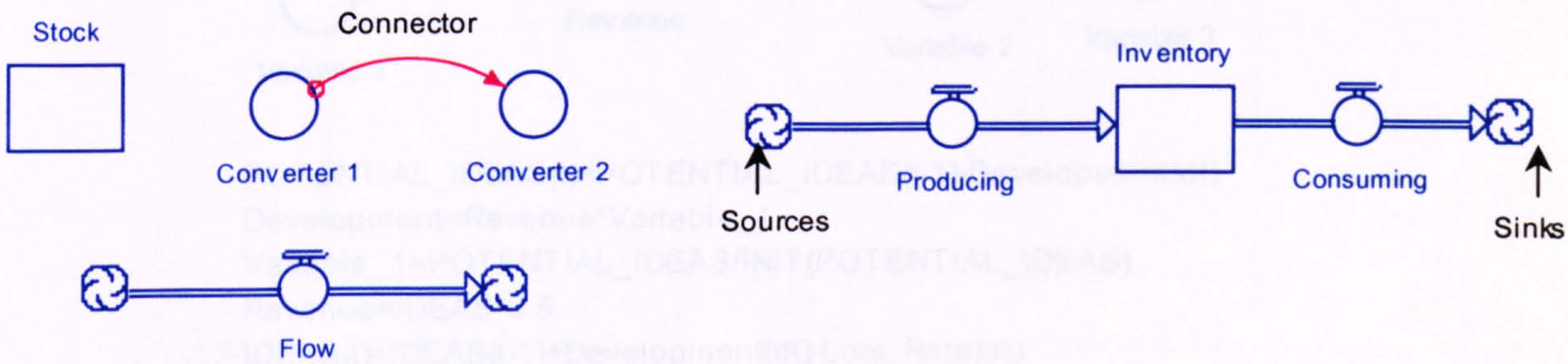
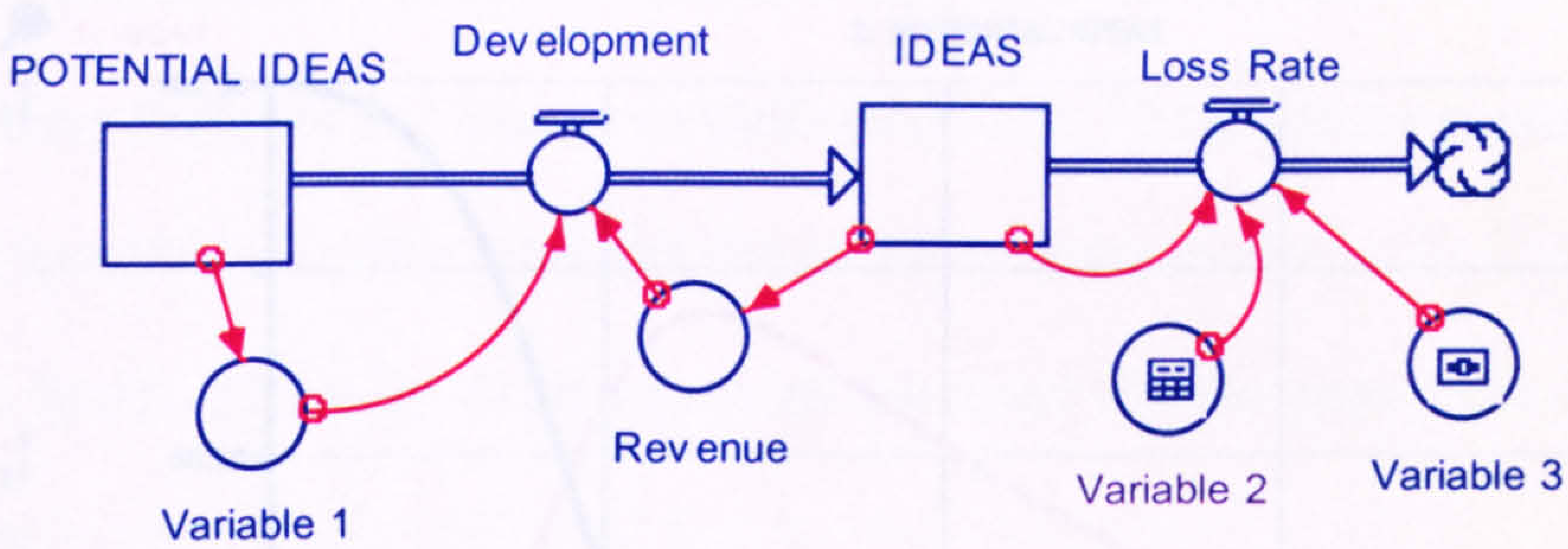


Figure 17. The basic elements of ithink package

Stocks are the 'nouns' of the ithink language and flows the 'verbs'. A simple way to recognise which are the stock and which are the flow factors in a system is to imagine a 'snapshot'. In this situation all the activities of the system are frozen. The picture will then show the state of the system at that point in time (the stocks). To move however from a static view of the system to a dynamic one, an analyst needs to consider the flows of the system (ithink manual, 1997).

Converters have several functions. They may convert inputs into outputs, they can represent either information or material quantities, or they can be used to open out the detail of the logic of a flow regulator. Unlike stocks, however, the converters have no 'memory' and their value is recalculated every time those calculations are performed. Finally connectors link, stocks to converters, stocks to flow regulators, flow regulators to other flow regulators, converters to flow regulators, and converters to other converters. Connectors do not take on any numerical value, they just transmit values taken by other elements (ithink manual, 1997).



POTENTIAL_IDEAS(t)=POTENTIAL_IDEAS(t-1)-Developemnt(dt)
Development=Revenue*Variable_1
Variable_1=POTENTIAL_IDEAS/INIT(POTENTIAL_IDEAS)
Revenue=IDEAS*0.5
IDEAS(t)=IDEAS(t-1)+Development(dt)-Loss_Rate(dt)
Loss-Rate=IDEAS*(Variable_2+Variable_3)
Variable_2=0.05
Variable_3=0
Initial Value of POTENTIAL_IDEAS=100
Initial Value of IDEAS=1

Figure 18. An example of ithink modelling

Figure 18 shows an example of modelling, designed by the author, and the equations that the ithink package uses. In this example 'Potential Ideas' are developed to 'Ideas' at a development rate. The Ideas are used and so decrease over time with a 'Loss Rate'. The rates of development and loss of ideas are controlled variables that are either external or connected to the use of the ideas level. The equations for the stocks of the system are generated automatically and the user does not need to type them. The rest of the equations however need to be developed and typed into the system.

Figure 19 gives an example of the interface that an analyst can use to run the model and observe its behaviour graphically. Elements such as 'spreadsheets' and 'sliders' can be used to change manually the variables of the system during its simulation or, equations, logical relations and time-series of variables can be used to change them automatically.

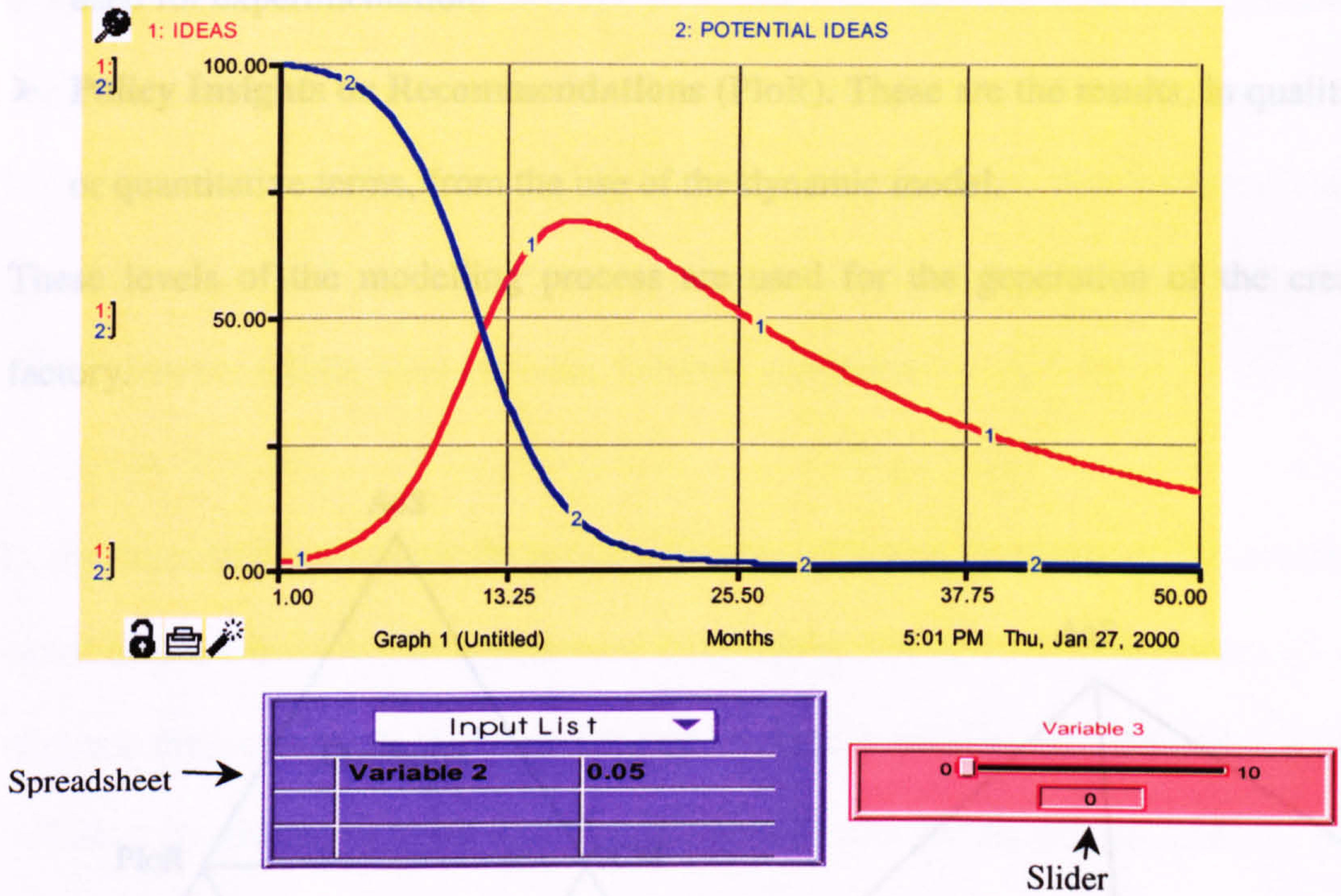


Figure 19. Example of the User Interface of the ithink package

2.3 Validation of System Dynamics Models

Pidd (1996) adopts the idea of Lane (1995) named 'the folding star' (Figure 20), which is a tetrahedron whose sides have been unfolded to represent the different levels of a system dynamics modelling process:

- **Appreciation of the Situation** (AoS). This is the result of the effort of the analysts to collect information about the real system. It can be related to Zeigler's notion of a real system (see Section 2.1.1.2) as a source of data.
- **Communicated Conceptual Model** (CCM). This is the expression of the AoS under a structured framework, such as the influence diagrams, and can be communicated to, and understood by other people. This is like the lumped model of Zeigler's model.
- **Formal Model** (FM). This transforms the CCM using a computer package to be used for experimentation.
- **Policy Insights or Recommendations** (PIoR). These are the results, in qualitative or quantitative terms, from the use of the dynamic model.

These levels of the modelling process are used for the generation of the creative factory.

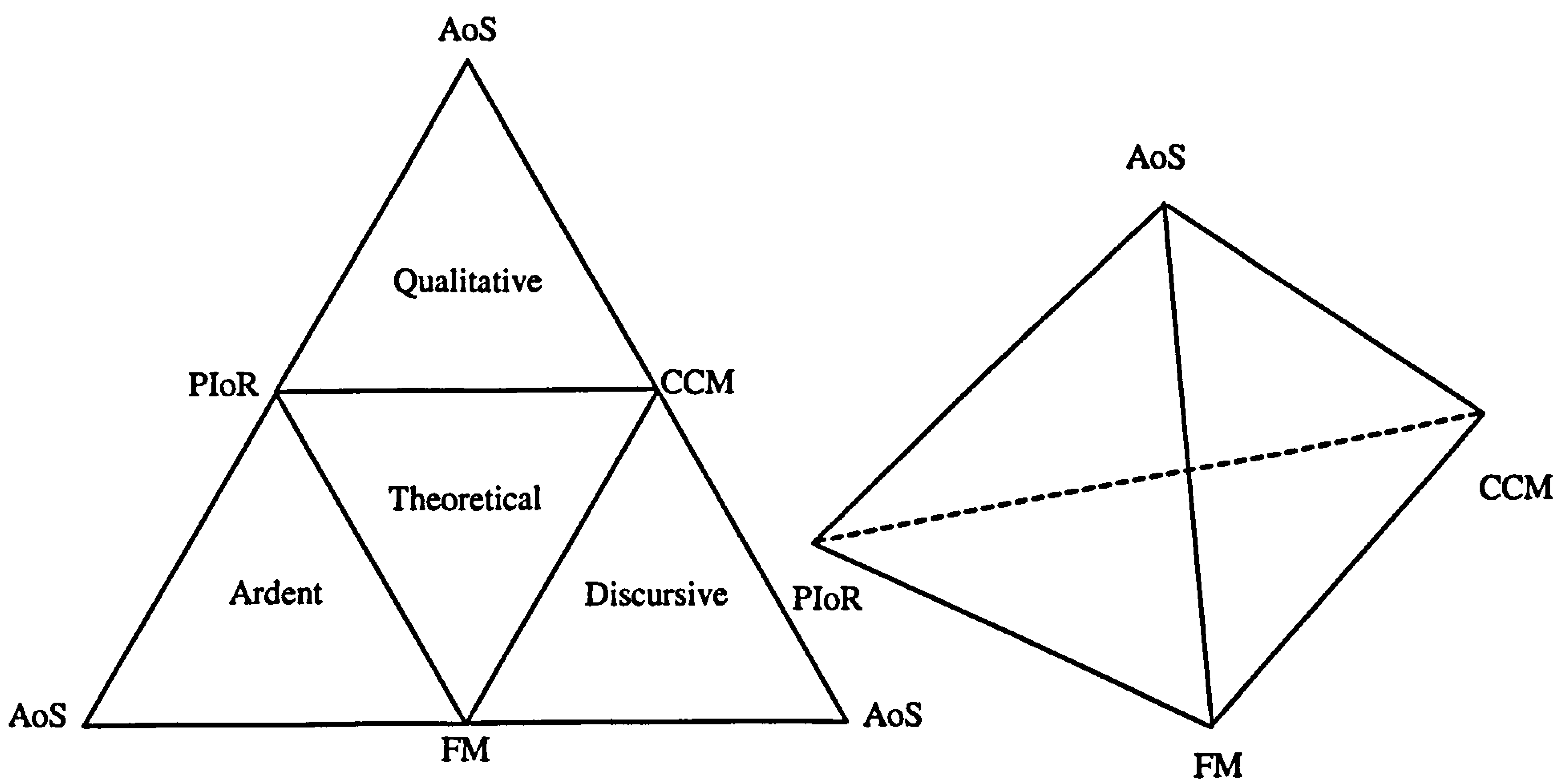


Figure 20. The Folding Star
Source: Pidd, 1996 p333

The levels of the modelling process can be used in four different ways for analysing a system (Pidd, 1996): ardent; qualitative; discursive and theoretical. Thus, different validation techniques need to be applied for each case. Three steps of model validation are required in order to build enough confidence for each case of analysis in a new system dynamics model. First, strong theoretical support should be identified either through the literature or by observation of the real system. This study should reveal the logic of the real system's features and the influence diagrams should be built on this basis (open-box validation). Second, a close fit test of the output data should be conducted between the system under study and the simulation (black-box validation). Finally, a verification test that will ensure that the influence diagram logic has been transformed correctly to the computer based model; that the equations are dimensionally valid and that the model does not produce any illogical results (Pidd, 1996). Janszen (2000) calls the latter 'internal validation'.

In the case of the Creative Factory model the influence diagrams of the model are based on the literature that is presented in Chapters 3, 4 and 5. The transformation of the logic diagrams to the ithink package takes place in parallel with the building of the influence diagrams, in order that it is possible to run the simulation and test that it follows the expected reaction described in the theory, i.e. open-box validation. This additionally, verifies that the equations that have been used are correct and consistent with the logic of the theoretical system, an internal validation. The Creative Factory model, in this form, is considered valid as a theoretical model.

The black-box validation is presented in Chapter 6. Three case studies have been conducted, with multinational firms, from different industrial sectors. The three firms selected to be from three different sectors (automotive, food and electronics), in order to test the applicability of the creative factory in a broad framework of industrial sectors. Additionally, each firm has a different market that considers as a home market (the USA and the EU for the automotive company, the EU for the food company and the Greek for the electronics one). This is because the author wants to examine the ability of the creative factory model to be adjusted to different national innovation environments.

Oppenheim (1992) gives the following advantages for the use of interviews instead of posted questionnaire surveys:

- Interviews are much more explicit when the interviewer has numerous open-ended questions or, where the interviewer has to record verbatim the answers given by the respondents.
- When the length of the questionnaire is long and the complexity high, the response rate of posted questionnaires is usually very low. This can be overtaken through interviews, which can transfer the motivation of the researcher into the interviewee.
- The interviewer can give explanations about the study better than a cover letter. Additionally the researcher can prevent any misunderstandings about the issues that covered by the survey.
- The researcher gets more insights from an interview than from little ticks in boxes returned by 'you-know-not-who'. These insights may provide useful information for the researcher.
- The interviewer may be able to make on-the-spot assessments about the accuracy of the data and may require further information to validate this data.

The creative factory is a complex network of factors and the number of data is very long. Additionally many of these factors mean different thinks for different people with different backgrounds, thus the interviewees need to be informed about the view that this study takes about these elements. Furthermore, most of the necessary variables have qualitative values, which means that are based on personal opinions of the interviewees. Thus the author needs to evaluate them and regularise them according to the elements that are considered as best practice in this study. Often however the industrialists may have an opinion that compared to best practices it is overoptimistic. To avoid any such bias of the data, the outputs of the simulation were presented to the participants on the case studies discussed with them and compared with published information for each firm to show that they represent the real situation for each of the factors of the system.

The qualitative nature of data determines the use of a continuous '1-10' scale of grades (Hussey and Hussey, 1997) for each of this factors with the average on '5'. The best practice for each factor has a '10' grade. Two words or phrases are selected to represent the two ends of a continuum and the responses are indicated on this scale.

Thus, the necessary historical series of data has been collected using a series of structured interviews (three interviews were necessary for each of the automotive and food firms and four for the electronics one). The questionnaire that was the basis of these interviews is shown in Appendix B. At each firm, the model was presented to a group of managers related to the field of NPDD. The type of information that was required was explained to them and then they appointed one person – from project management for the automotive firm and from the marketing of new products for the other two – to take part in a series of interviews based on the questionnaire. The interviewees in all cases consulted other people in their firms from different departments, such as marketing, human resource, finance, in order to obtain information for questions that they could not answer. In cases that the interviewees were suggesting that some areas of the system are not appropriate for the industrial sector or their firm, then this opinion was evaluated by the author on the basis of the literature findings and different weighting between the relations of the innovation related factors were given in the model.

This codified data is then possible to be entered into the several variables of the model (transformed to a '0-100' scale in order to avoid decimal points) in order to adjust the creative factory to the reality of each firm. The outputs of the model's factors are compared with the real situation that these factors have in each firm. This black-box test gives us the confidence that the model can represent the innovation activity and its related factors for each firm. Then it is possible to assess a firm and conduct 'what-if' experiments that provide us with information about the reaction of the model to changes in several variables (Chapter 7).

3 The Overall Innovation Process and New Product Design and Development Process

A firm invests in innovation in order to meet the market demands and to ensure long-term survival against competition (Utterback, 1994). The short term and visible result, however, for a firm and its shareholders is the profits that the new innovative products generate. The core innovation process as defined in Section 1.5 consists of the knowledge creation, the new product design and development and the product success stages. From the definition and the description of the different theories of innovation (Section 1.3) the author then designed a high level model, without many details (Section 3.1). This model shows the stages of the innovation process and the relation of its outcome to the sales and profits of a firm.

From the high level model it can be seen that the NPDD process is central to the innovation process, thus this chapter focuses on the NPDD process (Sections 3.2 to 3.6). The knowledge creation and product success factors, which, in the view of the author, complete the core innovation process, are studied in chapter 4. The other factors – the firm's internal factors and the national innovation environment – that influence this process will be presented in Chapter 5. Together these three chapters form the theoretical background of the innovation system that is used to build the detailed creative factory model, using the system dynamics methodology.

3.1 The High Level Model

At the point that a firm decides to invest in innovation, it must commit financial and human resources. The higher the level of these resources, the higher the level of the R&D effort of a firm (Cooper, 1999). Its R&D effort however is limited by the general availability of human and knowledge resources in the sector, nationally or internationally (OECD, 1997).

In-house research, together with other resources, such as market needs and public research, provide information for new ideas. The direction of in-house research is influenced by the existing ideas for new products that need investigation and by the firm's internal factors, such as technological capabilities and strategy (Wheelwright and Clark, 1992). The number and quality of ideas that are generated by the use of the accumulated information depends on the degree of creativity that the firm's employees show (Tidd et al., 1997). On the basis of the knowledge that a firm gets from its in-house research, it selects ideas to proceed to development (Cooper, 1993).

The ability of a firm to develop these ideas to final products and the speed of their development depend on the good execution of the product development's process stages as well as on other internal factors such as the risk taking policy, the technological capabilities and the organisational structure of the firm (Tidd et al, 1997). In parallel however, the internal factors of a firm may be changed by the development of new products and may be adapted to the national innovation environment. This is a consequence of the knowledge that is developed during this process; the changes in the firm's environment that take place during the development period and the needs of new projects from the internal factors of the firm. For example, changes to organisational structure; corporate strategy; organisational culture and technological capabilities may be necessary for satisfactory development of a new product (Porter, 1990). The influence diagram of these relationships is shown in Figure 21.

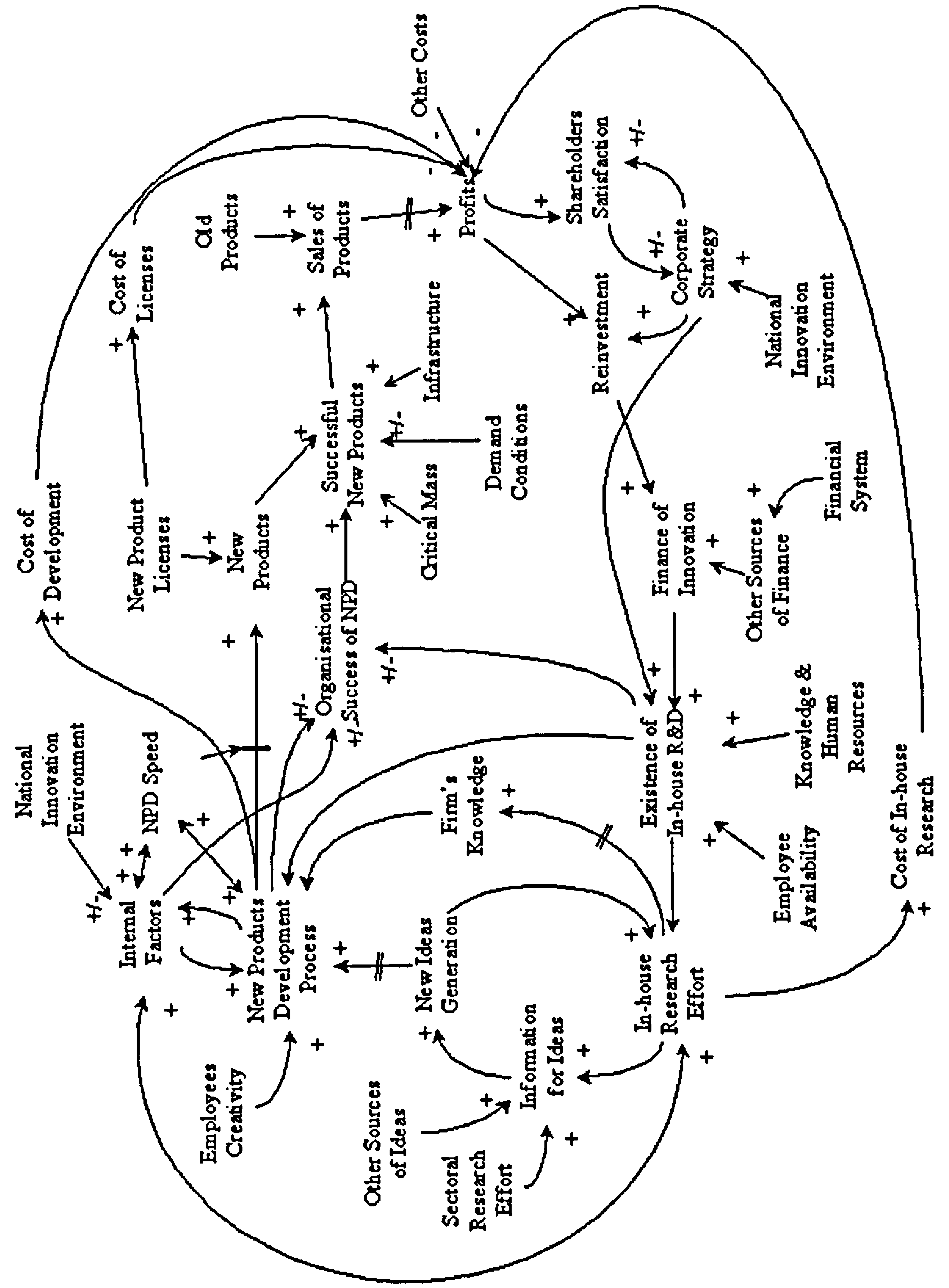


Figure 21. Innovation Process Effect to a Firm's Profits Influence Diagram

A firm can introduce new products into the market that have been developed by its own NPDD process or it can license products from other firms. Their success however, depends on the satisfactory execution of the NPDD process; the specific project execution; the ability of the firm to produce these products economically and of a consistent quality and to support their marketing and promotion in the market. The consistency of production and launch of products depend on internal and external factors such as: adequate technological capabilities; the existence of a critical mass of industries that will supply a firm with the necessary materials and services; the infrastructure that may affect the economical and consistent distribution of the product in the marketplace; and the existence of adequate market demand (Burgelman et al., 1996). Figure 21 shows the influence diagram for these elements.

The sales of new products together with older ones, after deducting the several costs, generate profit for the firm. Part of the profit is distributed to the firm's shareholders and another part is reinvested in the innovation process. The finance for innovation can additionally be achieved partly by external finance which, however, relies on the general financial system of a nation, and partly on the ability of the firm to participate in co-operative research projects (Lundvall, 1992). The level of reinvestment depends on the strategy of the firm. The corporate strategy is formed by the firm's major shareholders and the national innovation environment within which a firm operates (O'Reilly and Tushman, 1997).

Furthermore, the shareholders' expectations of redistribution of the profit are developed by the strategy that senior managers form and present to them (Tidd et al., 1997). Often however, managers prefer to cut innovation related reinvestments to present better results to their shareholders. This has the effect of reducing the introduction of new products and eventually, when the life-cycle of existing products has been completed, of reducing sales and market share and even of bankruptcy. Thus a balance of reinvestment and distribution of profits to shareholders is necessary in order to keep the firm active and profitable in the long-term and the shareholders satisfied.

The influence diagram Figure 21, is a high level model that can be used to provide a general understanding of the relations between the different factors that form an innovation system. Transforming this, using the ithink package (Appendix A.1), can give the analyst a dynamic model of the overall effects of innovation activity on a firm's sales, profits and shareholder satisfaction and the influence of management decisions and other external factors on the innovation process. The details of each factor however give us the ability to study all the elements that are involved in an innovation system and to analyse the influences they exert. All the details that affect the main part of the model are described in the following sections of this chapter and in the next two chapters.

3.2 Stages of a NPDD Process

Several models have been used to describe the NPDD process[5]. The construction of the NPDD process that the author considers however is based on the Stage-Gate

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[5] See for example: Pugh, (1991); Roussel et al. (1991); Himmelfarb (1992); McGrath et al. (1992); Robert (1995);

model by Cooper (1993; 1999) and the Development Funnel by Wheelwright and Clark (1992). The author believes that these two models are the most complete, they come close to the real NPDD process and they are widely accepted by researchers and industry.

3.2.1 Stage-Gate and Development Funnel Models

The Stage-Gate model (Cooper 1993; Cooper, 1999) is a series of processes (Figure 22): ideation; preliminary investigation; detailed investigation; development; testing and validation; full production and market launch and post implementation review. Each stage is designed to gather the necessary information in order to advance the project to the next decision gate. The stages consist of parallel activities undertaken by people from different functional areas within the firm. The process concludes with a post implementation review that feeds the organisation with experiences from the specific project and provides essential organisational learning.

An additional stage in the process is strategy formulation, which stays atop the process model and feeds the process with operational tactics or with criteria for selection. Each process proceeds through a screening session that presents a strong Go/Kill/Hold/Recycle and prioritisation decision in order for the project to continue to the next stage or to loop inside the same or previous one. Gates are usually managed by senior managers from different functions who hold the resources that each stage requires. They define the deliverables that each project leader needs to bring to each decision point and the evaluation criteria of each stage. Additionally, they decide the output (Go/Kill/Hold/Recycle) of the decision process in order for a project to proceed to the next stage and they allocate the necessary resources.

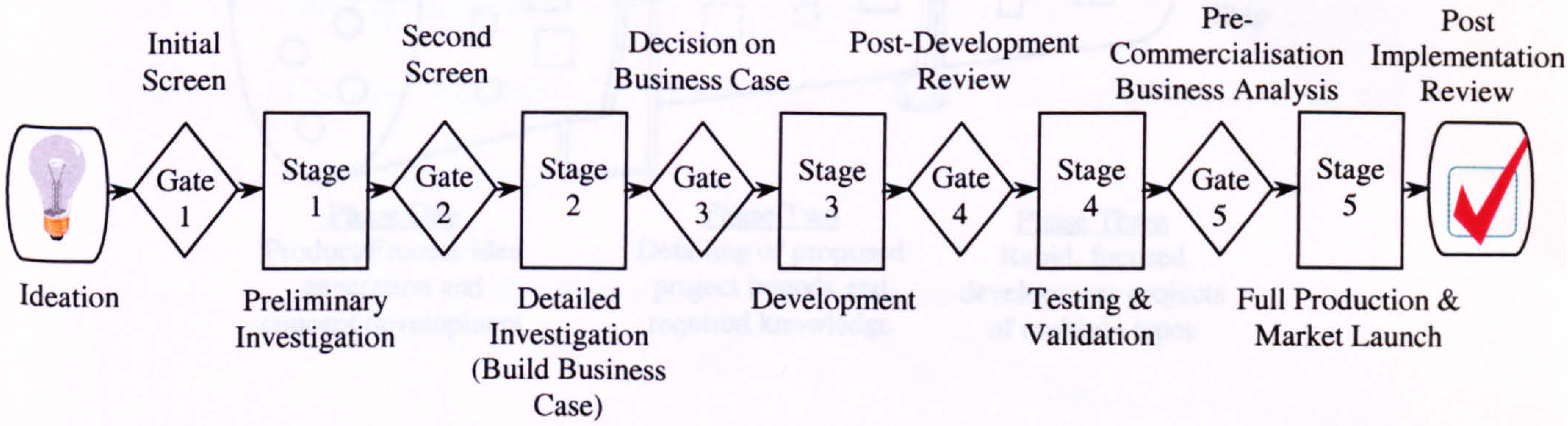


Figure 22. An Overview of a Typical Five Stage-Gate Process.

Source: Cooper, 1993 p108

The development funnel model (Figure 23) (Wheelwright and Clark, 1992) has some points in common with the stage-gate model, for example, multifunctional teams, parallel operations, screening of ideas and post project evaluation. It has, however, fewer screening and process stages, because it keeps the administration and decisions within the project teams instead of separating them by gates. The initial phase of the development funnel is the concept development and idea generation for potential products. The aim of this phase is to expand the input of the funnel by gathering information from as many different sources as possible and involving many parts of the organisation, customers and suppliers.

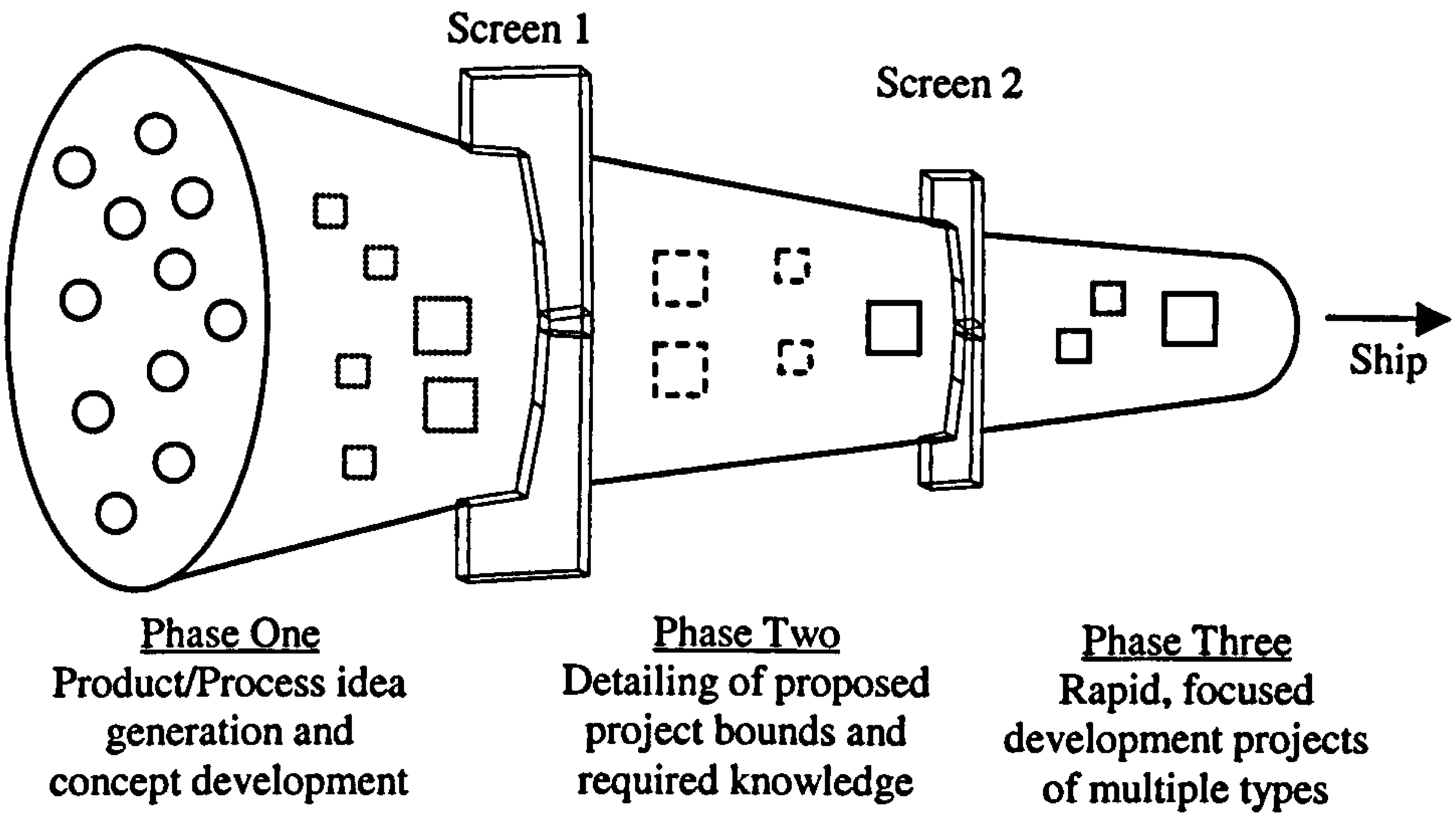


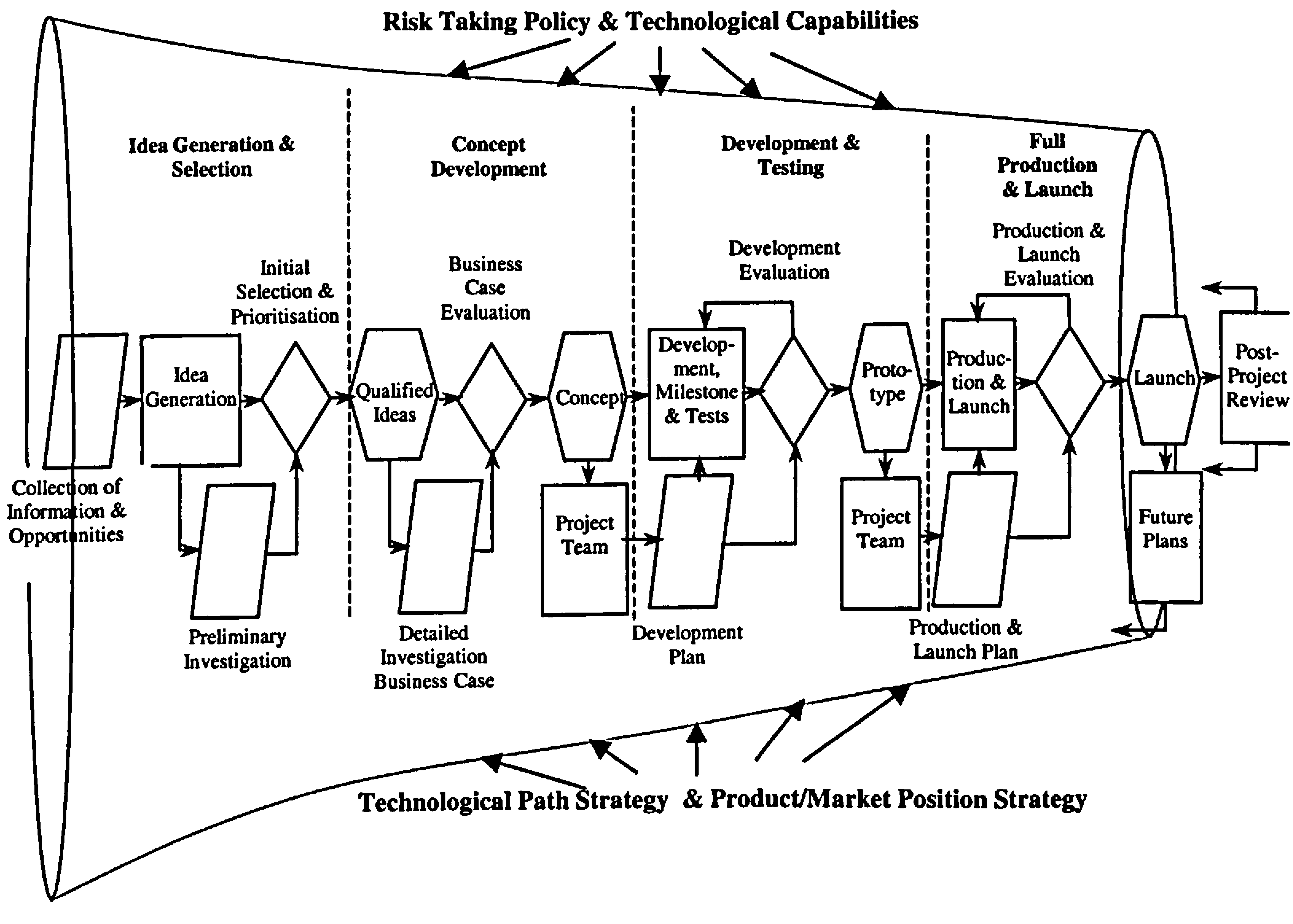
Figure 23. Development Funnel Model.
Source: Wheelwright and Clark, 1992 p124

Phase two takes the product concepts and develops them in a form that will enable the senior managers to evaluate them against others, to select them and to allocate the necessary resources to them (a similar function to stage two and gate three of the stage-gate model). This evaluation is taking place in screen two, which gives the go/no-go signal to the projects. After this screen the development team is given responsibility for completing the project successfully.

3.2.2 The Creative Factory NPDD Process

The Creative Factory's NPDD model is made up of the following stages, which are based on the Development Funnel and Stage-Gate models (Figure 24): idea generation and selection; concept development; development and testing and full production and launch. These stages are described in the next sections.

Finally, the whole NPDD process is influenced by the corporate strategy (technological paths and product/market positioning, Section 5.1), the risk taking policy (Section 5.2) and the technological capabilities (Section 5.3), which play key role in focusing development efforts on the projects that clearly reflect the benefits that they offer and the ability of the firm to undertake these projects through the selection and prioritisation gates.



Note: The 'Kill' and some 'Hold' decisions are not shown in the diagram because of space restrictions

Figure 24. The Creative Factory Model NPDD Process

3.3 Idea Generation and Selection

The creation of a new idea by an individual frequently seems an unconscious process that often involves capricious luck or a flash of insight and does not correlate with levels of intelligence (Martin, 1994).

3.3.1 Idea Generation

Green, as early as 1964 identified a series of steps that appear to be repeated in any creative process and to involve both conscious and methodical thinking as well as unconscious actions that have been developed by previous work and experience. These steps are codified by Martin (1994: p234) as:

- *'The problem faced by the individual arises by the nature of the R&D process. The individual develops at least one preliminary conception of the problem and moves to:*
- *Accumulation of data, ideas, and concepts through literature reading, discussion, investigation, and experiment.*
- *Incubation when the conscious and non-conscious mind assimilates and digests the information gathered.*
- *Intensive thinking next occurs whereby the individual seeks to solve the problem by weaving ideas in new combinations, but despite the intense effort, without success. This leads to:*

> *Frustration, dissatisfaction, and fatigue, so in the face of this psychological blockage, the individual abandons conscious consideration of the problem, [and] takes some:*
> *Relaxation and "sleep on it," leading later to:*
> *Illumination or sudden inspiration, the so-called flash of genius or EUREKA, and (in science and engineering anyway) finally:*
> *Solution, verification, and embodiment.'*

These steps can be transformed to an influence diagram, which is shown in Figure 25. The first step in the idea generation influence diagram includes a wide framework of information and opportunities by which a firm can identify ideas, including the R&D process (see Section 3.3.1.1 and Section 3.3.1.2). The accumulation of these sources of ideas are assimilated by the organisation to the level that is allowed by the firm's knowledge and the organisational structure. The degree that the firm invests (research effort and capital availability) in the investigation of the information then may bring new ideas.

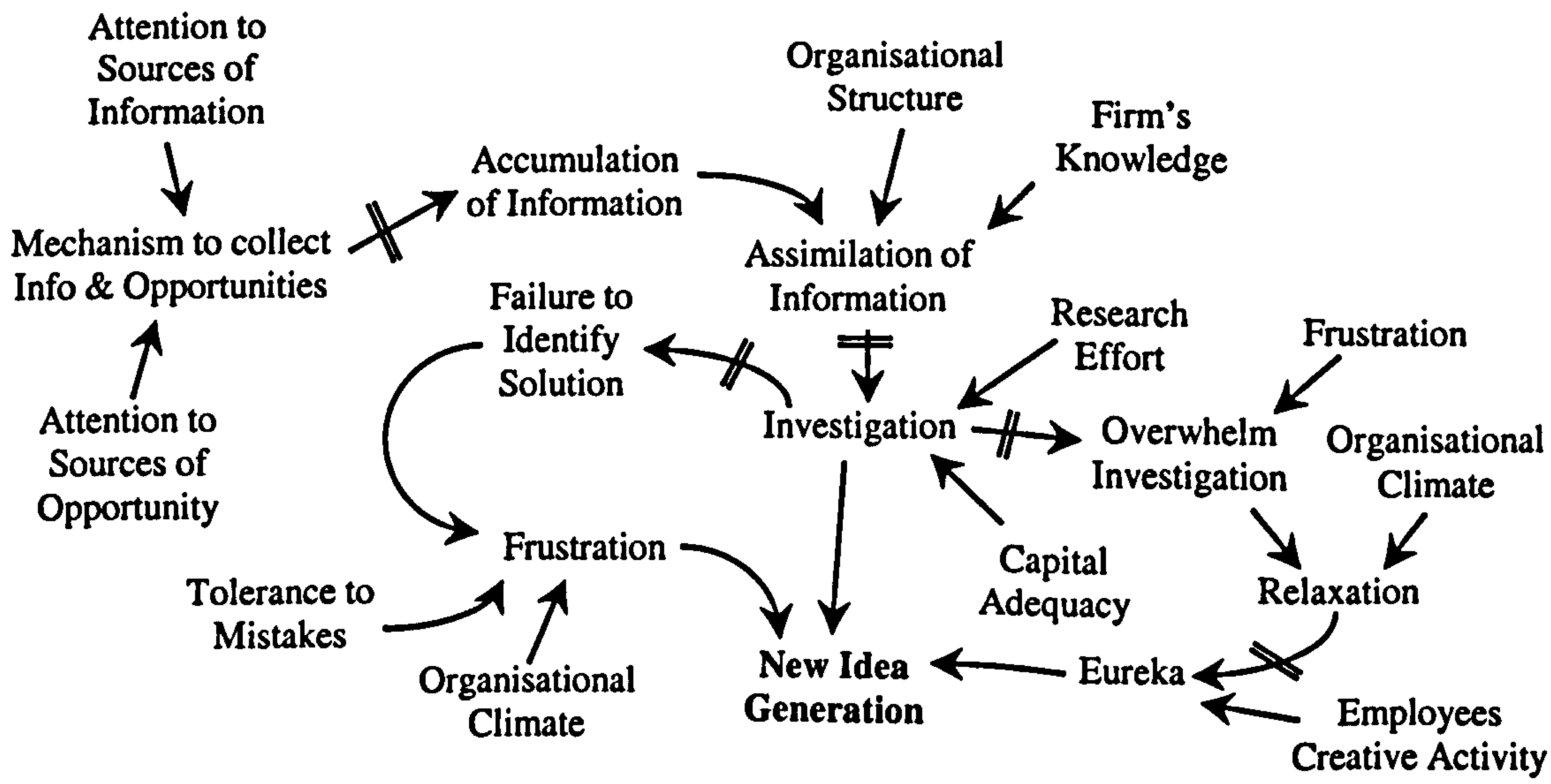


Figure 25. New Idea Generation Influence Diagram

Failure to identify new ideas may create frustration inside the firm and between the employees that reduces the ability to generate new ideas. The organisational climate and the firm's tolerance of mistakes may influence the level of frustration that the employees show. On the other hand, an appropriate organisational climate may help to relax this frustration and lead to the inspiration necessary for new idea generation.

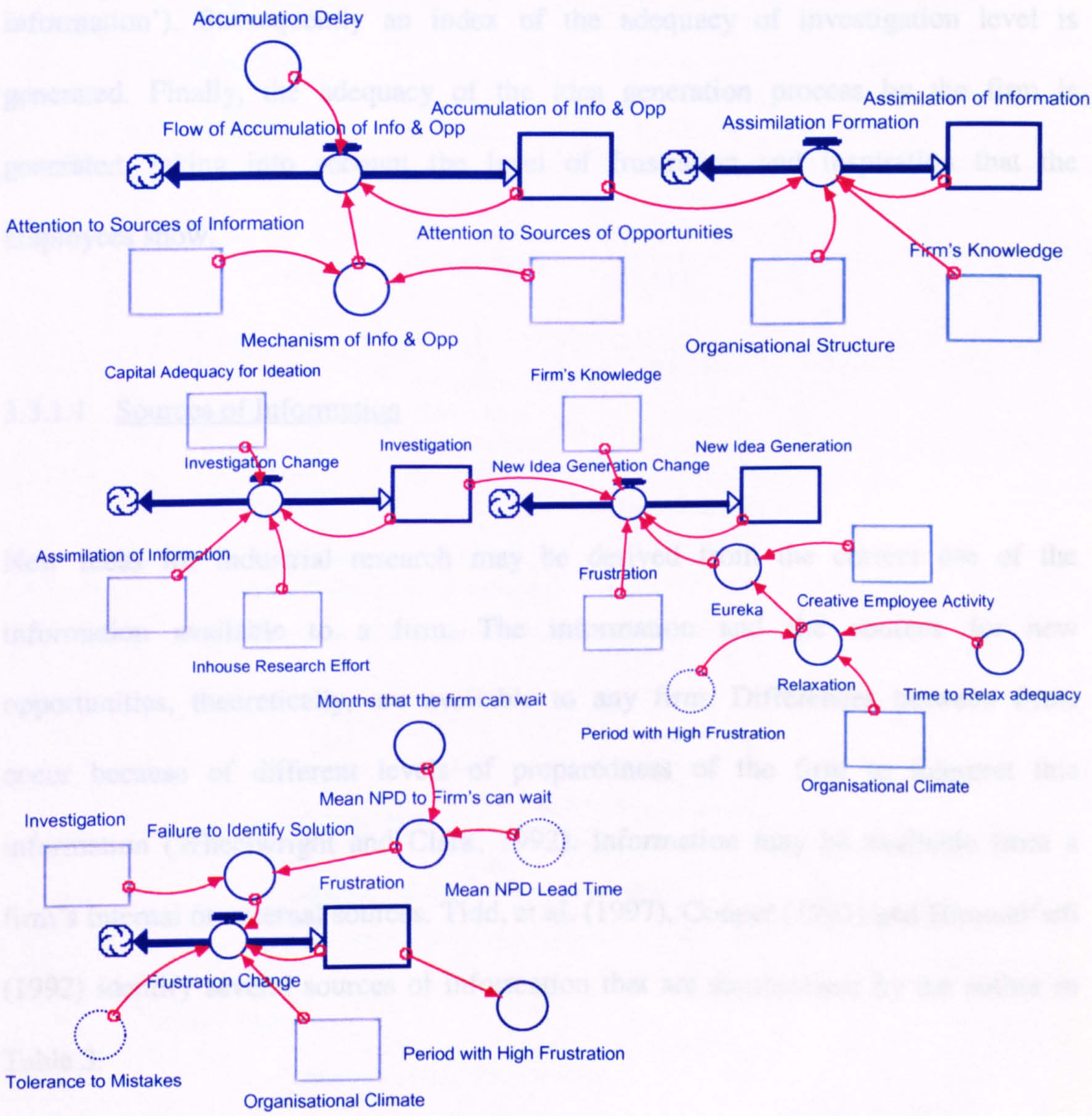


Figure 26. New Idea Generation Model using the ithink Package

The transformation of the influence diagram to an ithink model that produces a dynamic index of quality of the new idea generation process (stock icon named as 'New Idea Generation') is shown in Figure 26. In the first part of the model, the degree of attention that a firm pays to the collection of information and opportunities gives an index for the level of information and opportunities that the firm accumulates (stock icon named 'Accumulation of Info & Opp'). This index is transformed to the ability of the firm to assimilate these sources (stock icon named 'Assimilation of Information'). Subsequently an index of the adequacy of investigation level is generated. Finally, the adequacy of the idea generation process by the firm is generated, taking into account the level of frustration and inspiration that the employees show.

3.3.1.1 Sources of Information

New ideas for industrial research may be derived from the correct use of the information available to a firm. The information and the sources for new opportunities, theoretically, are available to any firm. Differences between firms occur because of different levels of preparedness of the firm to interpret this information (Wheelwright and Clark, 1992). Information may be available from a firm's internal or external sources. Tidd, et al. (1997), Cooper (1993) and Himmelfarb (1992) identify several sources of information that are summarised by the author in Table 3.

The influence diagram of the level of attention that the firm pays to the sources of information is shown in Figure 27. The dynamic model (Figure 28) accumulates the different levels of attention that the firm gives to each source and produces an average index of attention to sources of information, depending on the weighting that each source has for the type of a firm.

Table 3. Sources of Information for new Ideas

Source of Information	Characteristics
Managers	Entrepreneurs; Start-up firms
Customers	Needs and Wants
Suppliers	Own research; Co-operation
Production, Engineering & Quality Departments	Problems; Bottlenecks; Quality problems
Individual Inventors	Inventions; Idea Brokers
Patents & Other Publications	New Developments in the market
Rival Products	Learn from the rival's successes and failures
Ideas held in an Idea Tank	Old ideas; Matured markets and technology
Outsiders	Different sector; Converging technologies

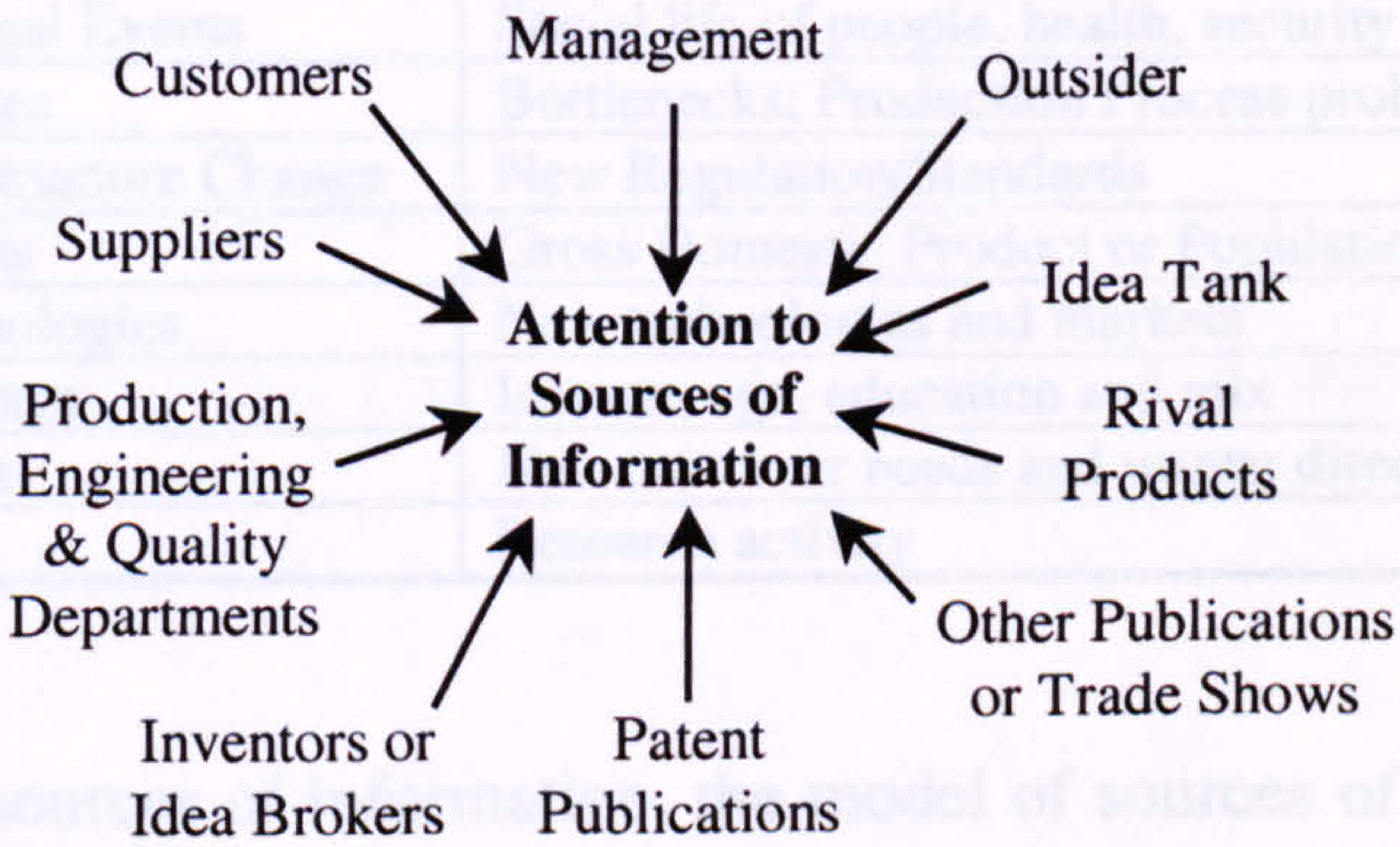


Figure 27. Attention to Sources of Information Influence Diagram

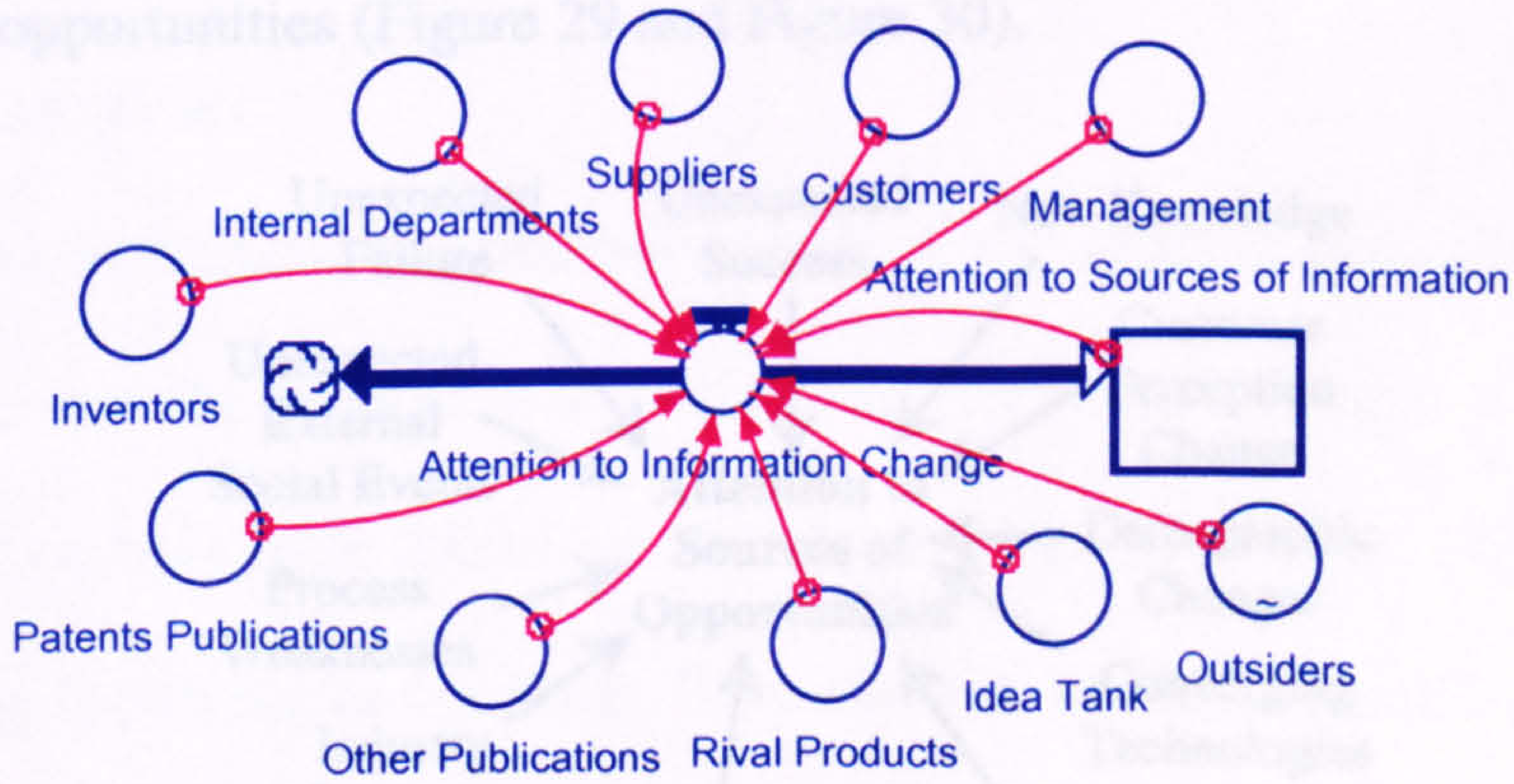


Figure 28. Attention to Sources of Information model using the ithink Package

3.3.1.2 Sources of Opportunities

The search for new opportunities that appear in the marketplace is one more source of product ideas. Robert (1995) and Afuah (1998) refer to several indicators of opportunities that major innovative firms monitor in order to identify them and transform them to new products. These sources are summarised by the author in Table 4.

Table 4. Sources of Opportunities for new Ideas

Source of Opportunities	Characteristics
Unexpected Successes	Changing patterns of customer behaviour
Unexpected Failures	End of life cycle; New Strategies are required
Unexpected External Events	Social life of people, health, security or environmental disasters
Process Weaknesses	Bottlenecks; Production Process problems; Supply Chain
Industry/Market Structure Change	New Regulation/Standards
High-Growth Areas	Gross Domestic Product or Population increases
Converging Technologies	New technologies and markets
Demographic Change	Income, age, education and mix
Perception Change	New customer needs and wants; directions from Advertisement
New Knowledge	Research activity

Similar to the sources of information, the model of sources of opportunities produces an index that represents the average level of attention that a firm pays to the several sources of opportunities (Figure 29 and Figure 30).

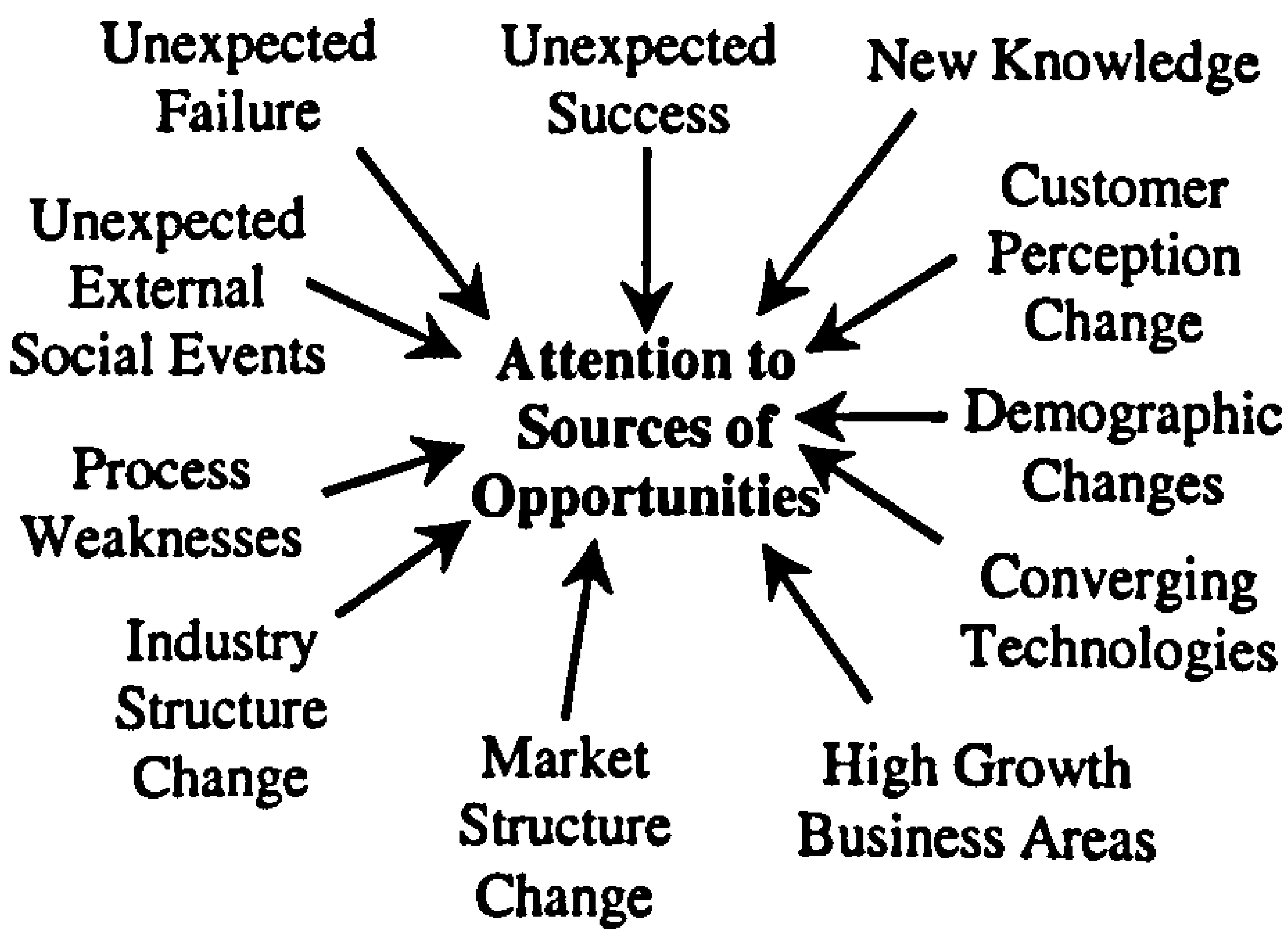


Figure 29. Attention to Sources of Opportunities Influence Diagram

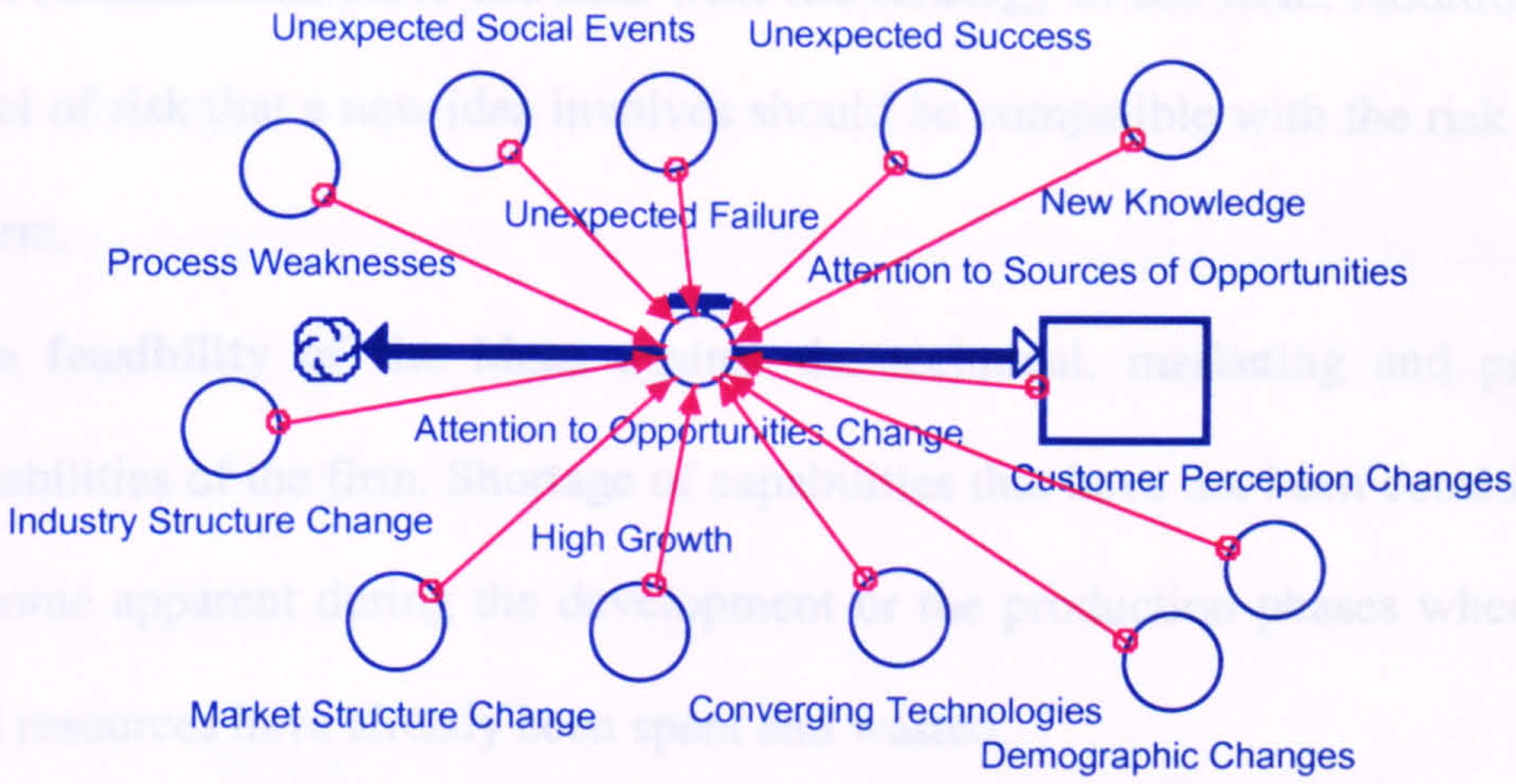


Figure 30. Attention to Sources of Opportunities using the ithonk Package

3.3.2 Idea Selection

This initial screening of ideas is characterised as a 'gentle' one, because the selection is based on the subjective opinions of the participants of the proposed ideas against the criteria (Cooper, 1999)

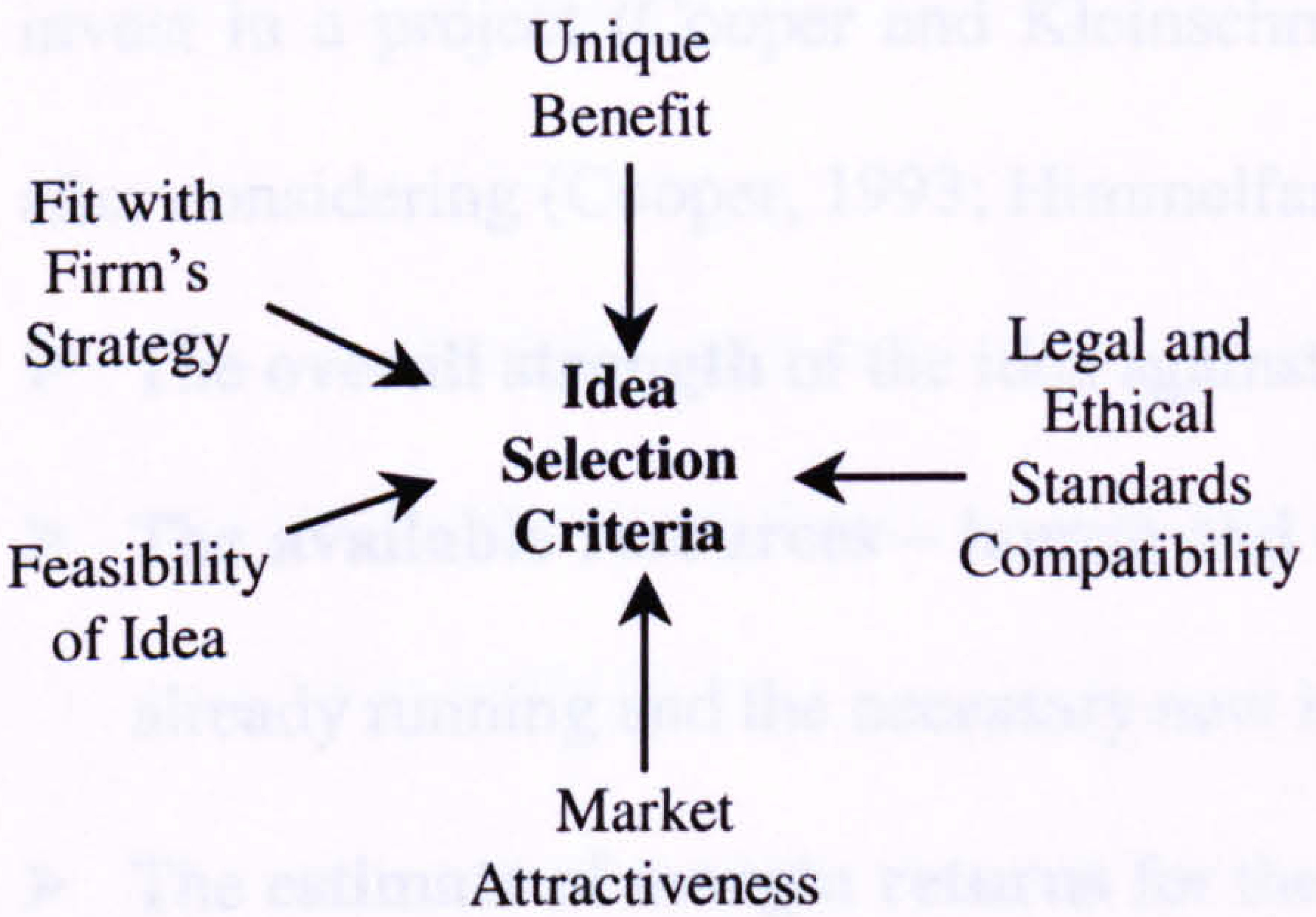
Idea selection criteria have been proposed by several researchers (Cooper, 1993; Himmelfarb, 1992; Roussel et al., 1991). Here the author summarise them into the following categories:

- **The unique benefit that the new product will offer to the customers**. The new features that the product will include, i.e. the value-for-money, or the customer needs that have been identified and covered by this product, should be clear and compared with the competition. This element has been identified as the number one factor for the success of a new product (see Section 4.2) and should be reflected in the evaluation criteria.

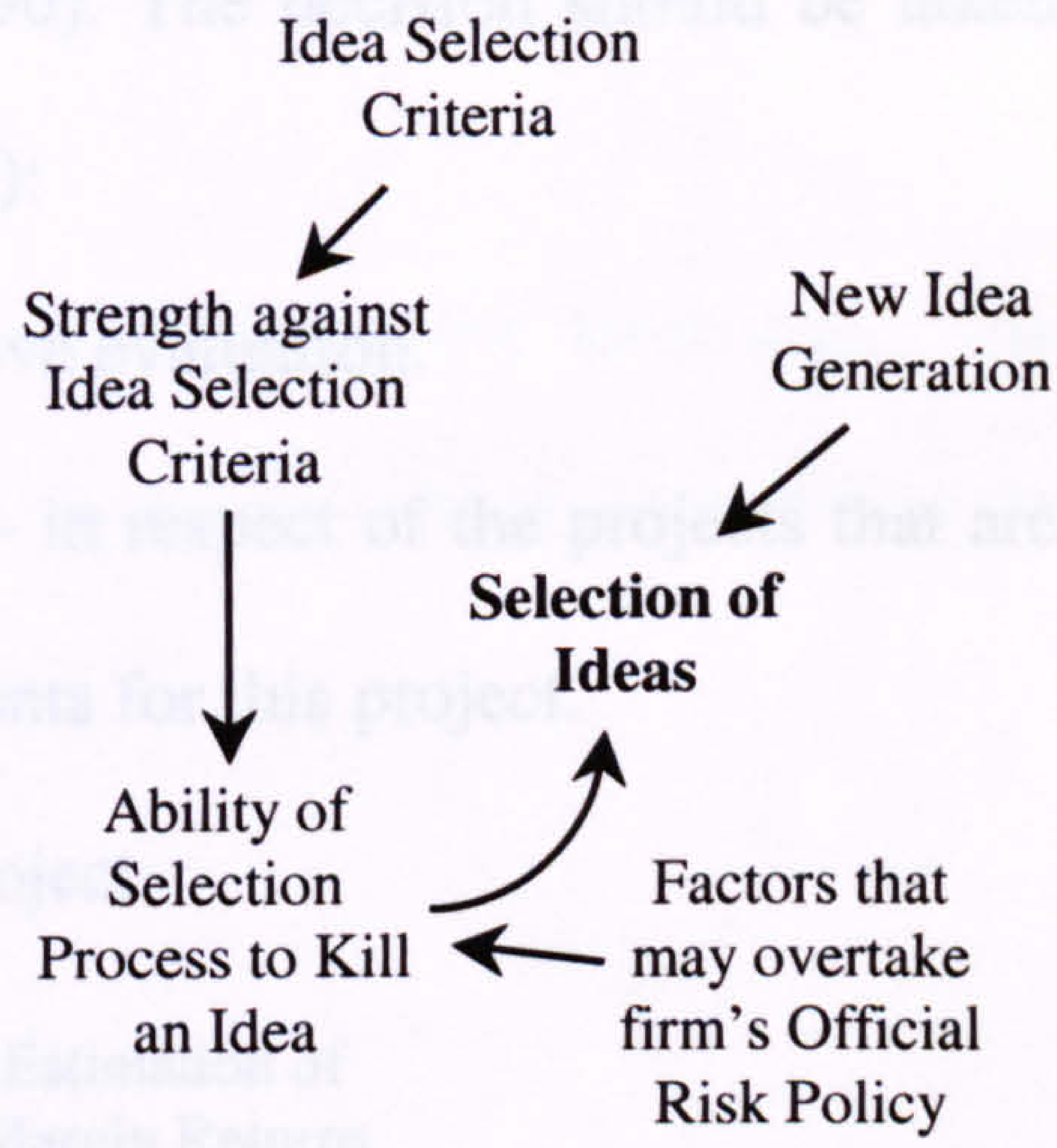
- **The fundamental fit of the idea with the strategy of the firm.** Additionally, the level of risk that a new idea involves should be compatible with the risk policy of a firm.
- **The feasibility of the ideas** against the technical, marketing and production capabilities of the firm. Shortage of capabilities that have not been considered will become apparent during the development or the production phases where capital and resources have already been spent and wasted.
- **Market attractiveness.** The market target, market size and target price need to be identified. This creates a framework for identifying the payback period and whether the project is economically worthwhile for the firm's investment. This information will be tracked in more detail in the next stages, but a first evaluation often identifies the non-feasible ideas.
- **Legal, health, environmental** and **ethical standards.** Potential changes in **legislation** or even new technologies that emerge and may be dominant at the time that the product will be launched on the market need to be considered.

A low score on any of these criteria should be considered as a 'kill' sign for the project. The easiest points of the NPDD process at which to kill a project are stages one and two, where resources have not yet been committed and people do not yet feel a strong ownership for the particular project (Cooper, 1993). The ability of the firm to kill a project is influenced by factors that attempt to overtake the firm's official policy. These factors are studied in Section 5.2.2.

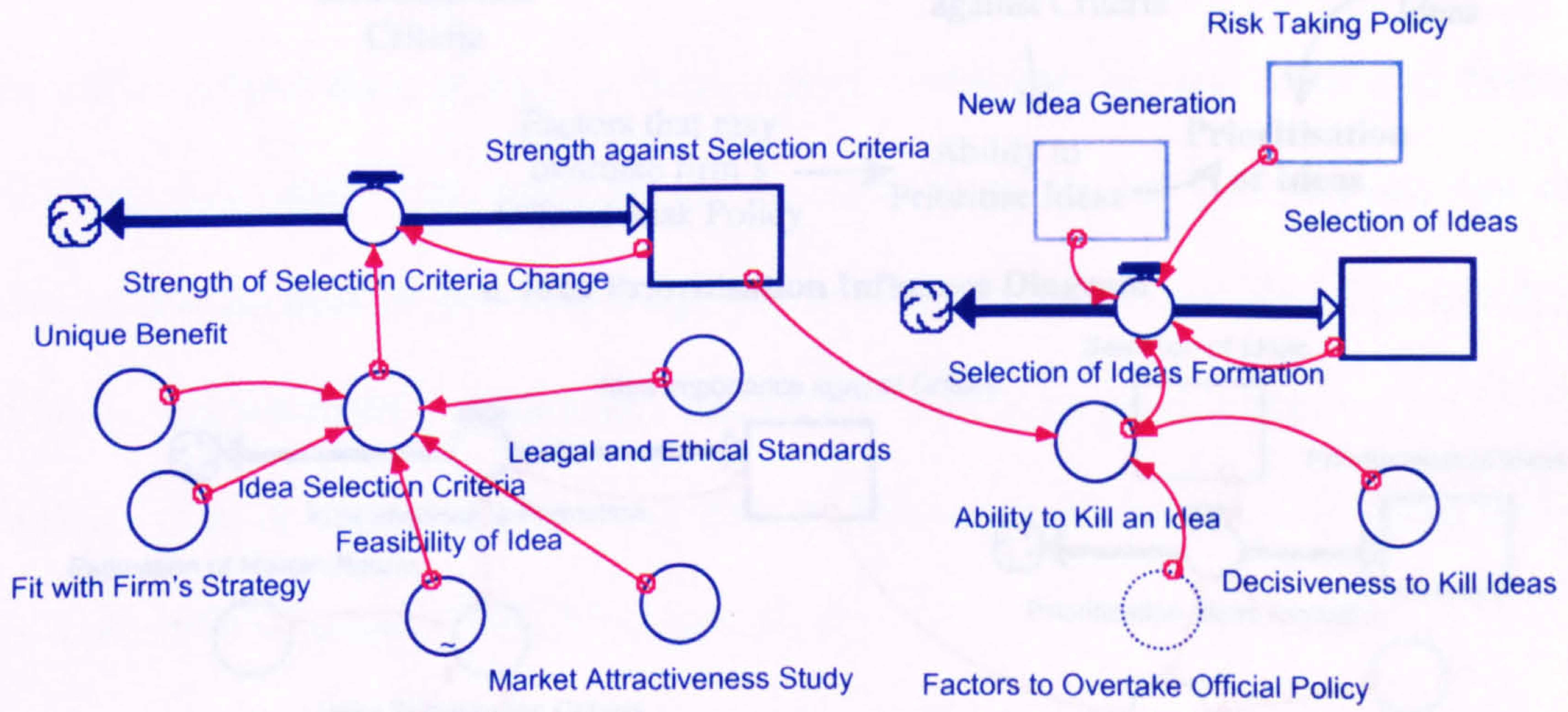
The creative factory model uses an index that compares the average strength of the ideas that are selected for development against the selection criteria. This index is used as a quality index that, in combination with the existence or not of factors that overtake the official policy, determine the ability of a firm to kill an idea. The new idea generation process quality index and the ability of the firm to kill an idea produce an index that represents the quality of the idea selection process (Figure 31), stock icon named 'Selection of Ideas'.



a. Attention to Selection Criteria Logic Framework



b. Adequacy of Idea Selection Process Logic Framework



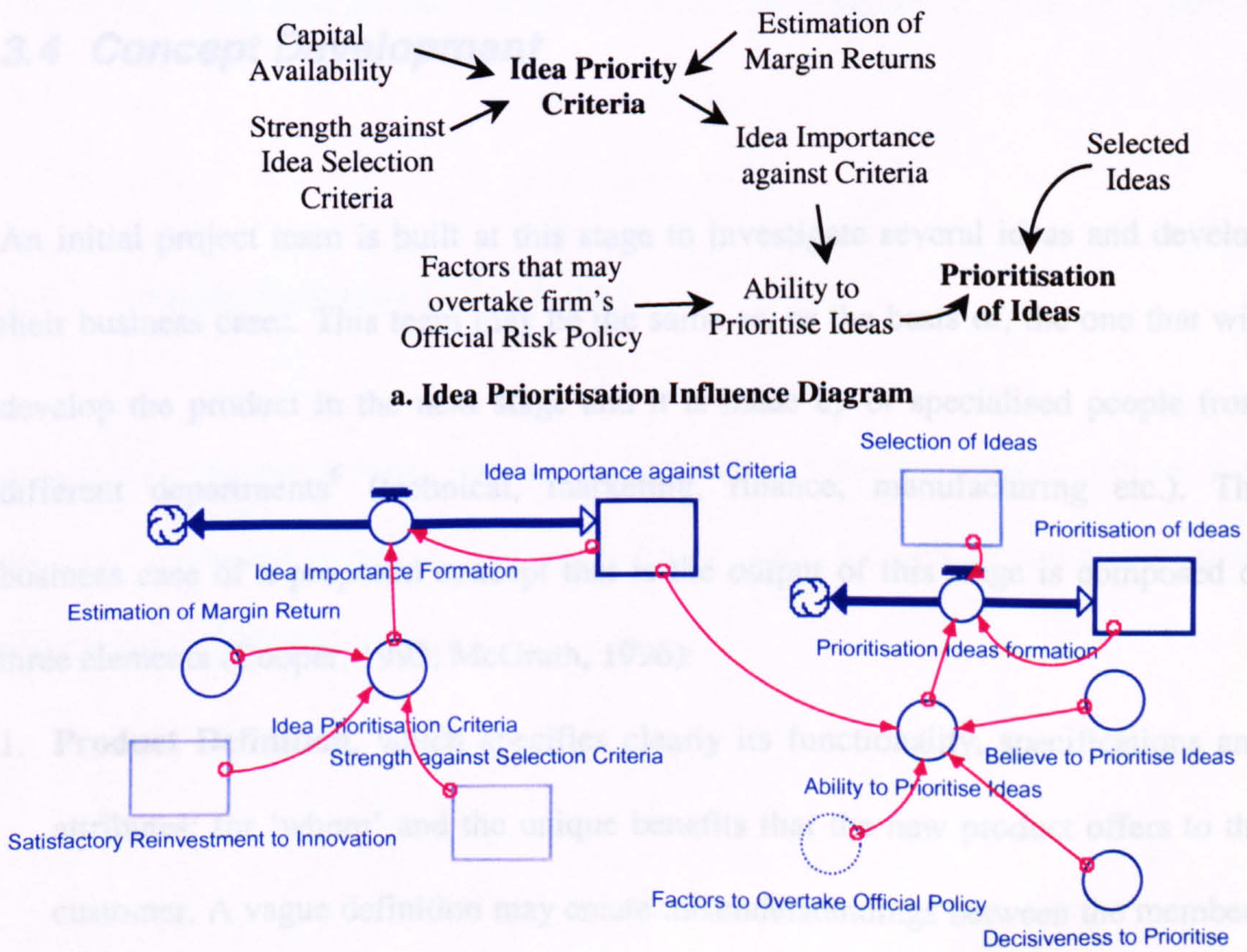
c. Adequacy of Idea Selection Process Model using the ithink Package

Figure 31. Adequacy of Idea Selection Process Model

3.3.3 Idea Prioritisation

The ideas that have qualified to proceed to the investigation phase need to be prioritised. If the projects are not prioritised and proceed to the next phase, then the available resources (capital and human) are split into too many directions. This leads to problems, for example, teams not dedicated to one project, or inadequate capital to invest in a project (Cooper and Kleinschmidt, 1990). The decision should be taken after considering (Cooper, 1993; Himmelfarb, 1992):

- The **overall strength** of the idea against the above evaluation.
- The **available resources** – human and capital – in respect of the projects that are already running and the necessary new investments for this project.
- The **estimate of margin returns** for the new project.



b. Idea Prioritisation Process Model using the ithink Package

Figure 32. Idea Prioritisation Model

The prioritised products continue to the new product development phase. The rest are held for future use in the ideas tank and are evaluated together with new ideas. Figure 32 shows the generation of an index that represents the ability of a firm to prioritise an idea based on the criteria described above. The combination of this index with the index of the quality of the idea selection process form the adequacy index of the prioritisation of ideas process, stock icon named the 'Prioritisation of Ideas'.

The construction of the creative factory model continues using the same logic. The rest of the diagrams are shown in Appendix A. The equations behind the graphics are shown in Appendix D.

3.4 Concept Development

An initial project team is built at this stage to investigate several ideas and develop their business cases. This team may be the same as, or the basis of, the one that will develop the product in the next stage and it is made up of specialised people from different departments[6] (technical, marketing, finance, manufacturing etc.). The business case of a proposed concept that is the output of this stage is composed of three elements (Cooper, 1993; McGrath, 1996):

1. **Product Definition,** which specifies clearly its functionality, specifications and attributes: for 'whom' and the unique benefits that the new product offers to the customer. A vague definition may create misunderstandings between the members

[6] For more details about the project team see section 5.4.2.2.

of the project team about the targets of the project and may often create the phenomenon of moving targets.

2. **Project Justification** of the company's investment in the development of a project. This requires a review of financial and risk considerations or the competitive advantage that the firm will obtain from the new product.
3. **Project plan** of actions that need to be carried out; the milestones to be achieved from the development until the launch of the product and timelines for these actions. The project plan describes the resources, people, money and equipment that are necessary for each action and identifies the ability of the firm to undertake it successfully in the specified time, taking into account the set of projects that are executed simultaneously (Wheelwright and Clark, 1992).

The model of the concept development for the creative factory is shown in Appendix A.2.1.

3.4.1 Detailed Business Case studies

In order to build the elements and define the details of a business case, a firm needs to construct a detailed technical and manufacturing study, a customer and market study and a detailed financial study.

3.4.1.1 The Detailed Technical and Manufacturing Study

The understanding of the customers and their environment is transformed to customers' requirements according to the product's specifications and functionality. The customer requirements need to be translated into technically and economically feasible solutions. Typical considerations, which are also used in the creative factory to evaluate the quality of the technical and manufacturing study for a firm, include the following elements (Cooper, 1993; McGrath et al., 1992; Robert, 1995):

- **Alternative technical solutions,** or even new inventions, in order to arrive at a product with the defined requirements.
- **The actions** that need to be undertaken should be described and planned over **time** according to the available capital and personnel.
- **The risk and the cost** that each solution involves. The creation of an invention or the use of an unproved technology involves a high risk and cost of development that may not be justified by the expected margins.
- **The technical capabilities** of the firm to develop the proposed technologies.
- **The possible patents and legislation** relevant to the new product that must be followed.
- **The ease of manufacturing** the product and the need for new facilities, and personnel.

A concept test study using a prototype may be necessary at this stage, to identify the actual reaction of the customers to the proposed product, interest in buying it and at what price. This test will provide confidence for the interest of the customer before the heavy investment stage of product development takes place, and can be used to support the case for the project if it has to compete with other proposals from different project teams (Wheelwright and Clark, 1992). Additionally it can provide qualitative data, such as the attractiveness of the product to the customer, which is useful for the customer and market study and necessary for the justification of the concept.

3.4.1.2 The Customer and Market Study

The objective of the customer and market study is to understand the customers and to develop a complete view of the customers' environment (Burchill and Fine, 1997). A rough idea has been developed in stage one, but now a detailed study is necessary that will back this up with actual information. Based on the studies of Cooper (1993; 1999) and Himmelfarb, (1992) the creative factory concept requires the following information in order to create an index that evaluates the execution of the customer and market study:

- **Market portrait**: the market segments, the buyer behaviour, the size, growth and trends are studied in order to specify the potential marketplace.
- **Competition**: the identification of the competitors, the products that they have on the market and a comparison of the additional value that the new product can offer to the customer.
- **User needs and wants**: this is market research that must involve face-to-face customer interviews or in-depth customer surveys. The objective here is to identify a product that delivers real value to the customer, having identified what the customer means by real value.
- **Macroeconomic analysis:** this analysis looks beyond the immediate marketplace to the whole economic situation that the firm has to face.

3.4.1.3 The Detailed Financial Study

Having carried out detailed technical solutions and market studies, the financial analysis of the project can be developed. Market size and share estimates together with a pricing analysis should give the expected revenues from the new product. The detailed technical assessment of the product should provide information about the cost of development, investments in new assets, marketing promotion and personnel and production costs of the new product. Thus an estimate of the profit margins and payback period can be calculated (Cooper, 1993; Himmelfarb, 1992).

3.4.2 Concept Selection

The three elements of the business case for the concept – product definition, project justification and project plan – form the basis on which a project is evaluated. The evaluation of the concepts is conducted by senior managers who are responsible for handling the available resources and they have an overall view of the projects that run simultaneously. The evaluation at this stage has the responsibility of Go/Kill and Prioritisation decisions, as in the previous stage (section 3.3.2 and 3.3.3). However, senior managers use this evaluation to test the quality of the project's execution (Cooper, 1993). If the business case does not match the expected quality, it should be returned to the beginning of this stage. The 'Go' decision for a project should be accompanied by a final plan of the subsequent steps and actions that need to be followed until its launch to the market. The models of concept selection and prioritisation for the creative factory model are shown in Appendix A.2.2 and A.2.3 respectively.

3.5 Development and Testing

At this stage, the project team takes the approved concept and develops it to a prototype product. The product is tested via lab tests and with customers. When the team feels that the product has reached the customer expectations and the problems have been solved, it will be ready to proceed to full production. The project team which has been built around the needs and characteristics of the project, using the concept development team as a base, represents the different design, technical, marketing, financial and production specialties that are needed to develop the product.

The development of the product is driven by the project plan that has been designed at the previous stage. The milestones of achievements need to be measurable and to have a realistic time framework attached because they are used as checkpoints to determine if a project is on track, on schedule and on budget. If several milestones cannot be achieved then this is an indicator that a project is in trouble and the project leader must review it, identify the problems and evaluate if it can continue and under which conditions or, if it needs to return to the previous stage or even to be killed (Cooper, 1999). The review and evaluation takes account of other factors that other members of the team are working on, in parallel. These factors are the latest market analysis, in part based on the feedback from the test with customers; the financial and risk analysis which now give more detailed information about the product's features, the manufacturing cost, the technology that is involved and the investment in equipment and people that is necessary and the regulatory and legal compatibility of the product (Patterson, 1993). The evaluation of the milestone execution is the main output of the development and testing sub-model in the creative factory (Appendix A.2.4).

Furthermore, a development team uses the latest market analysis to be prepared to react in the case that a similar product appears on the market, or customer perception changes (Cooper, 1993). The lab tests can ensure the functionality of the product and its quality, they cannot however, identify the attractiveness of the product for the customers. In the field tests, part of the product (in the early stages of the development) or the prototype product is presented to customers where they can use it, identify its functionality and appreciate the benefits that it gives to them. These tests uncover the real needs and wants of the customer; show if the concept development team has translated them correctly; identify the enthusiasm of the customers to buy it at a given price and compare the product with rival ones that are known to the customers. The earlier the customers are involved in the tests the earlier the ability of the team to identify changes in customer opinions and the easier, faster and cheaper it is to make changes in the product (Bruce and Cooper, 1997).

In parallel with the development and testing processes the team develops detail plans for the next stage – production, marketing, logistics and quality assurance plans. These plans could start to be implemented from this stage in order to accelerate the whole NPDD process. In addition, production plans can provide information about difficulties that the product may face during its manufacture, which can be solved in the development phase (Stalk and Hout, 1990). These problems, if left until production starts, will be very difficult to solve and will incur a large cost.

Furthermore, the schedule of material requirements should be ready when full production starts. Cooper (1993), has found that many problems and many product failures occur because the production and marketing plans are not ready at the beginning of the production and launch stage but are developed only when the prototype has been approved. As a consequence the firm is doing 'too little, too late'.

The final decision of 'Go' to full production is largely a financial one. The project team should now have a clear idea about the market size, the sale price at which the product will be attractive, the production and marketing costs and the profit margins (Cooper, 1993). Thus the financial analysis would indicate whether the return from the product is higher than the minimum acceptable to the firm in a pessimistic scenario and then the decision for commercialisation is taken. The creative factory uses the adequacy level of this justification for a project and the ability of the firm to execute the milestones and prioritise different projects to create an index that can assess the selection process of prototype products in a firm.

3.6 Full Production and Launch

The prototype product that has been approved in the previous stage is now ready for full production and launch on the market. Thus, the production and marketing plans are implemented. The logistics plan, for example, raw material supplies, scheduling of production and tooling, need to be executed. In addition the quality assurance and the legal support of the product need to be implemented.

The marketing plan should set clear and measurable targets (objectives) that the product should achieve during its life cycle, and a strategy for achieving these objectives. These should be ready, before the product appears on the market (Cooper, 1999). The achievement of these targets is a sign of success for the product in the marketplace and they should be monitored after launching the product (Bruce and Cooper, 1997). The information that is needed for the market plan is the same for the customer and for market study of the business case development (see section 3.4.1.2).

Plans for expansion of the product to new markets, or with new variations, are prepared in this stage, ready to be implemented in the future. These could be new ideas starting again from the beginning of the NPDD process or they could be based on continuing with the current product and knowledge earned from it. The creative factory model (Appendix A.2.5), based on the ability of a firm to implement the actions necessary for the production and launch stage, generates 'Full Production' and 'Product Launch' indices to assess these stages.

3.6.1 The Post Development Review

At some point after the launch of the product on the market (depending on the length of the life cycle of the product), the new product project must be terminated. The new product is now a 'regular product' for the firm and its performance, as well as the project's performance need to be reviewed. The data according to costs, sales, profits and timing should be compared with the planned projections and the performance of the product should be identified. Differences from the planned results need to be examined and the reasons identified (Cooper, 1993). The post-project review should be conducted by the same project team and is a critical element in order to improve the performance of the NPDD process (Cooper, 1999).

Wheelwright and Clark (1992) stress the importance of post-project learning, mentioning that those who do not learn from their past projects will neither prosper nor survive. When a firm seeks competitive advantage through its NPDD, it is not only to succeed on one particular project, but also to continue to build and improve the organisation's procedures, processes, tools and methods in order to do things faster, more efficiently and with higher quality. Table 5 summarises the types of critical events that may occur during a project, the observations that need to be taken and the learning issues for the organisation. Based on these observations, the creative factory model generates an index of influence by the post project review for the firm, to characterise the degree of learning from this process.

Table 5. The focus of learning in development projects

Category	Nature of Observations	Issues for learning
1. Recurring problems linked to critical performance dimensions	➢ Persistent quality problems with design ➢ Engineering changes at pilot for problems that could have been uncovered long before	➢ Does the organisation capture solutions and make them permanent? ➢ Discipline and methodology in engineering
2. Crucial individual activities/tasks and associated capabilities	➢ Time to complete key tasks (e.g. testing) ➢ Quality of tasks	➢ Do we measure/track the right information about tasks? ➢ Do we have the skills needed
3. Working-level linkages (e.g. engineering – manufacturing)	➢ Timing of downstream (e.g. manufacturing) improvement ➢ Degree of influence exerted by upstream and downstream on problem solving in the other group	➢ Do we have a process and framework for integration? ➢ Do we have the skills, attitudes, and values that drive integration?
4. Design-build-test cycles	➢ Speed of the cycle/number of cycles ➢ Quality of solutions	➢ Do we have the right people involved in design-built-test cycles? ➢ Do we have the right tools, supporting resources, and skills?
5. Processes for making decisions and allocating resources	➢ Time required to decide/number of reiterations ➢ Resource constraints/problems	➢ Are the right people involved at the right time with the right information? ➢ Do we have too many projects? Do we have an aggregate project plan?

Source: Wheelwright and Clark, 1992: p288

4 Knowledge Creation and Product Success

This chapter focuses on the Knowledge Creation system and the Product Success Factors, which complete the Core Innovation Process of the Creative Factory. The models of these factors are presented in Appendix A.

Knowledge can be generated by public or industrial research and includes new scientific and technological knowledge. Universities, public research institutes and private enterprises conduct research, and try to utilise their resources to maximise their output. Each of the actors however, has different priorities, is triggered by different ideas and focuses on different types and areas of research. As Section 4.1 shows, a balance between basic and industrial research is required in order to create a complete knowledge creation system. Additionally, because of the high cost and complexity of many research areas and the fusion of technologies and sciences, collaboration between different firms and/or universities may be required in order to economise resources and to mix specialities. In Appendix A.3 the creative factory builds an index that can represent the status of a firm's knowledge that is gained from the in-house research effort and the research activities in the sector and nation inside of which the firm operates. Finally, the successful diffusion of the final product into the market place is presented in Section 4.2. This section analyses the success factors according to a product's functional competencies and a firm's organisational competencies. Appendix A.4 presents the model that can be used to assess the existence of these success factors.

4.1 Knowledge Creation

New knowledge used to be considered as that which was produced by the science system, mainly through basic research in universities and public research centres. Traditionally this new knowledge was termed 'science' distinguishing it from knowledge that was generated by industrial research for commercial use, which came closer to market needs and was termed 'technology' (OECD, 1996b).

Basic research has been identified by the OECD (1993: p29) as '*the experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view.*' Industrial research on the other hand includes the applied research and experimental development, which are defined as (OECD, 1997a: p29):

- ***Applied research** is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.*
- ***Experimental development** is systematic work, drawing on existing knowledge gained from research and/or practical experience, that is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improve substantially those already produced or installed.*

Gibbons and his colleagues (1994) however, argue that there is no longer a meaningful distinction between science and technology. It is often observed that the search for technological solutions can be a productive source both for new scientific questions as well as answers. As a result, the traditional science system of universities and public research institutes cannot be assumed to dominate the production of scientific knowledge. Additionally, new scientific and technological knowledge appears to be generated differently from country to country or even from one industrial sector to another. The organisations and institutes in each innovation system may have different roles and importance. For example, industry based research may be important for one system while research in universities may perform a similar function in another (Edquist, 1997b). Table 6 summarises the differences between academic (public) and industrial research (Konecny et al., 1995).

Table 6. Comparison of Academic and Industrial Research

Academia	Industry
Purpose • To advance knowledge of the physical world.	*Purpose* • To advance Company business against competition
Choice of Topics • Chaining based on experience.	*Choice of Topics* • Match between Company needs and individual experience.
Predominant Expertise • Phenomena and techniques.	*Predominant Expertise* • Products and processes of interest to the Company.
Approach • Completeness is important.	*Approach* • Timelines often more important than completeness.
Publication of Results • Usual.	*Publication of Results* • If they are not of value to competitors.
Highly Valued • Advance of subject. • Intrinsic virtues of work.	*Highly Valued* • Impact on the business.

Source: Konecny et al., 1995: p19

These differences focus on the purpose of the research undertaken by academia and industry, the criteria for selecting a topic of research, the sources of expertise of industry and academia, the approach to project development, the publication of the results and the evaluation of the importance of the project (Konecny et al., 1995).

4.1.1 Basic Research vs. Industrial Research

By the beginning of World War I industrial laboratories had become the principal source of new technologies and products in several sectors such as the chemical industries and electrical industries, undertaking traditional public research. These laboratories co-operated with universities that trained new scientists and engineers. Over time, they undertook research in applied science and engineering as well as in basic science (Nelson and Rosenberg, 1993). In recent years however, the total research spending in the OECD area showed a decline, giving the impression that in some countries basic research may be suffering because of the limited government funding for basic research (OECD, 1996b).

In today's environment, where products are complex and involve knowledge from different scientific and technological areas, the question is whether basic research or industrial research, separately, are adequate to produce new knowledge (Ganguly, 1999). Rahm and his colleagues (2000) conclude, in their comparison of the research systems of the US, UK and Japan, that during the 1990s Japan was re-evaluating the consequences of its own lack of a strong basic research base. Japan was starting to focus on the need to build and maintain a strong university-based research capability. Ironically however, the UK and US were revising their policies in order to direct them more into industrial research and development because of the competitive threat that they faced from the Japanese industries.

The author believes that in order for an innovation system to show significant and sustainable innovative activity, both basic research and industrial research are necessary. The public sector needs to take an active role in the innovation system in order to promote basic research, give direction, and prioritise research areas that are of greater interest to the nation. At the same time however, the public sector should create a helpful environment for industries to become involved in research. Industries, by realising the benefits of their investment in research and their collaboration with other industries, universities or public research centres, could economise resources and take advantage of the fusion of the technologies and the mix of specialties.

4.1.2 The Public Sector Role in the Knowledge Creation System

As the statistics show, most research that is conducted by universities or by public research centres that are linked to universities is concerned with basic research. In some countries this research represents 30 percent, or more, of the national R&D effort (OECD, 1998b).

Freeman and Soete (1997) show that basic research activities have actually proved to be essential, even in less developed countries whose main concern is to import, imitate and assimilate existing technologies already available in other countries. Some minimal research activity in universities and public institutes, together with the education of some postgraduate students abroad is essential for understanding and gaining some depth in new technology. Over time and with gradual improvement of facilities and the upgrading of standards, the science system in such countries may make a substantial contribution to science and technology.

4.1.2.1 The Role of Universities

The university system of a country, through teaching and training, provides the skilled workforce for its industries and researchers for research centres. An education system that focuses on specific scientific and technological areas, or where some areas are more prestigious than others, can generate the expertise for industries related to these areas and a shortage of human resources in others (Prais, 1993; Porter, 1990). Differences in the education system can be reflected in areas of national technological strengths and weaknesses. Such differences can be considered as the source of strength for example of the UK and the US in pharmaceuticals and software, and the strength of Japan and Germany in automobiles, machinery and production engineering (Porter, 1990; Pavitt and Patel, 1999).

The function of teaching and training, although it is important in the innovation system, is only one of the roles that universities can play. Goto (2000) identifies two more roles for universities in an innovation system. The second role is to develop the 'seeds' of innovation, which are the generation of the critical logic that is used in research to provide new science and technology. The third role is that of a repository of advanced knowledge which may solve a firm's technological problems. Advanced knowledge, produced through university research, needs to be publicised fully by the universities in order to ensure a wide utilisation of the results by firms or other institutes. Many universities have lost their role of creating new knowledge and provide only a reproduction of existing knowledge. One of the reasons for this is because governments do not support their research activity or because the prospect of a research career does not appeal to students (Goto, 2000).

4.1.2.2 The Enhancement of Basic Research

The necessity of public spending in basic research has come under attack by Kealey (1996). Like many other researchers, in his work he identifies the inability of the linear R&D model to produce successful innovation. But whereas most researchers support the need of an interactive model between basic research, applied research, engineering, production and markets, Kealey argues that public funding of basic research should be totally withdrawn. His argument is based on the idea that a pluralistic pattern of funding is preferable to a single source pattern. He believes that private industries, private individuals and private foundations would replace this funding.

In economic terms Nelson (1959) and Arrow (1962) made clear quite early that expenditure on basic research would tend to be lower than the economically and socially desirable level if left just to private funding. Although a pluralistic funding pattern may be desirable, several studies question the ability or the will of the private sector to fund basic research (see for example: OECD, 1996a; OECD, 1998b; Freeman and Soete, 1997; Rahm et al., 2000). Basic research is, by definition, truly uncertain; the researchers do not know whom, if anyone, will benefit from its outcome and a project may take twenty or thirty years to give an outcome. Thus, it is unlikely that industries will finance much or any basic research because they cannot generate short- or medium-term justification (Freeman and Soete, 1997).

Another point that contributes to the belief that the private sector would be unlikely to invest in basic research, is that industrialists cannot recognise the benefits of basic research. A first reading of statistical data shows that countries with very good records in basic research (e.g. UK) have performed technologically and economically less well compared with others with less basic research activity (e.g. Germany and Japan). However this contradiction occurs because the benefits of basic research are broader than the 'information', 'discoveries', 'patents' and 'ideas' that tend to be measured in economic surveys (Pavitt and Patel, 1999). The benefits of basic research need to be considered by industrialists as including trained researchers, improved research techniques and instrumentation, tacit knowledge and membership of professional networks which can advance their business (Hicks et al., 1996). Most of these contributions however, are person-embodied (for example, tacit knowledge and a person's qualifications) and institution-embodied knowledge, rather than information-codified knowledge, which could be passed from one person or one organisation to another (Faulkner et al., 1995).

Pavitt and Patel (1999) believe that this explains why the benefits of basic research turn out to be localised instead of being 'public good' for every person, organisation and nation and why a nation or a firm can profit from involving itself in basic research. Empirical studies in many countries support the argument that firms in a variety of industries, such as biotechnology, chemical, telecommunications, need continuous involvement or contact with basic research for successful innovation (see for example: Senker and Faulkner, 1994; Mansfield, 1991; Faulkner et al., 1995).

Finally, the social benefits of basic research are much wider than the development of competitive advantage for a firm or the growth of an industry. Characteristic examples are the research in public health problems and environmental problems. As Pavitt (1996) points out, it is highly uncertain that private firms would invest in research about the effect of smoking or on the cure of cancer or the resolution of the 'greenhouse effect' and the hole in the ozone layer. Society may perceive this investment as necessary even though no private firm would undertake it. Without government funding, these types of research simply would not exist.

4.1.2.3 Public Support of Basic Research

Rahm et al (2000) identify three ways that governments can intervene in a nation's research effort and promote basic research:

- **Grants, loans or government contracts.** In this way, governments can select a policy that would allow research to be directed by the researchers (universities or industries) without requiring specific directions or results. Most of the advanced industrialised nations however, operate a centralised selective scientific and technological policy mechanism in order to control the increasing cost and complexity of the research (OECD, 1994; Freeman and Soete, 1997; Gregersen, 1992). Characteristic examples of this type of involvement are the USA, UK and France, in industries such as aircraft and nuclear weapons, where there has been heavy government involvement, both in R&D and as large customers (Freeman and Soete, 1997; Gregersen, 1992). The decision to make this type of investment is usually justified politically and to a lesser degree economically (Freeman and Soete, 1997).

- Indirect monetary assistance through **incentives and tax law provisions.** This assistance targets industries (as the public universities and research centres are not liable to taxes) and is common across Europe.
- **National or international organisational research collaboration.** Co-operation economises on the required resources and achieves the scale benefits of joint activities. This cooperation requires the development of a network between industries and people that will allow the effective transfer of information and co-ordination of research. This collaboration can be of two types (Rahm et al., 2000):
  - *Collaboration between private sector companies.* This type is common in Japan, although the firms co-operated in order to achieve competitive advantage in the global market and not to enhance their research effort. Such co-operation is illegal in most of the countries in the west, where anti-monopoly legislation is highly developed. Research collaboration however, at a level where the results are not yet commercialised is possible. Such programmes exist in the European Union for example through the five Framework programmes that have existed since 1984.
  - *University-industry collaboration.* This type includes the transfer of technology development from the university research centres to the private sector; joint research activities conducted in university-industry shared research centres; assistance to start up firms located in university research parks; campus-based industrial extension services; university contract research work and university experts acting as consultants to industries. The university-

industry partnership in research projects injects social and economic relevance into basic research instead of this being triggered only by the researcher's curiosity (OECD, 1998b).

The major limitation for future advanced basic research however, according to OECD reports (1998b), is the lack of human rather than financial resources.

4.1.3 Drivers of Industrial Research

In industry, research is not driven by curiosity, but by the specific social or economic needs of the market or the firm to generate profits. In US, 70 per cent of R&D spending is on development (design, testing, prototypes and pilot plans), 22 per cent on applied research and 8 per cent on basic research (Industrial Research Institute, 1995).

On the question of why industries invest in something that is highly uncertain and does not show immediate benefits, Burgelman and his colleagues (1996) and Konecny and his colleagues (1995) found the following reasoning: to discover new areas of technology and markets; to connect existing knowledge with new technological developments; to adjust to, or to avoid technological surprises from, radical innovations from other firms, often called 'creative destruction'; to bring to the firm higher levels of knowledge that support its existing business and create 'knowledge barriers' for other firms who wish to enter the market, and to adjust to legislation such as public safety and environmental protection.

Jain and Triandis (1997) and Ganguly (1999) identify the factors that need to be controlled in order for a firm to achieve a high degree of success from its research activity. These factors are creative people; a creative environment; the easy flow of ideas; the dedication and availability of resources; the organisational culture and the control of risk and uncertainty. These elements are studied further in the next chapter.

4.2 The Success of New Products

The Success of new products can be measured with several different indicators, such as, the market share; the ratio of new products to old ones; the impact on the overall sales of the firm; the achievement of sales and profits targets; the opening of new windows of opportunities for the firm; technical successes and the speed-to-market in order to increase the life cycle of the product (Cooper and Kleinschmidt, 2000).

Several surveys show that the new products that are launched on the market face a commercial failure rate, depending on the industry, that can be somewhere between 25 to 65 percent (see for example: Crawford, 1979; Cooper, 1982; Cooper, 1984a; Page, 1991). Additionally, during the NPDD process many proposals for projects fail to be developed and about 45 percent of all the resources that are allocated to NPDD process are for projects that are cancelled or fail in the market (Cooper, 1993). Page (1991), shows that for every 11 new product ideas, 3 enter the development phase, 1.3 are launched and only 1 is a commercial success (Figure 33).

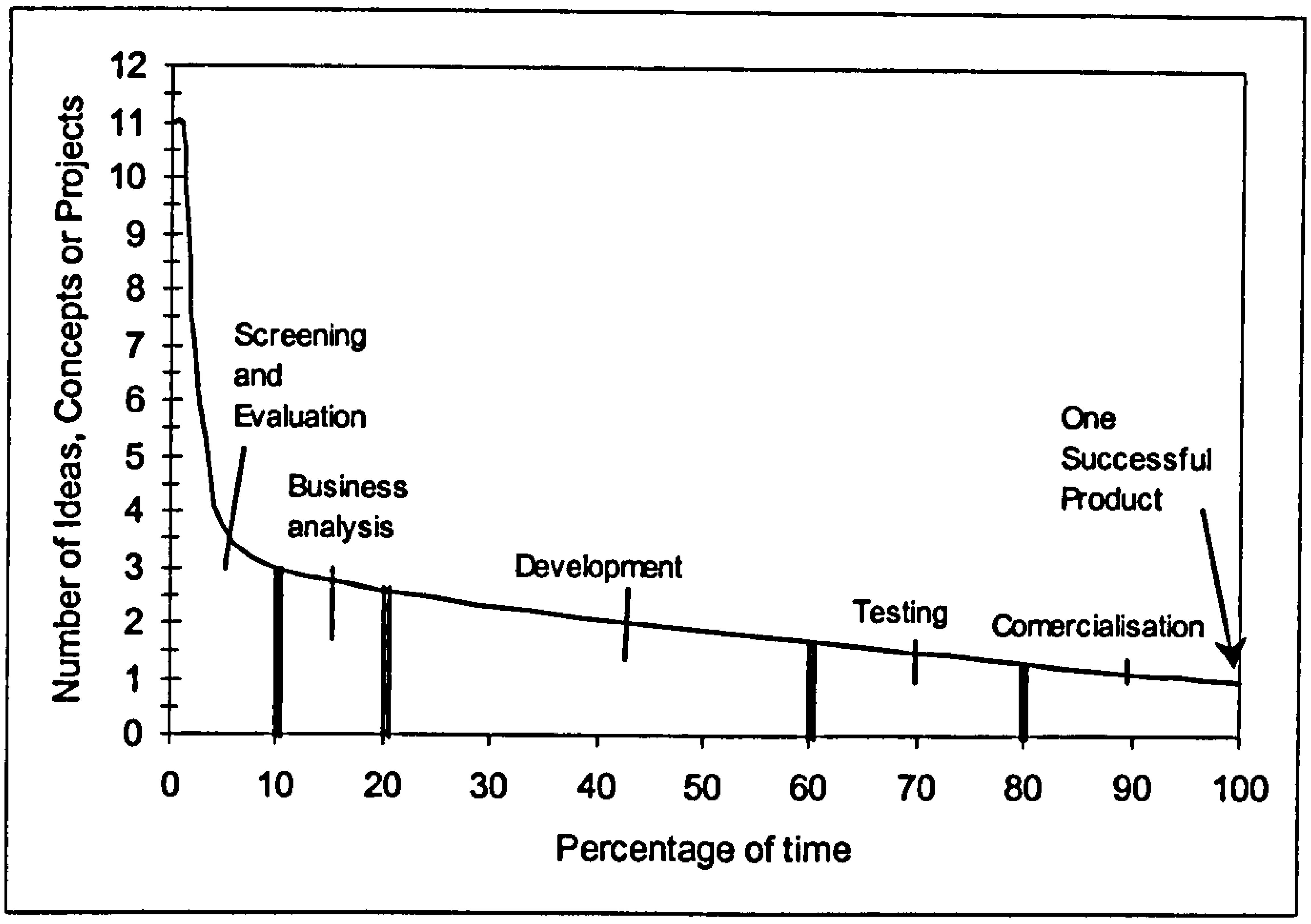


Figure 33. The attrition of New Product Projects.
Source: Page, 1991 as found in Cooper, 1993 p9.

Cooper (1993) however, identifies that, in some firms, the success rate reaches 80 percent of products launched. This is an indicator that some firms outperform the average by a considerable margin. In the following subsections, the reasons for product failure are discussed and the factors that separate winners and losers are presented. The creative factory model then uses them to identify the possibility of a firm's innovation outcome to be successful

4.2.1 The Key Factors of New Product Success

The differences that make one product succeed and another fail have been studied in several surveys, which targeted different industries and countries (see for example: Rothwell et al., 1974; Rothwell, 1992; Calatone and Cooper, 1979; Cooper, 1980; Maidique and Zirger, 1984; Link, 1987; Booz-Allen and Hamilton, 1982). Most of these studies turn the attention of the industrialists to the study of market needs and customer wants, as well as the importance of offering a unique benefit to the customer.

One of the most recent and perhaps most extensive surveys is one by Cooper and Kleinschmidt (1990). In this survey 203 projects that were launched on the market from 125 industries and either succeeded or failed, have been studied. Eight key factors that separate success from failure were identified and listed in order of importance (Cooper, 1999):

1. **A superior product** that delivered unique benefits to the user and was innovative.
2. **A well-defined and justified product prior to the development phase.**
3. **High quality of execution of technological activities.**
4. **Strong technological synergy** between the technological strategy of the firm, its technology competencies and its production resources and skills.
5. **High quality of execution of predevelopment activities.**
6. **Strong marketing synergy** between the needs of the project and the firm's sales force and distribution system, its advertising resources and skills, its marketing research and its customer service capabilities.
7. **High quality of execution of marketing activities.**
8. **Market attractiveness** determined by the size and growth rate.

Two more factors, the competitive situation and the top management support, although they were originally believed to be important were found to make little difference between success and failure. The message was that top management often supports the wrong projects and that products that offer high value and unique benefits to the customer are not significantly affected by competition. The creative factory model uses the above list of success factors to identify how close the new products that a firm develops come to these requirements and thus what are their prospects of success.

4.2.2 Acceleration of the NPDD Process

The unique benefits that a new product may offer to customers, which is the most important factor of success, may be eliminated because, during the months or years that are required to develop a product and launch it on the market, the customers and their needs may change or a rival product may appear providing these benefits (Stalk and Hout, 1990). Several suggestions, which have been presented in the literature, can be used in the whole NPDD process in order to reduce its time. A summary of them is presented in Table 7. These suggestions are used in the creative factory to evaluate the speed of the NPDD process of a firm and identify the opportunity or the barrier that may present to the success of a new product because of the design and development delay.

Table 7. Actions to be taken in order to Accelerate the NPDD Process

Suggested Actions	Characteristic Literature
➤ Do it right the first time	Cooper, 1993; Cooper, 1999
➤ Homework and definition, or in other words, control the 'fuzzy front end'	Smith and Reinertsen, 1997
➤ Build in the voice of the customer as early in the process as possible	Patterson, 1993; Smith and Reinertsen, 1997
➤ Organise around a multifunctional team with empowerment and parallel processing of different stages	Stalk and Hout, 1990; Patterson, 1993; Cooper, 1999; Wheelwright and Clark, 1992
➤ Prioritise and focus to the most important projects	Cooper, 1993; Cooper, 1999

4.2.3 Organisational Factors of Success

Based on the factors that separate winning products from losing ones, Cooper (1999) executed a benchmarking study between hundreds of business units to identify the organisational elements of the NPDD process that drive high performance. He found three factors (Figure 34) that high performing businesses have:

- **A well-defined new product strategy for the business.**
- **The necessary resources in place.**
- **A high quality new product process.**

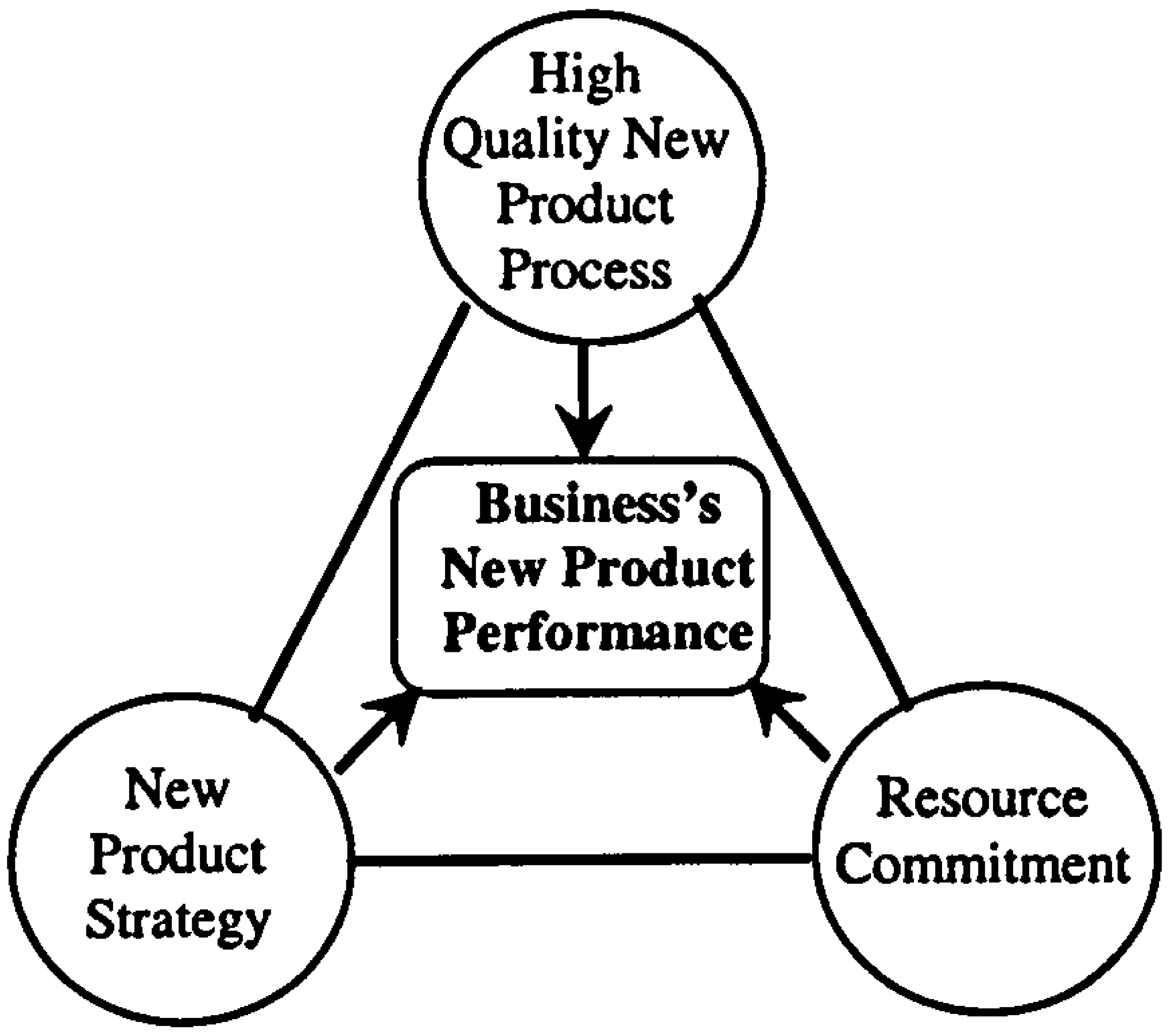


Figure 34. The three Cornerstones of Performance.
Source: Cooper, 1999 p31

These factors, in the creative factory, are developed by using elements from the NPDD process (Chapter 3) and the business factors that affect innovation (Chapter 5) and generate an index of success based on the status of the organisational factors of a firm.

5 Factors which Influence the Core Innovation Process

In this chapter, the elements relevant to the innovation process are presented. These elements (Figure 35) are either internal business factors within a firm, or, belong to the national environment in which a firm operates.

The business factors that appear, in the literature, to be related to the innovation process are: the corporate strategy; the technological capabilities; the organisational structure; the risk taking policy and the uncertainty of innovative projects; the organisational climate or culture; and the degree of creativity that employees and the organisation show.

Several external elements have been identified and categorised by researching the national innovation systems literature and the economics literature in order to build a complete picture of the creative factory concept: the financial system; the infrastructure of the country; the demand conditions; the supportive industries, i.e. critical mass and the availability of physical resources; the availability of human and knowledge resources; and the relevant legislation that may place barriers or help the activities of a firm. Although these elements can be very important to any investment decision, or may direct the innovation activity of a firm in one or another way, they are presented briefly because a firm does not have the power to affect them directly.

Additionally, these elements affect all the firms and differences are created by the reactions of the specific firm and the way that it selects to take advantage of them.

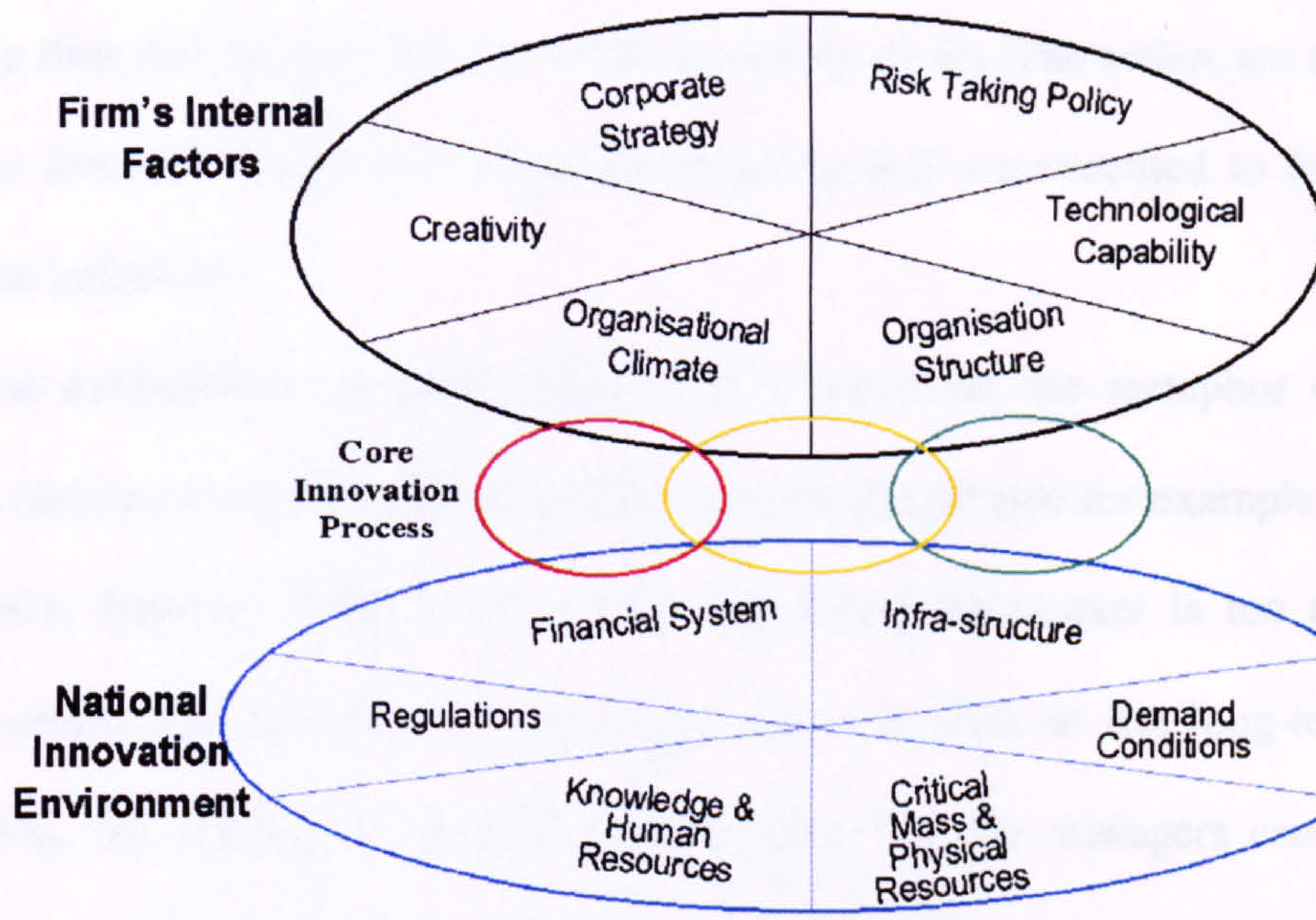


Figure 35. Influential Factors of the Core Innovation Systems Process

5.1 Corporate Strategy

Strategy is used in the business literature to define long-term objectives that are based on a clear vision or a mission (Burgelman et al., 1996) and directs a firm's activities in order to achieve and secure competitive advantage (Cooper and Press, 1995).

5.1.1 Strategy Approaches

Whittington (1993) identifies four different strategy schools, which differentiate targets and the processes from which the strategies are directed according to the outcome:

- The **classical strategy approach** rests on the military pattern of strategy (see for example Sloan, 1963; Ansoff, 1965; Porter, 1980). Top management, based on rational planning methods, identifies the best area in the marketplace to position the firm and the best defence methods against rivals. The orders are transferred to the lower levels of the structured hierarchy and are executed to lead to profit-maximisation.
- The **evolutionary strategy approach** is based on the metaphor of biological evolution, where the market is likened to the jungle (see for example Williamson, 1991; Hannan, 1993). Evolutionists argue that the market is too complex and unpredictable and that managers are unable to forecast the long-term changes. Thus, the strategy is directed by the market and the managers can only ensure their short-term survival by fitting their business as efficiently as possible to current environmental demands.
- The **processual strategy approach** maintains that neither the market nor the organisation is a perfect base from which to design a successful long-term strategy. Thus managers try to simplify a very complex environment by taking small steps one after the other, analysing the results, evaluating the new market environment and building on all of these progressively (Mintzberg, 1987). Success, which is not necessarily translated to profit-maximisation alone (Pettigrew, 1985), is achieved by concentrating on the firm's core competencies (Hamel and Prahalad, 1994).
- The **systemic strategy approach** argues that while rational planning matters, planning should also reflect the socio-economic environment of the firm. Managers plan a strategy that involves the micro-politics of individuals and the firm's departments, as well as the social groups' interests and resources of the

surrounding environment. Using this approach the classical, evolutionary and processual strategies emerge as special cases of the main approach that fit the needs of their socio-economic environments and as a response to the culture of the societies in which they operate (Wilks, 1990; Granovetter, 1985). Whittington (1993) mentions that in practice, the borders of the different approaches are usually blurred and one firm may move from one approach to another as the business and social environment change. The social background, nonetheless, gives to this approach additional output targets to that of profit-maximisation alone, such as a new product ratio, managerial power, professional pride or even national patriotism.

5.1.2 Corporate Strategy Requirements for an Innovative Firm

The innovation process requires a strategy that involves complexity, high risk and uncertainty, change in the firm's structure, technological capabilities and the proper socio-economic environment (Tidd et al., 1997). The outcome of an innovation process can be long-term growth and future market penetration instead of short-term profit maximisation. This requires patience and the management's vision, commitment and support (Rothwell, 1994b). Thus, the systemic strategy approach is the one that can define a strategy that is appropriate for firms that target highly innovative activity.

Using the systemic approach, Teece and Pisano (1994) describe three elements that constitute a corporate strategy:

- **Strategic Position.** This positions the firm according to the product, processes and technologies of the firm, compared to its competitors and according to the system of innovation within which the firm operates.
- **Strategic Technological Paths.** The firm takes risks by following new technological paths and seizing market opportunities that emerge, relevant to its core competencies.
- **Strategic Organisational Processes.** This approach builds organisational processes in order to create new knowledge and integrate it across functional and divisional boundaries.

The Creative Factory model uses these three elements to build the corporate strategy subsystem (Appendix A.5) and generates an index that can assess the strategy of a firm according to its innovation activity. The decisions for new strategic positions and technological paths depend on the vision of top management. The implementation of this vision is limited by the core competencies of the firm, the capital that is available for new investments and the risk that the firm is ready to undertake (Tidd et al., 1997; O'Reilly and Tushman, 1997). The ability to identify new opportunities is based on the technological knowledge that the organisation has, the research effort and the attention that is given to sources of opportunities (Cooper, 1993). The strategic organisational processes are changed by the changes made in individual business factors. These factors are: the ability of a firm to generate new knowledge through in-house research or by importing it; the integration of this knowledge into the whole organisation and the barriers that are raised by the organisational structure; the acceleration of the NPDD process and the organisational climate that supports the new strategies (Tidd et al., 1997; Mintzberg et al., 1998, Burgelman et al., 1996).

5.2 Risk Taking Policy and Uncertainty

Miller and Friesen (1982), in their research on innovation in 'conservative' and 'entrepreneurial' firms find a high correlation between innovation and risk. In addition O'Reilly and Tushman (1997), analysing the results of their survey in high technology firms, conclude that two main elements stimulate creativity: the support for risk taking and change and the tolerance to mistakes. The managers can show their support for risk taking and change first through the reward system that they follow and second by accepting failure and even rewarding it, if this will create positive messages to the company. The punishment of mistakes and failures, creates fear of trying new ideas among the employees thus worsening the creative environment of the firm. The construction of the Creative Factory's risk taking policy subsystem is described in Appendix A.6.

5.2.1 New Project Uncertainty

Baird and Thomas (1990) suggest that the use of the term risk in the strategic management literature involves the probability of direct or indirect financial losses even bankruptcy, in the case of failure to attain targets.

Failure of innovative projects can persist because of technical, market and general political and economic uncertainty. Uncertainty applies to any decisions concerning the future and is generally handled by estimating future income and expenditure on the project (Freeman and Soete, 1997). Table 8 associates the level of uncertainty with various types of innovation. Mansfield and his colleagues (1972), in their study about project selection in large US firms show that managers find it difficult to forecast the financial implications of the introduction of new products and they cannot easily detect technological and commercial winners. This may be because of lack of knowledge with which to interpret the meaning of existing information or because of the lack of the necessary information itself (Marshall et al., 1996). Technical uncertainty however, may be reduced by experimental development and trial production stages. Even so, a level of uncertainty remains in the early stages of the innovation relating to the satisfaction of the technical criteria as well as the increased cost of development, production or operation (Freeman and Soete, 1997).

Table 8. Degree of uncertainty associated with various types of innovation

1. True uncertainty	Fundamental research Fundamental invention
2. Very high degree of uncertainty	Radical product innovations Radical process innovations outside firm
3. High degree of uncertainty	Major product innovations Radical process innovations in own establishment or system
4. Moderate uncertainty	New 'generation' of established products
5. Little uncertainty	Licensed innovation Imitation of products and processes Early adoption of established process
6. Very little uncertainty	New 'model' Product definition Agency for established product innovation Late adoption of established process innovation and franchised operations in own establishment Minor Technical improvements

Source: Freeman and Soete, 1997: p244

5.2.2 Type of Projects that are Allowed to Proceed

Even the projects with lower levels of uncertainty are rarely financed directly by the capital market (banks or other institutions). Thus, either internally generated cash flow, or, government R&D funds predominate in innovation projects (Freeman and

Soete, 1997). The level of uncertainty and risk however that are involved with innovative projects leads most firms to prefer to carry out more defensive R&D projects, such as, imitative innovation, product differentiation and process innovation or they form a portfolio of mainly low risk projects and few higher risk ones (Freeman and Soete, 1997). In addition, Augsdorfer (1996) explains that because this attitude, on behalf of the managers is wide spread (i.e. to 'kill' high risk projects), many researchers and engineers continue to work 'under-the-table' (bootlegging) or are overoptimistic about their project description. The existence of bootlegging however, can sometimes lead to more radical innovations by individuals who may start-up new companies. Additionally, as early as 1936 Keynes (1936) recognised the phenomenon that he called the 'animal spirit' that often surpasses the measurable and planned decisions of the managers. This leads to decisions made on the basis of the researchers' optimism or the managers' 'hint' of success.

5.3 Technological Capability

The term technology is used in the economic and innovation literature as both the knowledge itself and the tangible expression of this knowledge (Freeman and Soete 1997; Dosi et al., 1988). Evangelista (1999: p 5) defines technological knowledge '*as a stock of knowledge embodied in people or expressed in some codified form*', and the technological assets (hardware and software) '*as the tangible technical assets and intangible operating systems involved in the production sphere*'.

Although there is some variation, depending on the nature of the business, the main sources of technology are: the direct investment in machinery; in-house or cooperative research; the new product development processes; the engineering department's problem solving; the operating experience; the specialised suppliers and users; the basic scientific research and the knowledge collected from the competitors' products and processes (Tidd et al., 1997). Evangelista (1996) found that innovation activity in several sectors for example, machinery, electrical and electronic components, is based on the new knowledge that is created through experience and a firm's own or co-operative research and development. On the other hand, in several industries for example, chemicals, food, rubber and metal, innovation activity is correlated with direct investment in machinery and production processes. Finally he finds that both types of technology, knowledge and assets, are important factors for creating innovation in large scale and high-technology organisations such as, aerospace, office machinery and telecommunications.

5.3.1 Development of Technological Capability

The knowledge and technology assets that a firm develops or imports from other firms constitute its core competencies around which it creates its market position and market power (Hamel and Prahalad, 1994). These core competencies need to follow the trends of technology in order to keep a firm in pace with market developments.

5.3.1.1 In-house Development of Technological Capability

In-house technological capabilities are developed in two ways. First, by everyday problem solving, that accumulates experience and improves operations in the business. Second, by in-house research and development of technologies (Hamel and Prahalad, 1994).

The employees who deal with a problem usually execute the problem solving process (same as the idea generation process described in Section 3.3). Their thinking, however, is often limited by their previous experiences, the use of tools and techniques that the firm employs and the preparedness of the firm to accept that there is a problem and deal with it (Leonard, 1998).

5.3.1.2 Importing Technological Capability

The recognition of the inability of a firm to develop the necessary competencies leads to a decision to import technology from external sources. These sources could be other companies (competing or non-competing), universities, research institutes, customers and consultants (Tyre and Orlikowski, 1997). The level of new competencies that a firm gains depends on the type of co-operation with the other party. Such cooperation could be, co-development of a new product, joint ventures or mergers (Granstrand et al., 1992).

5.3.2 New Technological Capability Success

Garud et al. (1997), illustrate that many times, even the best firms are mistaken in their technological forecasting and they either invest in technologies that fail in the market, or ignore others which eventually prove successful. This however is inevitable because of the uncertainty that the changing technological environment involves. '*Under such conditions, there is only a partial correlation between actions and outcomes*' (Garud et al. 1997: p21). Wrong directions in the selection or forecasting of new technology can occur because of the technological paths that the firm has decided to follow and because of the managers' previous experiences and knowledge (Garud et al., 1997). Additionally the relationships with its main suppliers and customers and their demands may mislead a firm by giving wrong signals about the direction that technology should follow (Christensen, 1997).

A limitation to technological change may be created by the broader technology availability itself (both assets and knowledge) in the business environment in which the firm operates (Stoneman, 1995) and also by the strength of the core competencies that the firm already has (Leonard, 1998). Leonard argues that core competencies that cannot be changed over time become core rigidities which keep a firm away from the latest developments. Additionally, a radical technological change in the market and the inability of a firm to follow it, could result in nullifying the knowledge and assets of existing firms, and could change their leading position to the advantage of others (Porter, 1990; Kodama, 1995; Utterback, 1994). Disembodied technology can be lost if employees with experience and knowledge leave the firm. Training and recruitment of new employees however, can replace this lost knowledge over time.

The above aspects of the development and success of technological capabilities are taken into account in the construction of the related subsystem of the Creative Factory, which is illustrated in Appendix A.7.

5.4 Organisational Structure

Several studies have been published which attempt to identify the organisational structure that best promotes innovation (see for example: Peters and Waterman, 1982; Ashkenas et al., 1995; Mintzberg, 1995; Nadler and Tushman, 1997; Tushman and Anderson, 1997). The studies criticise bureaucracy, top-down, one-way communication and 'brick-walls' that block communication. They support the use of teamwork, flattening hierarchies and spreading the responsibility for decision making. Most of them draw attention to the danger of disorganisation (chaos), mentioning that each business should develop a structure that fits its strategy.

5.4.1 Organisational Structure Theories

Burnes' and Stalker's (1961) research developed a basis for studying the structure of an organisation. They described two idealistic types of organisation:

- **Mechanistic,** which is hierarchical, prescribed and demanding of obedience; and,
- **Organic,** which avoids precise job descriptions, seeks flexibility and initiative and encourages commitment to the overall goals of the organisation.

They suggest that when the environment of an organisation changes rapidly and a high degree of innovation is required to follow the changes, the organic type of structure is the better choice.

Henry Mintzberg (1995) identifies seven possible types of organisational structure that fit between the above two and the author summarises them in Table 9. Mintzberg

(1995) points out that the above types of organisational structure are idealistic and they do not represent any real organisation even though some firms come remarkably close. However, most organisations seem to reflect combinations, with the first five being the most common forms of organisational structure.

Table 9. Types of Organisational Structure

Type of Organisation	Characteristics
1. The Entrepreneurial Organisation	Few top managers; Informal organisation; Minimum or absent middle managers and support staff; Small start-ups; Dependence on few Individuals and their decisions; Limited available capital and human resources
2. The Machine Organisation	Large hierarchy with many middle managers; Highly specialised and standardised jobs; Stability but slow response to rapid environmental changes
3. The Professional Organisation	Highly trained autonomous professionals; Highly decentralised horizontally; Hospitals, consultancies or legal firms
4. The Diversified Organisation	Independent entities with their own internal structure and loose central administration; Spread in market segments and product diversity; Often competition between the different entities
5. The Innovative Organisation (or Adhocracy Organisation)	Organic type; Market based project teams with highly trained and specialised experts; Decentralised decisions to project teams; No formal rules and standards; No central control
6. The Missionary Organisation	An ideology unifies the whole structure by a common aim; Shared values; Freedom of decision making as long as it is within the values of the firm; continuous improvement
7. The Political Organisation	Temporary organisation structure, usually between changes from one type of strategy or structure to another; Conflicts are not solved but transferred to the future type of organisation

5.4.2 Organisational Structure for Innovation

Several studies have shown that a 'loose-tight' structure is necessary for successful management of innovation (see for example: Peters and Waterman, 1982; Hampden-Turner, 1990; Tushman and Anderson, 1997) and is the concept that is used as a comparative base in the creative factory model. The 'loose-tight' structure, although it is based on the adhocracy organisation (Mintzberg, 1995) which supports the decentralisation of decision making, is built on cross functional integration and initiates some bureaucracy to gain a degree of control that provides both the freedom to create and the discipline to turn creativity into real innovation. Additionally, it introduces multifunctional project-teams that are responsible for the development of the new projects (Fairtlough, 1994). The structure inside the organisation is clear to everybody and each employee knows his/her role and responsibilities inside the group and the whole firm and so conflicts and meaningless debates are avoided. In addition, the innovative firms have a dominant ideology (culture) that is spread throughout the whole organisation; is supported by the top management's vision, and is based on the belief in continuous improvement and continuous change according to the new business environment (Schoonhoven and Jelinek, 1997).

5.4.2.1 Cross-Functional Integration

Cross-functional integration changes the nature of the different functions and, when and how they get the work done (Wheelwright and Clark, 1992). Figure 36 shows an example of the role of the functions in the development stage of the NPDD process. The figure shows three of the major functions, engineering, marketing and manufacturing, and their major activities. The key milestones and decisions that should be taken as the development proceeds are set in advance.

In contrast to the sequential type of process, where engineering will complete its work before passing it to marketing or manufacturing in each activity, in the integrated type of process, the different functions work together in order to achieve the milestones and take the required decisions. This affects the timing of when each activity takes place and in effect could reduce the whole development time (Wheelwright and Clark, 1992).

Functional Activities	Phases of Development: Concept Development	Product Planning	Detailed Design and Development: Phase I	Detailed Design and Development: Phase II	Commercial Preparation	Market Introduction
Engineering	Propose new technologies; develop product ideas; build models; conduct simulations	Choose components and interact with suppliers; build early systems prototypes; define product architecture	Do detail design of product and interact with process; build full-scale prototypes; conduct prototype testing	Refine details of product design; participate in building second-phase prototypes	Evaluate and test pilot units; solve problems	Evaluate field experience with product
Marketing	Provide market-based input; propose and investigate product concepts	Define targets customer's parameters; develop estimates of sales and margins; conduct early interaction with customers	Conduct customer tests of prototypes; participate in prototyping evaluation	Conduct second-phase customer tests; evaluate prototypes; plan marketing rollouts; establish distribution plan	Prepare for market rollout; train sales force and field service personnel; prepare order entry/process system	Fill distribution channels; sell and promote; interact with key customers
Manufacturing	Propose and investigate process concepts	Develop cost estimates; define process architecture; conduct process simulation; validate suppliers	Do detailed design of process; design and develop tooling and equipment; participate in building full-scale prototypes	Test and try out tooling and equipment; built second-phase prototypes; install equipment and bring up new procedures	Build pilot units in commercial process; refine process based on pilot experience; train personnel and verify supply channel	Ramp up plant to volume targets; meet targets for quality, yield and cost.
Key Milestones	• Concept for product and process defined	• Establish product and process architecture • Define program parameters	• Build and test complete prototype • Verify product design	• Build and refine 2nd phase prototype • Verify process tools and design	• Product pilot units • Operate and test complete commercial system	• Ramp up to volume production • Meet initial commercial objectives
Key Decisions	CONCEPT APROVAL	PROGRAM APROVAL	DETAILED DESIGN APROVAL	JOINT PRODUCT AND PROCESS APROVAL	APROVAL FOR FIRST COMMERCIAL SALES	FULL COMMERCIAL APROVAL

Figure 36. Activities under Cross-Functional Integration.

Source: Wheelwright and Clark, 1992 p173

Cross-functional integration rests on tight linkages in communication between individuals and groups working on related problems. The type of linkage however, is a choice that a firm makes either consciously or unconsciously (Clark and Fujimoto, 1991). The interaction between a project group that executes an early task (upstream group) and the project group that continues at a later stage (downstream group) is distinguished according to richness, frequency, direction and timing.

Wheelwright and Clark (1992) illustrate the extreme levels from a sparse, infrequent, one way and late pattern of communication, to a rich, frequent, reciprocal and early pattern (Figure 37).

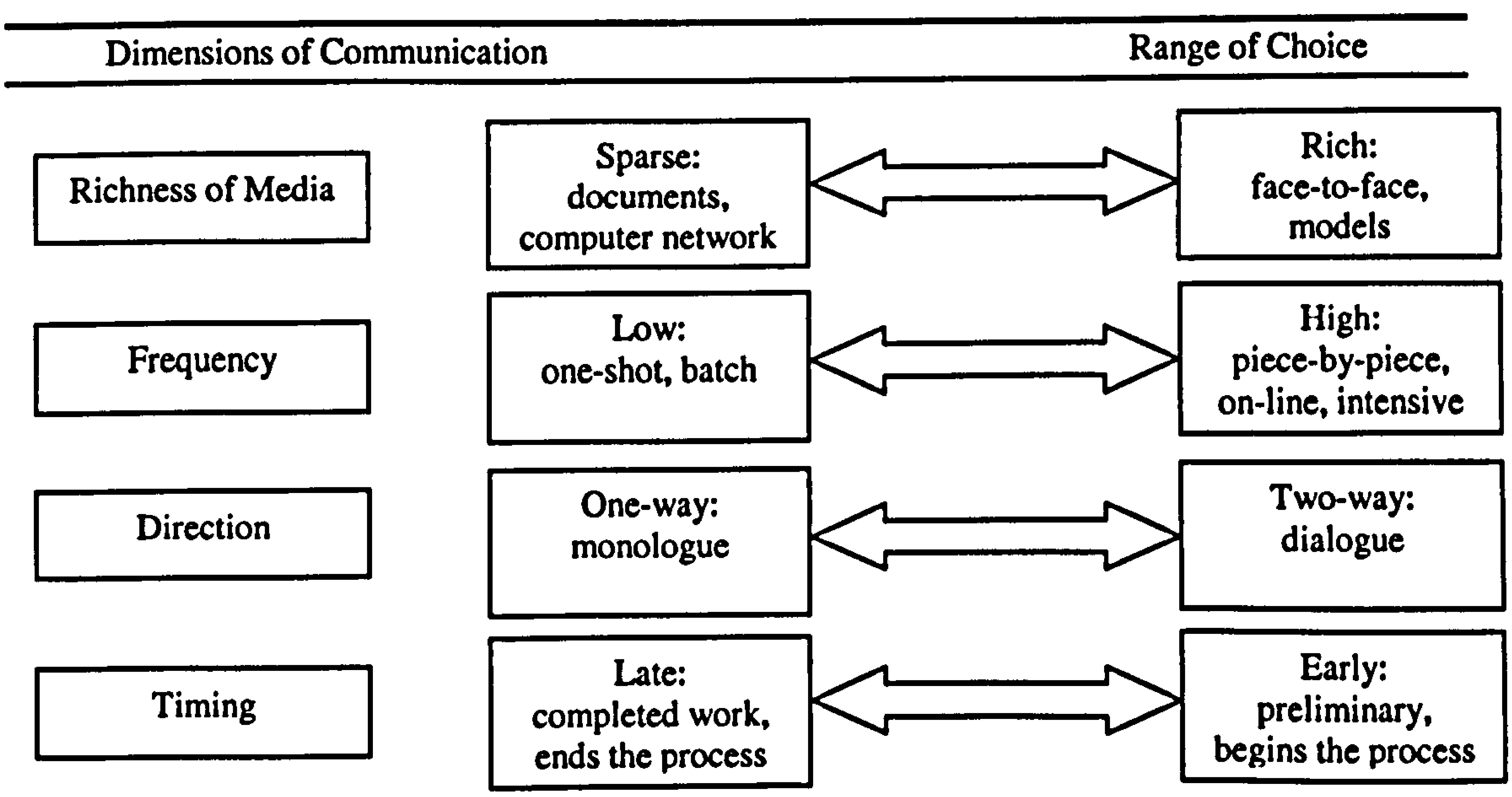


Figure 37. Dimensions of Communication Between Upstream and Downstream Groups.
Source: Wheelwright and Clark, 1992 p177

In addition to the communication pattern the firm chooses how to link the actual work in the different groups. The key issue here is the extent of the work that is undertaken in parallel. Figure 38 illustrates four different types of links that have been identified by Wheelwright and Clark (1992) from a clear sequential type to the integrated problem solving type.

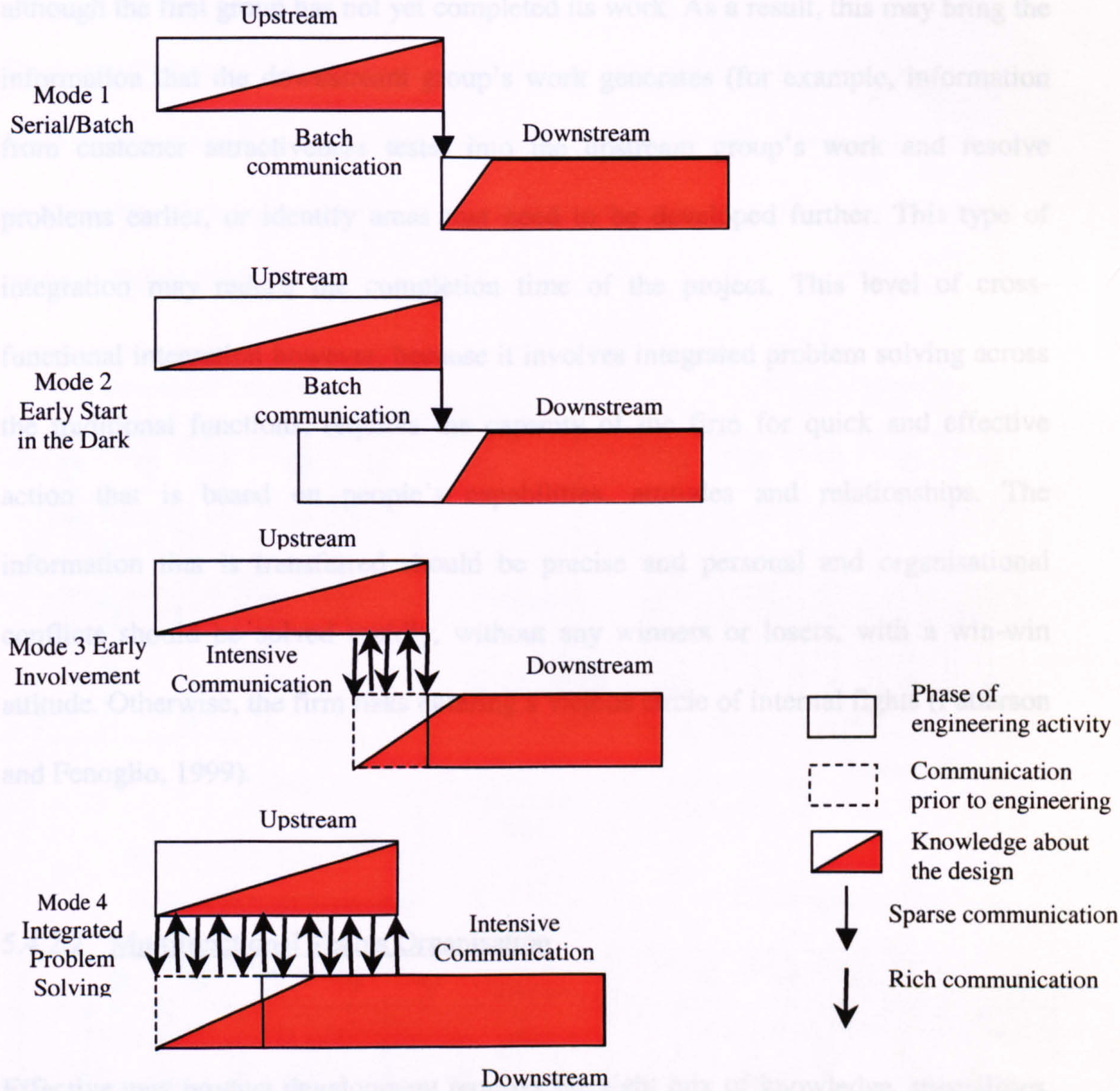


Figure 38. Four Models of Upstream-Downstream Interaction.

Source: Wheelwright and Clark, 1992 p178

The creative factory model uses the integrated problem-solving mode as the standard by which the state of the firm under study is compared. This type links the upstream and downstream groups in time and in the pattern of communication. Here the downstream group not only participates in the upstream work and problem solving, but also uses the information from the upstream group to start and build its own work although the first group has not yet completed its work. As a result, this may bring the information that the downstream group's work generates (for example, information from customer attractiveness tests) into the upstream group's work and resolve problems earlier, or identify areas that need to be developed further. This type of integration may reduce the completion time of the project. This level of cross-functional integration however, because it involves integrated problem solving across the traditional functions, requires the capacity of the firm for quick and effective action that is based on people's capabilities, attitudes and relationships. The information that is transferred should be precise and personal and organisational conflicts should be solved rapidly, without any winners or losers, with a win-win attitude. Otherwise, the firm risks entering a vicious circle of internal fights (Patterson and Fenoglio, 1999).

5.4.2.2 Multifunctional Teams Organisation

Effective new product development requires the right mix of knowledge, specialities, organisational skills and characters, because often, the new products are complex, they involve different technologies and require support from the organisation and the managers when their completion is threatened. During the 1960s these facts and the observation of how successful firms were organised brought about the concept of 'team organisation' – especially multi-functional teams – to create the right mix and increase the performance of the NPDD process (see for example: Barczak and

Wilemon, 1989; Peters, 1988; Wheelwright and Clark, 1992; Clark and Fujimoto, 1991; Galbraith, 1973).

Clark and Fujimoto (1991) identify the basic structure of four types of teams used in the NPDD process (the author summarises them in Table 10). Their study took place in the automotive industry, but the basic idea applies to manufacturing industries in general (Figure 39).

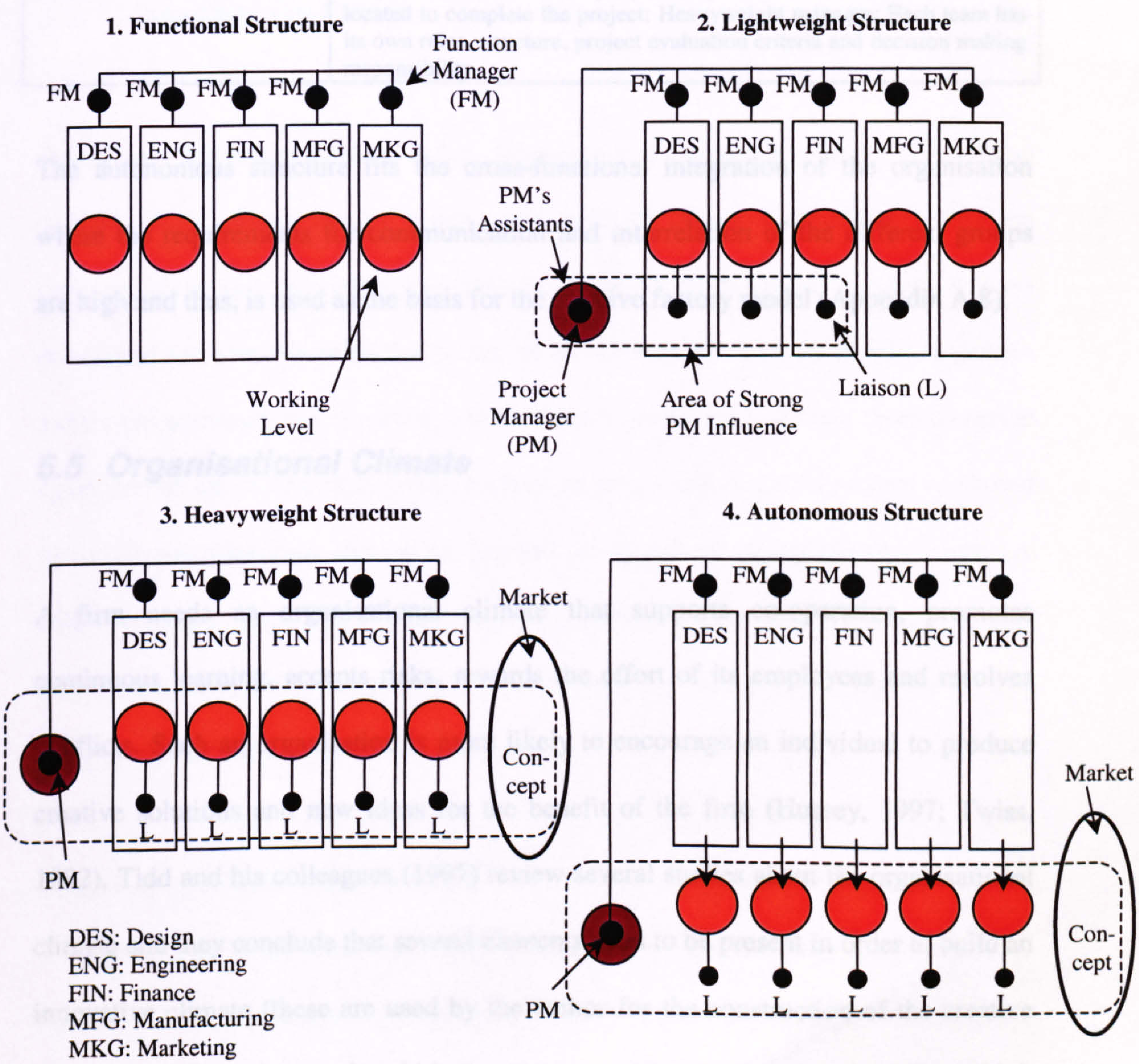


Figure 39. Types of Team Organisation.
Source: Hayes et al., 1988 p320 (with modifications)

Table 10. Team Structures

Team Structure	Characteristics
Functional team structure	Functional organisation by disciplinary functions; Specialised function manager; Sequential mode of project running from one group to the other
Lightweight team structure	Functional organisation with one representative on a project co-ordinating committee; Lightweight project manager to co-ordinate the activities of different functions; No power to project manager on resources and people's tasks
Heavyweight team structure	Usually senior managers or function managers act as project managers with direct access and control of resources and people; Dedication of the core people from each function to the project; Relocation of people around the heavyweight manager
Autonomous team structure	'Tiger teams'; Dedicated people assigned from each function and co-located to complete the project; Heavyweight manager; Each team has its own rules, structure, project evaluation criteria and decision making responsibility

The autonomous structure fits the cross-functional integration of the organisation where the requirements for communication and interrelation of the different groups are high and thus, is used as the basis for the creative factory model (Appendix A.8).

5.5 Organisational Climate

A firm needs an organisational climate that supports co-operation, promotes continuous learning, accepts risks, rewards the effort of its employees and resolves conflicts. Such an organisation is more likely to encourage an individual to produce creative solutions and new ideas for the benefit of the firm (Hussey, 1997; Twiss, 1992). Tidd and his colleagues (1997) review several studies about the organisational climate and they conclude that several elements need to be present in order to build an innovative climate (these are used by the author for the construction of the creative factory model): a clear and ambitious strategy; a risk taking policy that allows high innovative projects to proceed for development; a reward system that recognises success and does not punish failure; an organisational structure that provide open communication to any level of the organisation; an organisational culture that promotes all the above elements to the whole organisation and a recruitment policy that seeks to find creative people. All these elements except the organisational culture, which is presented in the next subsections, are presented in the previous or following sections.

5.5.1 Organisational Culture

Peters and Waterman (1982), define organisational culture in two words: 'shared values'. Some values can be generic and apply to human interactions within the organisation or to a general outlook on life. Some are more limited in scope, and are concerned for example with the choice of technology or the way in which generic values are accomplished (Leonard, 1998). Schein (1992: p12) gives a more complete definition of the culture of a group, such as an organisation, as: '*a pattern of shared basic assumptions that the group learned as it solved its problems of external adoption and internal integration, that has worked well enough to be considered valid, and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems*'.

Andrew Brown (1995), identifies three main sources of organisational culture:

1. The **societal** or **national culture** in which an organisation is physically situated.
2. The vision, management style and personality which the organisation's **founder** or other **dominant leader** brings.

3. The **type of business** that an organisation conducts and the nature of its **business environment.**

Allaire and Firsirotu (1984) add that an organisation's history and past leadership is one of the elements that determine the organisation's culture. Brown (1995) observes that organisations that are used to a relatively slow changing environment tend to develop cultures which value stability, integration, clear communication, support from top managers, fair satisfaction, and opportunities for employees to grow. In contrast, a dynamic marketplace with competitive and changeable environments makes, in general, the organisation set ambitious goals and strategies and appreciate innovative behaviour and individual inventiveness.

5.5.2 Organisational Culture Change

An organisation's culture changes either because of external effects (national culture, business environment) or because of internal factors that are driven by the managers' strategy such as the recognition of success and the internal structure of groups. Problems start when an organisation's culture gets out of date with the changes that are taking place (Handy, 1986). Burnes (1996) argues that unless a major shock occurs in the organisation, the change can be slow because it is difficult to make human beings accept change.

Among the most common sources of individual resistance to change are the habits that individuals have adopted during their career, the feeling of security that is threatened by any change, and the economic position and status that they already have

(Brown, 1995). Dyer (1986) identifies another source of resistance, that is the founders, who often foster cultural patterns that are no longer appropriate for the business environment because they are not willing to listen to advice, collaborate, or recognise their own weaknesses. Finally, Brown (1995) and Sathe (1986) add that perhaps the strongest resistance to cultural change is the existing culture of the organisation itself and that the resistance is proportional to the degree of change and the strength of the existing culture.

5.6 Firm's Creative Individuals

Innovation activities and process stages are executed by individuals who have the following roles in recognising, exploiting and developing potential innovations (Afuah, 1998):

- **Idea generators.** These individuals have a strong ability to synthesise the information that is available into new ideas for products, services or processes (Iansiti, 1993).
- **Gatekeepers and boundary spanners.** These people translate ideas into a common language for the whole firm in order to identify potential and need. They are often responsible for idea generation; for the right sources of information and for killing ideas that do not fit the firm's strategy (Nadler and Tushman, 1997).
- **Champions.** Champions are the entrepreneurs who take an idea – theirs or that of an idea generator – and do all they can to ensure the success of the innovation. Champions emerge from inside an organisation they promote their vision of innovation and often risk their position, and cannot be hired to be champions (Howell and Higgins, 1990).

- **Sponsors.** These are 'behind-the-scenes' people, usually senior managers, who provide support and motivation, access to resources and protection from political foes (Afuah, 1998).
- **Project managers.** These are planners who will plot the lines and milestones that a project needs to follow and achieve. They are responsible for decision making, questions and information on the project (Cooper,1993).

5.6.1 Characteristics of the Creative Individuals

Ackoff (1978) and Christiansen (2000) argue that usually the education system promotes specialisation to a narrow scientific or technical area instead of teaching how to investigate and combine different views and areas. These expectations however have been developed under a cultural environment that involves the students' families, their surrounding influences and their level of education and the nation's needs for specialities because of the growth of specific industrial sectors.

Even under these conditions, in the total pool of available employees, some people appear to keep their creativity alive. Christiansen (2000) identifies two different types of personality that can sustain their creativity. One is the 'individualist' type of character who is prepared to present and argue his/her ideas even when he/she is the only one to believe in them. The other is the 'adaptable' type of person who has his/her own ideas but presents them only if the environment is friendly and encouraging to new or different ideas.

Martin (1994) summarises the results of several studies about the characteristics of creative persons. He mentions that creative people set high standards and goals, they seek personal autonomy and are indifferent to general standards and control. Although independent, they have good communication skills and they are eager to discuss ideas with others in order to promote a two-way interaction to their ideas. This communication however is sensitive to aggression and conflicts and creative persons are prepared to break links with the other person or groups in a conflict.

5.6.2 Enhancing a Firm's Creative Activity

Shapero (1997) argues that a firm can consciously enhance its creative activity by:

- **Hiring.** The number of creative individuals inside a firm can be increased simply by recruiting more of them.
- **Motivation.** A firm could reward creative output, encourage risk-taking and support the expansion or change of use of new methods, technologies and processes (Katz, 1997).
- **Providing the necessary resources.** This may reduce the potential of individuals to work 'under the table' (bootlegging), or the ones who move with their ideas to a competitor (Augsdorfer, 1996).
- **Managing.** The selection of people, allocation of resources in the right time setting deadlines and resolve conflicts are essential activities that a manager should administrate during a creative project (Patterson and Fenoglio, 1999).
- **Organisational mechanisms.** The firm needs a standard mechanism that will be open to internal or external sources of new ideas, investigate them and support

them or take a firm decision to kill them (Cooper, 1993; Wheelwright and Clark, 1992).

5.7 The National Innovation Environment

The national innovation systems' literature that was developed in the late 1980s and 1990s studies a country's institutional and macroeconomic factors that influenced the innovation activity of a firm and of a nation, as the sum of innovative firms (see for example, Dosi et al., 1988; Porter, 1990; Lundvall, 1992; Freeman and Soete, 1997, Edquist, 1997). The factors of the national innovation systems that have an influence on the creative factory model are the financial system of the country, the infrastructure, the demand conditions (or market environment), the availability of physical resources and supportive industries (critical mass), the availability of human and knowledge resources and the regulations and legislation that a government designs and implements. These factors influence the core innovation process directly but also they influence the firm's internal factors that were presented earlier in this chapter. According to the NIE the theoretical framework discussed in this section is transformed into a system dynamics model (see Appendix A.11).

5.7.1 Financial System

Tylecote (1994) defines financial systems as the network of institutions which connects the owners of financial capital to the organisations which ultimately give it value. Risky investments in innovation are often financed internally, especially by large firms that can afford the investment. Small and medium size firms however, may have fewer abilities for self-finance and they depend on the nation's financial system (Christensen, 1992).

Three categories of financial systems are distinguished:

- **The capital market oriented systems.** These have a highly developed and competitive capital market with little or no government influence. The lending institutions are many and highly specialised around the capital market. Firms are supplied with long-term capital by the developed stock exchange market and the role of banks is limited to short-term lending (Christensen, 1992). UK and USA are considered characteristic examples of this category (Tylecote, 1994; Jacobs, 1991).
- **Credit based systems influenced by government.** Financial institutions – mainly banks – transfer savings to investments under heavy government control and regulation (Christensen, 1992). Several countries, such as Japan, France, Italy and Spain have a financial system of this type, where the state owns banks or industries (Tylecole, 1994). Lenders try to influence management by participating in the share base of the firm, giving consulting services or introducing restrictions to the loans to avoid failure (Christensen, 1992).
- **Credit based institutional systems.** These systems are based on financial institutions – banks and venture capital – with little government involvement. Government only creates and inspects the regulations for open market operations. The loss of the government's safety net, leads the financial institutions to monitor and keep close contact with the firms, by participating in management and

maintaining an oversight of the firm's financial position (Henderson, 1993). Germany's financial system is a typical example of this category (Tylecole, 1994).

During recent years, deregulation of financial markets and internalisation of markets by the entry of foreign banks and other institutions, have blurred the borders of the above categories with the innovators having a greater variability of sources and choices for financing their projects (Christensen, 1992). The creative factory assesses the ability of the financial system to combine as many sources of finance as possible.

5.7.2 Infrastructure

Most of the studies that refer to innovation systems give attention to the infrastructure as one of the factors that can support innovation activity (see for example: Porter, 1990; Lundvall, 1992; Edquist, 1997a). Smith (1997) identifies from several studies three technical characteristics that distinguish infrastructure from other capital stock. Infrastructure is **generic** core input for virtually any other economic activity. It is made up of systems or sets of systems with interrelated specifications and characteristics that are **indivisible** and cannot operate independently. These systems often serve not only a particular market but the entire industrial base of a region, a nation or even a continent – **multi-users**.

The combination of characteristics of indivisibility and multi-users means that the scale of investment in infrastructure is often very large, relative to any investment that an individual firm can afford to undertake. This scale is the reason that public investment needs to be combined with private – or perhaps public investment is the only investment. The potential of use of infrastructure is very long-term, as some of the systems have a very long lifecycle. In addition, the infrastructure providers are often a natural monopoly where the increased number of users and the long lifecycles give a high margin of return (Tassey, 1994). Some activities however, may be provided in a decentralised pattern, such as the education system or the medical care. In such cases, the different providers' work may be complimentary or even competitive under a given institutional framework in order to provide a higher degree of service to the final consumer and a higher return of investment for themselves (Day, 1994).

Besides the physical type of infrastructure a knowledge infrastructure is also essential, as innovation activity is based on the transformation of knowledge to products (Smith, 1997). Knowledge is developed maintained and disseminated by organisations of various kinds, for example: universities, public research centres and private firms' research centres. The combination of public and private investment and the collaboration necessary to generate new knowledge has been discussed in Section 4.1.2. Additionally, political decisions about the regulation of intellectual property rights; standards setting organisations and about legal and administrative regulations can raise or drop barriers to the use of knowledge infrastructure (Tassey, 1991). The creative factory analyses the ability of a nation to provide the necessary physical and knowledge infrastructure for the firms that operate in it.

5.7.3 Demand Conditions

The internationalisation of competition and trade should mean that home demand plays a less important role in the development projects of a firm. Freeman and Soete (1997) however, show the importance of a local network of firms; the education, training and research infrastructure and the local institutional set-up are elements that, together with the home market environment, still play an important role in innovation systems and the international competitiveness of a firm.

This happens as firms naturally give more attention to their home demand because of proximity. Furthermore, the reactions of customers to improved products, or changes in their perception and taste are felt more easily and more quickly in the home market, as the majority of R&D and marketing activity is taking place at home (Pavitt and Patel, 1999). The common culture that the firm and its customers share and the easier development of a communication network between them and between the firms in one national environment is one more factor that increases the influence of the domestic market.

The size, the extent of the competition, the sophistication of the home demand and the regulations that allow or restrict international influence could provide competitive advantage to a firm. This may happen either by developing economies of scale, or by forcing the firm to develop highly innovative products or processes to satisfy this sophisticated home market, or by encouraging the firm to expand in the international terrain (Fagerberg, 1992; Porter, 1990).

The adequacy of the demand conditions of a firm's national environment is evaluated in the creative factory model to study its effect on innovation activity.

5.7.4 Physical Resources and Critical Mass of Industries

The accessibility, quality and availability of physical resources in a country are often found to be a competitive advantage for a firm. Physical resources are elements such as the water, minerals or timber deposits; hydroelectric or other power sources; climate conditions; location relative to other nations and geographic size. These elements affect the cost of the raw materials, the transportation cost, the ease of accessibility to them by a firm and the tradition of a nation to be active in related industrial sectors (Porter, 1990). The internalisation of trade and the development in infrastructure however, can eliminate the shortages of the physical resources for a firm by creating networks of suppliers in other countries (Porter, 1990).

The existence of strong and internationally competitive supportive industries in the same nation can be a great advantage for a firm. The importance is not limited to the ability of the supportive industries to supply a firm in a cost effective manner, as this supply can eventually be found in other countries, but to the close linkages and network that these industries can create (Sako, 1994). The development of this network is easier when the companies have a common culture and language; a shared vision of national pride and a close physical location. This network can reduce risks as well as provide visibility of market wants and changes back to the supply chain and information about technological developments and the capabilities of the whole supply chain (Carlsson, 1994). The innovation process can be accelerated as exchanges of R&D and problem solving leads to faster and more effective solutions and as transmission of innovations through out the supply chain becomes easier (Porter, 1990).

The creative factory model investigates the adequacy of physical resources and supportive industries that a firm finds in a nation and connects it to the innovation activity of the firm.

5.7.5 Knowledge and Human Resources

Knowledge resources are the scientific, technical and market knowledge of products and processes, which are embodied in institutions such as universities, research centres or private research facilities. Additional knowledge is available for example in business and scientific literature; market research reports and databases and trade associations (Porter, 1990). Moreover, human resources availability is regarded as the quantity, skills and cost of personnel that are required by the industries and are available in the market (Porter, 1990). Human and knowledge resources are developed over time through the education, training and research system of a nation. The shortages of specialities however, can be overcome by the migration of people from other nations (Porter, 1990).

5.7.6 Regulations

Governments do not control the innovative activity of a nation, but they can influence it in one way or another through the regulations that they put in place (Porter, 1990). Three main areas of regulations can be distinguished (Gregersen, 1992; Porter, 1990):

1. Product and process performance, such as, standards and patents.
2. Market and competition environment such as, the barriers to imports and legislation.
3. Environmental and safety standards, such as energy consumption, environmental impact and workers safety.

Tightening of the regulations in some areas or relaxing them in others can support innovation activity. High standards of product performance within a nation, for example, could create products that, because of their advances, could compete effectively in the international field. Relaxing import regulations, on the other hand, could increase competition in the nation and trigger the national firms to react by creating more innovative products.

Environmental regulations are usually considered as those that decrease the competitiveness of firms. Irwin and Vergrat (1989) however, show that these regulations, if used correctly by a nation, can create strong advantages for firms and also social benefits for the nation. Tight standards for product performance, product safety and environmental impact contribute to create and upgrade competitive advantage as they pressurise firms to improving quality, upgrading technology and providing features in areas of important customer and social concern (Porter, 1990).

In addition, they may create new markets, activities and opportunities as well as new firms that take advantage of the new opportunities (Porter, 1990).

The creative factory model evaluates the regulations of a nation, assessing whether they raise or lower barriers to innovation.

5.8 The Complete Creative Factory Model

This chapter described the internal and external factors that affect the innovation process in a firm. These aspects, connected to the core innovation process that was described in Chapters 3 and 4, create the complete framework of the Creative Factory Model (Figure 40).

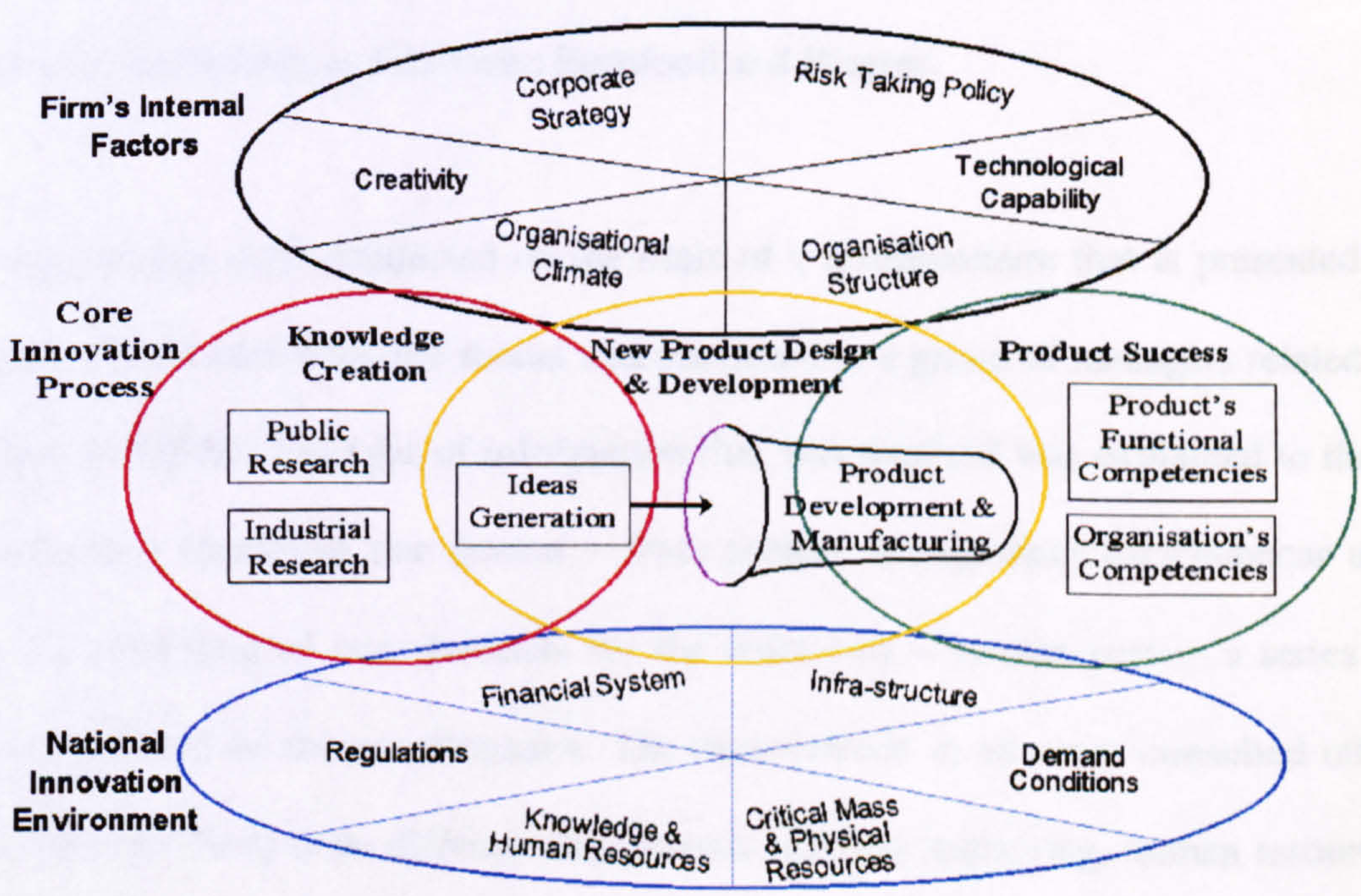


Figure 40. The Complete Creative Factory Framework

6 Test of Confidence in the Creative Factory Model

The theoretical creative factory concept uses a dynamic systems approach and can be applied to model innovation in a range of manufacturing activities. To test confidence in the creative factory as a practical and useful way of modelling a firm's innovation activity, three case studies have been carried out with large multinational firms. The firms, considered as leaders in their sector and home country, are first an automotive firm, with the USA and the EU as the home markets; second a food company with the EU as the home market and third an electronics and telecommunications company with Greece as the home market. For reasons of confidentiality the companies will be referred to respectively as Globocar; Eurofood and Elegrec.

The case studies were conducted on the basis of a questionnaire that is presented in Appendix B. At each firm, the model was presented to a group of managers related to the field of NPDD. The type of information that was required was explained to them and then they appointed one person – from project management for Globocar and from the marketing of new products for the other two – to take part in a series of interviews based on the questionnaire. The interviewees in all cases consulted other people in their firms from different departments, such as marketing, human resource, finance, in order to obtain information for questions that they could not answer.

The firms were selected to demonstrate the use of the model in different industrial sectors and national environments and to take account of different sources of strength within each firm. The following sections study to what degree the output from the model comes close to the expected outputs from the case studies. Information has been collected for the last three financial years and an estimate made for the present one. Because these data are a snapshot of the firm at the end of the financial year (in the middle of the calendar year), they should be considered as a discrete series and not continuous. Most of the data are qualitative on a scale of 0-100, representing an evaluation of each element by the participants (Table 11). Studying the published national economic, science and technology surveys by OECD, the author has codified the information about the national innovation environment and the sector's research activity.

Table 11. Qualitative Scale for the Creative Factory

Scale	Characterisation
90-100	'excellent'
75-90	'very good'
65-75	'good'
50-65	'adequate'
30-50	'poor'
<30	'very poor'

Note: Combination of them means a value that although is inside the limits of the first mentioned index, is very close to the second mentioned index, e.g. a measurement of 63 is characterised 'adequate-to-good': the factor is assessed 'adequate' but close to 'good'.

The data from the interviews and the published material are summarised here in tables that are used as inputs for the variables that the model uses. The simulation of the creative factory, adjusted with these data for each firm, generates the outputs for the factors of the model, which are presented in a graphical mode. These outputs then, can be compared with the real situation of each firm as it has been identified in the case studies and the published data. The proximity of the simulated outputs to the real situation for each firm builds a level of confidence that the Creative Factory can be used to study the innovation activity of these firms.

Section 1 presents the comparison of the creative factory's outcome according to the internal factors and core innovation process for Globocar. The subsequent two sections compare the results for the overall performance for Eurofood and Elegrec[7]. Section 4 presents the test of the creative factory output, according to the sector's knowledge and research environment for each case. Section 5 presents the comparison of the national innovation environment for each case and the NIE that has been generated from the creative factory. Finally, Section 6 gives a summary of the comparison of the firms' case studies with the simulation results.

6.1 Globocar

In this section the creative factory model is applied to the Globocar data. The NIE and the sector's research activity have been adjusted using information for the USA and EU (see Section 6.5). The case study provides information for an overall performance of Globocar, the Core Innovation Process and the factors that influence this process. The first subsection presents the data received from the case study and tests whether the model can successfully generate the status of the factors that make up the core innovation process for Globocar. The second section describes the data and the test of the factors that influence the core innovation process.

[7] The author has placed the rest of the results for Eurofood and the equivalent subsections from Elegrec in Appendix C to avoid repetition in the text.

6.1.1 Globocar's Core Innovation Process

Table 12 summarises the data of the overall performance for Globocar. The innovation process of Globocar generated 9 new products in 1998. This increased to 12 new products per year during the time of this study, while the R&D expenditure was kept between 4% and 5%. The increase in the number of new products in 1999 improved sales by about 14.5% on a yearly basis and profits by more than 23%. These data are presented in the table as an index with base '1000' for the year 1998. These results however were not sustained in subsequent years, and in the financial year 2001, the firm is expected to present losses. The shareholders' satisfaction, an index that is generated from the evaluation of the comments that have been made in the annual and quarterly reports of Globocar, is characterised as 'adequate' for the years 1999, coming from a 'poor' in 1998, and 'adequate-to-poor' in 2000. Because however, of the negative results that are expected in 2001, the satisfaction of Globocar's shareholders is down to a 'very poor' level for the financial year of 2001.

Table 12. Summary of the Overall Performance of Globocar

Overall Performance	**1998**	**1999**	**2000**	**2001***
Index of Sales	1000	1144	1197	1060
Index of Profits	1000	1231	895	Loss
% of Profits to Sales	3.43	3.69	2.57	-
Number of New Products per year	9	12	12	12
Total Number of Products	46	53	62	62
Yearly Increase (Decrease) of Sales	(3.25)	14.45	4.56	(11.45)
Yearly Increase (Decrease) of Profits	(3.66)	23.14	(27.32)	-
R&D Expenditure as % of Sales	4.49	4.44	4.84	5
Shareholder Satisfaction**	P.	Ad.	Ad.-P.	V.P.

* Estimations from second quarter 2001 report
** Evaluation of comments in the Globocar's 2000 annual report
Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor' V.P.: 'very poor'

The creative factory simulation generates a series of results for annual sales, profits and shareholders' satisfaction, using these data. The status of the sales and profits from the simulation agree with those that were expected from the data that have been received (Figure 41[8]). The shareholder's satisfaction is simulated as 'poor' in 1998, 'adequate' in 1999, 'adequate-to-poor' in 2000 and 'very poor' for the 2001, as was expected.

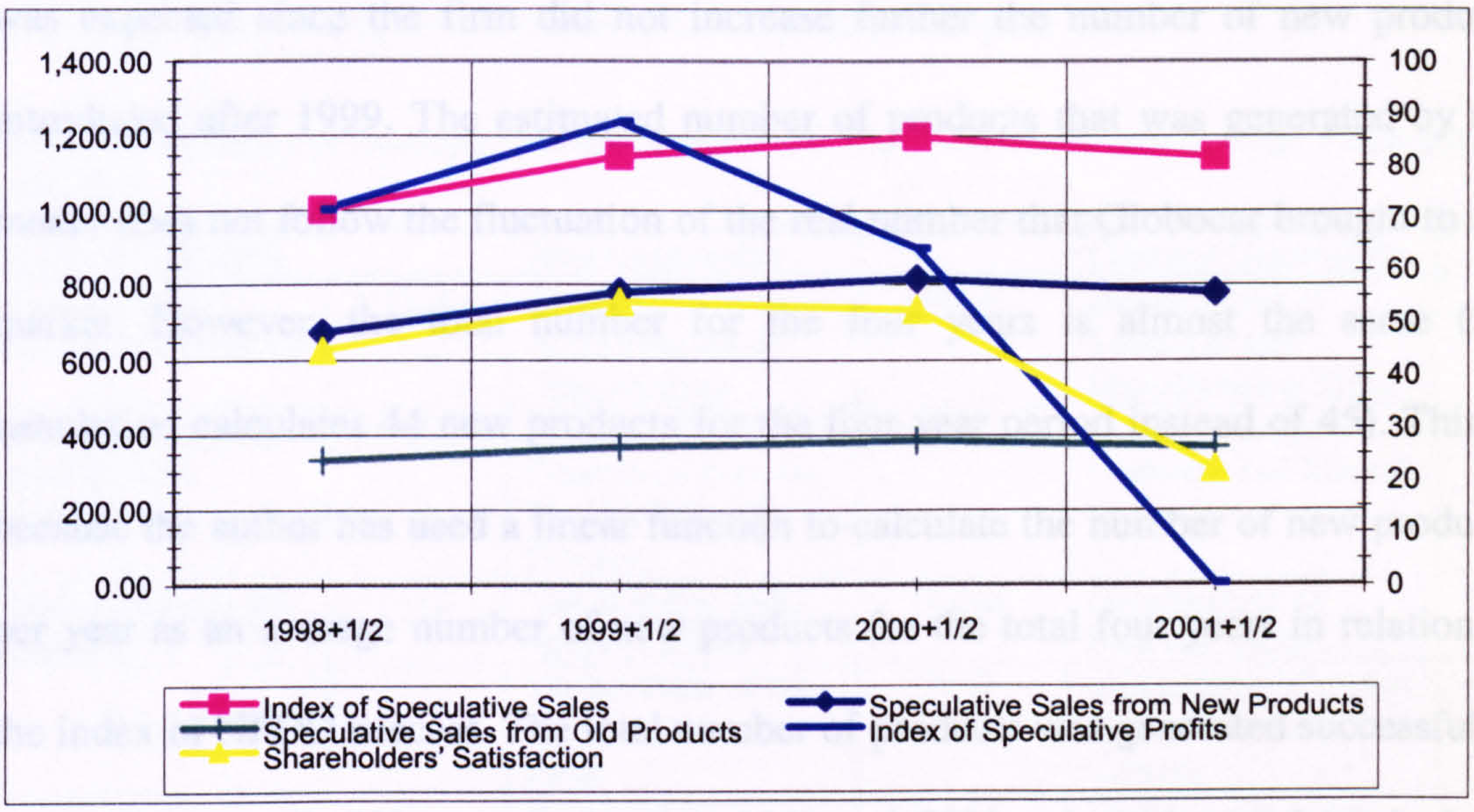


Figure 41. Simulation of the Financial Results for Globocar

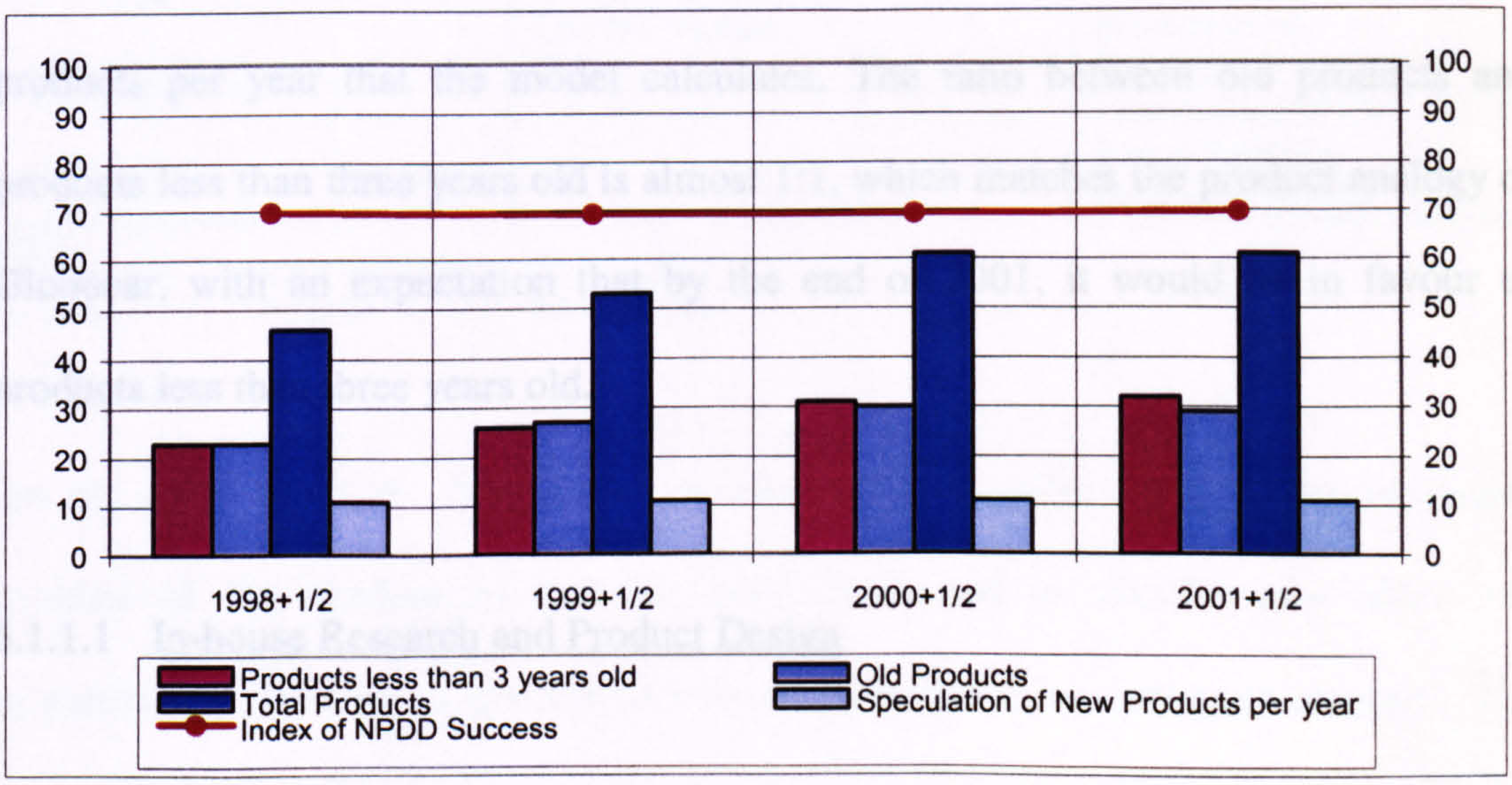


Figure 42. Simulation of the New and Old Products Numbers for Globocar

[8] The index of the x-axis indicates the financial year as the calendar plus one half.

The firm had a 'good' ability to generate new products during 1998 to 2001, something that made possible the increase in new products per year from 9 to 12. This index, which has been generated successfully from the creative factory, starts from a 'good' level in 1998 (70/100) and remains virtually stable until 2001. This behaviour was expected since the firm did not increase further the number of new products introduced after 1999. The estimated number of products that was generated by the model does not follow the fluctuation of the real number that Globocar brought to the market. However, the total number for the four years is almost the same (the simulation calculates 44 new products for the four year period instead of 45). This is because the author has used a linear function to calculate the number of new products per year as an average number of new products for the total four years in relation to the index of NPDD success. The total number of products was generated successfully, except for a small difference in the year 2000 and 2001, where the model calculates 61 total products instead of 62. This however has to do with the number of new products per year that the model calculates. The ratio between old products and products less than three years old is almost 1:1, which matches the product analogy of Globocar, with an expectation that by the end of 2001, it would be in favour of products less than three years old.

6.1.1.1 In-house Research and Product Design

Table 13 summarises the data for the in-house research and new product design stages as they were collected during the case study. Globocar's investment in research, both applied research and experimental development, is characterised as 'very good'. Its managers show very strong support for any research activity although their understanding of the benefits of this research is only considered as 'good'. Overall, the firm's research effort is characterised as 'very good'. The participants in the case study however observed that this effort has not always transformed successfully to new knowledge for the firm, which they evaluated as 'adequate'. These levels are generated successfully by the creative factory model (Figure 43).

Table 13. Summary of Globocar's In-house Research, Idea Generation and Concept Generation Activities

In-house Research		Idea Generation		Concept Generation	
Management's Support for Research	V.G.-Ex.	Attention to Sources of Information & Opportunities	Ad.-P.	Development of Technical and Manufacturing Study	V.G.
Understanding of the Benefits from Research	G.	Ability to Overtake Frustration from the Idea Investigation Process	G.	Development of Customer and Market Study	Ad.
Funds Adequacy for Research	V.G.	Validation of Ideas against Criteria	G.-Ad.	Development of Financial Study	Ad.
		Decisiveness of the firm to kill weak Ideas	V.G	Validation of Concept against Selection Criteria	Ad.-G.
		Prioritisation procedures of Ideas	G.-Ad.	Decisiveness of the firm to kill weak Concepts	V.G.
		Decisiveness of the firm to Prioritise Selected Ideas	V.G.-Ex	Prioritisation procedures of Concepts	G.
				Decisiveness of the firm to Prioritise Selected Concepts	V.G.

Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor' V.P.: 'very poor'

On the other hand, the firm shows a relatively low ability to generate new ideas because of the mechanism that has been developed to identify new ideas and opportunities for new products which is only evaluated as 'adequate-to-poor'. The procedures however to select and prioritise the ideas are evaluated as 'good-to-adequate' and 'good-to-very good' respectively. In 1999-2000, however, the firm managed a 'good' level in overcoming the frustration of its employees when something went wrong with their creative activities. These observations create an 'adequate' overall performance for the new idea generation stage. Using the data, which has been collected in the case study (Table 13), the factors described are generated using the creative factory (Figure 44).

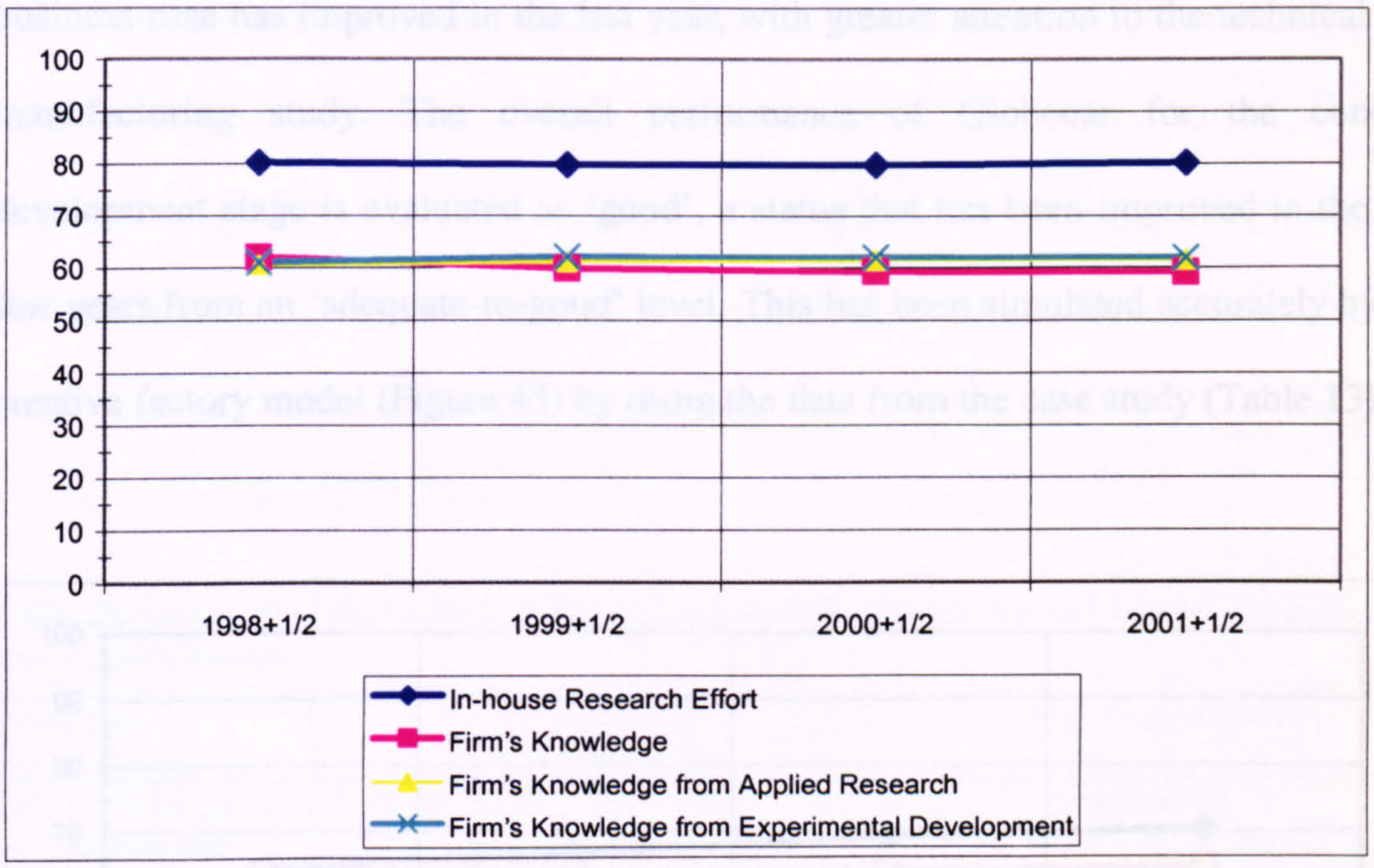


Figure 43. Simulation of In-house Research Effort for Globocar

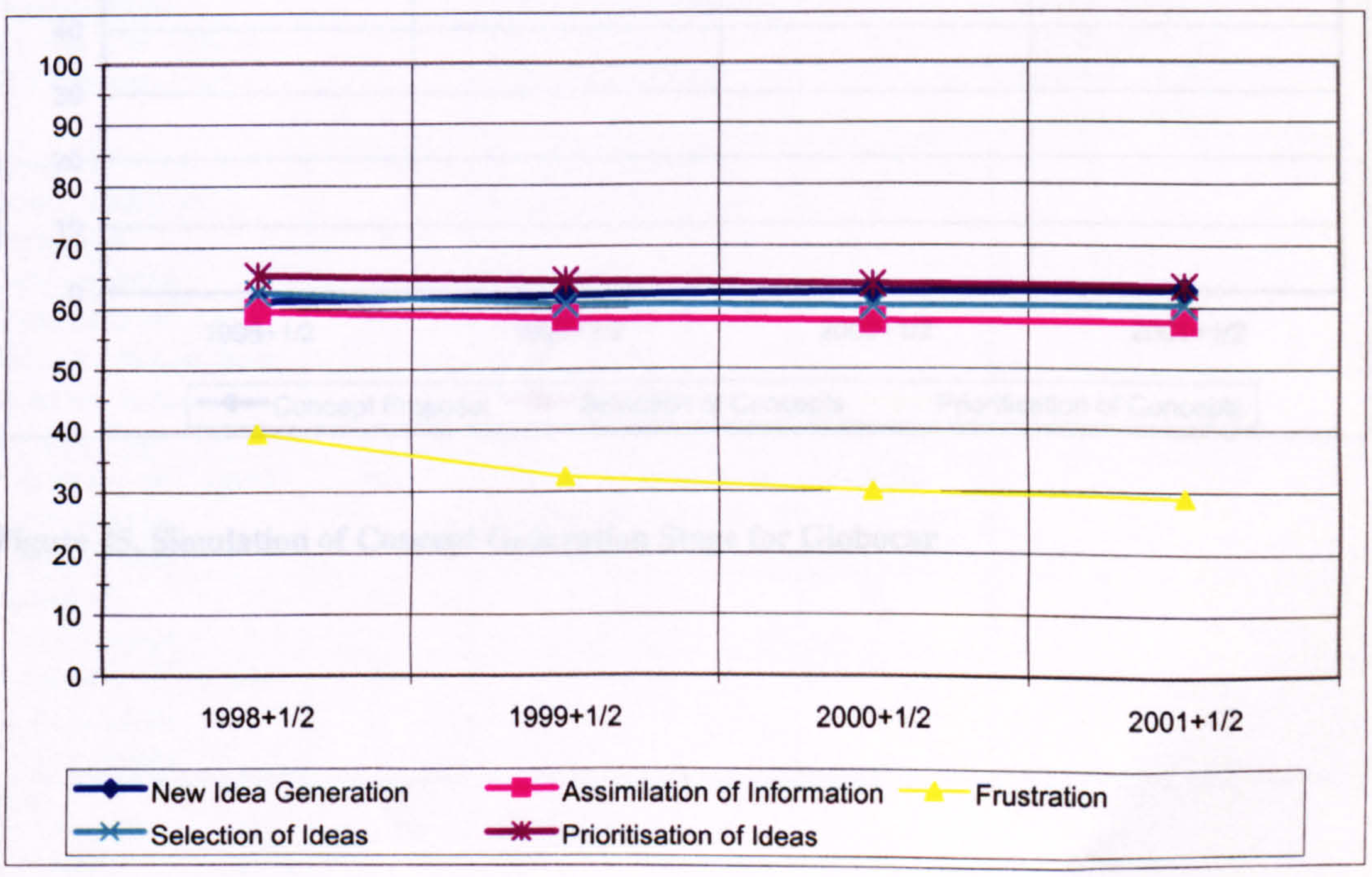


Figure 44. Simulation of Idea Generation Stage for Globocar

The observations for the concept development stage, that is the official processes for concept selection and concept prioritisation are similar to those for the idea generation process. The mechanism of conducting the necessary studies for the development of a business case has improved in the last year, with greater attention to the technical and manufacturing study. The overall performance of Globocar for the concept development stage is evaluated as 'good', a status that has been improved in the last few years from an 'adequate-to-good' level. This has been simulated accurately by the creative factory model (Figure 45) by using the data from the case study (Table 13).

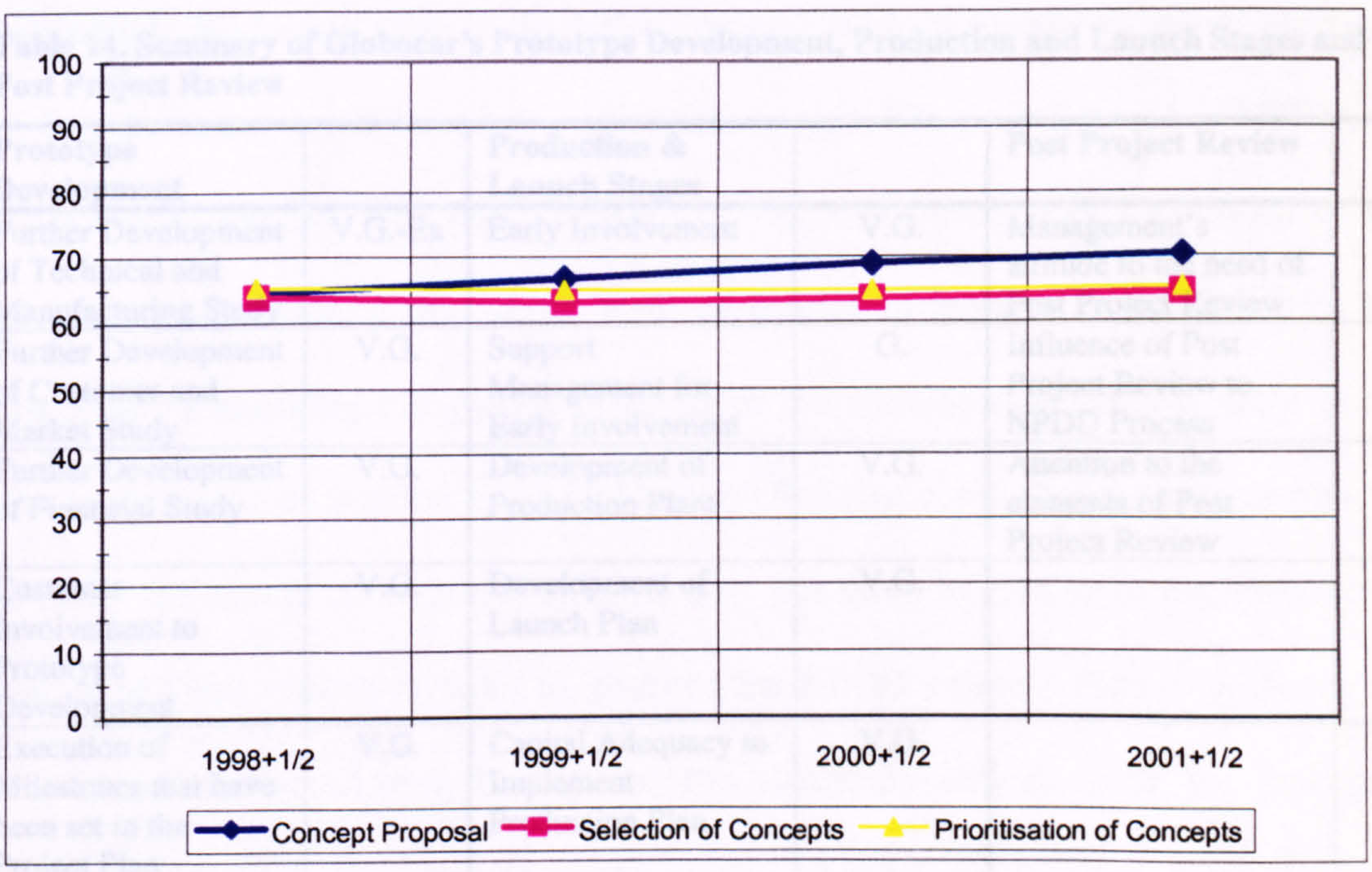


Figure 45. Simulation of Concept Generation Stage for Globocar

6.1.1.2 New Product Development, Production and Launch

Moving to the development stages of the NPDD process, Globocar has increased its effort and the factors affecting this stage are characterised as 'good' or 'very good' in 2001. The inputs for these last stages are summarised in Table 14. The studies that are involved in the development of the new products are conducted very carefully and the firm now pays attention to the opinion of its customers during the development process, something that has reduced the time of development in the last few years, which however, still remains at a 'good' level.

Table 14. Summary of Globocar's Prototype Development, Production and Launch Stages and Post Project Review

Prototype Development		**Production & Launch Stages**		**Post Project Review**	
Further Development of Technical and Manufacturing Study	V.G.-Ex	Early Involvement	V.G.	Management's attitude to the need of Post Project Review	V.G.
Further Development of Customer and Market Study	V.G.	Support Management for Early Involvement	G.	Influence of Post Project Review to NPDD Process	Ad.
Further Development of Financial Study	V.G.	Development of Production Plant	V.G.	Attention to the elements of Post Project Review	G.
Customer Involvement to Prototype Development	V.G.	Development of Launch Plan	V.G.		
Execution of Milestones that have been set in the Project Plan	V.G.	Capital Adequacy to Implement Production Plan	V.G.		
Adequacy of Capital for Prototype Development	V.G.	Capital Adequacy to Implement Launch Plan	V.G.		
Speed of Development	G.				
Adequacy of Capital to Accelerate Development	G.				

Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor'

The overall performance of the production stage however started from an 'adequate-to-poor' position in 1998 because of under-investment in previous years. After the efforts of the last three years, however, the status of the production process was characterised as 'good-to-adequate' in 2001, with expectations for further improvement. This trend is successfully simulated by the creative factory model (Figure 46).

The launch stage elements are similar to those of the production stage. In 2001 they were evaluated as 'good', having started from an 'adequate' position in 1998. Interestingly however, the support of the management for the early involvement of the production and launch team in the NPDD process is characterised as 'good' although, in fact, the teams are involved at much earlier stages. The overall speed of NPDD has improved in the last four years because of the investments that are related to the process and because of the 'good' level of functional integration that the firm has achieved by engaging the groups involved in the development process early in the design process (see Section 6.1.2.2). Finally, Globocar conducts post project reviews to study the results of its projects, but it does not seem to give great attention to the results of these studies in order to improve the NPDD process. Figure 46 shows the simulation of the creative factory for the milestone execution of the prototype development stage, the NPDD speed status, the full production stage, the new products launch stage and the status of the influence of the post project review. These results are similar to the observations made during the case study.

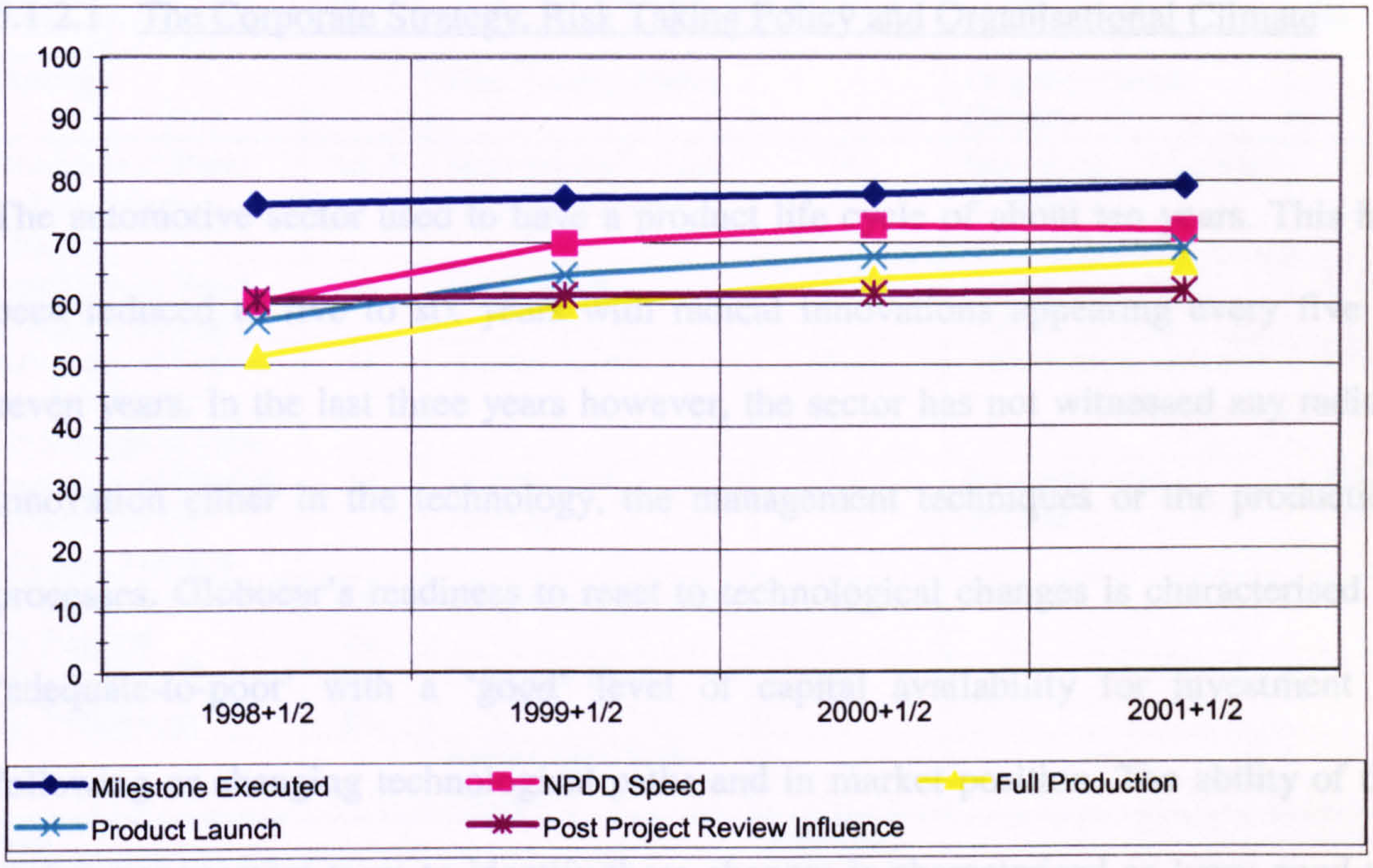


Figure 46. Simulation of the Development Stages, the Launch and the Post Project Review for Globocar

6.1.2 The factors which influence the Core Innovation Process at Globocar

The case study that was conducted in Globocar provided the data necessary to feed the inputs of the creative factory in the relevant sub-models that refer to the factors that influence the core innovation process. A summary of the inputs and the simulation results for the corporate strategy, risk taking policy and the organisational climate are presented in Section 6.1.2.1. In the following subsection the inputs and results of the simulation model for the core competencies, organisational structure and employee availability are summarised.

6.1.2.1 The Corporate Strategy, Risk Taking Policy and Organisational Climate

The automotive sector used to have a product life cycle of about ten years. This has been reduced to five to six years with radical innovations appearing every five to seven years. In the last three years however, the sector has not witnessed any radical innovation either in the technology, the management techniques or the production processes. Globocar's readiness to react to technological changes is characterised as 'adequate-to-poor' with a 'good' level of capital availability for investment in following or changing technological paths and in market position. The ability of the senior management team to identify these changes is characterised as 'very good-to-excellent'.

The risk that Globocar is prepared to take is on the scale of medium-to-high, with a trend towards medium. The products that have been introduced into the market during the last three years have, on average, medium-low novelty. The official risk taking policy leads its researchers to maintain a very high level of projects that are worked 'under the table' (bootlegging). A controllable project selection process has been maintained and phenomena such as overoptimistic justification, the 'animal spirit' of its managers or other factors that could overtake the official policy have been kept to a low level. On the other hand, participation in government-funded projects that could lead to high-risk products is very low.

Table 15. Summary of Globocar's Strategy's, Risk Taking Policy and Climate Characteristics

Strategy		Risk Taking Policy		Organisational Climate	
Readiness to React to Technology Changes	Ad.-P	Management's Risk Level Acceptance	M.	Importance of Culture to Success	V.H.
Readiness to React to Market Changes	G.	Bootlegging	V.H.	Senior Managers' Culture	V.G.-G.
Adequacy of Capital Availability for Technological Paths	G.	Animal Spirit	M.-L.	Tolerance to Mistakes	V.G.-G.
Adequacy of Capital Availability for Strategic Position	G.	Government Funding	V.L.	Recognition of Success	V.G.-G.
Management Ideas for Position	V.G.-Ex.	Cooperative Projects	H.		
Management Ideas for Technology	V.G.-Ex.	Over optimism	L.		
		Recent High Risk Success	L.		

<u>Index</u>
Ex.: 'Excellent'
V.G.: 'very good'
G.: 'good'
Ad.: 'adequate'
P.: 'poor'

V.H.: Very High
H.: High
M.: Medium
L.: Low
V.L.: Very Low

Note: This index has the same scale division with the previous one

The company believes that its culture plays a very important role in its success. On average the senior managers show a 'very good-to-good' level of success recognition and tolerance to mistakes. They try to develop a 'good' organisational climate and to reduce the fear of failure of the employees that could reduce the creative initiative. This, however, has not been followed by a proactive strategy and an acceptance of higher risk projects. The result has been a negative effect on the organisational climate. The above observations are summarised in Table 15.

Globocar, as identified in the case study, has not changed its strategy, its risk taking policy or its organisational climate significantly in the last three years. The simulation of the overall strategy of the firm is characterised as 'adequate', because of the influence of the ability of the firm to react to technological changes. The risk taking policy is characterised as 'adequate-to-good', as the choices of the firm are considered usual for the sector without any extremely high or low risk projects being taken forward. The culture and the overall organisational climate are considered as 'adequate-to-poor' because they do not adequate promote the employees' creative activity. This has led the overall strategy of the firm to a slightly lower level in 2001.

Figure 47 shows the output from the simulation of the creative factory model for Globocar. The output of the model follows the trends that have been described by the industrialists.

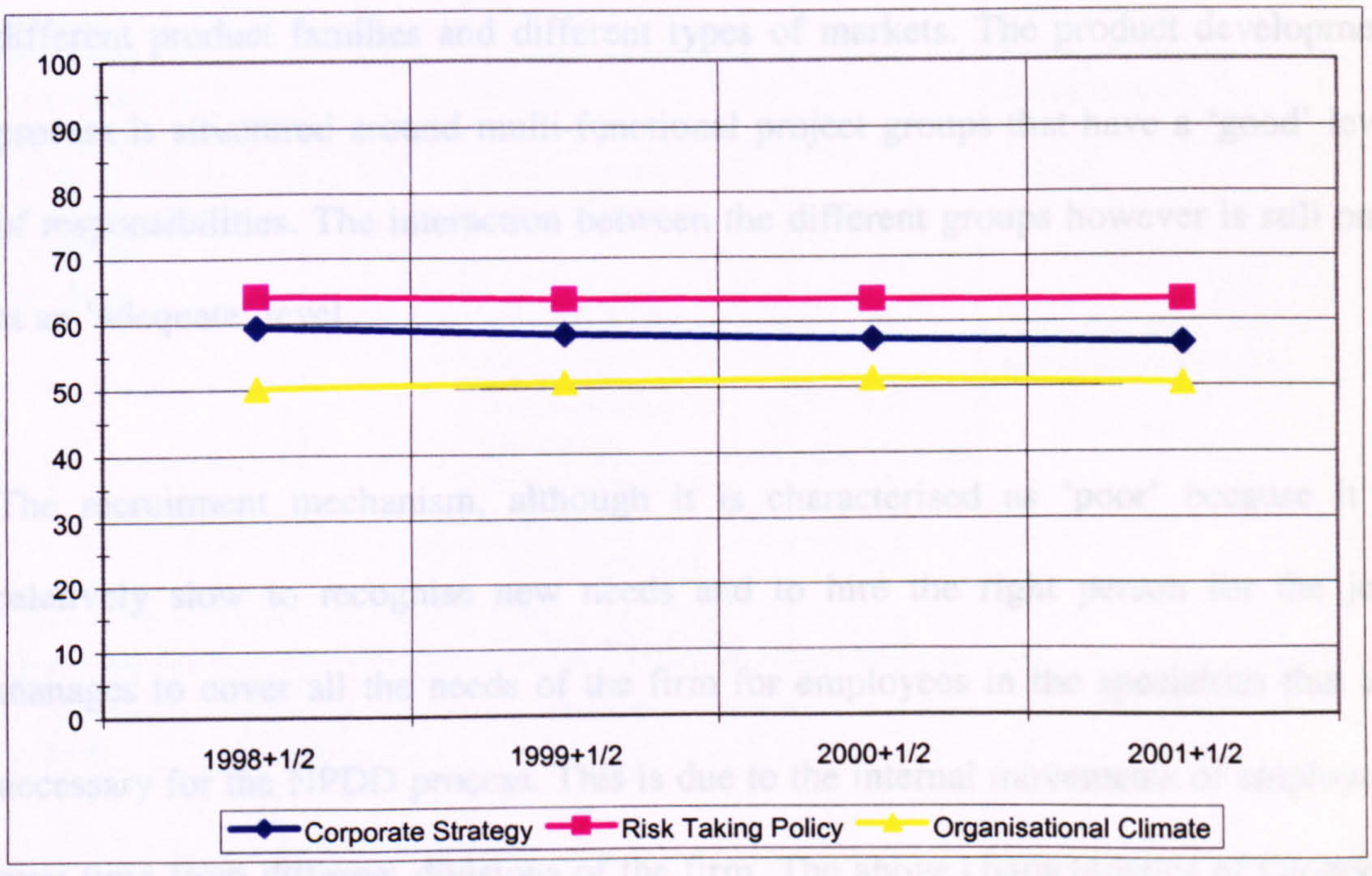


Figure 47. Simulation Output for Corporate Strategy, Risk Taking Policy and Organisational Climate for Globocar

6.1.2.2 The Core Competencies, Organisational Structure and Employee Availability

The level of the core competencies of Globocar is characterised as 'good', since very high capital investment has been made in order to maintain and improve them. During the last three years however, the firm has made a wrong selection of directions, and its ability to change this is still characterised as very low.

Although Globocar is a very large firm, it has managed to keep its structure at an 'adequate' level, by organising the firm around different divisions that specialise in different product families and different types of markets. The product development process is structured around multi-functional project groups that have a 'good' level of responsibilities. The interaction between the different groups however is still only at an 'adequate' level.

The recruitment mechanism, although it is characterised as 'poor' because it is relatively slow to recognise new needs and to hire the right person for the job, manages to cover all the needs of the firm for employees in the specialties that are necessary for the NPDD process. This is due to the internal movements of employees over time from different divisions of the firm. The above characteristics of Globocar are summarised in Table 16.

The core competencies of the firm are simulated as 'good' for the early years of the case study but, because of difficulties in identifying the future direction of technology and selecting the appropriate one, the firm's core competencies later declined. Thus, despite heavy investment in the direct acquisition of machinery and in the in-house development of technology, the core competencies appear to weaken over the last three years to a 'good-to-adequate' status.

Table 16. Summary of Globocar's Characteristics according to its Core Competencies, Structure and Employees Needs

Core Competencies		Structure		Employees	
Investment in Direct Machinery Acquisition	V.G.	Project Groups Direction of Interaction	Ad.-P.	Existence of Project Managers	Ex.
Investment in in-house Development of Technology	V.G.	Timing of Interaction	Ad.	Existence of Sponsors	Ex.
Investment in in-house Development of Knowledge	V.G.-Ex.	Frequency of Communication	V.G.	Existence of Champions	Ex.
Investment in Training	V.G.	Richness of Communication	V.G.	Existence of Gatekeepers	Ex.
Investment for Cooperation with other firms	V.G.	Strength of Group's Leader	G.	Existence of Idea Generators	V.G.-Ex.
Ability of firm to Avoid Wrong Technology Directions	V.P.	Independence from Firm's Structure	G.	Others	G.
		Responsibility for Decisions	G.	Adequacy of Recruitment Policies	P.
		Responsibility for Execution	V.G.		
		Responsibility for Evaluation	V.G.		
		Identification of Roles	V.G.		
		Multi-functionality	V.G.		

Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor' V.P.: 'very poor'

The simulation for Globocar reflects the status of the organisation structure which is based on autonomous divisions and cross-functional integration. This structure is constructed on the 'very good-to-good' level of availability of the necessary employees. However, the overall organisational structure has been characterised as 'adequate', because of the low level of interaction of the cross-functional groups. The above observations for core competencies, organisational structure and employee availability generated by the creative factory model are illustrated in Figure 48.

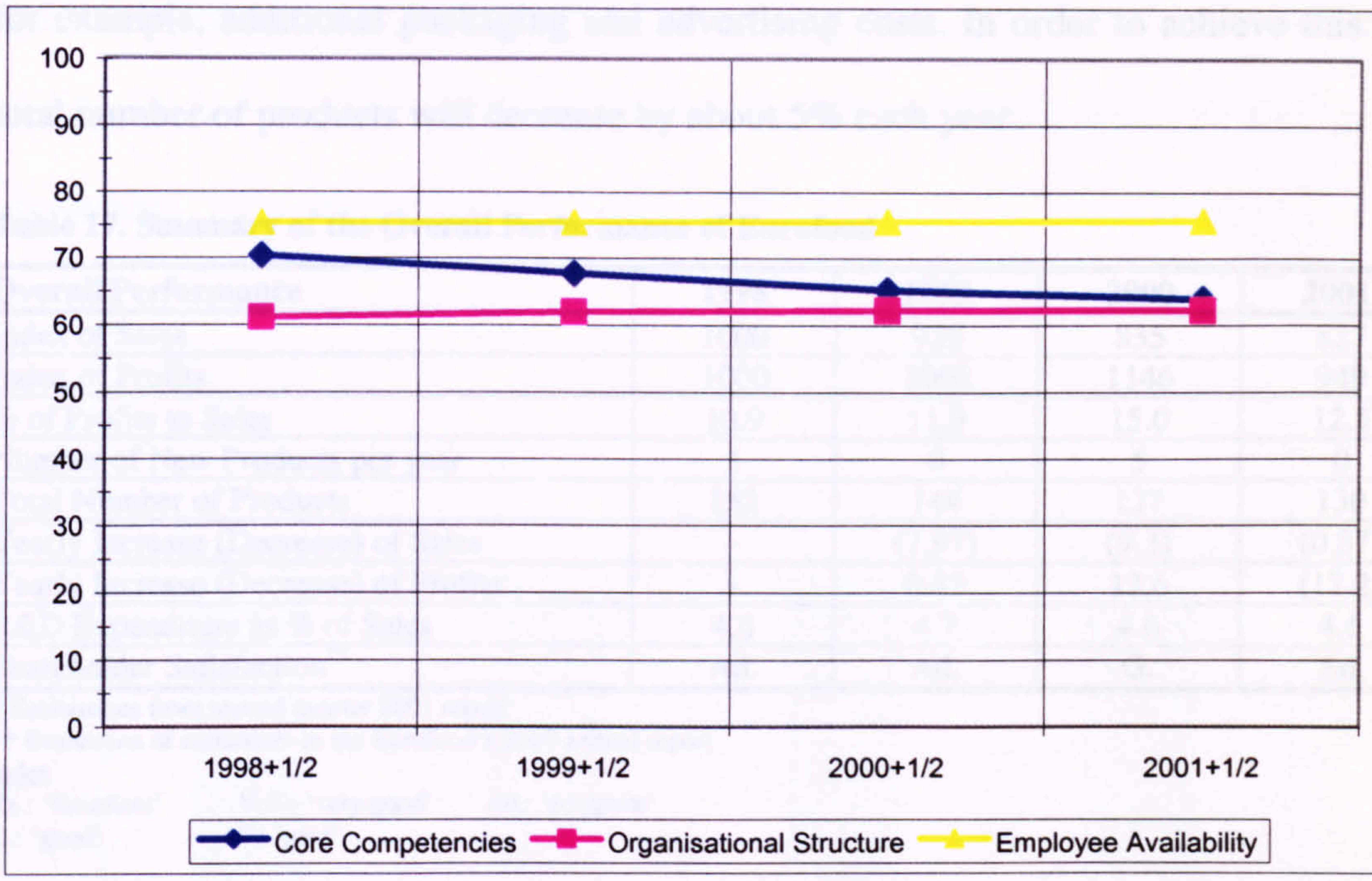


Figure 48. Simulation Output for Core Competencies, Organisational Structure and Employees Availability for Globocar

6.2 Eurofood

In this section the comparison of the overall performance of Eurofood with the simulation results from the creative factory model is presented. Table 17 shows the data for the overall performance of Eurofood according to its sales, profits, new product introductions per year and shareholders' satisfaction, as they were collected during the case study. The sales of the firm show a decline over the period of the study, but its profits are increasing, with the exception of the expectation of profits for 2001 (the year 1998 is used as base '1000' for the creation of the index for sales and profits). The firm introduces five new products every second year, but it wishes to reduce the cost of marketing these products, by using one brand name rather than marketing different brands of very similar products separately and thereby increasing, for example, additional packaging and advertising costs. In order to achieve this the total number of products will decrease by about 5% each year.

Table 17. Summary of the Overall Performance of Eurofood

Overall Performance	1998	1999	2000	2001*
Index of Sales	1000	920	835	827
Index of Profits	1000	1008	1146	949
% of Profits to Sales	10.9	11.9	15.0	12.5
Number of New Products per year	5	0	5	0
Total Number of Products	152	144	137	130
Yearly Increase (Decrease) of Sales	-	(7.97)	(9.3)	(0.87)
Yearly Increase (Decrease) of Profits	-	0.85	13.6	(17.2)
R&D Expenditure as % of Sales	4.6	4.7	4.6	4.6
Shareholder Satisfaction**	Ad.	Ad.	G.	Ad.

* Estimations from second quarter 2001 report
** Evaluation of comments in the Eurofood's 2000 annual report
Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor'

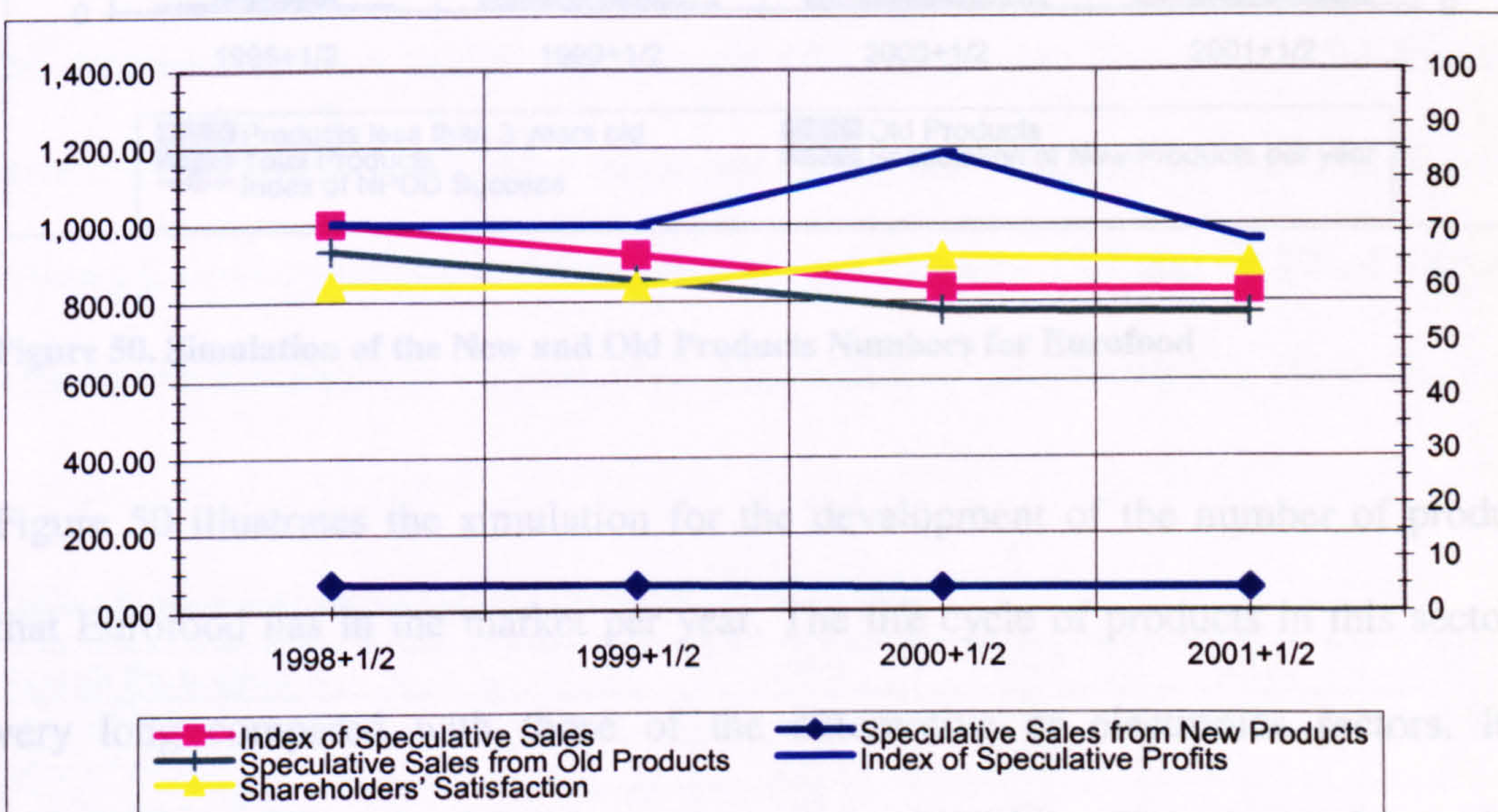


Figure 49. Simulation of the Financial Results of Eurofood

The shareholders show an 'adequate' level of satisfaction, as the firm presents profits every year, although they would prefer a faster restructuring of the firm's product portfolio with a further reduction of costs and an increase of sales and market share. The simulation of the creative factory is shown in Figure 49.

The results generate the indices of sales and profits and suggest that the shareholders' satisfaction is 'adequate' at the end of the financial years 1998 and 1999 and 'good-to-adequate' for 2000 and 2001.

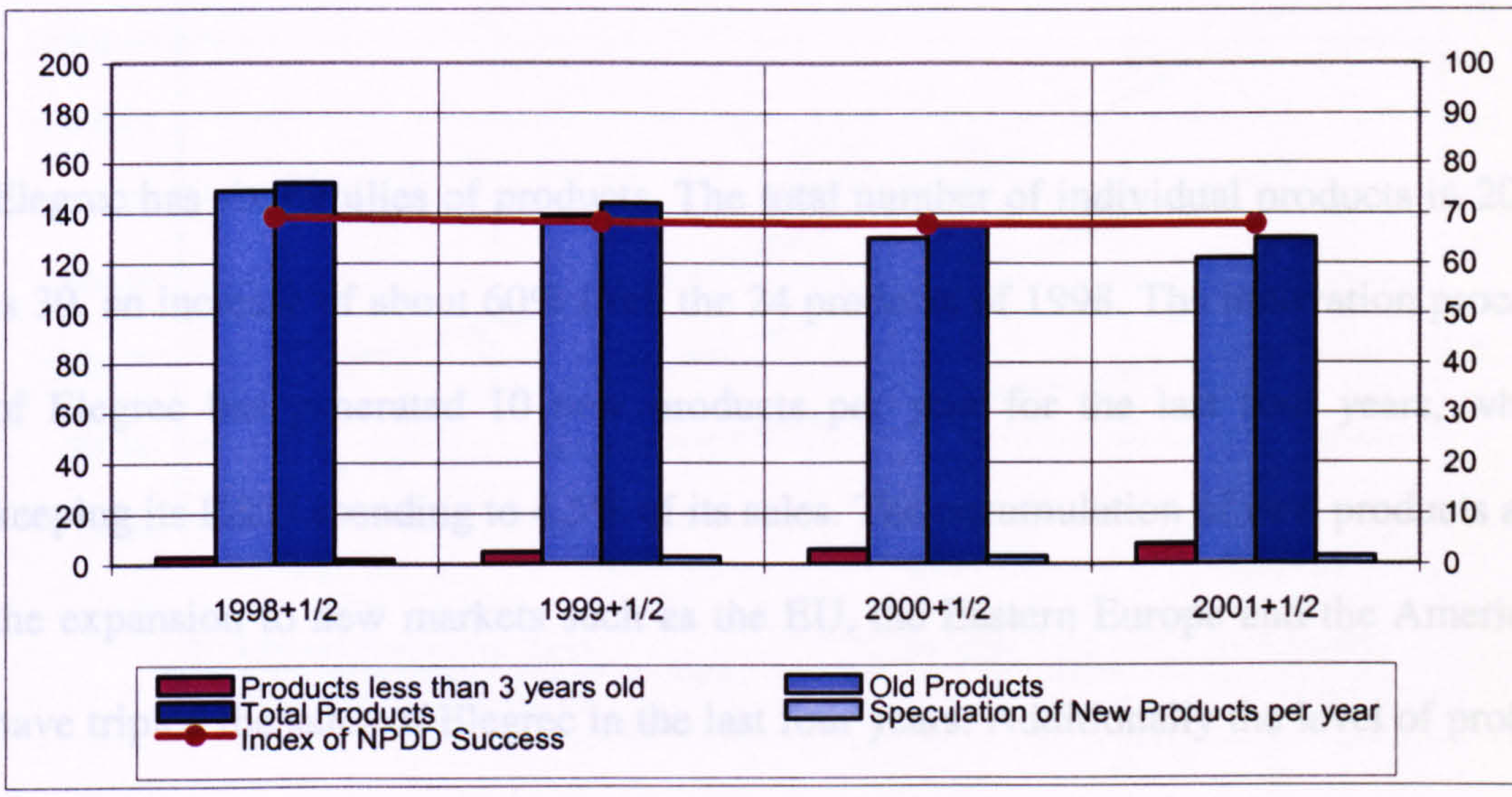


Figure 50. Simulation of the New and Old Products Numbers for Eurofood

Figure 50 illustrates the simulation for the development of the number of products that Eurofood has in the market per year. The life cycle of products in this sector is very long compared with those of the automotive or electronics sectors. It is characteristic of Eurofood that in some countries it still has very successful products which were introduced fifty years ago. Thus, the pressure for product innovation is not very high. On the other hand innovation is necessary in the production processes, in order to reduce costs, handle new materials and increase the flexibility of the factories to change production from one product to another. In this respect the innovation index of Eurofood was characterised as 'good' during the case study, and it is considered as one of the best in the European market. The model uses a linear function, in relation to the index of NPDD success, to calculate the number of new products per year. Thus, the simulation provides an average number which, in total, is the same as the real one for the four years of the simulation.

6.3 Elegrec

Elegrec has six families of products. The total number of individual products in 2001 is 39, an increase of about 60% from the 24 products of 1998. The innovation process of Elegrec has generated 10 new products per year for the last four years, while keeping its R&D spending to 4.5% of its sales. The accumulation of new products and the expansion to new markets such as the EU, the Eastern Europe and the Americas have tripled the sales of Elegrec in the last four years. Additionally the level of profits follows a similar increase and they were always between 17.4 and 19.5% of the sales, keeping the shareholders very satisfied. These data are summarised in Table 18.

Table 18. Summary of the Overall Performance of Elegrec

Overall Performance	1998	1999	2000	2001*
Index of Sales	1000	1430	2303	3308
Index of Profits	1000	1552	2233	3313
% of Profits to Sales	19	19.5	17.4	19
Number of New Products per year	10	10	10	10
Total Number of Products	24	31	37	39
Yearly Increase (Decrease) of Sales	-	43	61	44
Yearly Increase (Decrease) of Profits	-	55	44	48
R&D Expenditure as % of Sales	4.5	4.5	4.5	4.5
Shareholder Satisfaction**	V.G.-G.	V.G.	Ex.	Ex.

* Estimations from second quarter 2001 report
** Evaluation of comments in the Elegrec's 2000 annual report
Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor'

Figure 51 presents the simulation results of the creative factory model for the case of Elegrec. The model successfully generates the expected route of the sales, the profits and the shareholders satisfaction.

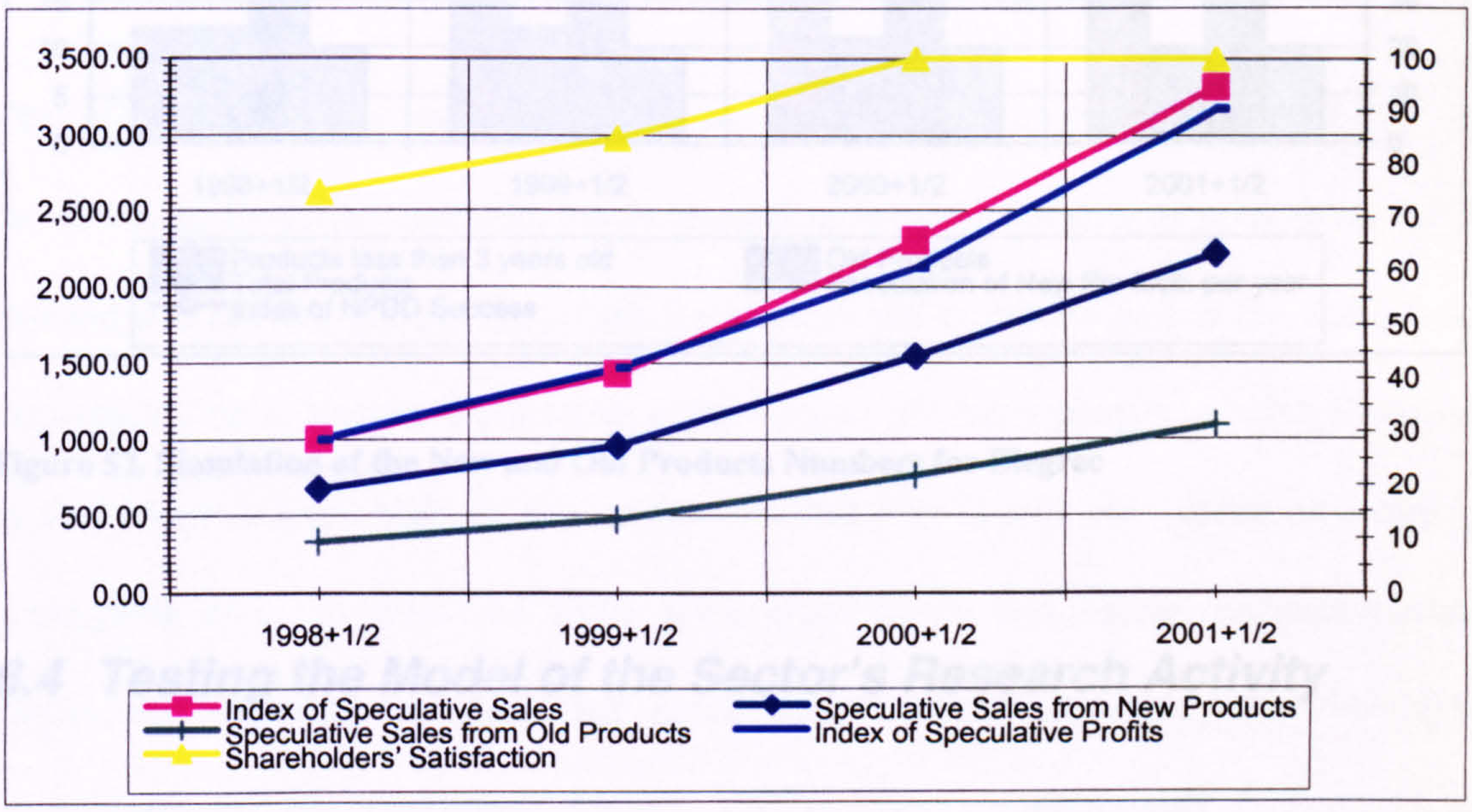


Figure 51. Simulation of the Financial Results for Elegrec

The number of products that Elegrec has in the market has increased from 24 in 1998 to 39 in 2001. The introduction of new products has been continuous during these years, something that is necessary for this type of industry, as the life cycle of products is four to five years. The simulation results are similar to these observations and are shown in Figure 52.

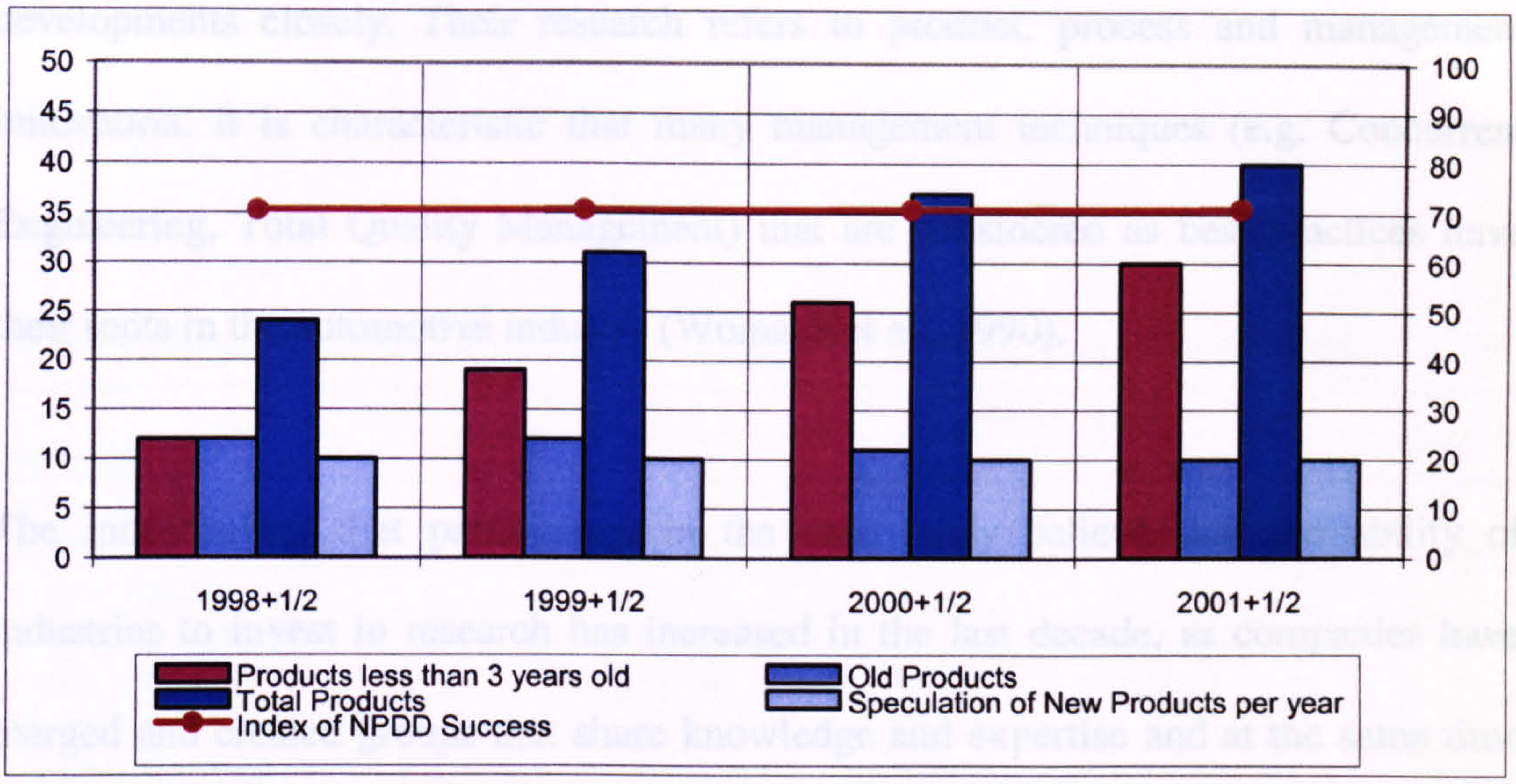


Figure 52. Simulation of the New and Old Products Numbers for Elegrec

6.4 Testing the Model of the Sector's Research Activity

In this section the author codifies the opinions of the industrialists that were collected during the case studies. These are taken into account together with the published information from OECD and the EU according to research that was conducted by public or private bodies within their industrial sectors to produce the results. The remarks refer to research activity in the USA and the EU for Globocar, in the EU for Eurofood, and in Greece for Elegrec.

6.4.1 Research Activity in the Automotive Sector

The automotive industries invest heavily in applied research and experimental development. Here the industrialists realise that in order to survive in this highly competitive sector they need to innovate continually and follow the latest developments closely. Their research refers to product, process and management innovation. It is characteristic that many management techniques (e.g. Concurrent Engineering, Total Quality Management) that are considered as best practices have their roots in the automotive industry (Womack et al., 1990).

The industrialists that participated in the case study believe that the ability of industries to invest in research has increased in the last decade, as companies have merged and created groups that share knowledge and expertise and at the same time economised on resources. Furthermore, the interest of young people in being involved in this sector is very high, as the automotive industry is still considered as a highly prestigious one. Governments show great attention to this sector, because failure carries an important political and social cost (see for example, the *Foresight* programme by EU (European Union, 1997)). Thus, governments (especially in continental Europe) often offer grants or low interest loans in order to help its restructuring and to improve its position.

Basic research however, has been neglected, financially, for a long time (OECD, 2001b). Usually universities and public research centres are involved in specific applied research sponsored by an automotive company. This reduces the probability of radical innovation and directs most of the effort to incremental innovations. Regulations, however, (especially environmental ones), have brought new opportunities and needs for both basic and applied research. Additionally, the convergence of technologies under the automotive umbrella (e.g. electronics, material technologies) has involved a wider range of expertise, and the need for further research efforts has been recognised in order to adapt and develop these technologies (Ganguly, 1999). All the above observations are summarised in Table 19.

Table 19. Summary of the Characteristics of Research Activity in the Automotive Sector

	Automotive Sector			
Industrial Research	98	99	00	01
Capital Availability	V.G.	V.G.	V.G.	V.G.
Benefits understanding	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.
Political Justification	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.
Researchers Interest	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.
Grants, loans etc.	V.G.-G.	V.G.-G.	V.G.-G.	V.G.-G.
Public-Private Collaboration	V.G.	V.G.	V.G.	V.G.
Private Collaboration	V.G.	V.G.	V.G.	V.G.
Basic Research				
Capital Availability	Ad.	Ad.	Ad.	Ad.
Benefits understanding	Ad.	Ad.	Ad.	Ad.
Political Justification	G.	G.	G.	G.
Researchers Interest	V.G.-G.	V.G.-G.	V.G.-G.	V.G.-G.
Grants, loans etc.	V.G.-G.	V.G.-G.	V.G.-G.	V.G.-G.
Public-Private Collaboration	Ad.	Ad.	Ad.	Ad.
Private Collaboration	P.	P.	P.	P.

Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor'

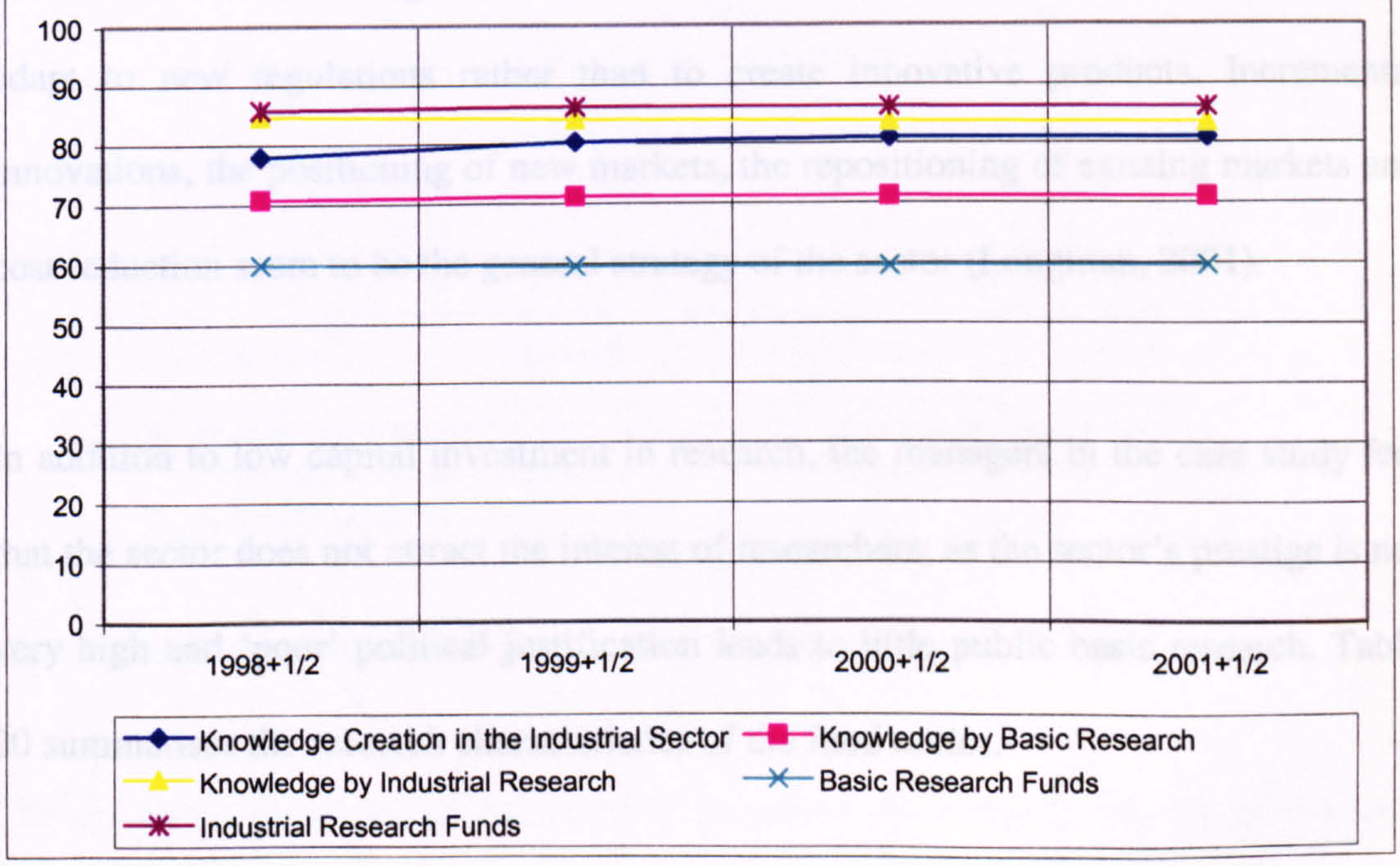


Figure 53. Simulation Results for the Automotive Sector Research Activity

Figure 53 shows the simulation results of the creative factory model for research activity in the automotive sector in USA and the EU. The overall performance of research has improved to a 'very good' level, but, as described above, the basic research necessary to create and sustain an 'excellent' level is missing. Improvement in the direct funding of basic research is the factor that will create the base for further radical innovation to be generated in this sector.

6.4.2 Research Activity in the Food Sector

The food sector is a sector where traditionally, competitive advantage is raised through marketing rather than product innovation (Longman, 2001). Products have a very long life cycle with only small changes. Production processes, although they have improved, are not considered to have shown radical innovation in the last few years. Firms are investing some resources in research but this is due to their need to adapt to new regulations rather than to create innovative products. Incremental innovations, the positioning of new markets, the repositioning of existing markets and cost reduction seem to be the general strategy of the sector (Longman, 2001).

In addition to low capital investment in research, the managers in the case study feel that the sector does not attract the interest of researchers, as the sector's prestige is not very high and 'poor' political justification leads to little public basic research. Table 20 summarises the research characteristics of the food sector.

Table 20. Summary of the Characteristics of Research Activity in the Food Sector

	Food Sector			
Industrial Research	98	99	00	01
Capital Availability	Ad.	Ad.	Ad.	Ad.
Benefits understanding	Ad.	Ad.	Ad.	Ad.
Political Justification	Ad.	Ad.	Ad.	Ad.
Researchers Interest	P.	P.	P.	P.
Grants, loans etc.	G.-Ad.	G.-Ad.	G.-Ad.	G.-Ad.
Public-Private Collaboration	Ad.	Ad.	Ad.	Ad.
Private Collaboration	P.	P.	P.	P.
Basic Research				
Capital Availability	P.	P.	P.	P.
Benefits understanding	P.	P.	P.	P.
Political Justification	P.	P.	P.	P.
Researchers Interest	P.	P.	P.	P.
Grants, loans etc.	Ad.	Ad.	Ad.	Ad.
Public-Private Collaboration	Ad.	Ad.	Ad.	Ad.
Private Collaboration	P.	P.	P.	P.

Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor'

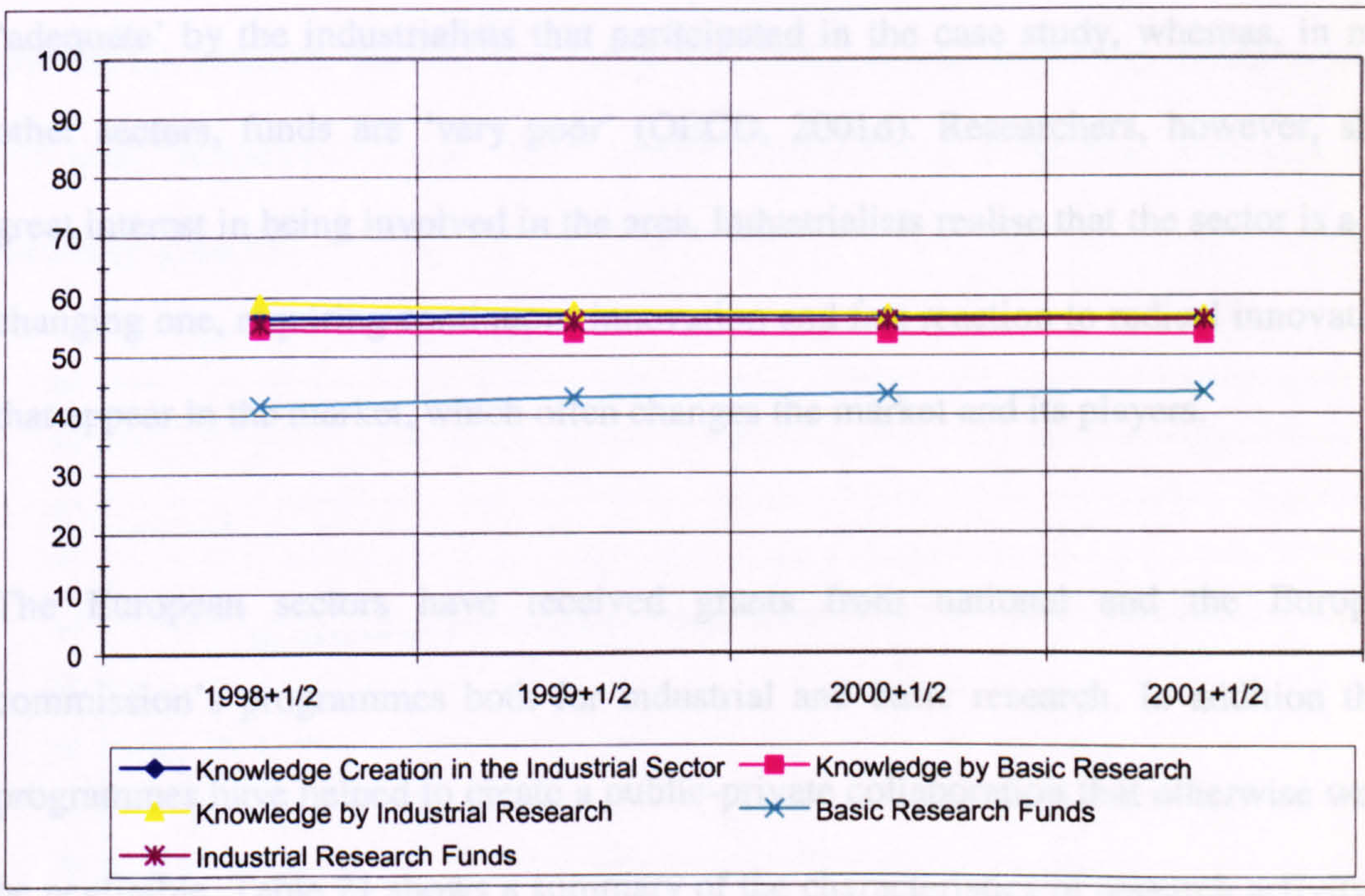


Figure 54. Simulation Results for the Food Sector Research Activity

The creative factory model successfully generates the research activity of the food sector for the European market. The results (Figure 54) show an 'adequate' level of research activity, which however is at the limit at which it can be sustained. This is because of the 'poor' financing of basic research and the low interest by researchers in being involved in this area.

6.4.3 Research Activity of the Electronics and Telecommunication Equipment Sectors

The electronics and telecommunication equipment industries generally have very high prestige. Research funds and personnel have been focused on them world wide including Greece during recent decades (OECD, 2001a; OECD, 2001e). The available funds for research both from the public and private sector are characterised as 'adequate' by the industrialists that participated in the case study, whereas, in most other sectors, funds are 'very poor' (OECD, 2001d). Researchers, however, show great interest in being involved in the area. Industrialists realise that the sector is a fast changing one, requiring continuous innovation and fast reaction to radical innovations that appear in the market, which often changes the market and its players.

The European sectors have received grants from national and the European commission's programmes both for industrial and basic research. In addition these programmes have helped to create a public-private collaboration that otherwise would be negligible. Table 21 shows a summary of the characteristics of research activity for these sectors.

Table 21. Summary of the Characteristics of Research Activity in the Electronics and Telecommunication Equipments Sectors

	Electronics and Telecommunication Equipments Sectors			
Industrial Research	98	99	00	01
Capital Availability	Ad.	Ad.	Ad.	Ad.
Benefits understanding	V.G.-G.	V.G.-G.	V.G.-G.	V.G.-G.
Political Justification	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.
Researchers Interest	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.
Grants, loans etc.	Ad.-G.	Ad.-G.	Ad.-G.	Ad.-G.
Public-Private Collaboration	Ad.	Ad.	Ad.	Ad.
Private Collaboration	P.	P.	P.	P.
Basic Research				
Capital Availability	Ad.	Ad.	Ad.	Ad.
Benefits understanding	V.G.-G.	V.G.-G.	V.G.-G.	V.G.-G.
Political Justification	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.
Researchers Interest	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.
Grants, loans etc.	Ad.	Ad.	Ad.	Ad.
Public-Private Collaboration	Ad.	Ad.	Ad.	Ad.
Private Collaboration	P.	P.	P.	P.

Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor'

Overall the research activity in these sectors in Greece is improving, being however still only 'adequate-to-good'. The creative factory model simulation generates these results (Figure 55).

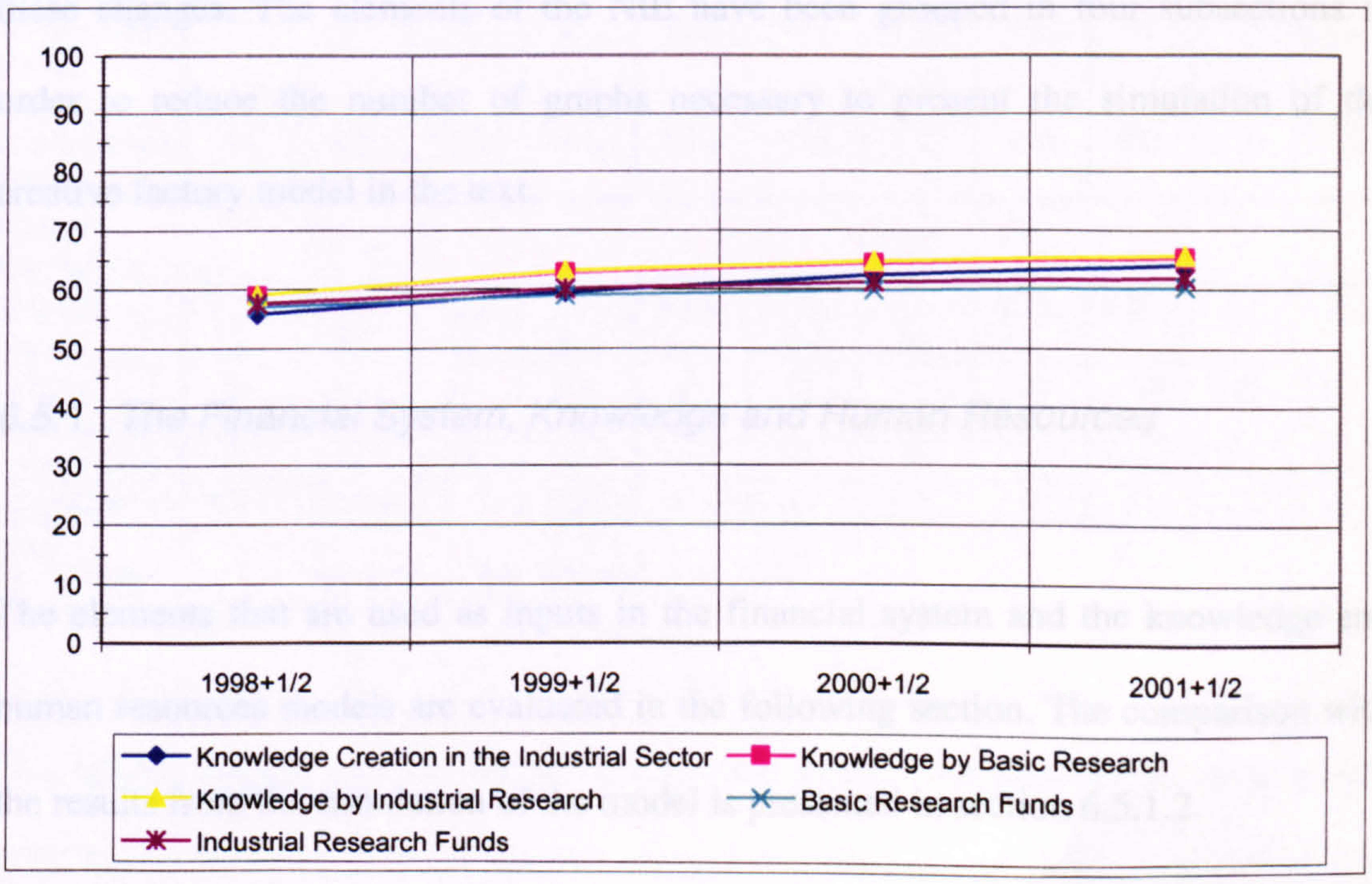


Figure 55. Simulation Results for the Electronics and Telecommunication Equipment Sectors Research Activity

6.5 Testing the National Innovation Environment Model

The National Innovation Environment (NIE) model is constructed in six parts: the financial system; the demand conditions; the infrastructure of the country; the critical mass and physical resources; the available knowledge and human resources and the imposed regulations. Each one of the firms under study has to be adjusted within its environment, taking into consideration not only the characteristics of the particular industrial sector, but also the characteristics of the whole system. In general the NIE changes slowly compared with the changes that a firm may have to face as a consequence of its own actions. However, in the last three years during which the study of the firms has taken place, there have been significant changes in the NIE. The following two subsections will demonstrate the ability of the model to simulate these changes. The elements of the NIE have been grouped in four subsections in order to reduce the number of graphs necessary to present the simulation of the creative factory model in the text.

6.5.1 The Financial System, Knowledge and Human Resources

The elements that are used as inputs in the financial system and the knowledge and human resources models are evaluated in the following section. The comparison with the results from the simulation of the model is presented in section 6.5.1.2.

6.5.1.1 Inputs for the Financial System, Knowledge and Human Resources Models

The elements of the financial system, and human resources availability that are studied in the creative factory model are summarised in Table 22. Knowledge resources availability is partially a consequence of the human resources and the knowledge infrastructure available.

Table 22. Summary of the Financial System Description and Human Resources Availability

	USA				EU				Greece			
Financial System	98	99	00	01	98	99	00	01	98	99	00	01
Capital Market	V.G	V.G.	G.	G.	G.	G.	G.	G.	P.	P.	Ad.	Ad.
Banks	V.G.	V.G.	V.G.	V.G.	G.	G.	G.	G.	P.	Ad.	G.	G.
Venture Capital	V.G.	V.G.	G.	G.	G.	G.	G.	G.	P.	P.	P.	Ad.
International Openness	G.	G.	G.	G.	V.G.	V.G.	V.G.	V.G.	P.	P.	Ad.	Ad.
Financial Regulations	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	Ad.	Ad.	G.	V.G.
Independent Regulators	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	Ad.	G.	G.	V.G.
Government Direct Investment	P.	P.	P.	P.	V.G.	V.G.	V.G.	V.G.	Ad.	G.	G.	V.G.
International Projects	Ad.	Ad.	Ad.	Ad.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.
Human Resources												
Size of Nation	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	P.	P.	P.	P.
Labour Regulations	G.	G.	G.	G.	G.	G.	G.	G.	Ad.	Ad.	Ad.	Ad.
Labour Cost	G.	G.	G.	G.	G.	G.	G.	G.	V.G.	V.G.	V.G.	V.G.
Migration	V.G.	V.G.	V.G.	V.G.	G.	G.	G.	G.	G.	G.	G.	G.

Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor'

The USA's capital market, banks and venture capital are considered very mature (OECD, 2000) while those of the EU are still fragmented and show large differences from one member state to another (OECD, 2001c). On average however, the capital market and financial institutions are considered 'good' because the large countries of the union (especially Germany, UK and France) have large and mature financial markets. Furthermore, there is a higher degree of international openness in the EU than in the USA. This is due to the networks of the financial institutes between the member states, as well as between other areas of the world (e.g. Eastern Europe and Latin America) where the member states have traditional and historical influences (OECD, 2001c).

Greece is at the bottom of the table of EU financial systems (OECD, 2001d). The capital market is very small[9], the banks are small and fragmented and venture capital is almost negligible. In addition, the influence of the international financial system is still low. During the last three years however, the system has received attention because of the country's membership of the European Monetary Union (EMU). The regulations have been adjusted to EU standards and the government has given over financial decision making to independent bodies (Central Bank, Capital Market Regulator).

A first stage of mergers between Greek banks took place in 1999-2001 creating three or four main players in the country. In addition, these banks are starting to expand into the Balkans. Some European banks have shown interest in participating in Greek ventures during the last two years and, in 2002, a new round of mergers and further international investments are expected to take place (OECD, 2001c). In the year 2000 a government supported venture capital institution was established which aims to help investment in the areas of the 'new economy'. Although this is just a first attempt to

[9] Less than 1% of the market capitalisation between the EU member states

create such an institution of a considerable size, the openness of the market to the euro-area is expected to have a positive influence of the finance of new business and innovative ideas in the next few years (OECD, 2001d).

In the EU firms receive further financial support from their governments' direct investments and from national and European-wide projects. The union, through the five framework programmes that have been running since the mid 1980s, has financed many projects especially in small and medium enterprises (SMEs) and universities. Greece has received a large share of available finance, especially in the last five years, in addition to direct funds from the government (Guena, 1999). These types of investments however are not available to the same extent in USA.

The financial situation of a nation however does not indicate that enough people with the necessary expertise are available to cover the needs of industries. The size of the nation, labour regulations, migration and labour costs are factors that need to be considered. In the USA these factors are assessed as 'good' to 'very good' (OECD, 2000). In the EU labour regulations vary from one country to the other, but in general they are characterised as 'good' for the firms under investigation and their needs (OECD, 1998a). In Greece, in addition to the small size of the nation, labour regulations are rigid. Labour costs however, are one of the lowest in the union and migration from Eastern Europe and the Middle East has increased in the last few years further reducing labour costs, as Greece attracts the less skilled end of the labour force (OECD, 2001d).

6.5.1.2 Results for the Financial System, Knowledge and Human Resources

Globocar operates both in the USA and in the EU. The influence of the USA on the results is greater than that of the EU because the market is larger and the firm has more sales in USA. Thus, the results of the model should reflect this direction.

According to the OECD reports (OECD, 2000; OECD, 2001c; OECD, 2001d), the overall financial system and knowledge and human resources in USA were 'very good' in 1998 when the study started. The EU however, was starting from a 'good-to-very good' position. The ability to finance new business and innovation fell in the USA during the last two years, although at the end of the period it was still considered 'good'. This decline happened because of the fall in the capital markets, the expectation of recession and lower direct public spending. This decline did not affect Globocar's environment sharply because the realisation of monetary union has brought with it an improvement in the financial system, integrated markets and a reformed labour market. Additionally the European system is supported heavily by direct government spending, something that is missing in the USA.

Similar developments are illustrated by the simulation of the creative factory model. Figure 56 shows the outcome for Globocar and Figure 57 illustrates the simulation results for Eurofood, which has the EU as its home market.

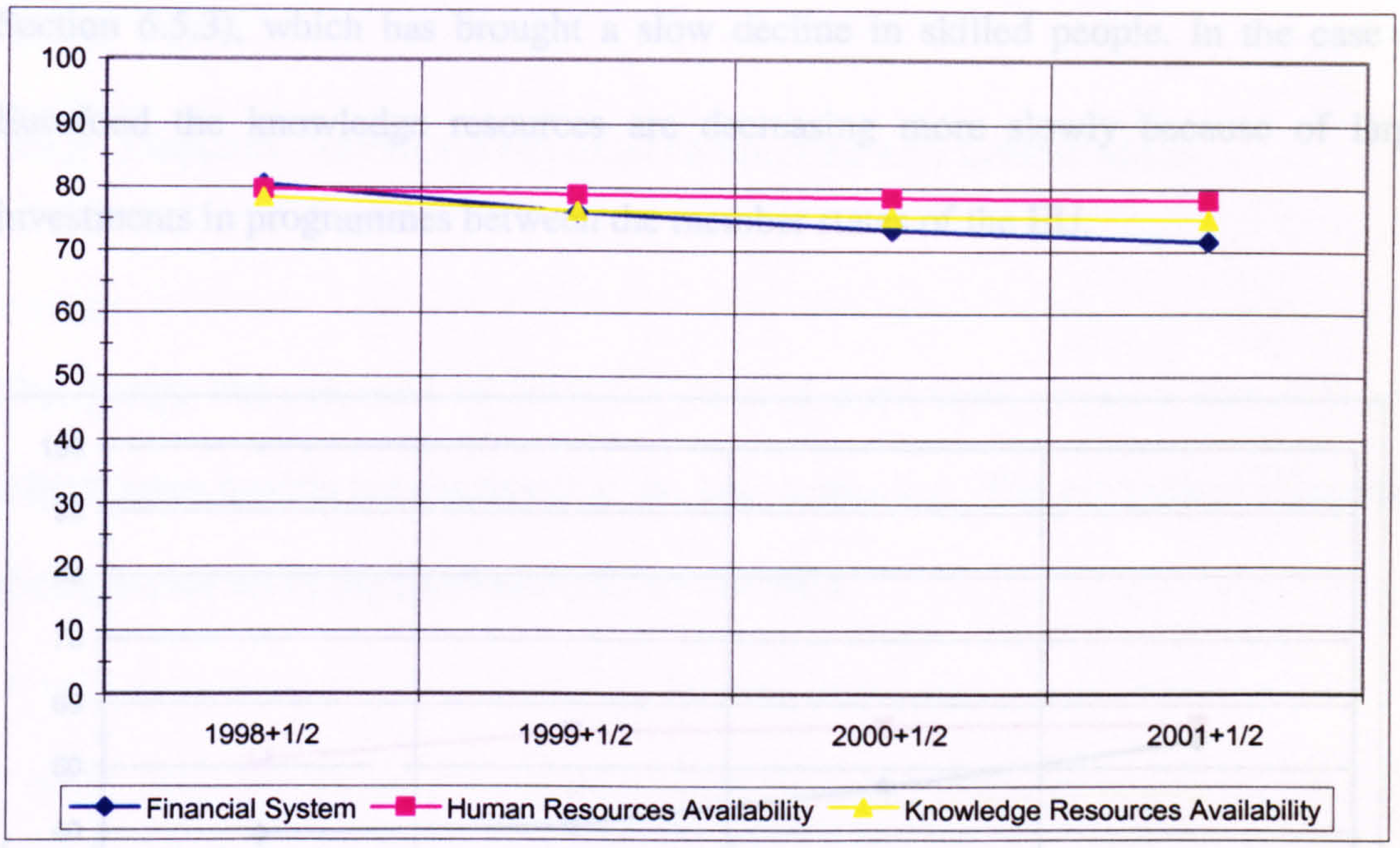


Figure 56. Simulation of the Financial System, Human and Knowledge Availability for Globocar

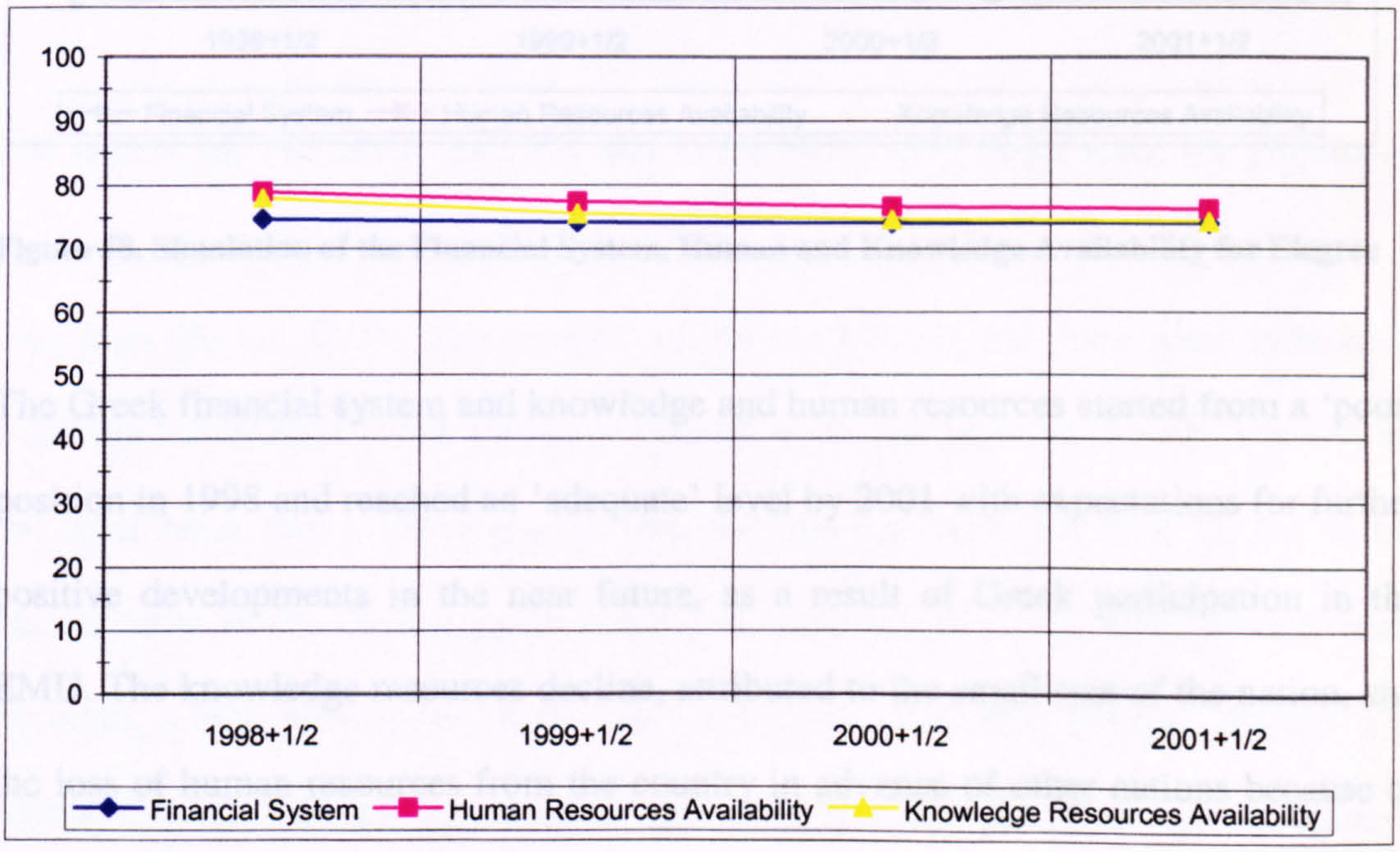


Figure 57. Simulation of the Financial System, Human and Knowledge Availability for Eurofood

Knowledge resources have reduced over time for Globocar, because of the decay of the availability of the knowledge infrastructure both in the USA and the EU (see

Section 6.5.3), which has brought a slow decline in skilled people. In the case of Eurofood the knowledge resources are decreasing more slowly because of large investments in programmes between the member states of the EU.

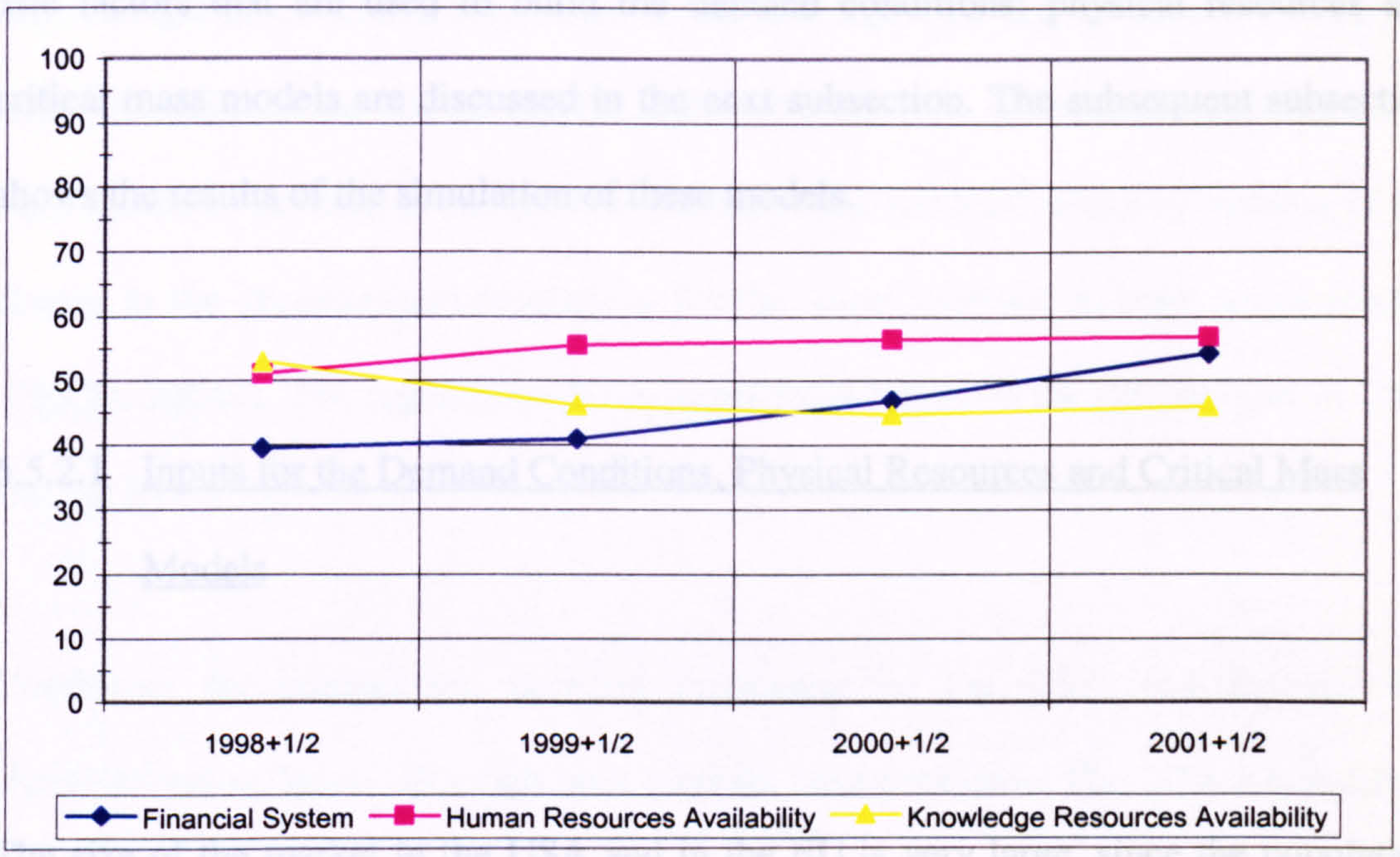


Figure 58. Simulation of the Financial System, Human and Knowledge Availability for Elegrec

The Greek financial system and knowledge and human resources started from a 'poor' position in 1998 and reached an 'adequate' level by 2001 with expectations for further positive developments in the near future, as a result of Greek participation in the EMU. The knowledge resources decline, attributed to the small size of the nation, and the loss of human resources from the country in advance of other nations because of the 'poor' knowledge infrastructure of Greece, has slowly reversed in the last two years. This is due to improvements both in quality and capacity of the knowledge infrastructure (see Section 6.5.3). Figure 58 shows the output of the model for the case of Greece, where the simulation successfully demonstrates the above observations.

6.5.2 Demand Conditions Physical Resources and Critical Mass

The factors that are used to build the demand conditions; physical resources and critical mass models are discussed in the next subsection. The subsequent subsection shows the results of the simulation of these models.

6.5.2.1 Inputs for the Demand Conditions, Physical Resources and Critical Mass Models

The size of the market in the USA and in the EU is very large, since the population numbers, purchasing power (OECD, 2001b) and the sophistication of customers is very high (Porter, 1990). The growth rate for the USA in the three years 1998-2000 was high but in 2001 it fell with expectations, even, for negative growth. The EU, on the other hand, had a lower growth rate, but this has been sustained for the whole period under study. Greece, as an individual country, has a very small market with, however, a high growth rate in the last three years 1999-2001 (OECD, 2001c). The sophistication of Greek customers is generally low and the consumer association which started to operate just three years ago is not very active. The country's participation in the EU however, will allow firms to take advantage of this broader and more sophisticated market (OECD, 2001d).

Supportive industries and physical resources exist in most of the industrial sectors in the USA and the EU (Mowery and Rosenberg, 1993). In Greece the physical resources are 'poor' and imports are expensive because of the country's geographical position and the current status of its infrastructure. Additionally, the support that a firm can get from related industries is low although this can be solved by support from industries in the rest of the EU. Networks between Greek and European firms have started to develop in the last few years and this has become easier because of the change in the import/export regulations for the union, creating an open single market (OECD, 2001d). The regulations for external trade however are stricter both in USA and the EU.

Conditions for competition between companies in the USA and the EU are characterised as 'good' although both markets have problems. The USA has recently accepted mergers and the market has been penetrated by very large firms, a situation which creates oligopolies or even monopolies and which does not help competition and innovation. The EU however, still has a large involvement in publicly owned monopolies, especially in the energy and telecommunication sectors (OECD, 2001c). Greece is also one of the countries with large public monopolies in many sectors, even though this has been changing slowly in the last three years (OECD, 2001d). In the EU and in Greece, then, competition and innovation are constrained for a different reason from those in the USA.

The internationalisation of the market in all three cases is very high, with many multinational firms being based in or operating in these markets. Customer mobility is high, transferring habits of consumption from one country to the other. Because of the level of international tourism and links with former colonies (e.g. Latin America, South Asia) in the EU, habits of consumption have been transferred to these countries and vice versa. The USA on the other hand, influences the whole world by its domination of the cultural and entertainment industries promoting a global type of consumer. The opposite influence however, does not take place anymore on the scale that used to be the case in the early and middle 20th century (EU, 1995). All the above observations are summarised in Table 23.

Table 23. Summary of the Demand Conditions, Physical Resources and Critical Mass

	USA				EU				Greece			
Demand Conditions	98	99	00	01	98	99	00	01	98	99	00	01
Market Size	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	P.	P.	Ad.	Ad.
Customer Sophistication	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	P.	P.	P.	Ad.
Growth Rate	V.G.	V.G.	G.	P.	G.	G.	G.	G.	G.	V.G.	V.G.	V.G.
Sectors Fragmentation	G.	G.	Ad.	Ad.	G.	G.	G.	G.	Ad.	Ad.	Ad.	Ad.
Competition Regulations	G.	G.	G.	G.	G.	G.	G.	G.	P.	Ad.	G.	G.
Multinational Firms	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	V.G.-Ex.	G.	G.	G.	G.
Customer Mobility	G.	G.	G.	G.	V.G.	V.G.	V.G.	V.G.	G.	G.	G.	G.
Import/Export Regulations	G.	G.	G.	G.	G.	G.	G.	G.	G.	G.	G.	G.
International Influence	G.	G.	G.	G.	V.G.	V.G.	V.G.	V.G.	G.	G.	G.	G.
Physical Resources & Critical Mass												
Physical Existence	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	P.	P.	Ad.	Ad.
Cost of Use	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	P.	P.	Ad.	Ad.
Cost of Replacement	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	P.	P.	P.	Ad.
Supportive Industries	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	P.	P.	G.	G.
Links	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	P.	P.	Ad.	G.

Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor'

6.5.2.2 The Results of the Creative Factory Model for Demand Conditions, Physical Resources, Critical Mass

From the above observations the author classifies the demand conditions, the physical resources availability and the critical mass of supportive industries in which Globocar and Eurofood have to operate as 'very good' in 1998. During recent years however, because of the economic slowdown and the concentration of firms through merger, especially in the USA's market, the demand conditions for Globocar have decreased (Figure 59).

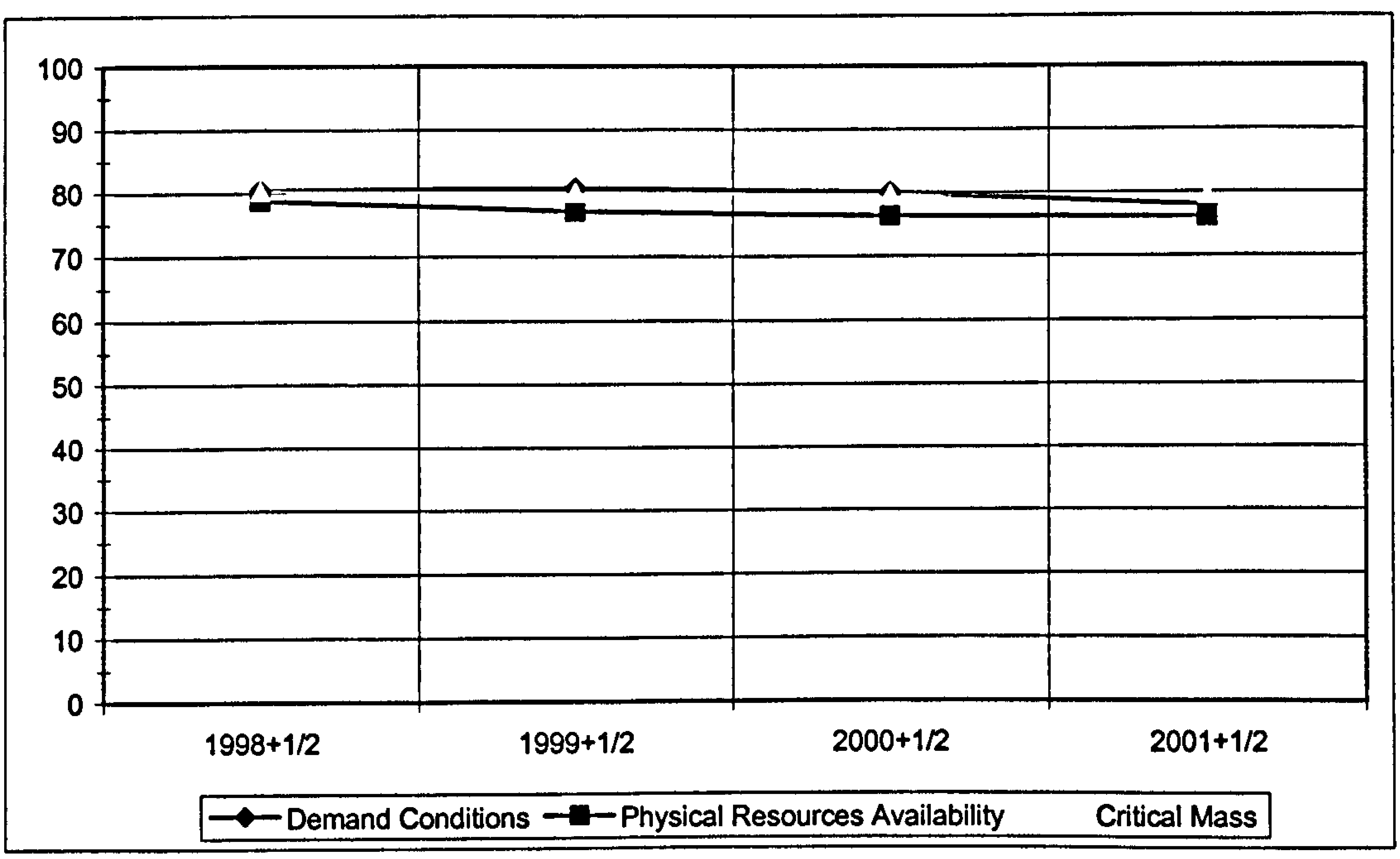


Figure 59. Simulation of the Demand Conditions, Physical Resources Availability and Critical Mass for Globocar

The effect of the slowdown in the EU however, is smaller and, although the demand conditions have declined, a higher level has been sustained than in the USA. Thus the effect for Eurofood is milder (Figure 60).

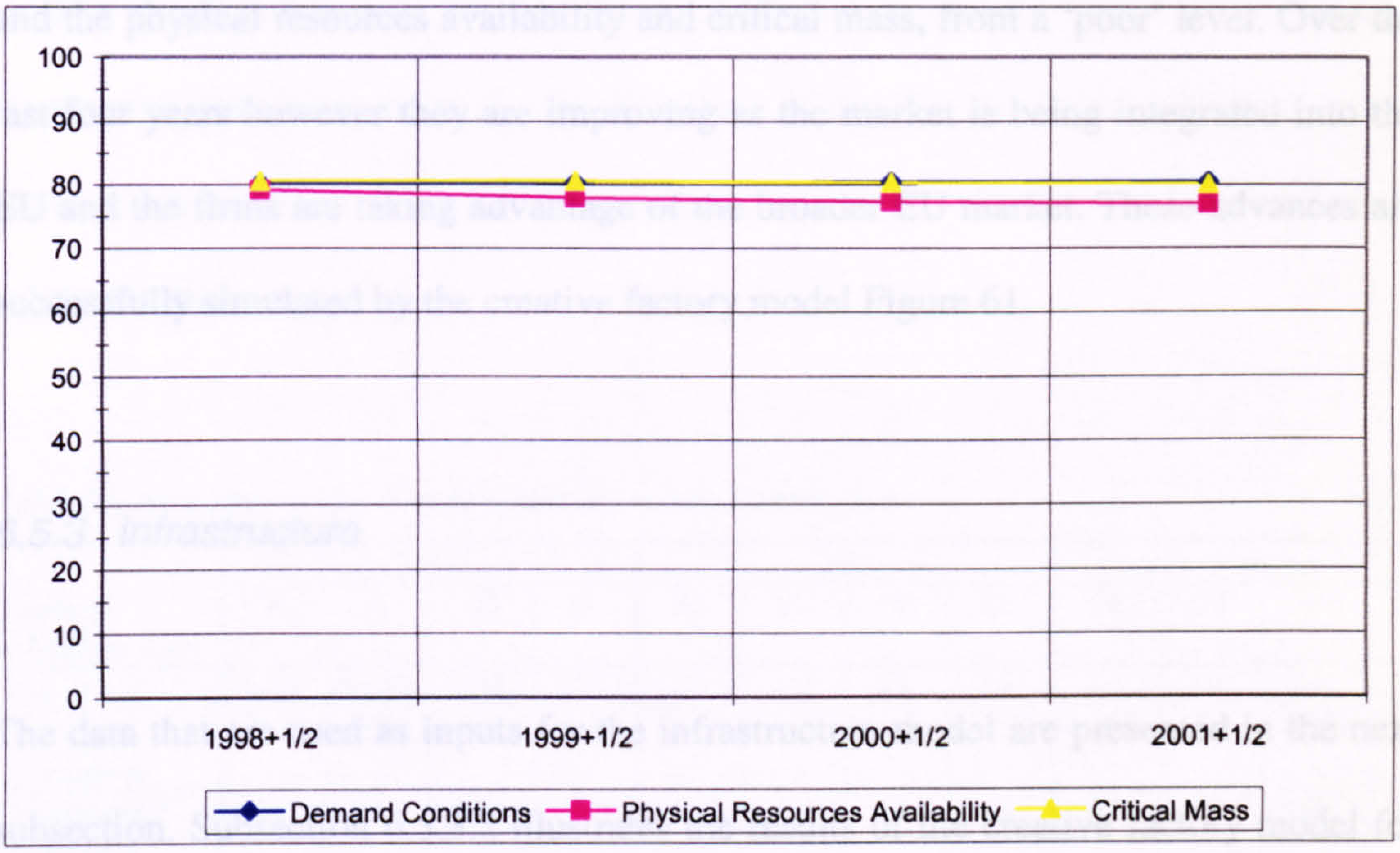


Figure 60. Simulation of the Demand Conditions, Physical Resources Availability and Critical Mass for Eurofood

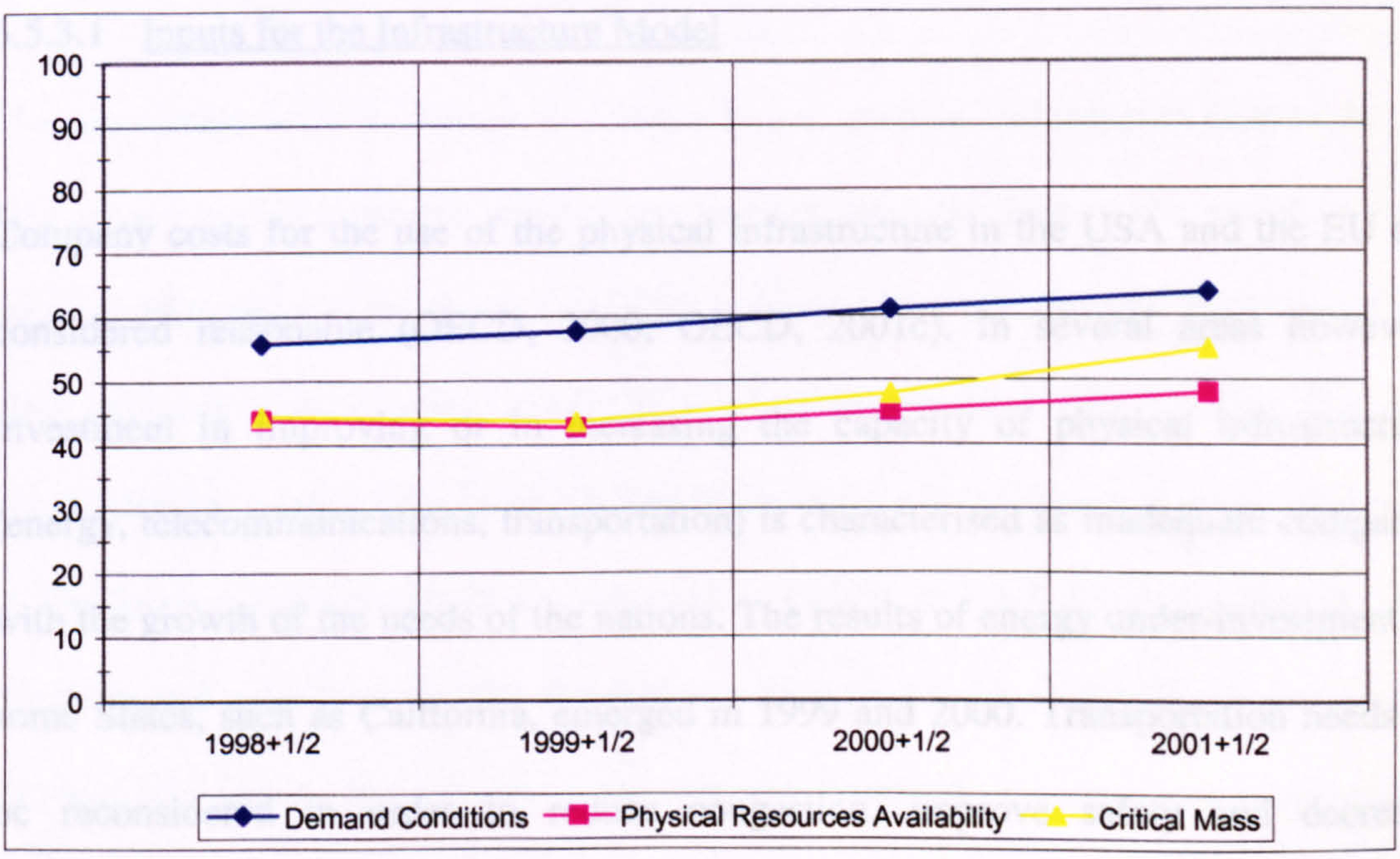


Figure 61. Simulation of the Demand Conditions, Physical Resources Availability and Critical Mass for Elegrec

In the case of Elegrec however, the demand conditions start from an 'adequate' level and the physical resources availability and critical mass, from a 'poor' level. Over the last four years however they are improving as the market is being integrated into the EU and the firms are taking advantage of the broader EU market. These advances are successfully simulated by the creative factory model Figure 61.

6.5.3 Infrastructure

The data that are used as inputs for the infrastructure model are presented in the next subsection. Subsection 6.5.3.2 illustrates the results of the creative factory model for each of the three case studies.

6.5.3.1 Inputs for the Infrastructure Model

Company costs for the use of the physical infrastructure in the USA and the EU are considered reasonable (OECD, 2000; OECD, 2001c). In several areas however, investment in improving or in increasing the capacity of physical infrastructure (energy, telecommunications, transportation) is characterised as inadequate compared with the growth of the needs of the nations. The results of energy under-investment in some States, such as California, emerged in 1999 and 2000. Transportation needs to be reconsidered in order to reduce congestion, improve safety and decrease transportation time. Several countries in the EU are investing in fast railway systems as an alternative to air transportation. France is a leader in this area, where government support has brought remarkable results, and other countries, such as

Germany, Spain and Italy, are close followers. Greece on the other hand started from a very 'poor' position at the beginning of 1990s. In recent years however, heavy investment and deregulation (to the directions of the EU regulations) have started to show results (OECD, 2001d). Table 24 summarises the above remarks for physical infrastructure.

Table 24. Summary of the Physical Infrastructure Description

Physical Infrastructure	USA				EU				Greece			
	98	99	00	01	98	99	00	01	98	99	00	01
Cost of Use	V.G.	V.G.	V.G.	V.G.	G.	G.	G.	G.	Ad.	Ad.	Ad.	G.
Short-term Investment	Ad.	Ad.	Ad.	Ad.	V.G.	V.G.	V.G.	V.G.	G.	G.	V.G.	V.G.
Maintenance Investment	G.	G.	G.	G.	G.	G.	G.	G.	Ad.	G.	G.	G.
Long-term Investment	Ad.	Ad.	Ad.	Ad.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.
Regulations	G.	G.	G.	G.	G.	G.	G.	G.	Ad.	G.	G.	V.G.

Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor'

The knowledge infrastructure is developed by universities and research centres. In the USA many research centres and universities are rated the best in the world in their areas. Additionally their connection with industries has successfully led to many of their research results being used for marketable products (EU, 1995). The EU knowledge infrastructure is characterised by its variety in the member states. The ones in the Anglo-Saxon countries are regarded as closest to the USA, according to their direction and collaboration with the private sector (Rahm et. al., 2000). In continental Europe, the knowledge system is government financed, without clear connections between research and market needs. This however is seen as an advantage in scientific areas, where pure research is often considered more important than applied. Additionally, the continental system gives considerable attention to social sciences and humanities, areas that do not appeal to the same extent in the USA (OECD, 1998b). In the last two years a discussion of a common university system in the EU has been started, however without a conclusion.

Table 25. Summary of the Knowledge Infrastructure Description

Knowledge Infrastructure	USA				EU				Greece			
	98	99	00	01	98	99	00	01	98	99	00	01
Education System	V.G.	V.G.	V.G.	V.G.	G.	G.	G.	G.	Ad.	Ad.	Ad.	Ad.
Public Research Centres	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	P.	P.	Ad.	Ad.
Private Research Centres	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	P.	P.	P.	P.
Cost of Use	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	G.	G.	G.	G.
Short-term Investment	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	Ad.	Ad.	Ad.	Ad.
Long-term Investment	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	P.	P.	Ad.	Ad.
International/ National Programmes	G.	G.	G.	G.	V.G.	V.G.	V.G.	V.G.	G.	G.	V.G.	V.G.
Regulations	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	V.G.	Ad.	Ad.	G.	G.

Index
Ex.: 'Excellent' V.G.: 'very good' Ad.: 'adequate'
G.: 'good' P.: 'poor'

In Greece the knowledge infrastructure is characterised by its limited capacity and very low public and private funding. The connections with industry are very weak and so the directions of research are unclear. The participation in European funded programmes has given a boost to University research in recent years, although further investment is necessary in order to reach an 'adequate' level. The above observations are summarised in Table 25.

6.5.3.2 Results of the Infrastructure Model Simulation

From the above observations the author concluded that the infrastructure facilities that Globocar has to face in its home markets were 'adequate-to-good' at the beginning of the period under study. The growth of the economy however has created further needs that have not been covered adequately in recent years. In the USA under-investment in physical infrastructure has created the need for extra capacity and modernisation. The knowledge infrastructure on the other hand has been sustained at a high level. The decline of attention to several scientific areas in the USA has reduced the overall level of this aspect. These observations are demonstrated successfully by the creative factory model and are illustrated in Figure 62.

The infrastructure in the EU is in a better condition than that in the USA. Physical infrastructure costs, however, are higher than in the USA and the regulations still need to be reformed. These costs and conditions currently reduce the ability of firms to use infrastructure. Knowledge infrastructure, in general enjoys a 'good-to-adequate' status in the EU. The education system, however, because of its differences from one member state to the other, reduces the ability of the whole union to take full advantage of it. These observations are illustrated in Figure 63, which is the simulation of the infrastructure model for Eurofood.

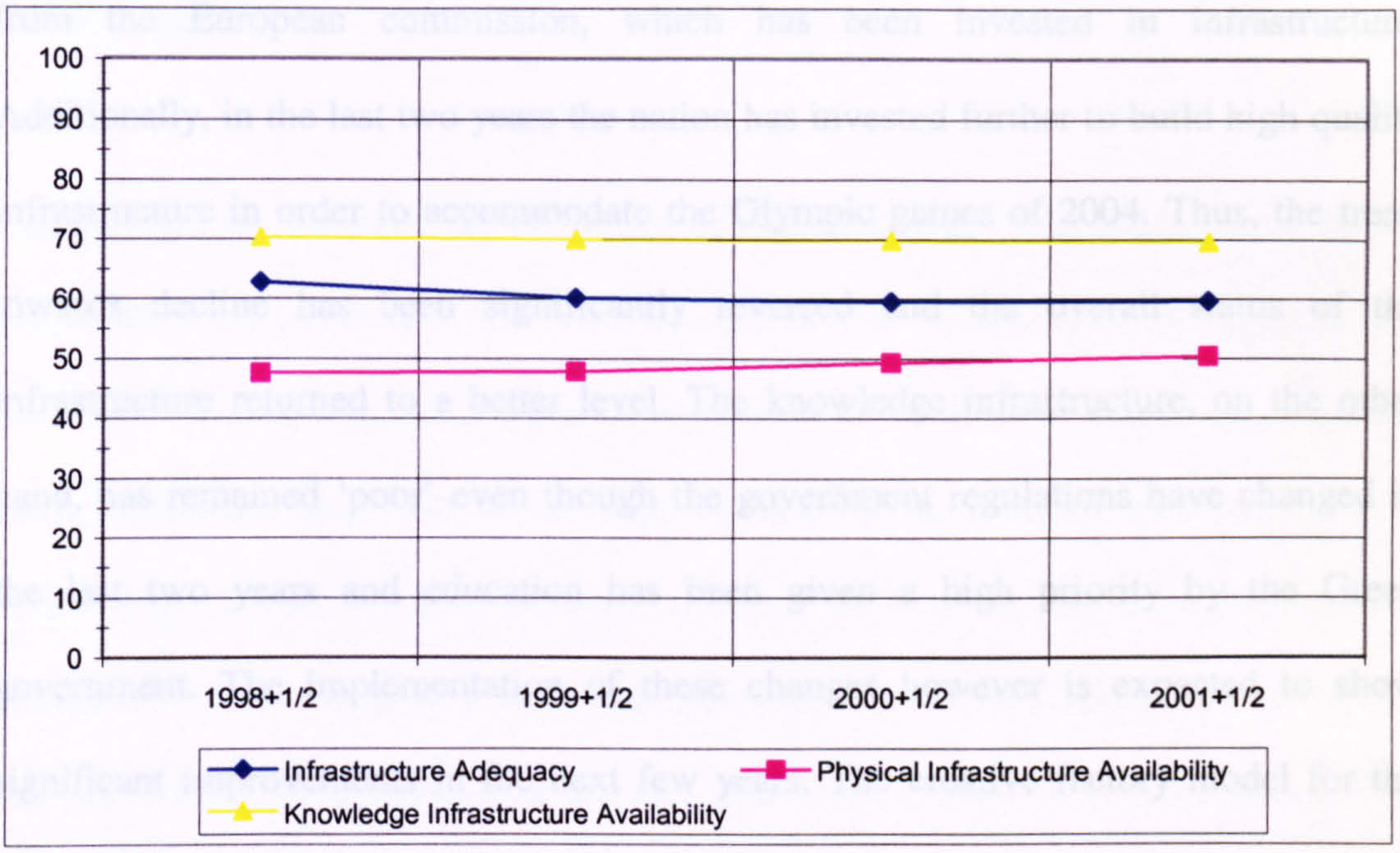


Figure 62. Simulation of the Infrastructure Model for Globocar

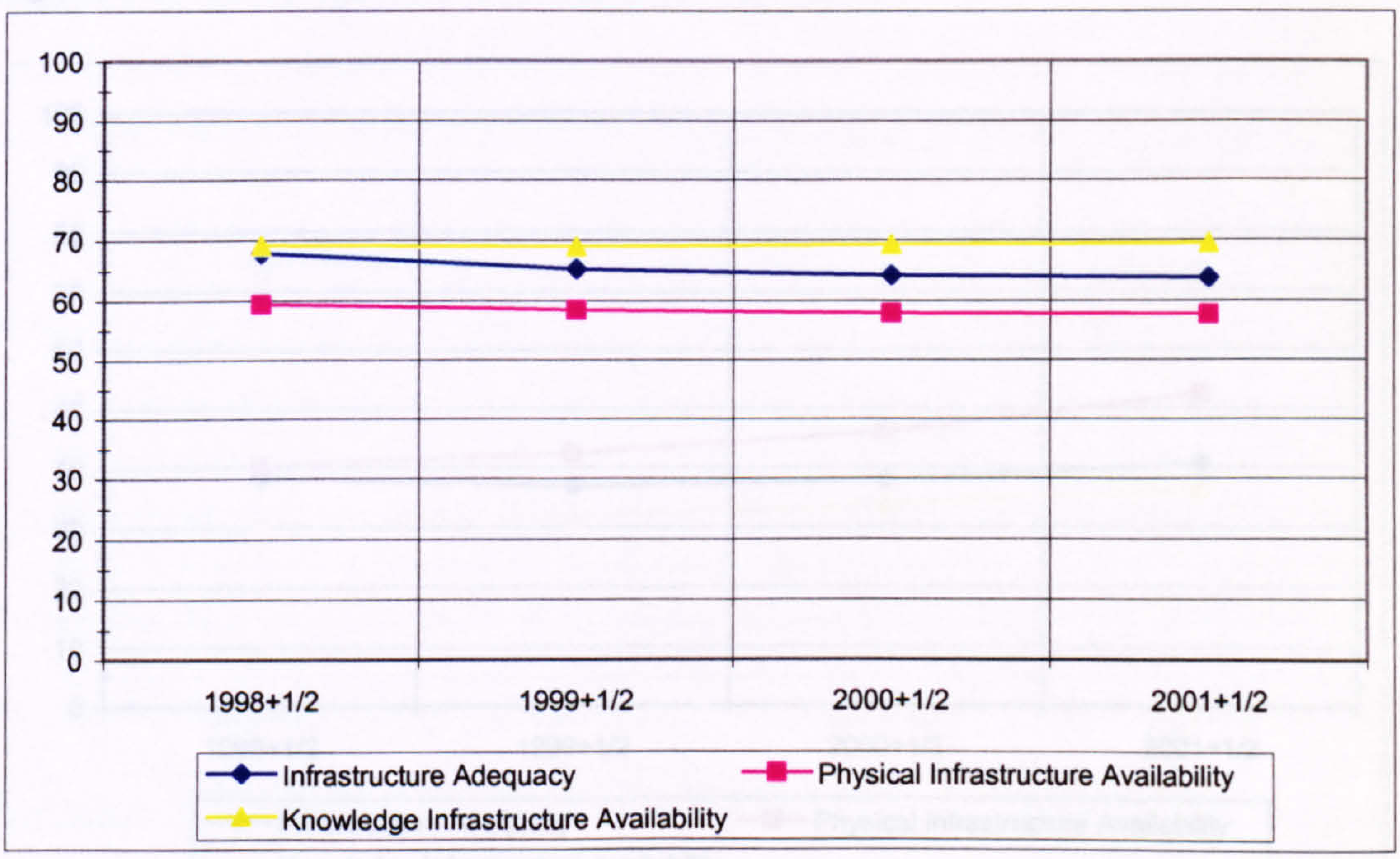


Figure 63. Simulation of the Infrastructure Model for Eurofood

At the beginning of the study Greece started from a 'poor' position with reference to its physical infrastructure with a trend towards decline because of long-term under-investment. In recent years, however, the country has received large amounts of aid from the European commission, which has been invested in infrastructure. Additionally, in the last two years the nation has invested further to build high quality infrastructure in order to accommodate the Olympic games of 2004. Thus, the trend towards decline has been significantly reversed and the overall status of the infrastructure returned to a better level. The knowledge infrastructure, on the other hand, has remained 'poor' even though the government regulations have changed in the last two years and education has been given a high priority by the Greek government. The implementation of these changes however is expected to show significant improvements in the next few years. The creative factory model for the case of Greece efficiently predicts the reverse of these trends and this is shown in Figure 64.

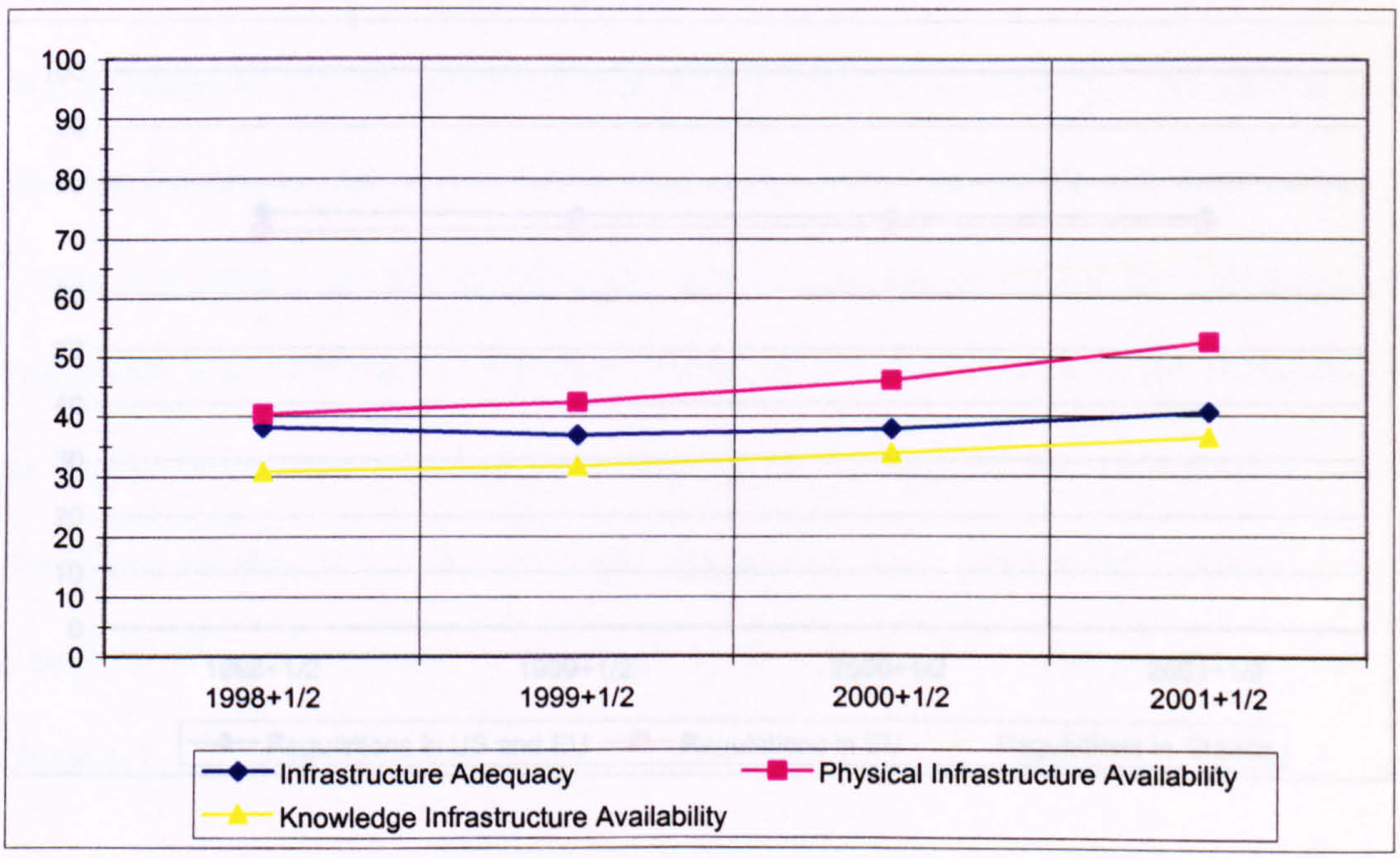


Figure 64. Simulation of the Infrastructure Model for Elegrec

6.5.4 Regulations

Regulations, as discussed in the above subsections, play a significant role in the formation of all the factors of a NIE (OECD, 1998a). Additionally, in the areas that have been mentioned, other types of regulation can influence company decisions. Such regulations may refer to the legal system, the bureaucratic mechanisms of a nation or to environmental restrictions. In general the USA and the EU regulations are considered 'good', helping a firm with innovation activities (OECD, 2000; OECD, 2001c). Greece, as a member of the EU, has adopted most of its regulations. The further modernisation that is in progress in the bureaucratic public services will improve the Greek situation and help firms' activities.

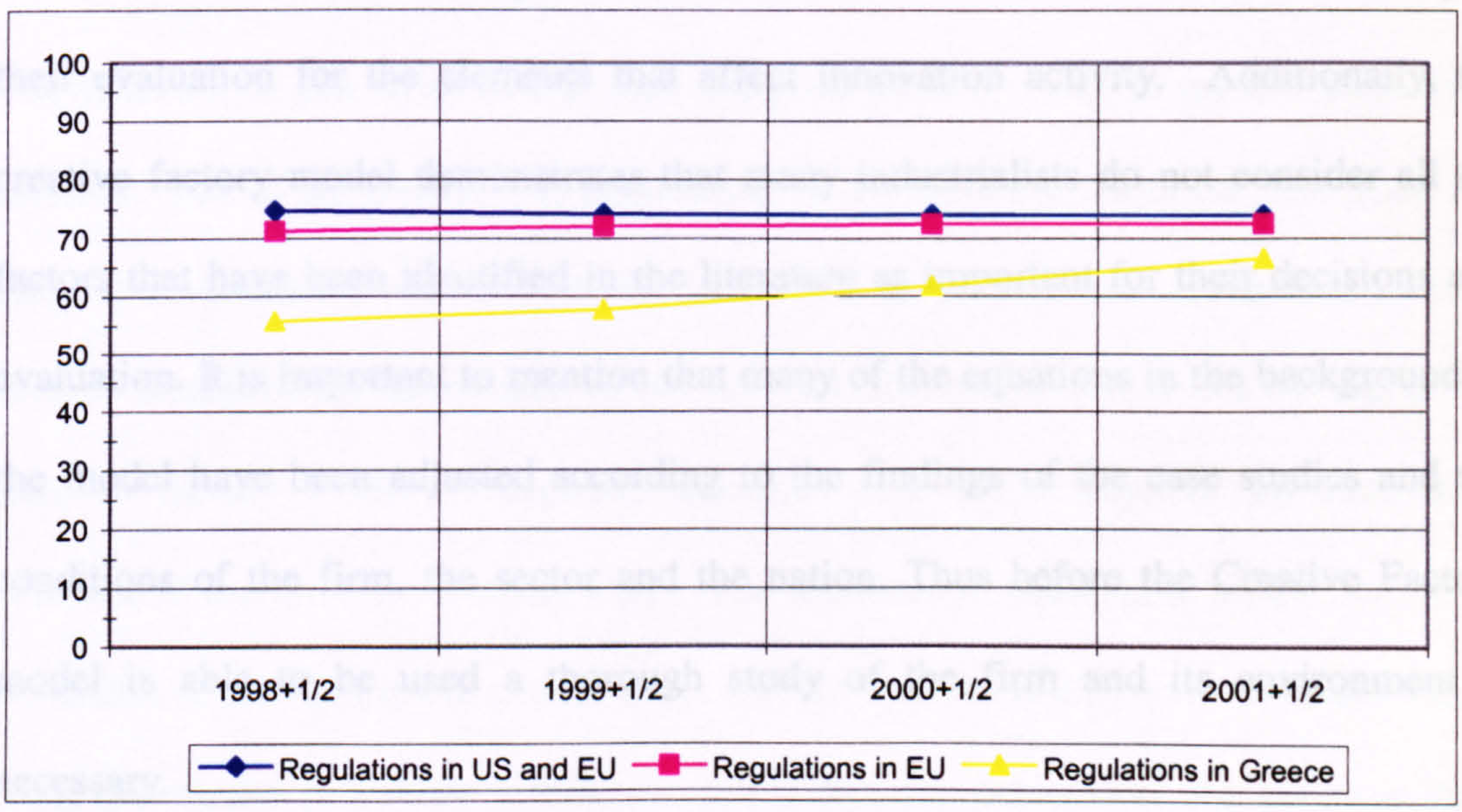


Figure 65. Simulation of the Regulations Model for the three cases

Figure 65 shows the simulation of the regulation model for Globocar, Eurofood and Elegrec. The results are of a similar 'good-to-very good' level but improvement could be achieved by the stricter regulation of mergers in both the USA and the EU, which would increase trade between these two economic areas and by bypassing the reluctance of the authorities to proceed decisively to environmental regulations that could create new areas of innovation activity for the firms. Additionally, in the EU, further deregulation of several industrial sectors needs to be completed. In Greece the regulation status started a long way below the European level but they had come closer by the end of the period under study.

6.6 Confidence in the Creative Factory Model

This Chapter – together with Appendix C – show that the Creative Factory model can demonstrate innovation activity and the factors that influence this activity for a firm. Often the model illustrates optimism from the side of the industrialists according to their evaluation for the elements that affect innovation activity. Additionally, the creative factory model demonstrates that many industrialists do not consider all the factors that have been identified in the literature as important for their decisions and evaluation. It is important to mention that many of the equations in the background of the model have been adjusted according to the findings of the case studies and the conditions of the firm, the sector and the nation. Thus before the Creative Factory model is able to be used a thorough study of the firm and its environment is necessary.

The author feels confident that the model can now be used to assess the status of each firm according to its innovation activity and simulate different scenarios for each case in order to demonstrate how a firm can improve its innovation outcome. Additionally, the model can now be used to illustrate how changes in the National Innovation Environment can affect a firm that operates in it.

7 Applications of the Creative Factory Model

Having gained confidence in the Creative Factory model through the three case studies it can now be used as an assessment tool. The model then simulates scenarios of management actions that could change the innovation outcome of these firms. Additionally a scenario has been created to demonstrate to what extent the external environment of a firm affects its ability to generate new products, and how sudden and unexpected external events can influence the innovation activity of a firm.

The structure of this Chapter has been designed in such a way to present these three different uses of the model. The application of the model to Globocar, Eurofood and Elegrec is presented respectively in Sections 1 to 3. The first subsection of each section describes the assessment of the firm and the second illustrates the use of the creative factory model to simulate scenarios that could improve the innovation outcome of the three firms under study. The assessment results give a snapshot of the condition of the firm at the end of each calendar year, thus they have different values from the results presented in Chapter 6[10]. Thus, the assessment for the year 2001 refers to the expectation of the firm's status. Section 4 demonstrates the effects of the National Innovation Environment and of a radical innovation – a creative destruction in Schumpeterian terms (Schumpeter, 1939) – to the innovation outcome of the firms

[10] All the graphs are discrete. Thus, the intermediate status does not be represented by the lines.

under study. Finally, in Section 5 the author summarises the results from the simulation.

7.1 Globocar

The creative factory model is used to assess Globocar's core innovation process and the firm's factors that affect this process. Subsequently the author identifies the elements that could be changed in the firm and presents a scenario that simulates these changes and illustrates the performance changes in the innovation activity of the firm.

7.1.1 Assessment of Globocar

The status of the factors that separate successful products from failures (see Section 4.2.1) for Globocar are assessed as 'good-to-very good[11]' with room for improvement. However, the measure of the firm's overall ability to generate successful innovations, the 'index of NPDD success', is only assessed as 'good' with a very small improvement over the four years of simulation (Figure 66). The difference between these two indices is generated because of the level of performance of the organisational factors, which has been evaluated as 'good-to-adequate'. These organisational factors refer both to the core innovation process and to the elements that influence innovation.

[11] The scale that has been used in the evaluation is: <50: 'poor', 50-65: 'adequate', 65-75: 'good', 75-90 'very good', 90-100: 'excellent'. Their combination gives a value that, although it is inside the limits of the first mentioned index, is very close to the second mentioned index, e.g. 'adequate-to-good': the factor is assessed 'adequate' but close to 'good'.

The relatively low level of the NPDD index of success kept the generation of new products below the level required to renew the number of products in favour of those less than three years old before 1999 (Figure 67). This translated to a greater increase in the number of old products over those less than three years old in 1998 and 1999. Sales were affected because they depend, by two thirds, on newer products. The profits of the firm consequently decline from late 2000 and, in 2001, the firm expects to present losses.

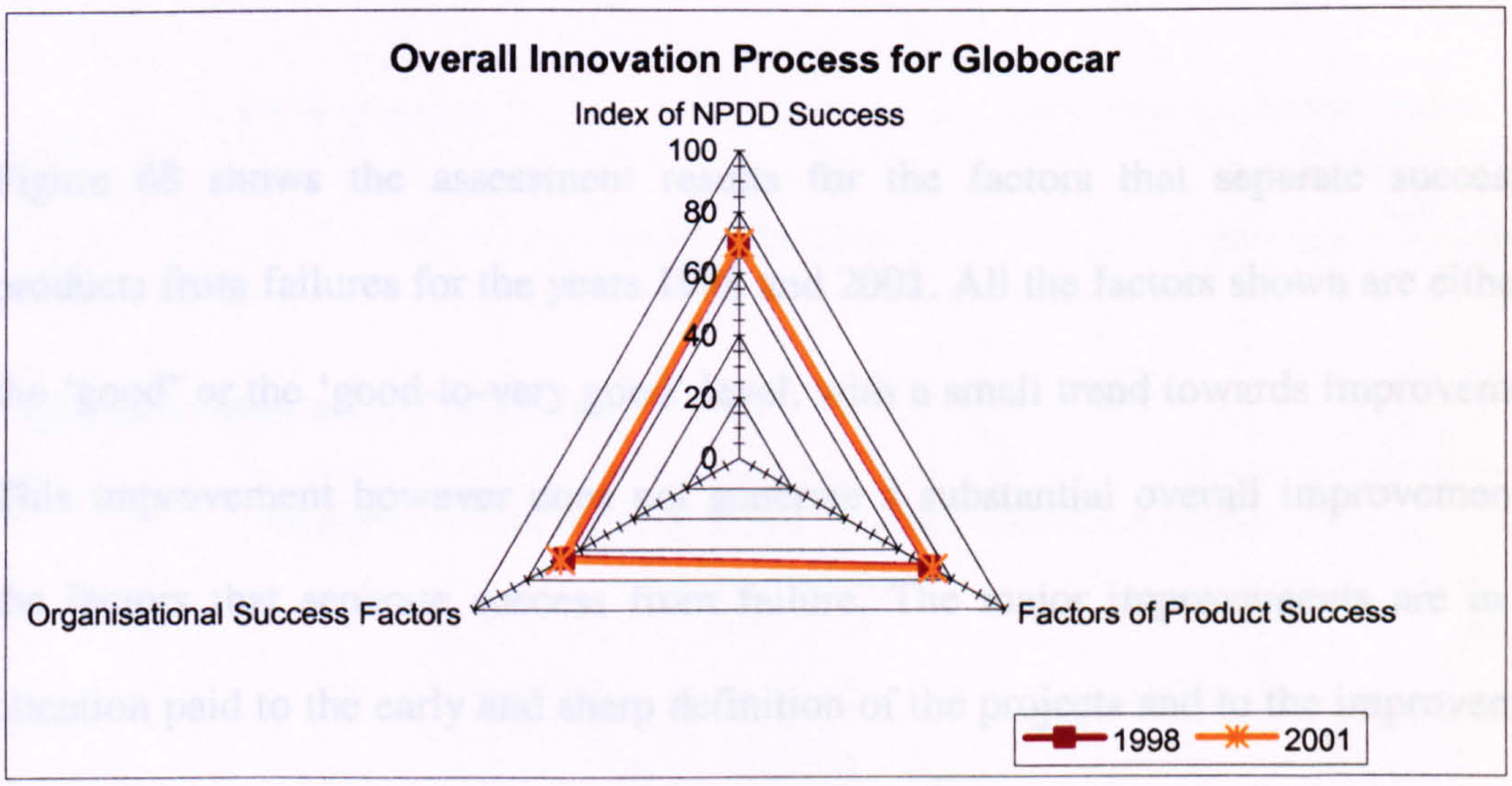


Figure 66. Overall Innovation Process for Globocar

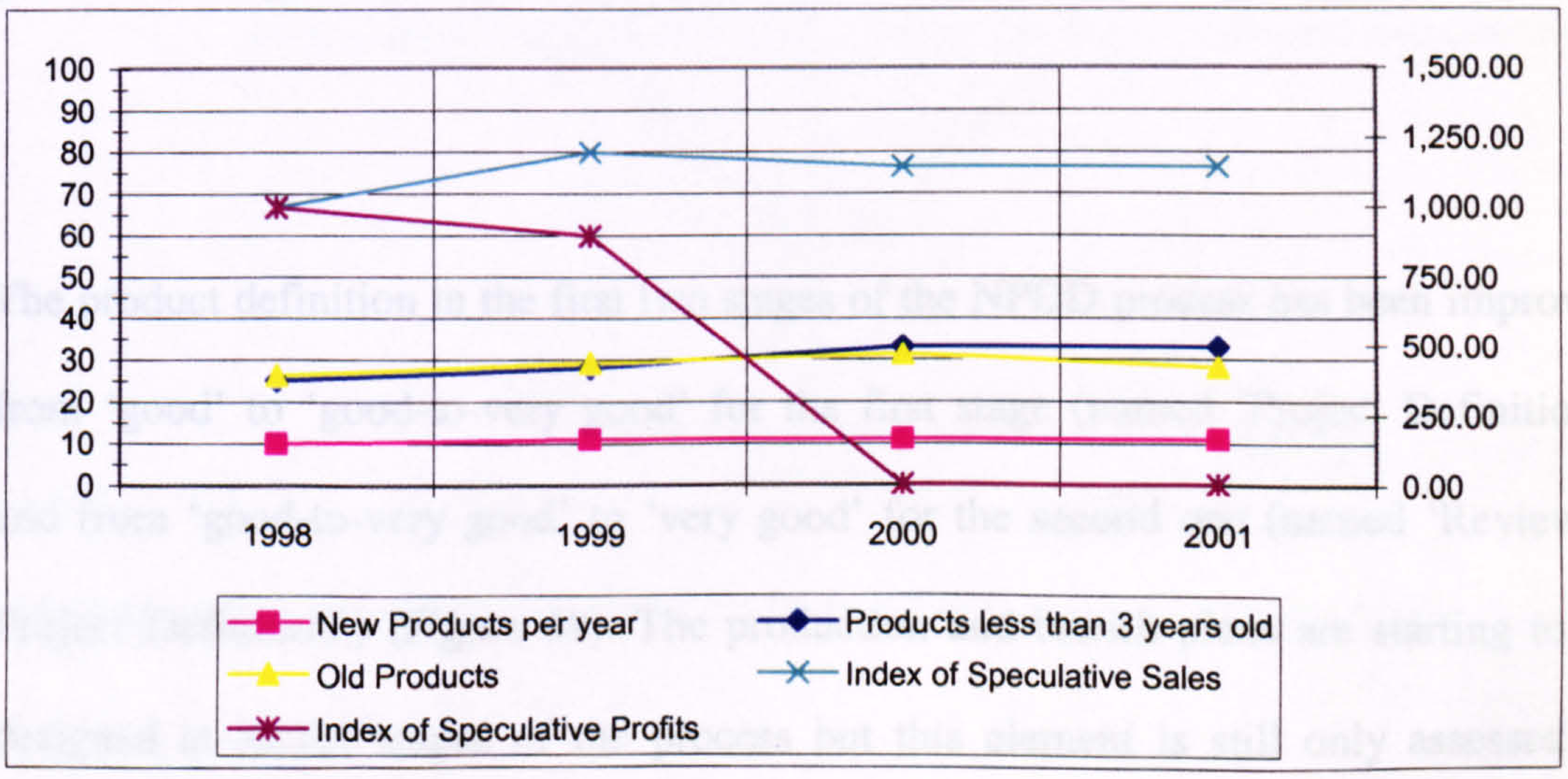


Figure 67. Globocar's Financial Results and Number of New Products Related to NPDD index of Success

The small improvement of the firm's innovation activity when the introduction of new products is increased brings the ratio of less than three year old products to older ones, in favour of the former. If these new products prove to be successful in the market, this will probably bring the firm back into profit in the next financial year (year 2002).

7.1.1.1 Assessment of Product Success Factors for Globocar

Figure 68 shows the assessment results for the factors that separate successful products from failures for the years 1998 and 2001. All the factors shown are either at the 'good' or the 'good-to-very good' level, with a small trend towards improvement. This improvement however does not generate a substantial overall improvement in the factors that separate success from failure. The major improvements are in the attention paid to the early and sharp definition of the projects and to the improvement in technical activities. The latter is a consequence of improvement in the full production stage (see Section 7.1.1.2).

The product definition in the first two stages of the NPDD process has been improved from 'good' to 'good-to-very good' for the first stage (named 'Project Definition') and from 'good-to-very good' to 'very good' for the second one (named 'Reviewed Project Definition') (Figure 69). The production and launch plans are starting to be designed at earlier stages of the process but this element is still only assessed as 'good-to-adequate'. The speed of the NPDD process has finally been improved in the last few years, but it is still only within the 'good' range.

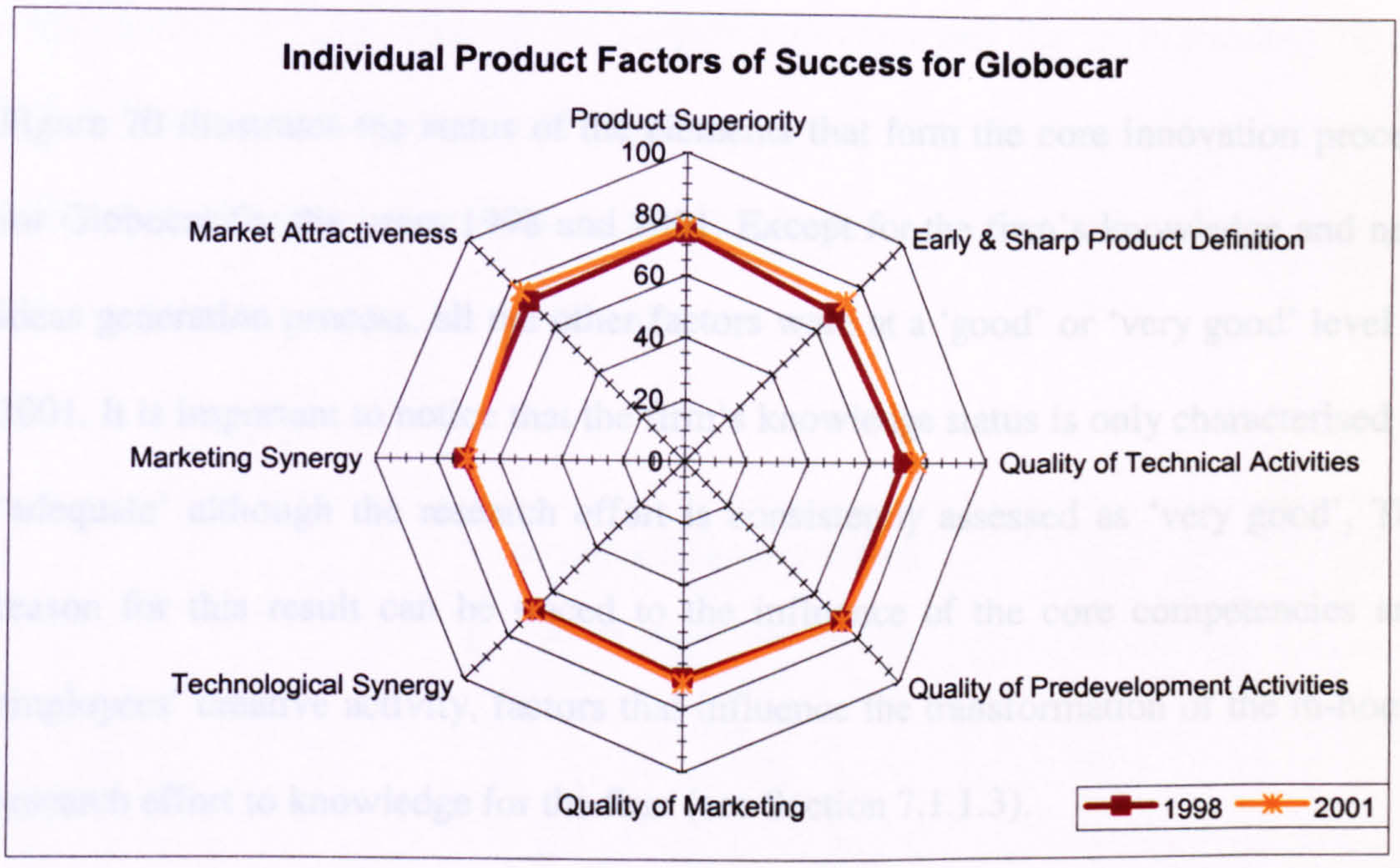


Figure 68. Product Success Factors for Globocar

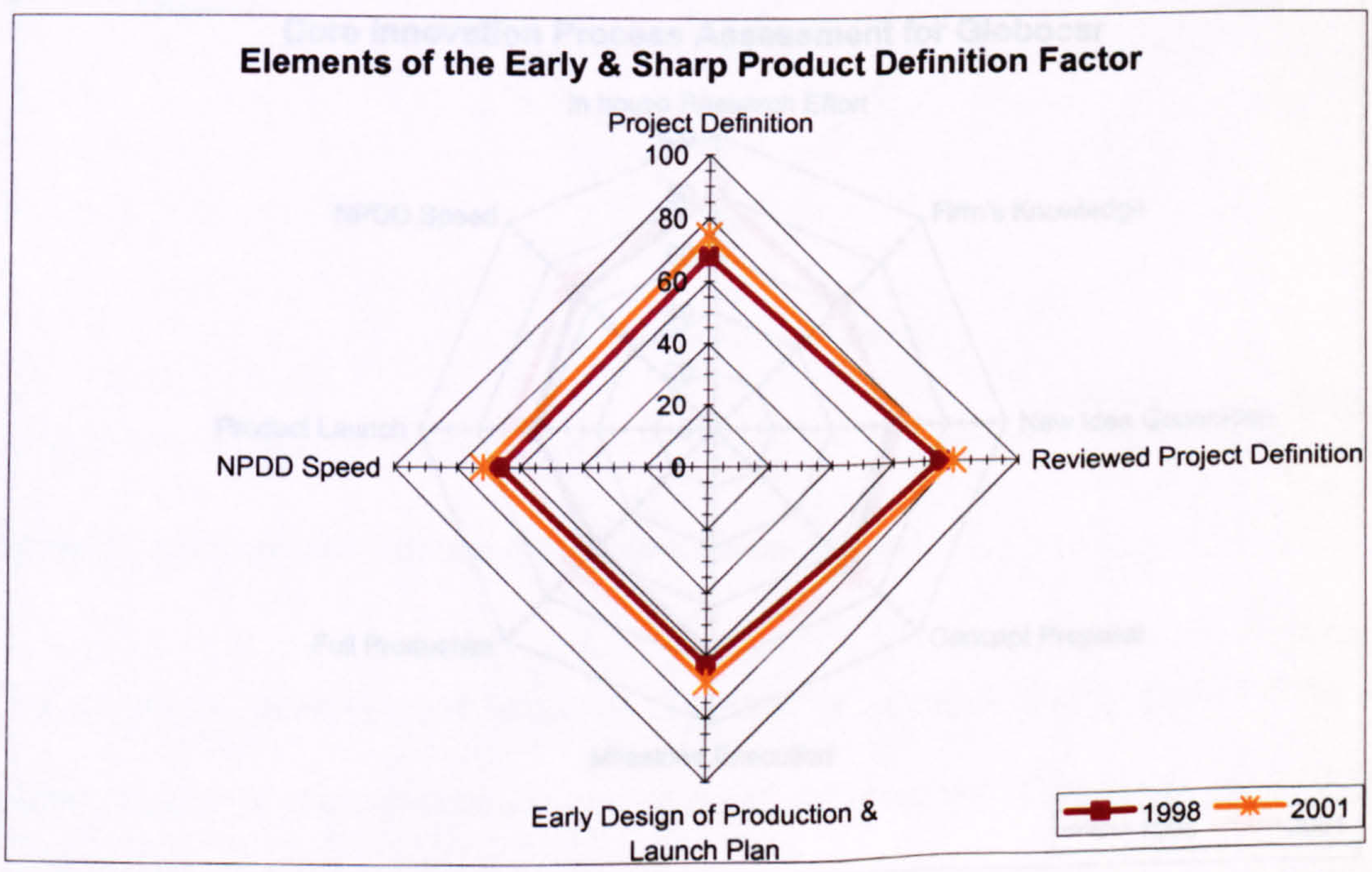


Figure 69. Assessment of the Elements for the Early & Sharp Product Definition Factor

7.1.1.2 <u>The Core Innovation Process for Globocar</u>

Figure 70 illustrates the status of the elements that form the core innovation process for Globocar for the years 1998 and 2001. Except for the firm's knowledge and new ideas generation process, all the other factors were at a 'good' or 'very good' level in 2001. It is important to notice that the firm's knowledge status is only characterised as 'adequate' although the research effort is consistently assessed as 'very good'. The reason for this result can be traced to the influence of the core competencies and employees' creative activity, factors that influence the transformation of the in-house research effort to knowledge for the firm (see Section 7.1.1.3).

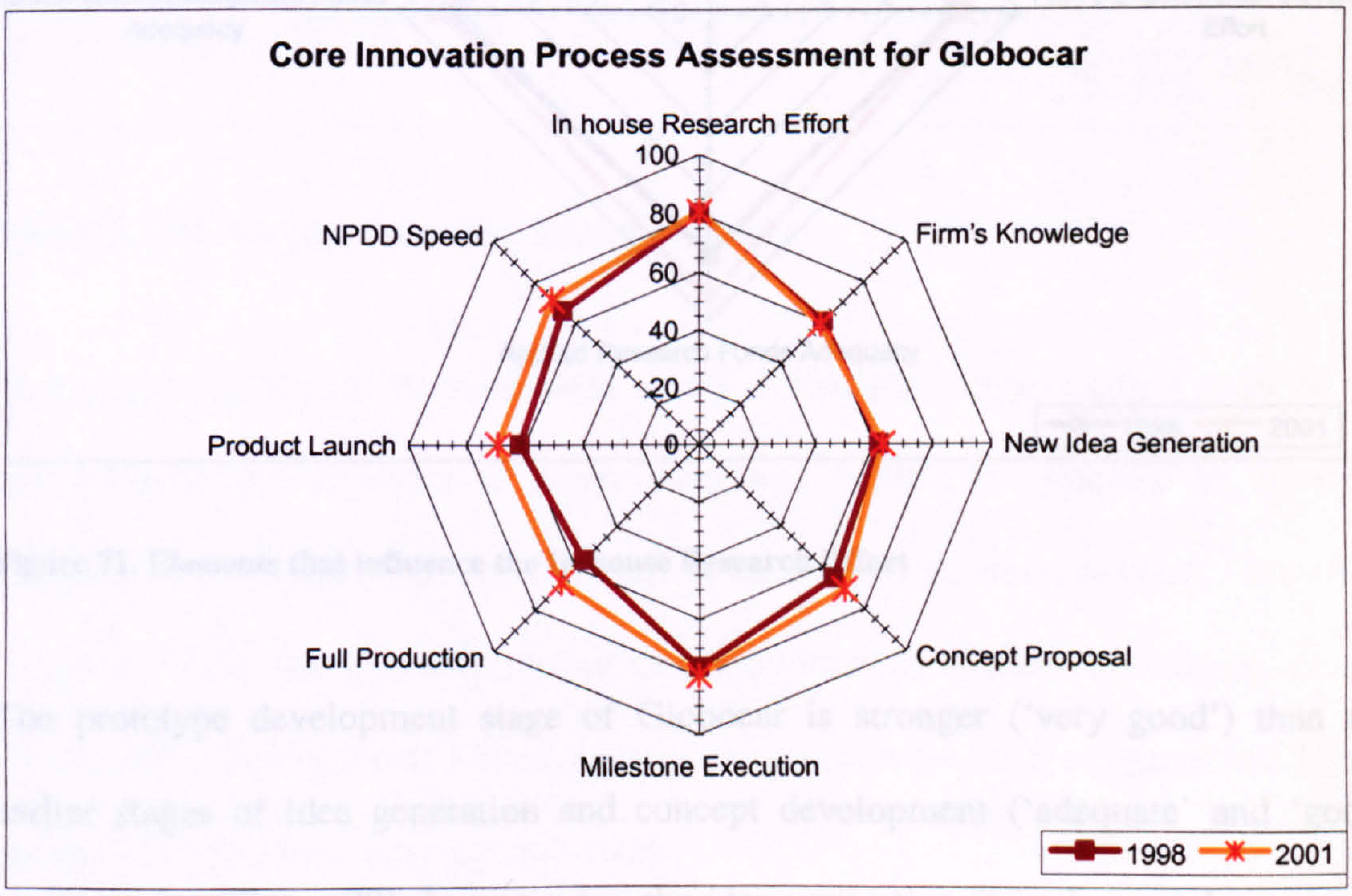


Figure 70. Core Innovation Process Factors for Globocar

Although the capital investment in applied research improved to an 'excellent' level in 2001 (Figure 71), this has not resulted in a significant change in the applied research effort or in the overall in-house research effort. This is because organisational factors, such as the corporate strategy and the understanding of the benefits that the firm gains from research, remain at the 'adequate' level. Thus the investment of capital alone, if it is not followed by organisational improvements, is not adequate to improve the research activity.

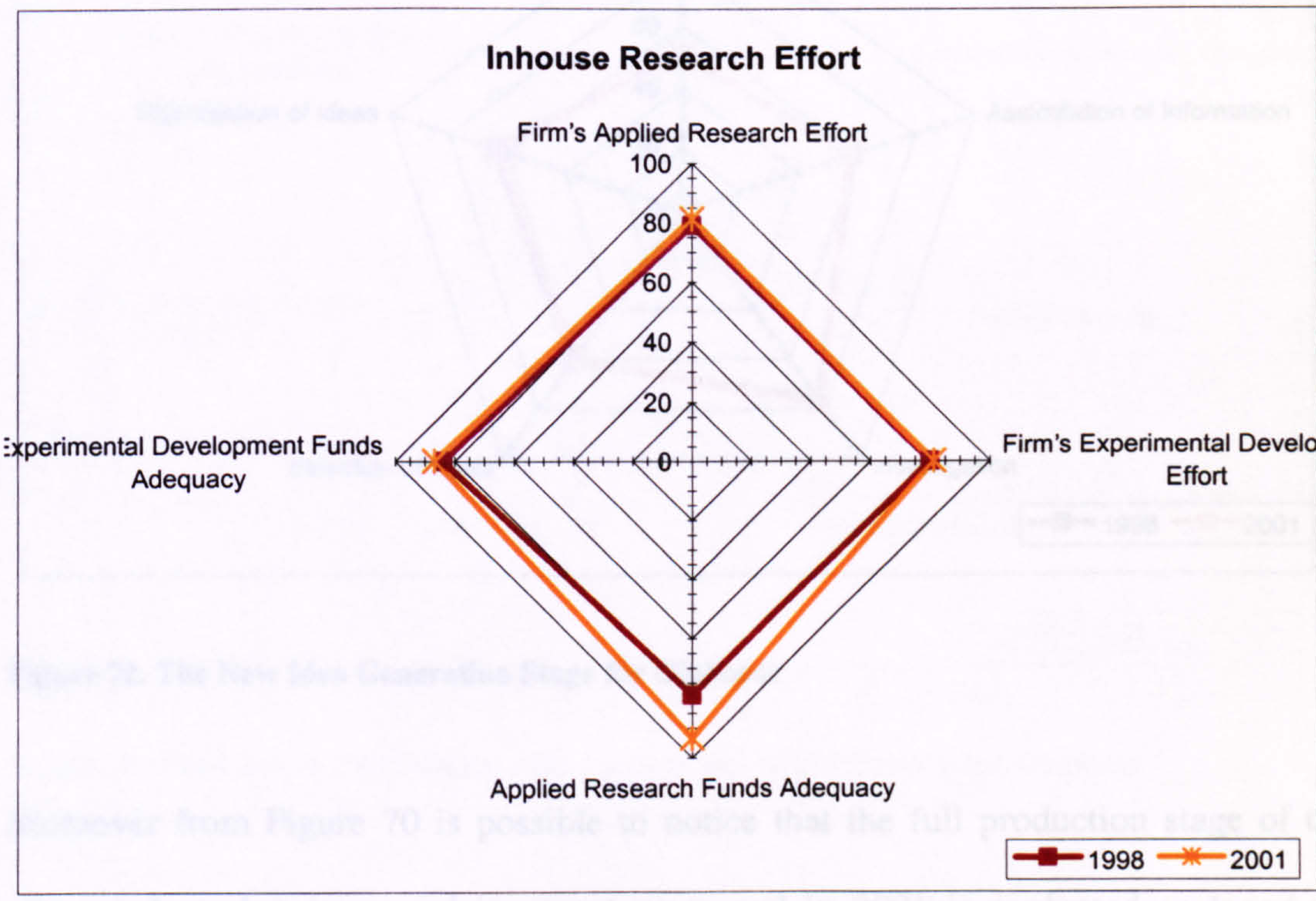


Figure 71. Elements that influence the In-house Research Effort

The prototype development stage of Globocar is stronger ('very good') than the earlier stages of idea generation and concept development ('adequate' and 'good' respectively) (Figure 70). In particular, the idea generation stage is weak because the firm does not give enough attention to the early stages of the process, which are to collect information and opportunities for new products ('adequate-to-poor') and to assimilate this information into the firm ('adequate'). The investigation of new ideas on the other hand is 'very good-to-good' but the selection and prioritisation processes are evaluated at lower levels, as 'adequate' and 'adequate-to-good' respectively (Figure 72).

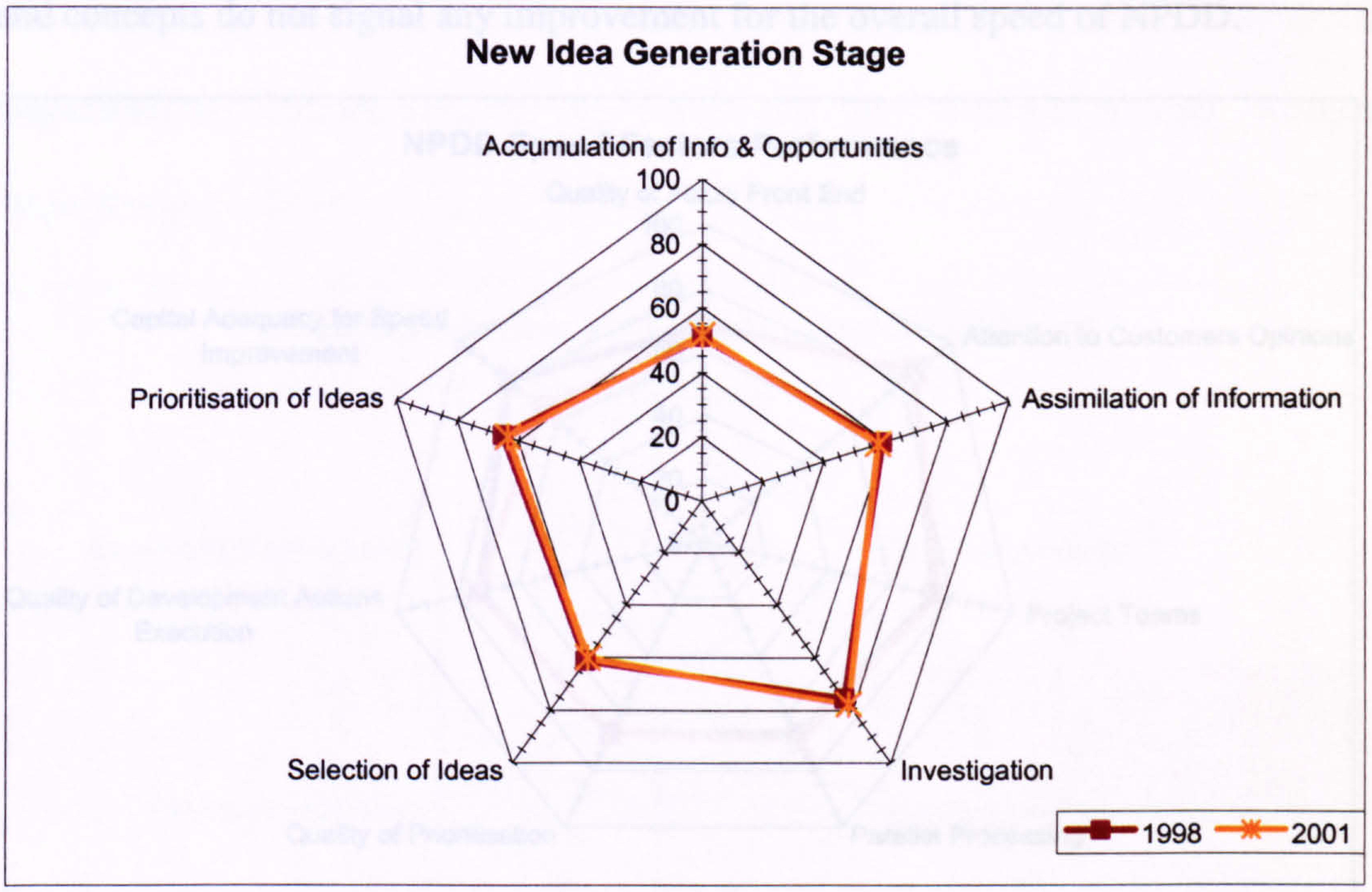


Figure 72. The New Idea Generation Stage for Globocar

Moreover from Figure 70 is possible to notice that the full production stage of the new products has improved in recent years and in 2001 is evaluated as 'good-to-adequate'. The competencies of Globocar to launch new products have also improved to 'good'. These last two stages however, need further investment in order to become 'very good' and to provide a level equal to the expectations that are generated by the status of the prototype development stage.

Finally the speed of Globocar in introducing new products is assessed as 'good' with only a small improvement over the last four years because of the problems of capital investment in the factors related to the speed of NPDD. The capital investment has decreased in the last two years (Figure 73), something that may signal a decline in the speed of NPDD. Additionally, the status of execution of the early stages of the NPDD process, degree of concurrency of the different stages and the prioritisation of ideas and concepts do not signal any improvement for the overall speed of NPDD.

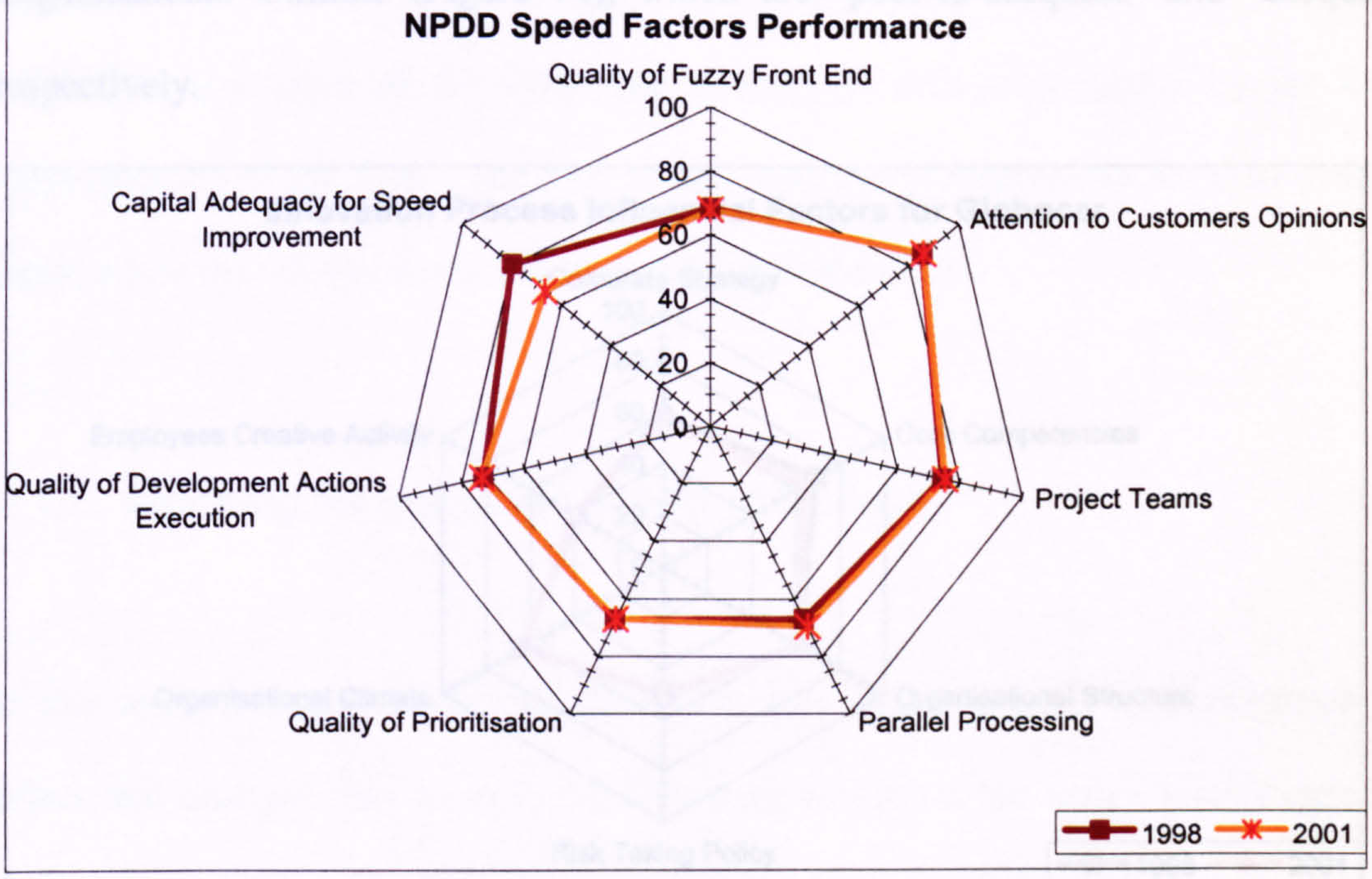


Figure 73. The Factors that Influence the speed of the NPDD Process for Globocar

7.1.1.3 The Organisational Factors that Influence the Core Innovation Process for Globocar

The organisational factors that influence the innovation process are assessed as 'adequate' or 'poor' for 2001. In particular, the Employees' Creative Activity is evaluated as 'poor'. Even the Core Competences dropped to 'adequate-to-good' in 2001 from a 'good' status in 1998 (Figure 74).

Although Globocar has a 'very good-to-good' level of employee availability, its effort to promote creativity between its employees is 'adequate-to-poor', resulting only in an 'adequate' outcome in the level of the firm's knowledge (Figure 75). The promotion of creativity is influenced partly by the Risk Taking Policy and partly by the Organisational Climate (Figure 74), which are 'poor-to-adequate' and 'adequate' respectively.

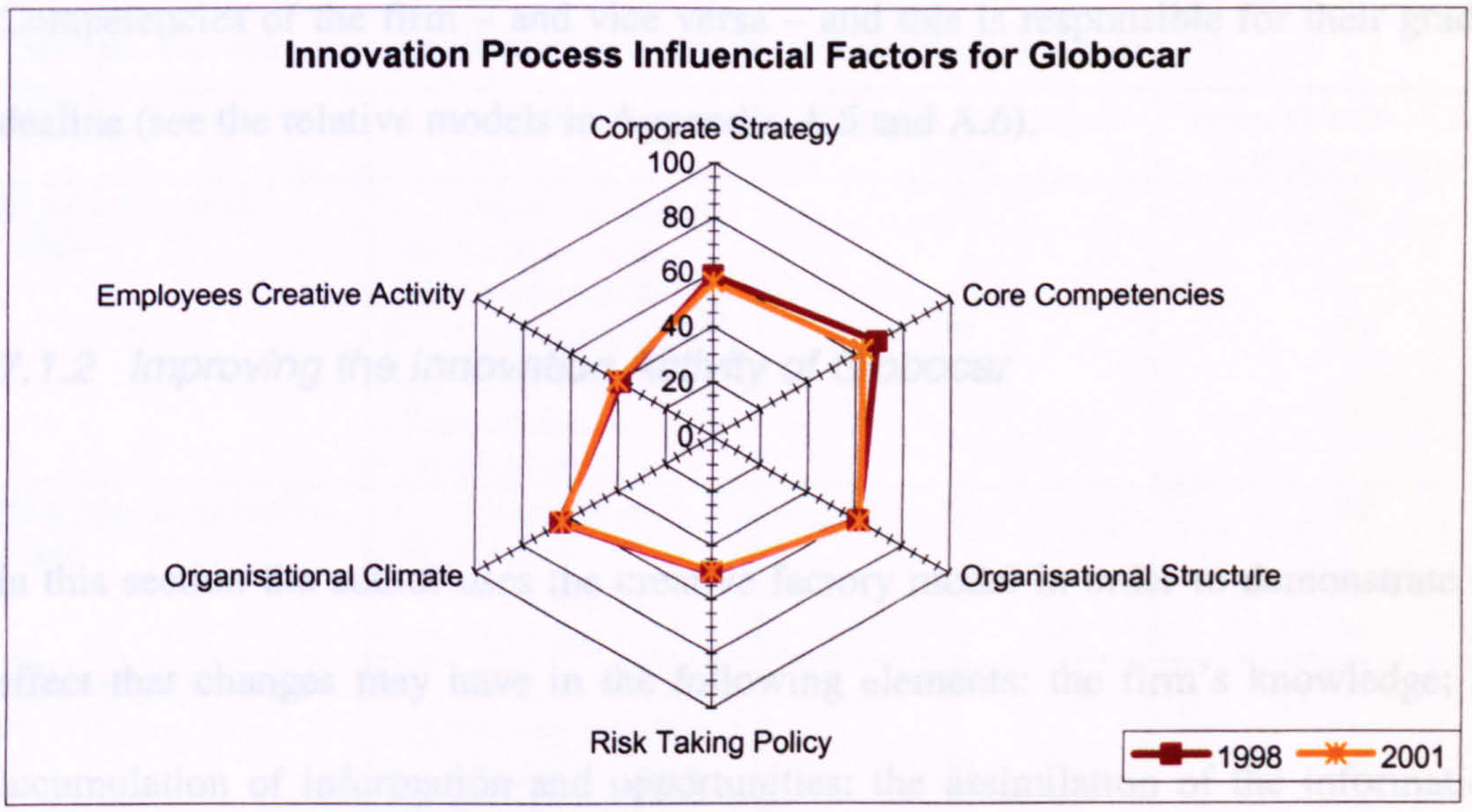


Figure 74. Influential Factors in the Innovation Process for Globocar

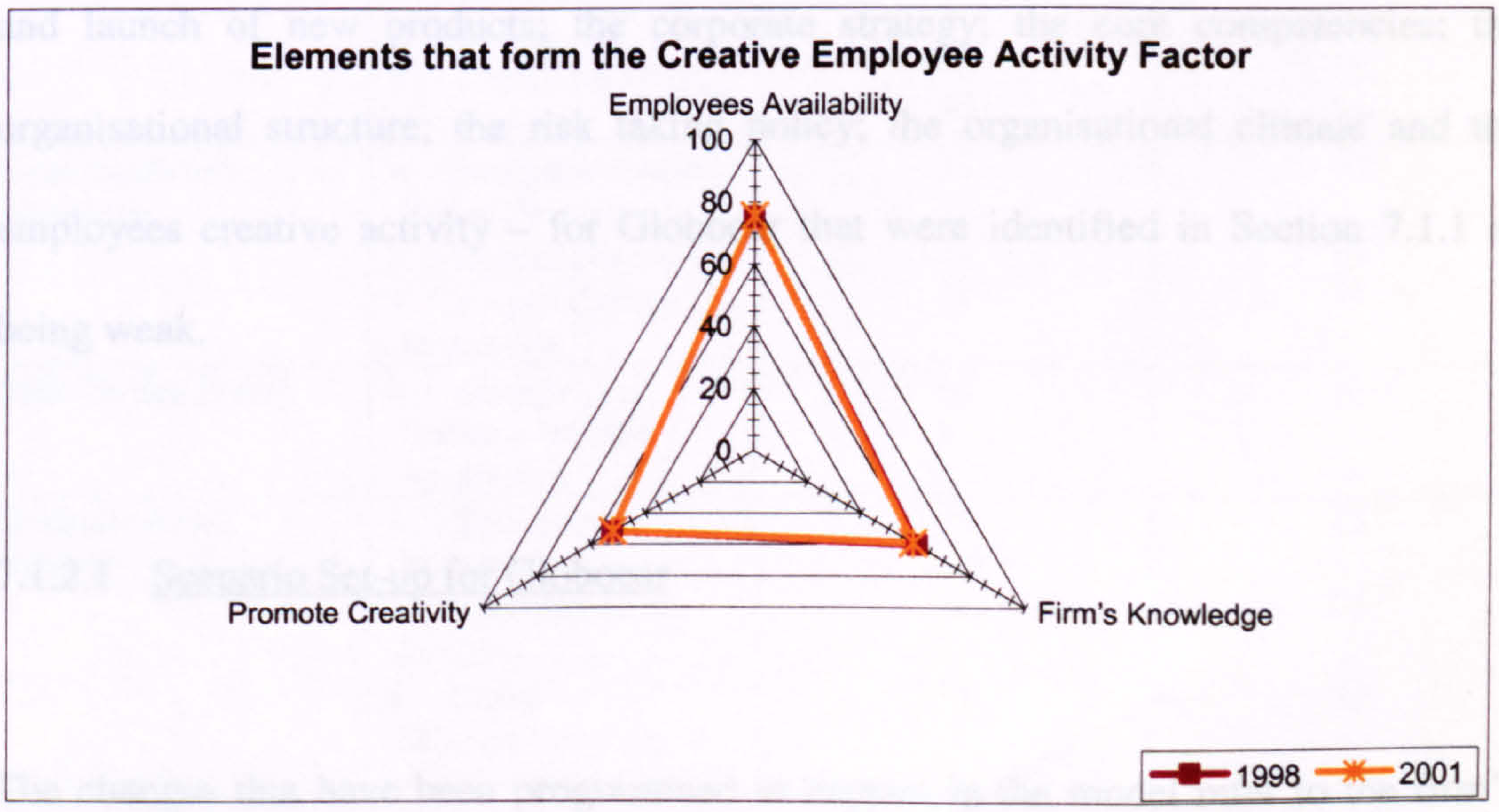


Figure 75. The Elements that Form the Creative Employees Activity Index for Globocar

The Structure of the firm is 'adequate' and is sustained at this level over the years of the study. However, the Core Competencies and the Corporate Strategy have shown a decline over the last few years. This is because of the connection of the Core Competencies to the level of the firm's knowledge, which is stable at the 'adequate' level. The formation of the Corporate Strategy is influenced partly by the Core Competencies of the firm – and vice versa – and this is responsible for their gradual decline (see the relative models in Appendix A.5 and A.6).

7.1.2 Improving the Innovation Activity of Globocar

In this section the author uses the creative factory model in order to demonstrate the effect that changes may have in the following elements: the firm's knowledge; the accumulation of information and opportunities; the assimilation of the information; new idea generation; the selection and prioritisation of ideas; the full production stage and launch of new products; the corporate strategy; the core competencies; the organisational structure; the risk taking policy; the organisational climate and the employees creative activity – for Globocar that were identified in Section 7.1.1 as being weak.

7.1.2.1 Scenario Set-up for Globocar

The changes that have been programmed to happen in the model refer to the firm's knowledge, the new idea generation stage and the six factors that influence the core innovation process, keeping the capital availability for the NPDD process at the same level. The variables that change in the simulation are summarised in Table 26. They have been given a value on a scale of 0-100 for the status at the end of the year 2001, when the case study finished, and a value after five years of simulation time (simulation year 2001+5). The simulation then continues with this level for five more years (simulation year 2001+10), to show the long-term effect of these changes.

Table 26. Variables that are changed to Improve the Performance of Globocar

Model Sub-system	Variables	Value at the end of 2001	Value at 2001+5 years of simulation
Firm's Research Effort	• Understanding of the Benefits from Applied Research • Understanding of the Benefits from Experimental Development	70 70	90 90
New Idea Generation Stage	• Collection of Information • Collection of Opportunities	50 50	90 90
Corporate Strategy	• Ready to React to Technology Changes • Ready to React to Market Changes	50 70	90 90
Core Competencies	• Invest in Development • Invest in Machinery • Import Technology • Training	80 80 70 80	95 95 95 95
Organisational Structure	• Individual Project Group Structure • Decentralisation • Project Groups Integration	75 75 70	95 95 95
Risk Taking Policy	• Management Decision for Risk Acceptance	60	95
Organisational Climate	• Tolerance to Mistakes • Recognition of Success • Senior Management Culture • Weight of Culture	75 75 75 90	95 95 95 40
Creative Employees Activity	• Recruitment Policy	40	95

The firm's knowledge is expected to have improved mainly as a consequence of the improvement in the core competencies and in the employees' creative activity. The research effort of the firm however needs to be kept at a high level by convincing the management of the benefits that the firm may gain from applied research and experimental development. The new idea generation stage, as described in the assessment section 7.1.1.2, needs to improve the mechanism of collecting information and to identify opportunities from more sources. The improvement of the firm's idea generation and the selection and prioritisation of these ideas is expected to be achieved in accordance with the expected improvements in the firm's knowledge, the risk taking policy and the employees' creative activity.

The full production and launch of new products stages already show an improving trend. This trend will be supported further by progress in the core competencies and their steady financing.

The corporate strategy of the firm and the risk taking policy are two factors that need to be re-examined by Globocar. The corporate strategy needs to create an environment that will allow the technology directions and market position to be more flexible and ready to react to changes. A higher risk acceptance by the management will improve the strategy of the firm and the creative activity of the employees. Also it will signal a higher level of tolerance to mistakes and recognition of success, something that will improve the organisational climate. The core competencies on the other hand, although they have a 'good' level of investment already, could benefit from further investment and by the improvement of the firm's knowledge. The structure of the firm could improve further and be decentralised and integrated around the project teams. Finally the recruitment policy could be improved to identify creative employees; to cover the needs of specialties and to promote the creative activity of the employees.

7.1.2.2 Scenario Results for Globocar

At the end of the simulation, the level of the Globocar factors that were previously assessed as weak, had reached a 'very good' status, except for the firm's knowledge, new idea generation and organisational structure (Figure 76 and Figure 77).

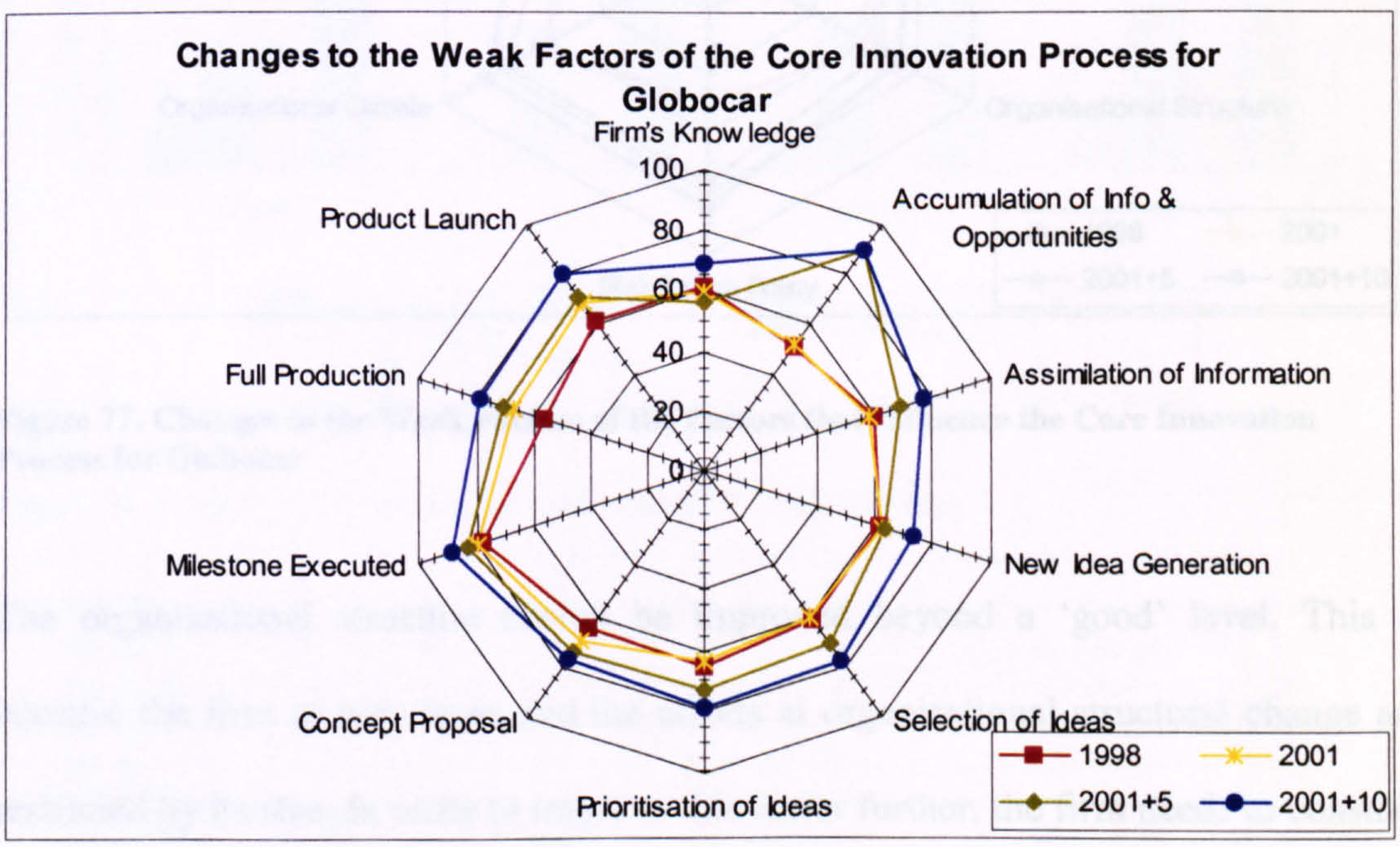


Figure 76. Changes to the Weak Factors of the Core Innovation Process for Globocar

The firm's knowledge and new idea generation status are shown as 'good' and 'good-to-very good' because, during the period that the measurement has taken (simulation year: 2001+5), the model simulates a creative destruction (see Section 7.4.2) that reduces their value substantially. Figure 76 shows, however, that after the firm recovers from the creative destruction the firm's knowledge and idea generation have a strong trend towards improvement. This means that the proposed changes protect the firm from such unexpected events.

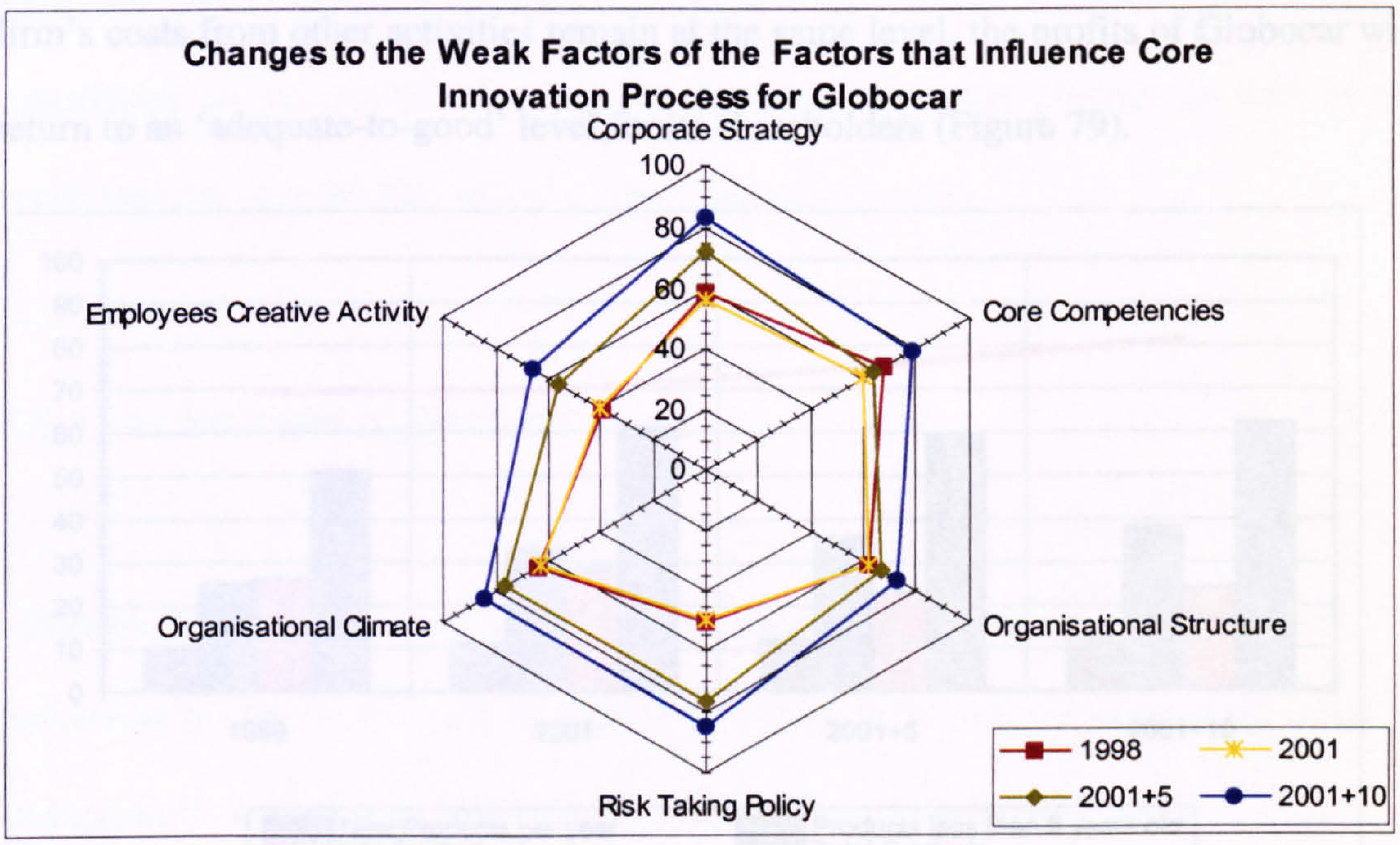


Figure 77. Changes to the Weak Factors of the Factors that Influence the Core Innovation Process for Globocar

The organisational structure cannot be improved beyond a 'good' level. This is because the firm is very large and the efforts at organisational structural change are restricted by its size. In order to improve this factor further, the firm needs to consider a new type of structure with different divisions of the firm, each totally independent and organised individually.

The result of the improvement in these factors to the overall performance of Globocar is shown in Figure 78. The index of success for new products is improving by the end of the simulation to a 'very good' level. Based on this NPDD index of success the number of new products per year is 12 after five years of improvements and 13 at the end of the simulation. This is a number that brings the ratio of less than three years old to old products in favour of the former. This ratio will improve the sales of the firm as two thirds of sales are of products less than three years old. Assuming that the firm's costs from other activities remain at the same level, the profits of Globocar will return to an 'adequate-to-good' level for its shareholders (Figure 79).

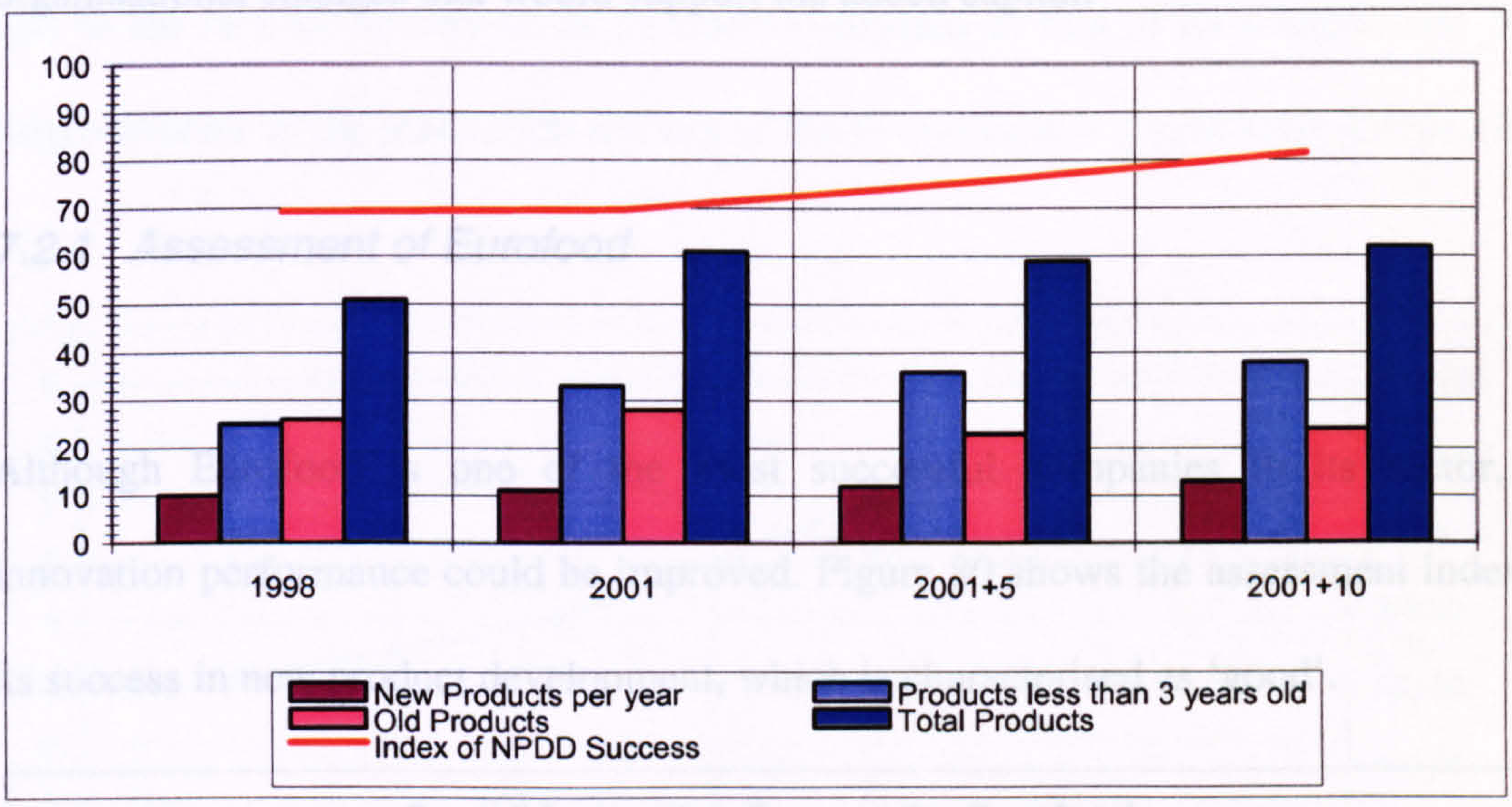


Figure 78. Overall Performance for Globocar after Improvements

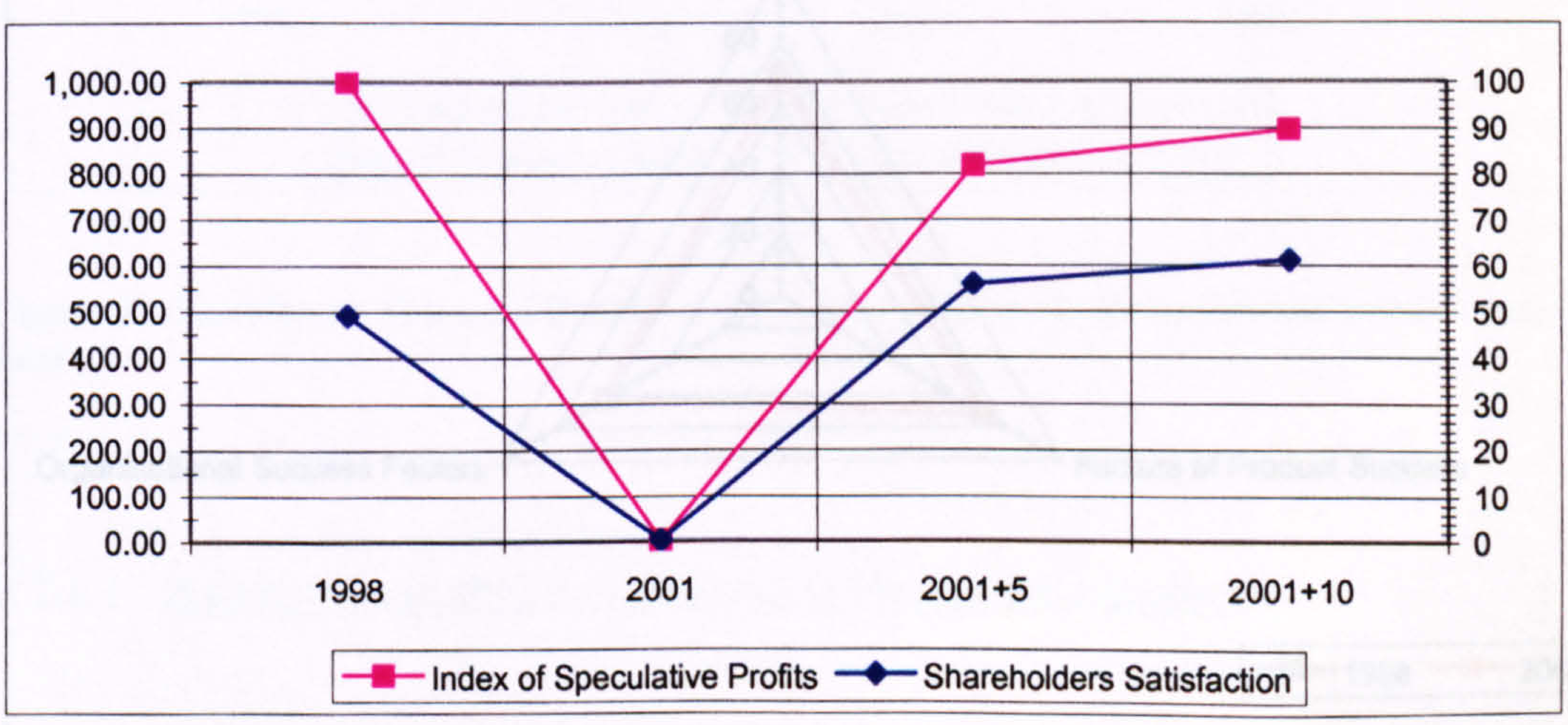


Figure 79. Simulation of Profits and Shareholder Satisfaction for Globocar

7.2 Eurofood

The Creative Factory model is used in this section to assess the innovation activity of Eurofood and to propose changes that could improve this activity. These changes concentrate on the capital adequacy for the core innovation process, as well as the organisational changes that would support the added capital.

7.2.1 Assessment of Eurofood

Although Eurofood is one of the most successful companies in its sector, its innovation performance could be improved. Figure 80 shows the assessment index of its success in new product development, which is characterised as ‘good’.

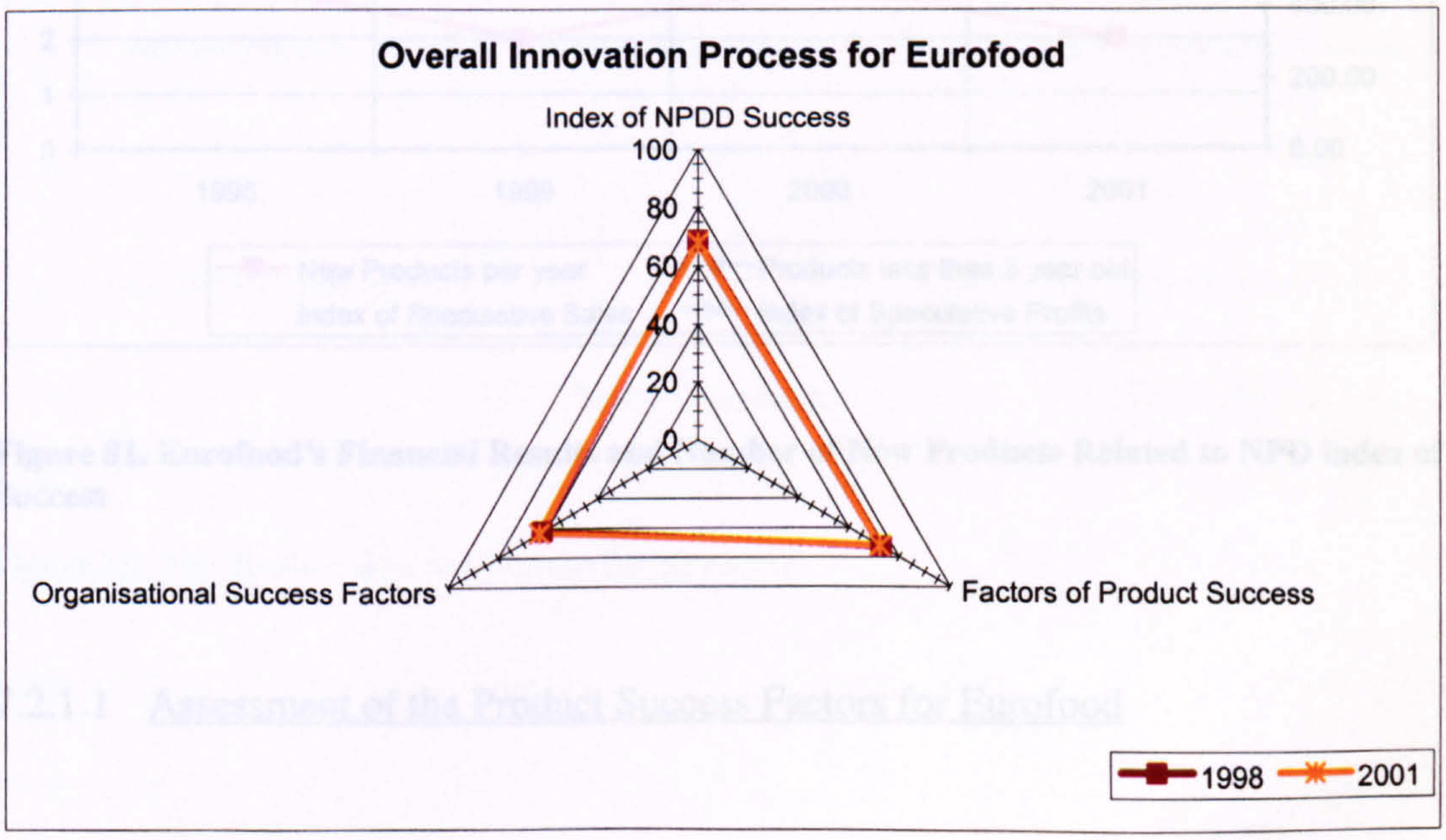


Figure 80. Assessment Results for the Overall Innovation Process for Eurofood

This level has been generated as a result of the 'good-to-very good' characteristics of the final product, and the 'adequate-to-good' organisational factors.

Eurofood has slightly increased the number of products less than three years old (Figure 81), but its sales are heavily dependent on the older products. The improvement in profits has been achieved by the reduction of costs (see Section 6.2). This improvement however seems to be at its limit as the firm's sales are decreasing due to the lack of novelty of its products compared to that of its competitors. Thus improvements in the innovation activity of the firm should improve sales and profits.

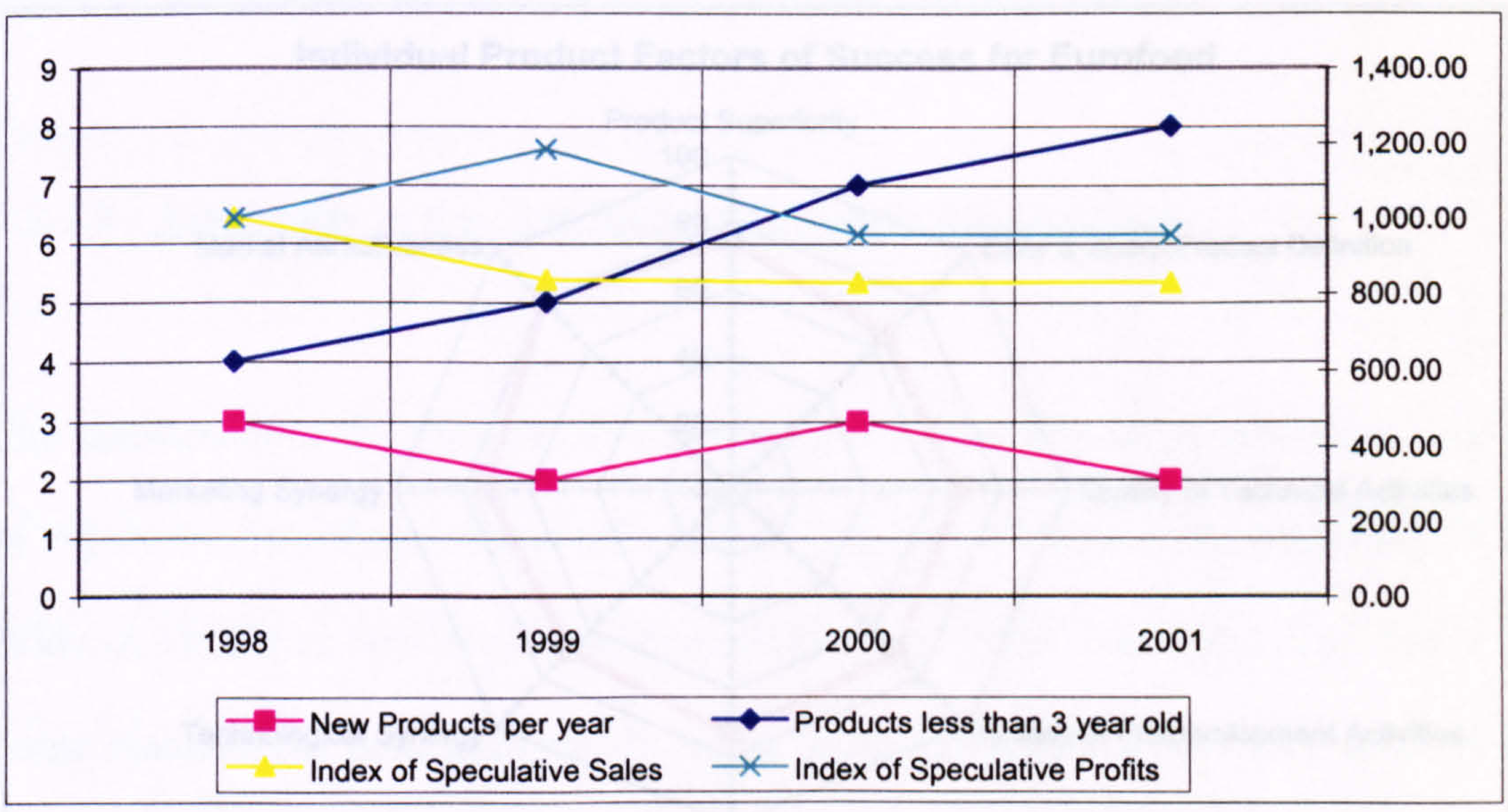


Figure 81. Eurofood's Financial Results and Number of New Products Related to NPD index of Success

7.2.1.1 Assessment of the Product Success Factors for Eurofood

The factors that predict a high probability of the success of a new product at Eurofood are evaluated as 'good' or 'very good' (Figure 82). In particular, the factors related to the marketing activity of the firm are assessed as 'very good' for the whole period of the study. The new products that have been introduced into the market, although they are not characterised by high novelty, appear to give benefits to the customers and to meet their expectations to a very high degree. The technologically related factors however, are only characterised as 'good'. The Early and Sharp Product Definition factor, in particular, is relatively low, only 'good-to-adequate', because of the late involvement of the production team and the launch team into the NPDD process, which are characterised as 'adequate' and the project definition characterised as 'adequate-to-good' (Figure 83).

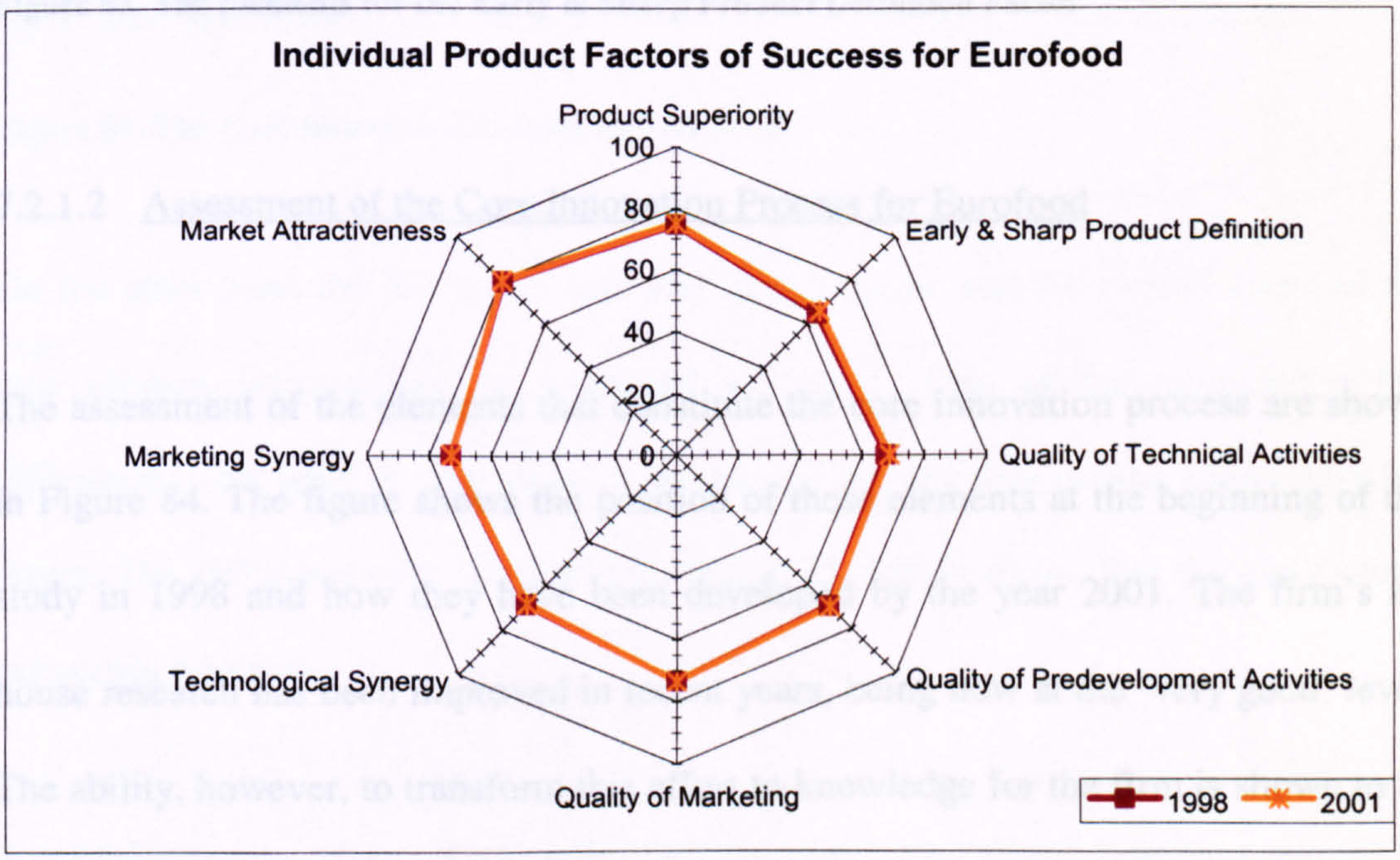


Figure 82. The Product Success Factors for Eurofood

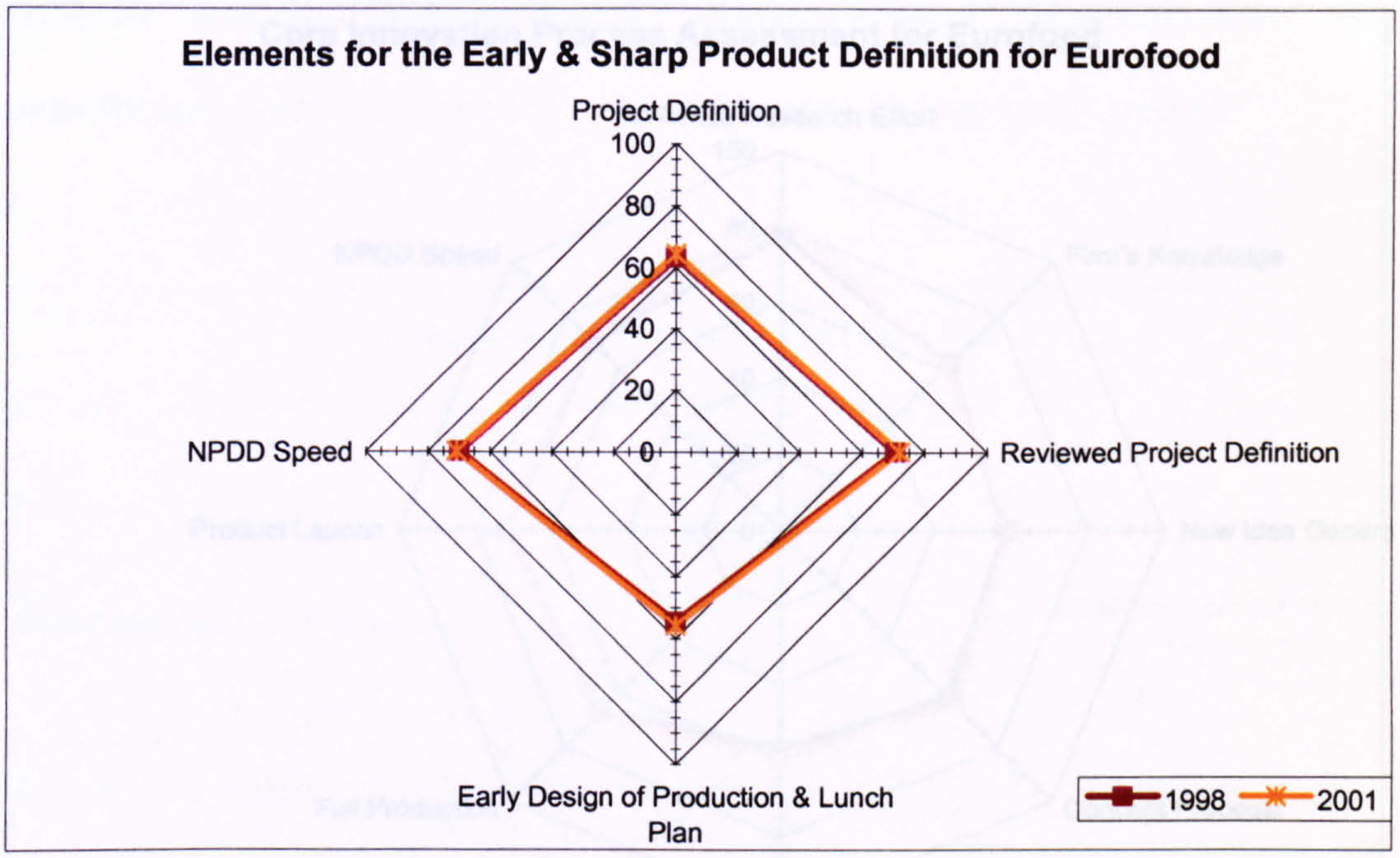


Figure 83. The Elements for the Early & Sharp Product Definition Factor

7.2.1.2 <u>Assessment of the Core Innovation Process for Eurofood</u>

The assessment of the elements that constitute the core innovation process are shown in Figure 84. The figure shows the position of these elements at the beginning of the study in 1998 and how they have been developed by the year 2001. The firm's in-house research has been improved in recent years, being now at the 'very good' level. The ability, however, to transform this effort to knowledge for the firm is shown to be weaker, being classified as 'adequate'. This result can be traced to the status of the core competencies and the level of employees' creativity (Section 7.2.1.3). The three first stages of the NPDD process are assessed as 'adequate', with very little improvement in recent years.

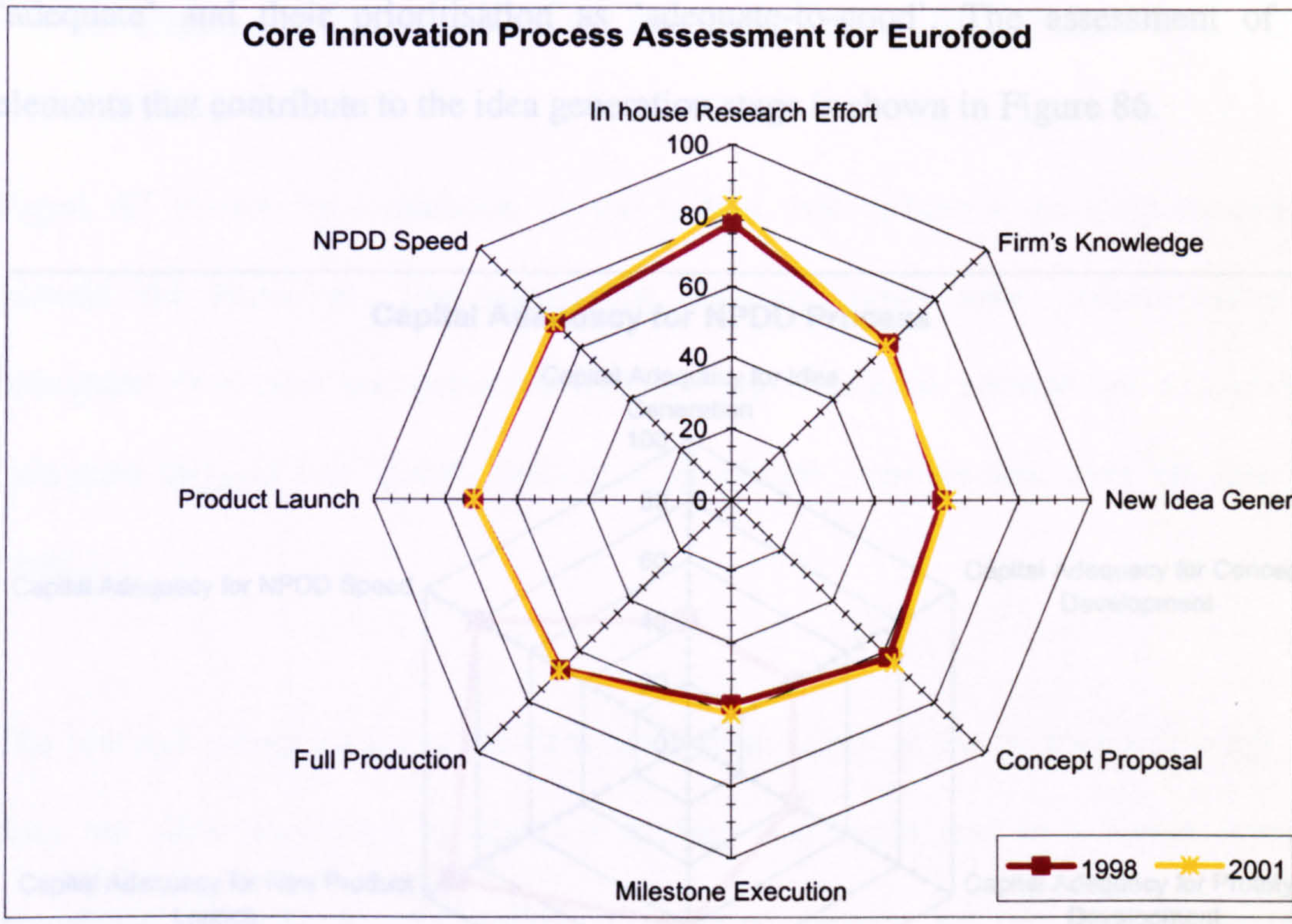


Figure 84. The Core Innovation Factors for Eurofood

On the other hand the full production and launch stages and the overall speed of the new product introduction are evaluated as 'good'. One of the reasons for this difference is the relative proportion of the capital that the firm invests in the different stages. The differences are illustrated in Figure 85, which shows that the early stages are poorly financed.

In addition to the 'poor' finance of the idea generation stage, Eurofood pays little attention to the accumulation of information and opportunities from different sources. This is assessed as 'adequate'. Furthermore, the assimilation of this information into the firm is 'adequate', a factor that is a consequence of the organisational structure and the firm's knowledge. This subsequently affects the investigative ability of the firm which is classed as 'adequate-to-poor'. The selection of new ideas is evaluated as 'adequate' and their prioritisation as 'adequate-to-good'. The assessment of the elements that contribute to the idea generation stage is shown in Figure 86.

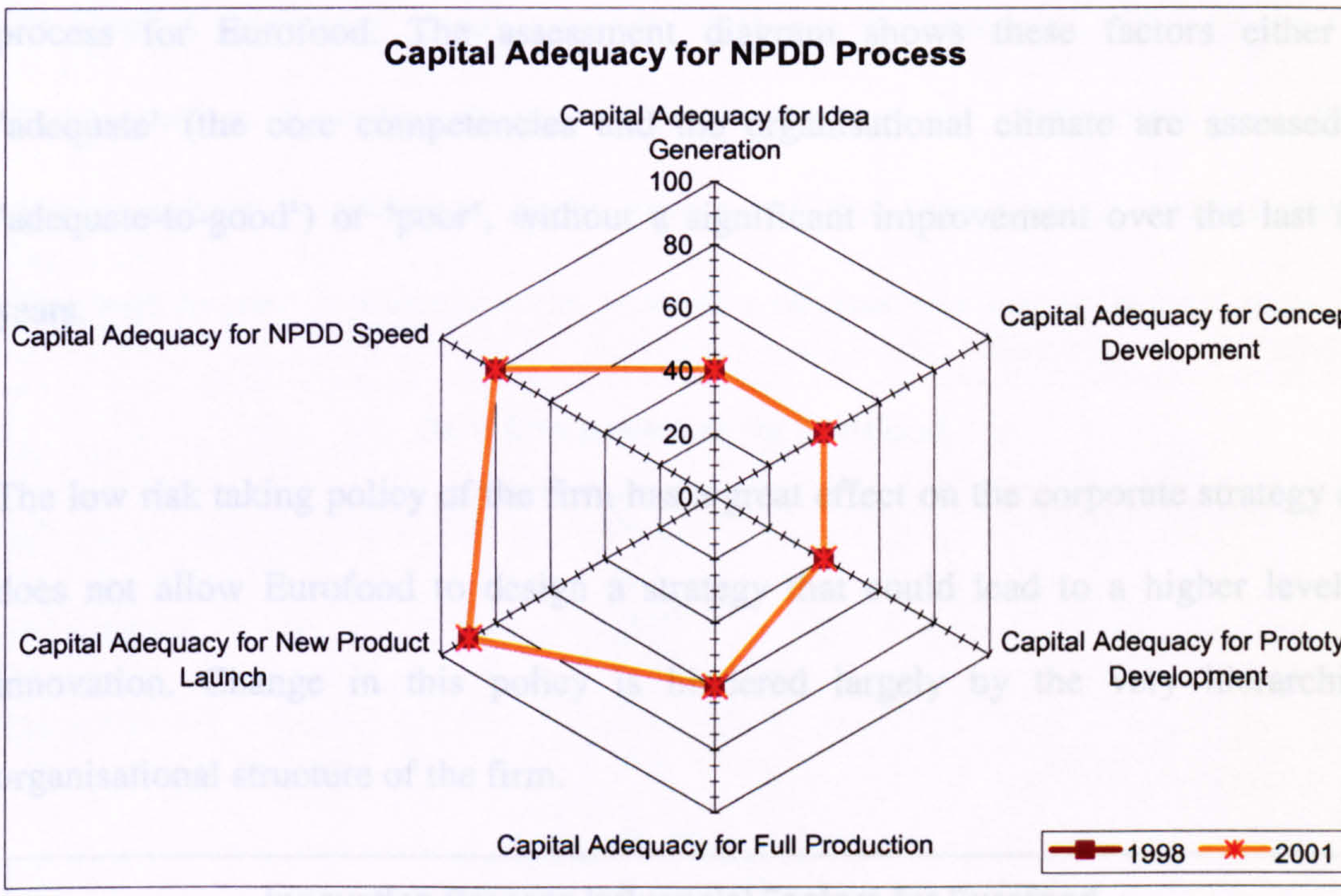


Figure 85. The Capital Adequacy for the NPDD Process of Eurofood

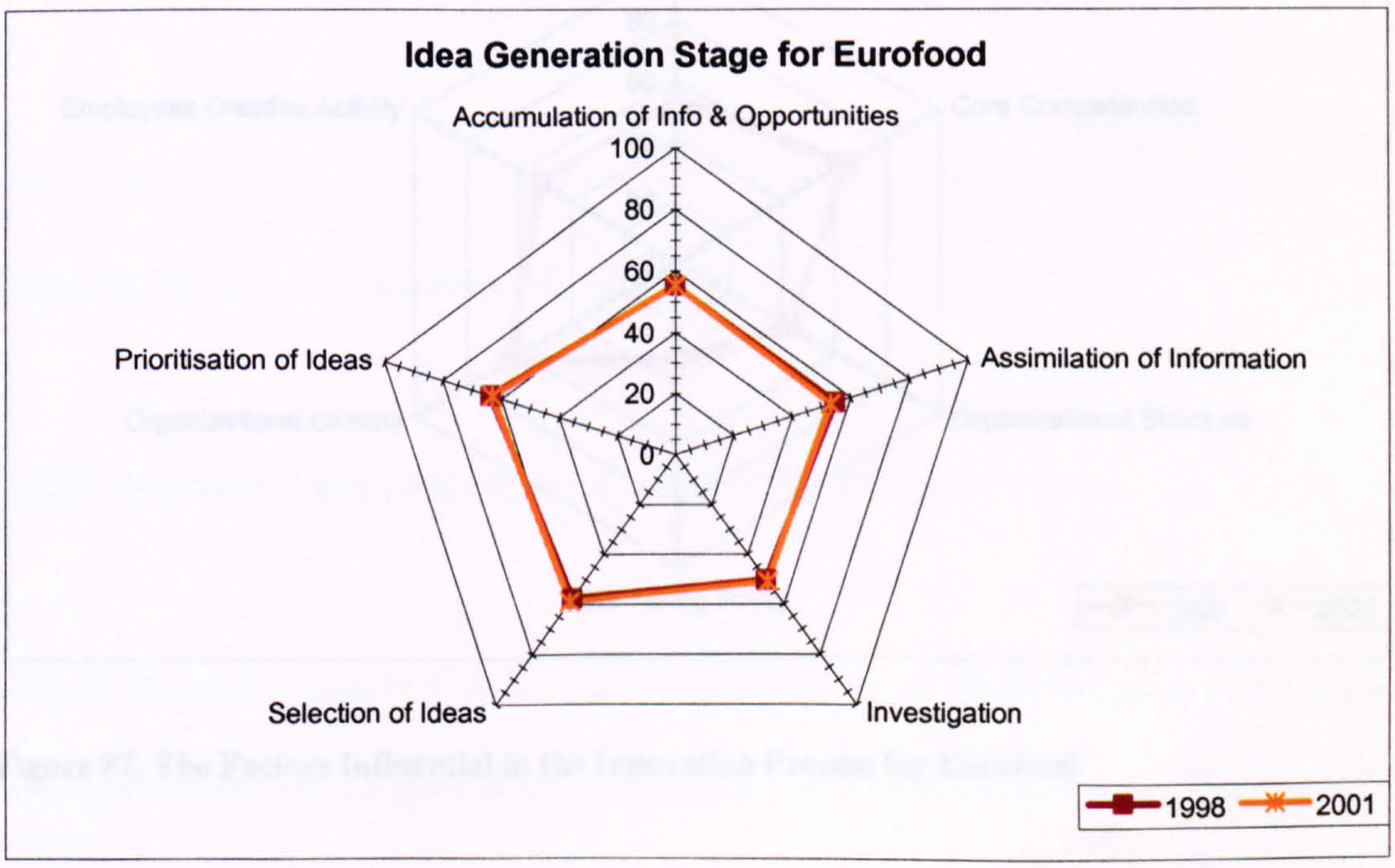


Figure 86. The Idea Generation Process for Eurofood

7.2.1.3 Factors that Influence the Core Innovation Process for Eurofood

Figure 87 shows the evaluation of the factors that influence the core innovation process for Eurofood. The assessment diagram shows these factors either as 'adequate' (the core competencies and the organisational climate are assessed as 'adequate-to-good') or 'poor', without a significant improvement over the last few years.

The low risk taking policy of the firm has a great effect on the corporate strategy and does not allow Eurofood to design a strategy that could lead to a higher level of innovation. Change in this policy is hindered largely by the very hierarchical organisational structure of the firm.

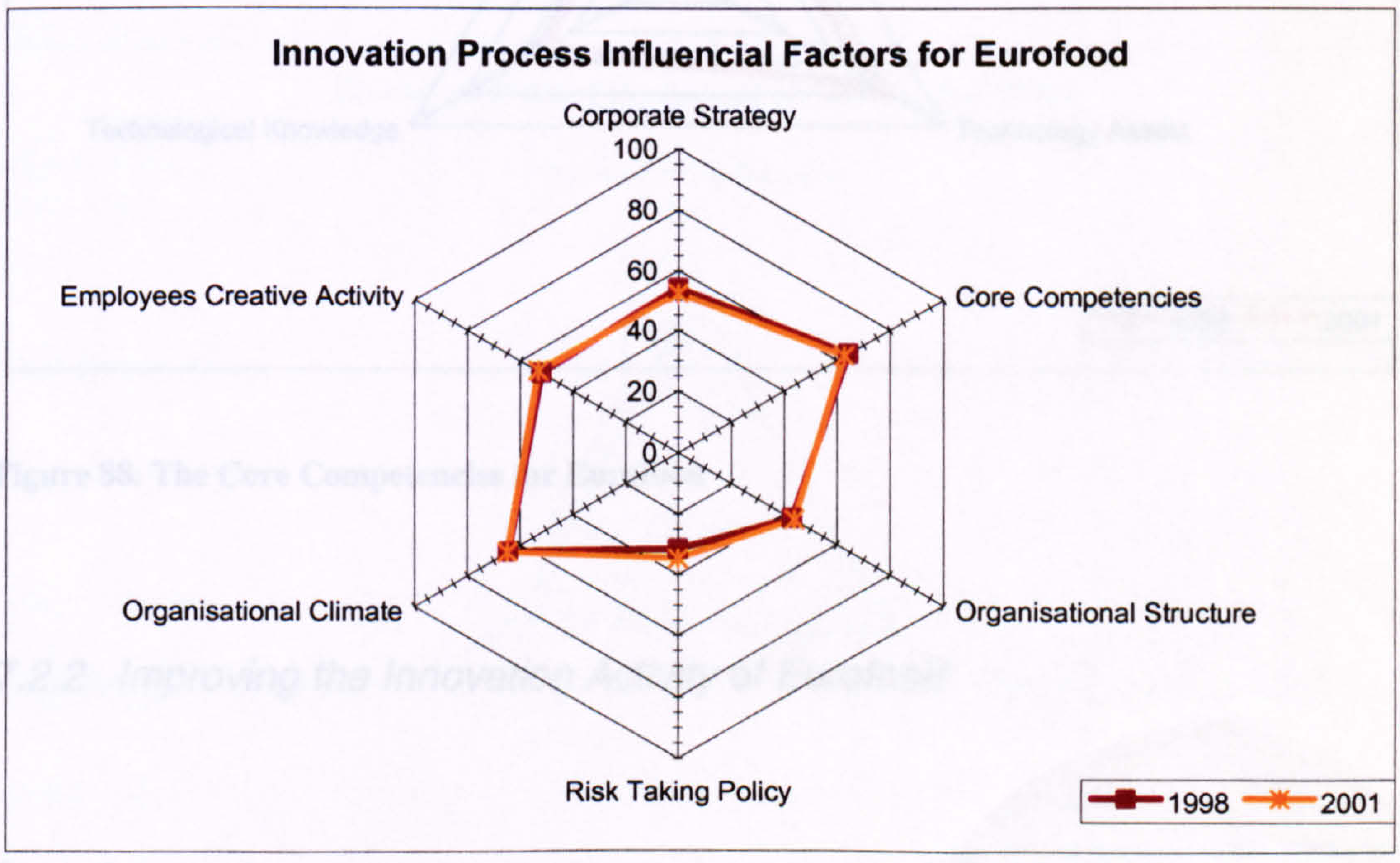


Figure 87. The Factors Influential in the Innovation Process for Eurofood

Although the firm invests heavily in new machinery, its core competencies have not been improved from the 'adequate-to-good' level during recent years (Figure 88).

This is due to the low status of the firm's knowledge that influences the technological knowledge of Eurofood, which has declined in 2001 to a 'poor-to-adequate' level.

The level of employees' creative activity is shown as 'adequate', although the firm has no problem in meeting its need of employees from the employment pool. Their creative activity is influenced by the firm's low risk taking policy and knowledge along with its poor investment in the promotion of creativity among its employees.

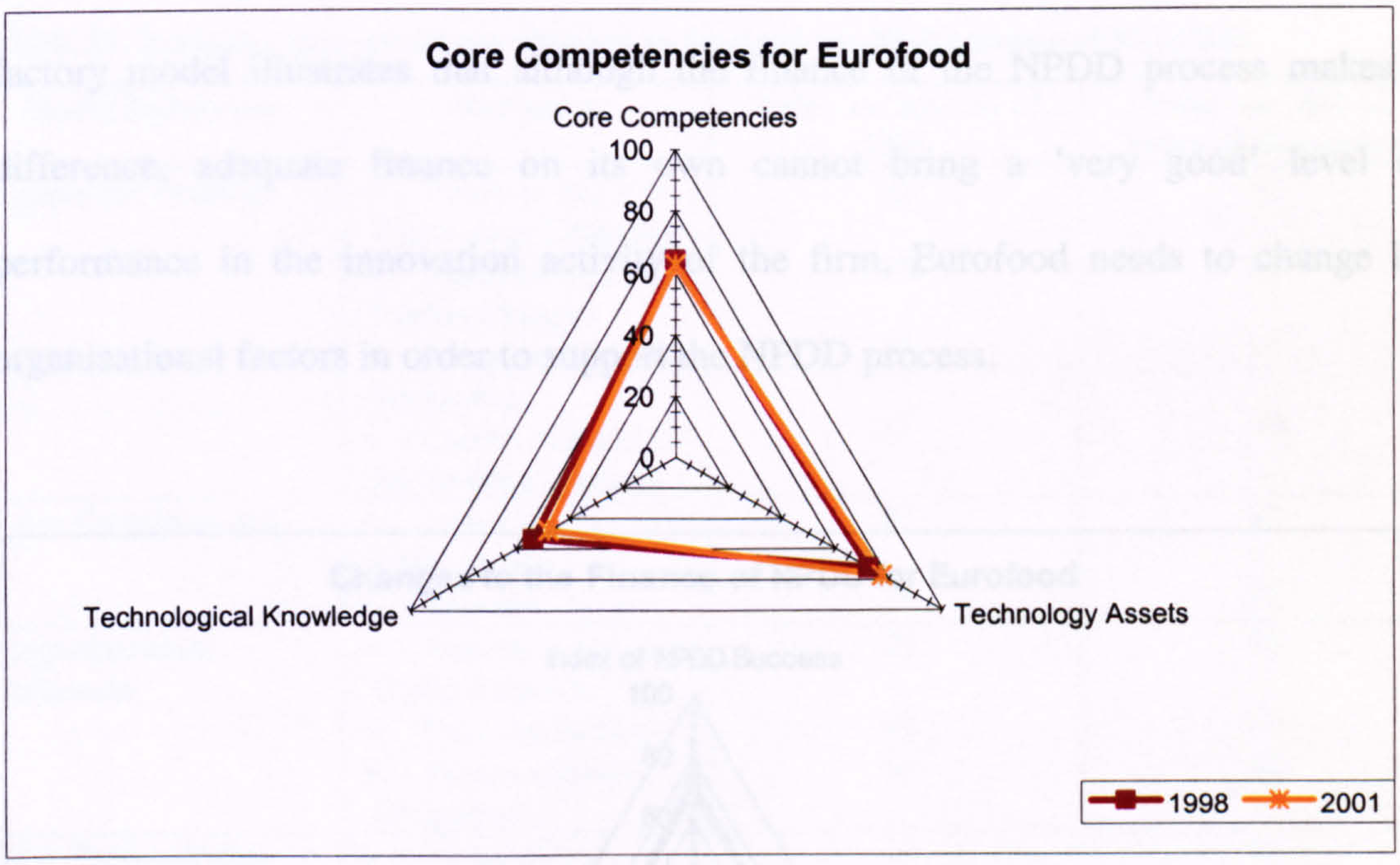


Figure 88. The Core Competencies for Eurofood

7.2.2 Improving the Innovation Activity of Eurofood

One of the main reasons that the innovation activity of Eurofood is maintained at a low level is the low finance at the early stages of the NPDD process. The model has been programmed to assess the effect of reaching a 'very good' level of finance for all stages of the NPDD process within five years from the end of the case study.

Subsequently, the model is programmed to demonstrate the effect of organisational changes in addition to the financial ones.

7.2.2.1 The Effect of Financial Adequacy to the Innovation Activity of Eurofood

Figure 89 shows the indices of innovation activity for Eurofood after the finance of the NPDD stages have reached a 'very good' level. The simulation of the creative factory model illustrates that although the finance of the NPDD process makes a difference, adequate finance on its own cannot bring a 'very good' level of performance in the innovation activity of the firm. Eurofood needs to change its organisational factors in order to support the NPDD process.

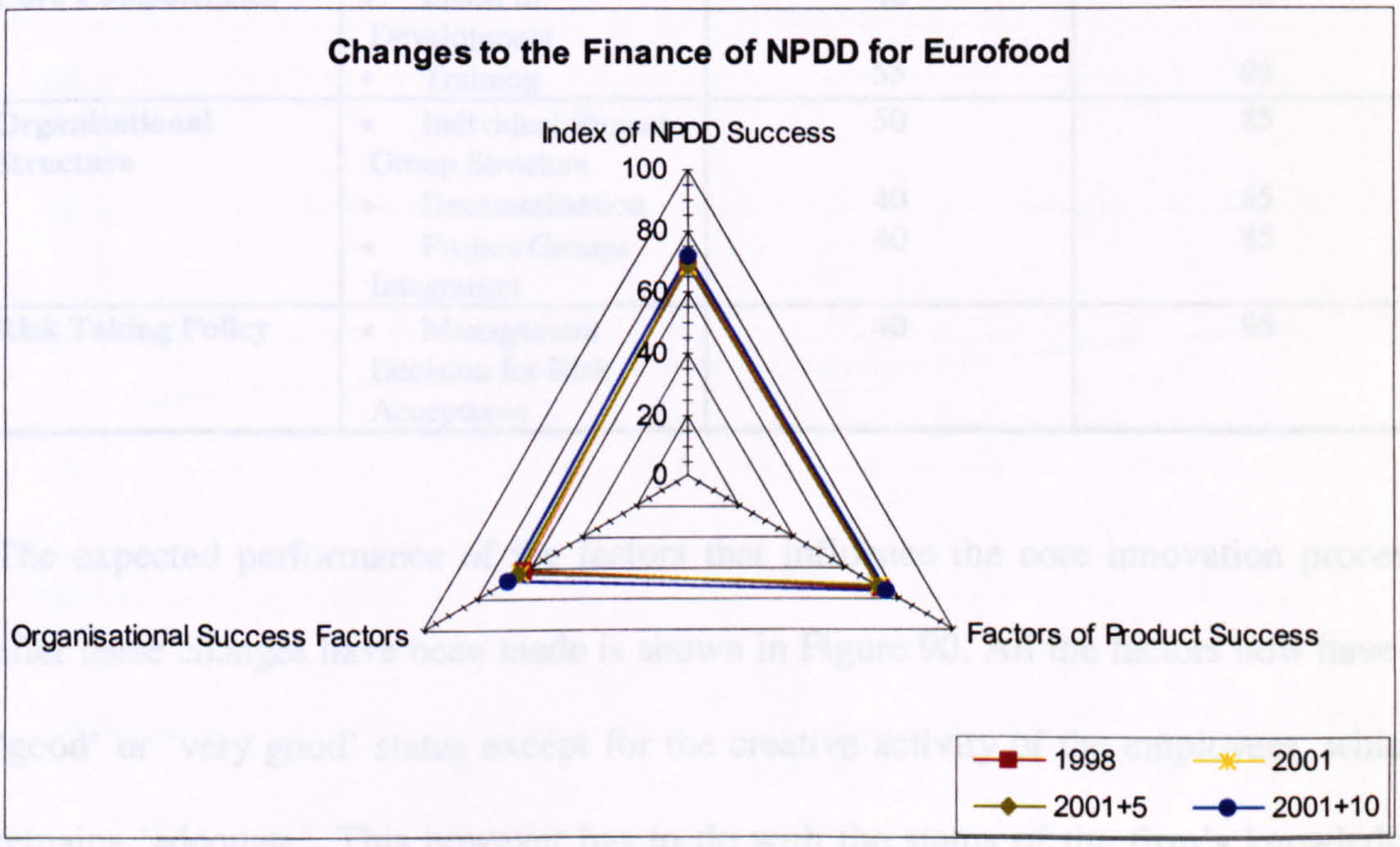


Figure 89. Indexes of Innovation Activity for Eurofood with Very Good Finance of NPDD Process

7.2.2.2 The Effect of Organisational Changes on the Innovation Activity of Eurofood

The organisational factors that the author selected to change are summarised in Table 27. These factors have been assessed either as 'adequate' or 'poor' in Section 7.2.1.3 and they can influence the rest of the factors that show low performance.

Table 27. Variables that have been changed to Improve the Performance of Eurofood

Model Sub-system	Variables	Value on the end of 2001	Value on 2001+5 years of simulation
Corporate Strategy	• Ready to React to Technology Changes	55	95
	• Ready to React to Market Changes	55	95
	• Managers Ideas for Technology	40	95
	• Capital Adequacy for Strategy Changes	75	90
Core Competencies	• Invest in Development	40	95
	• Training	55	95
Organisational Structure	• Individual Project Group Structure	50	85
	• Decentralisation	40	85
	• Project Groups Integration	40	85
Risk Taking Policy	• Management Decision for Risk Acceptance	40	95

The expected performance of the factors that influence the core innovation process after these changes have been made is shown in Figure 90. All the factors now have a 'good' or 'very good' status except for the creative activity of the employees, which remains 'adequate'. This however has to do with the status of the firm's knowledge (Figure 91), which, although it has improved, takes a long time to recover from the possible creative destruction (see Section 7.4.2) that has been programmed to take place in the 2001+5 simulation year.

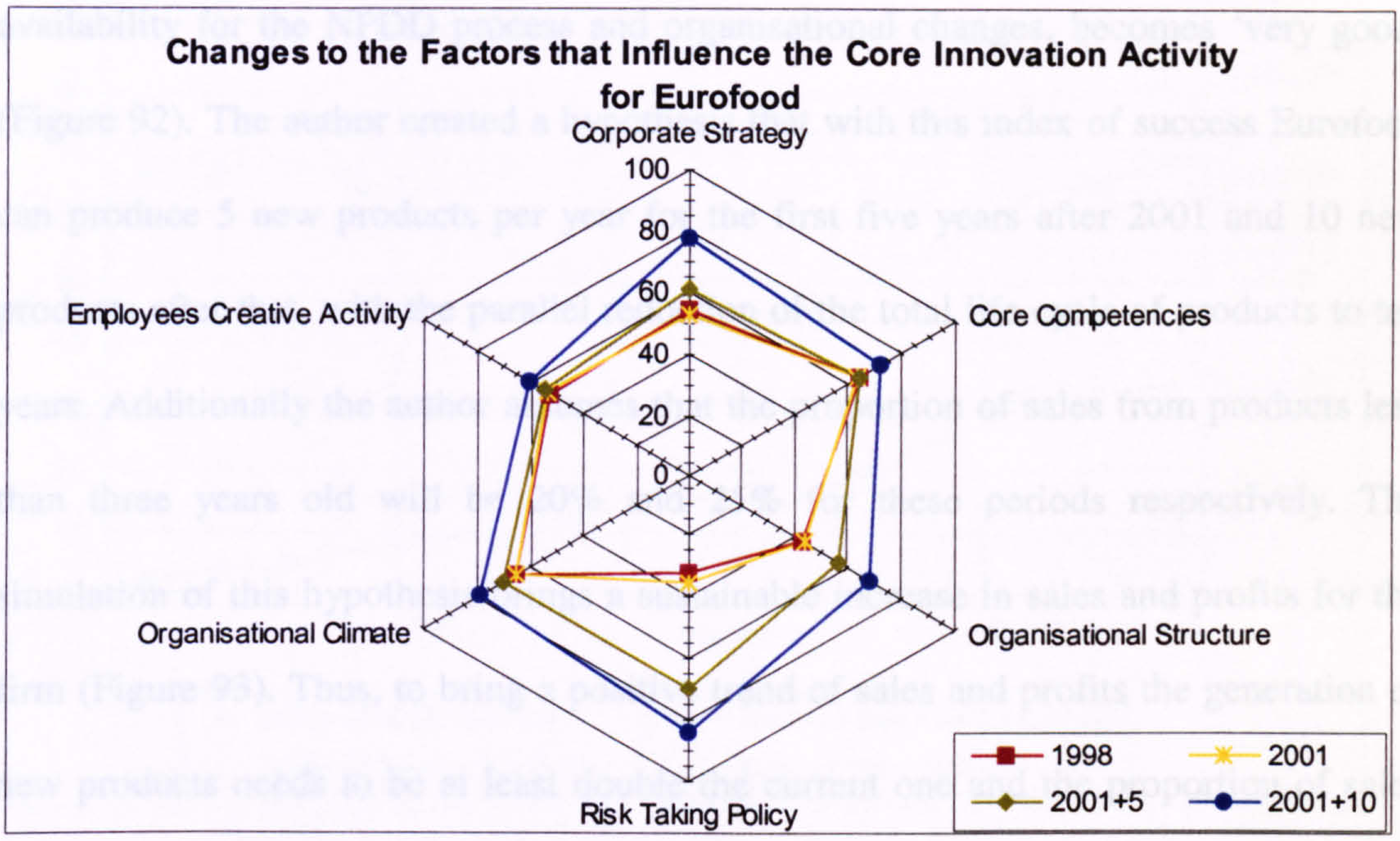


Figure 90. The Expected Performance of the Factors that Influence the Core Innovation Process after the Changes for Eurofood

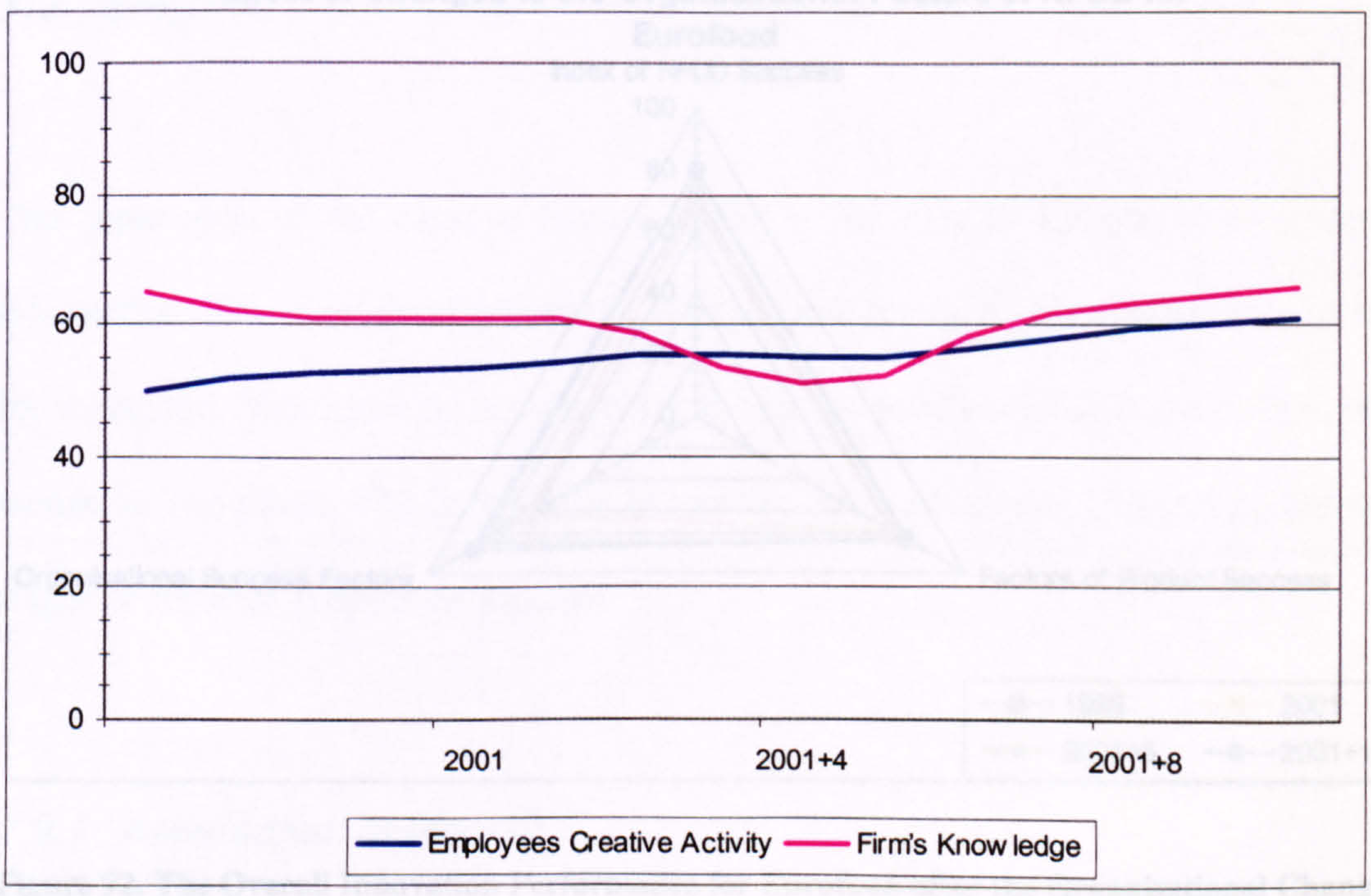


Figure 91. The Expected Performance of the Creative Activity of Employees and the Firm's Knowledge for Eurofood

The index for the innovation activity of Eurofood, after changes in the capital availability for the NPDD process and organisational changes, becomes 'very good' (Figure 92). The author created a hypothesis that with this index of success Eurofood can produce 5 new products per year for the first five years after 2001 and 10 new products after that, with the parallel reduction of the total life cycle of products to ten years. Additionally the author assumes that the proportion of sales from products less than three years old will be 20% and 25% for these periods respectively. The simulation of this hypothesis brings a sustainable increase in sales and profits for the firm (Figure 93). Thus, to bring a positive trend of sales and profits the generation of new products needs to be at least double the current one and the proportion of sales from new products needs to be increased to more than 20%.

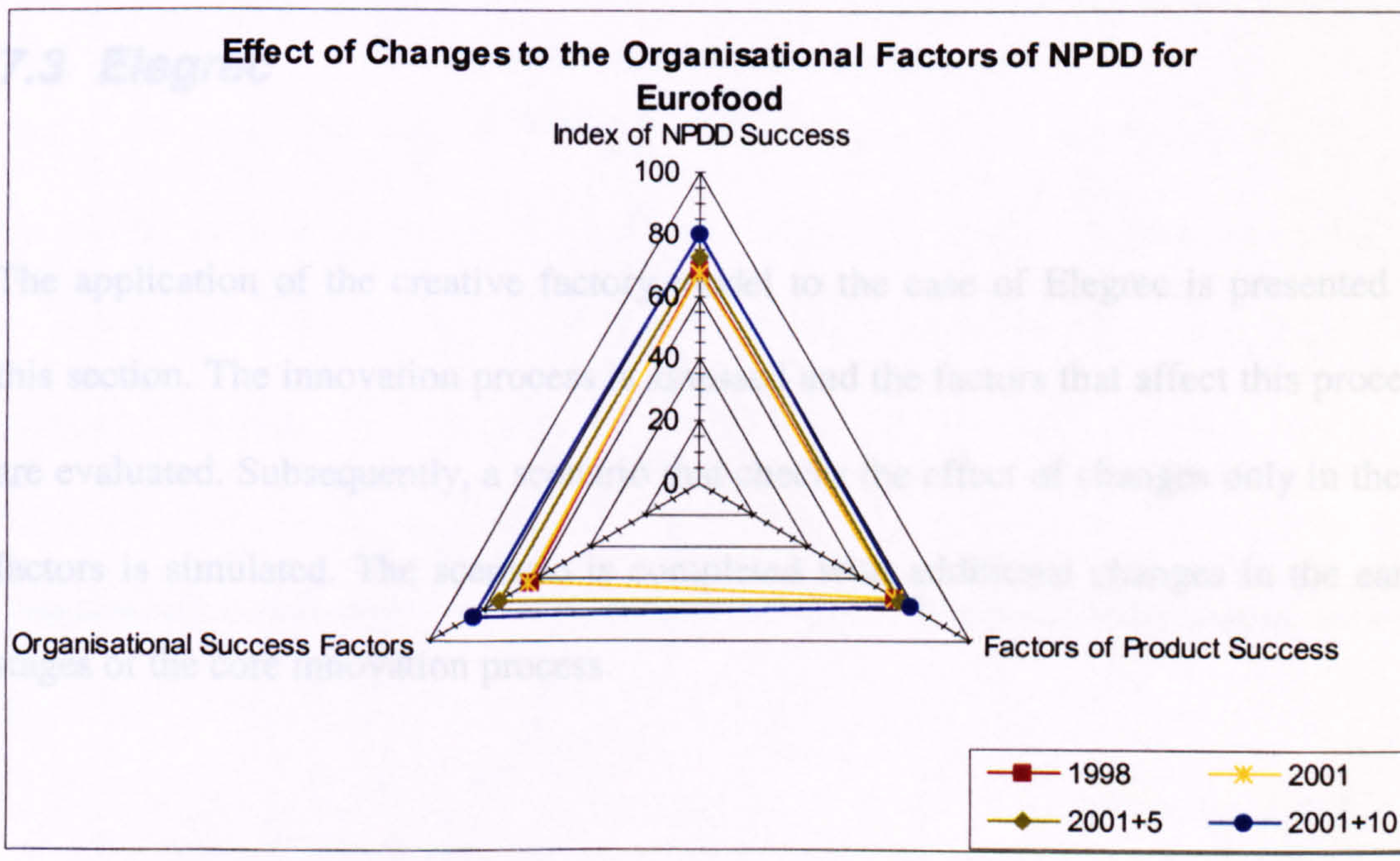


Figure 92. The Overall Innovation Performance for Eurofood after the Organisational Changes

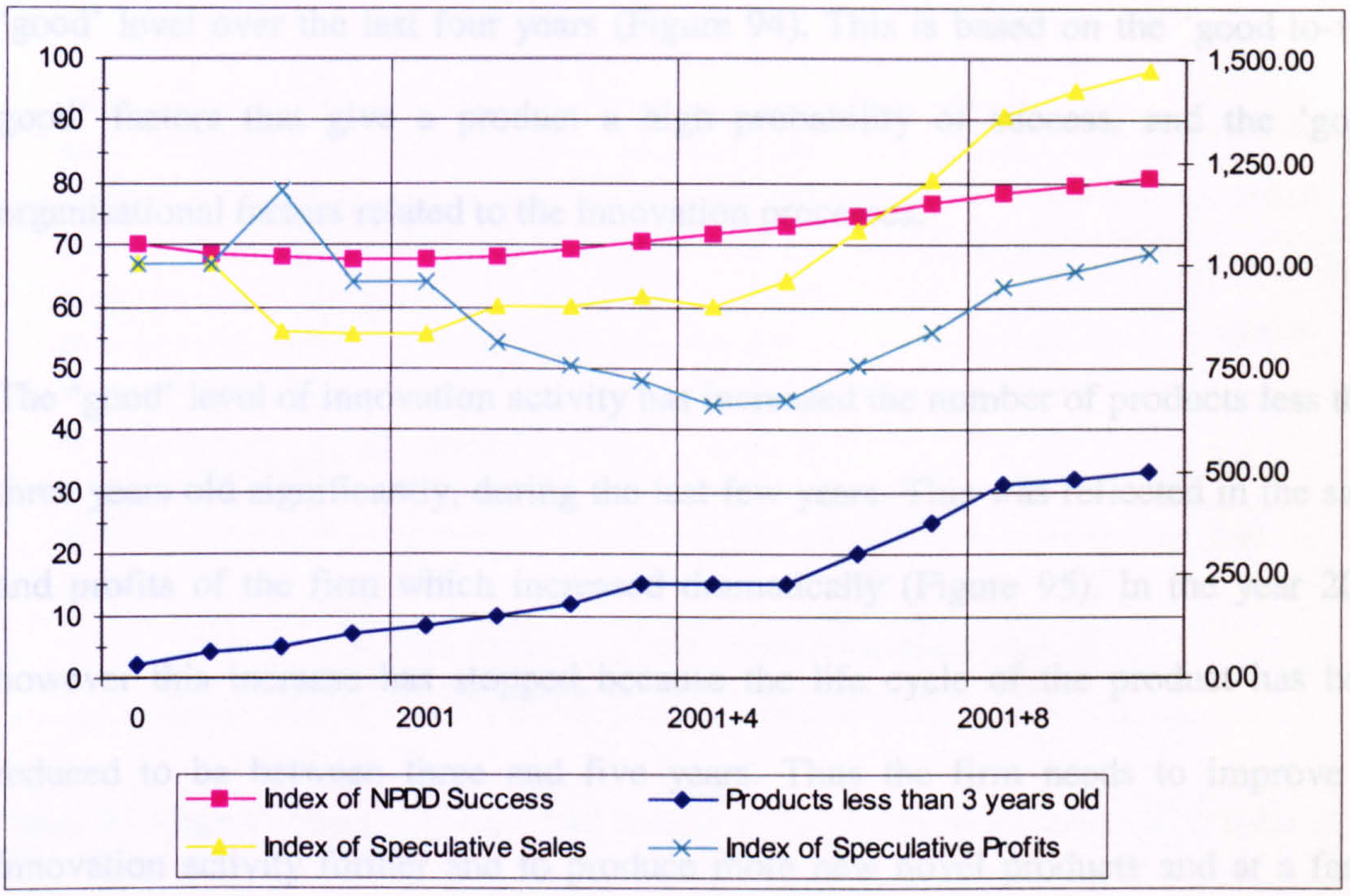


Figure 93. Simulation of the Increased No of New Products Hypothesis

7.3 Elegrec

The application of the creative factory model to the case of Elegrec is presented in this section. The innovation process is assessed and the factors that affect this process are evaluated. Subsequently, a scenario that checks the effect of changes only in these factors is simulated. The scenario is completed with additional changes in the early stages of the core innovation process.

7.3.1 Assessment of Elegrec

The simulation, using the creative factory model, of Elegrec shows that the index of the firm's overall ability to generate successful innovations has been sustained at a 'good' level over the last four years (Figure 94). This is based on the 'good-to-very good' factors that give a product a high probability of success, and the 'good' organisational factors related to the innovation processes.

The 'good' level of innovation activity has increased the number of products less than three years old significantly, during the last few years. This was reflected in the sales and profits of the firm which increased dramatically (Figure 95). In the year 2001 however this increase has stopped because the life cycle of the product has been reduced to be between three and five years. Thus the firm needs to improve its innovation activity further and to produce more new novel products and at a faster rate than formerly.

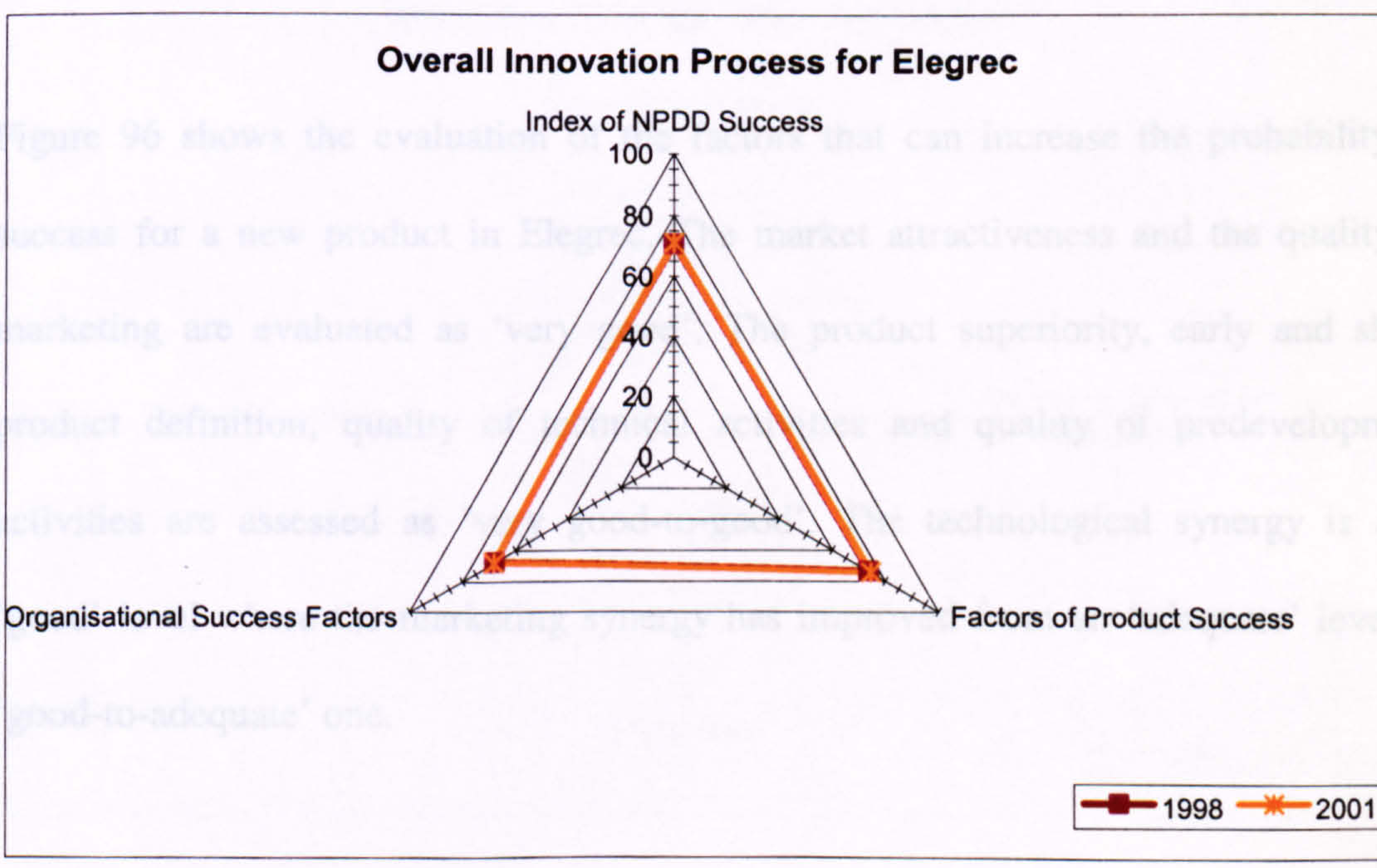


Figure 94. Overall Innovation Process for Elegrec

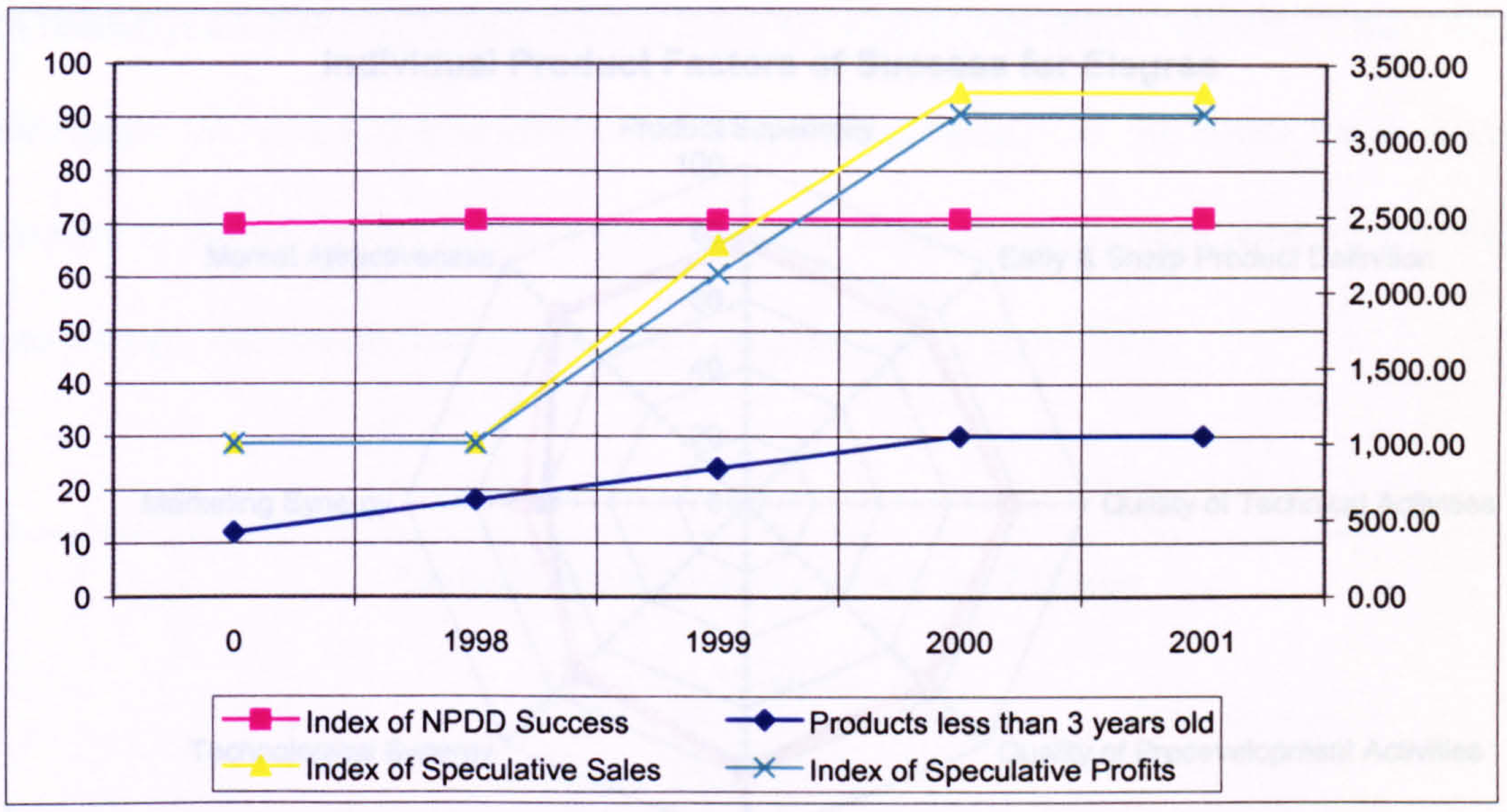


Figure 95. Elegrec's Financial Results and Number of New Products Related to NPD index of Success

7.3.1.1 Product Success Factors for Elegrec

Figure 96 shows the evaluation of the factors that can increase the probability of success for a new product in Elegrec. The market attractiveness and the quality of marketing are evaluated as 'very good'. The product superiority, early and sharp product definition, quality of technical activities and quality of predevelopment activities are assessed as 'very good-to-good'. The technological synergy is at a 'good' level where the marketing synergy has improved from an 'adequate' level to 'good-to-adequate' one.

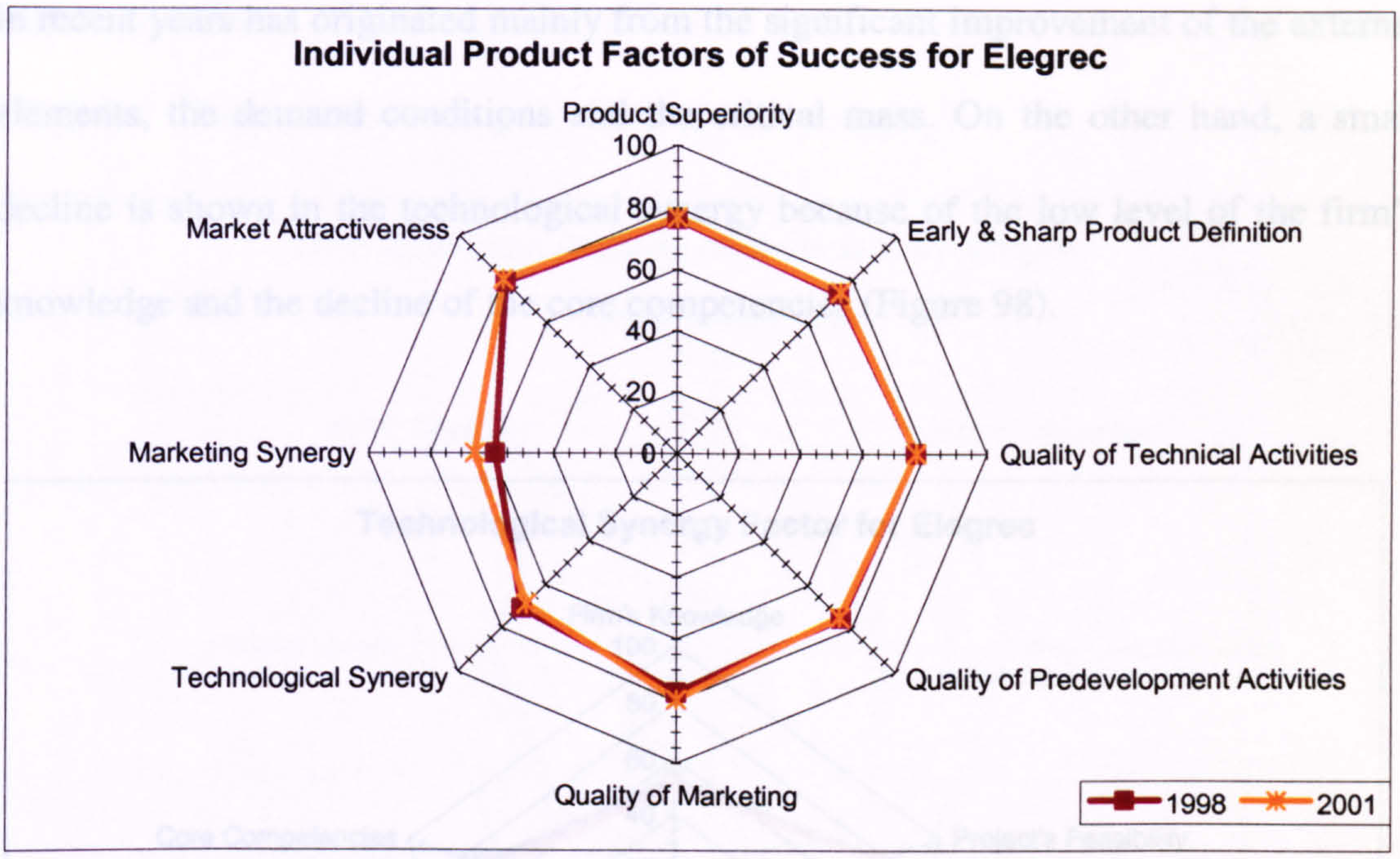


Figure 96. Assessment of the Product Success Factors for Elegrec

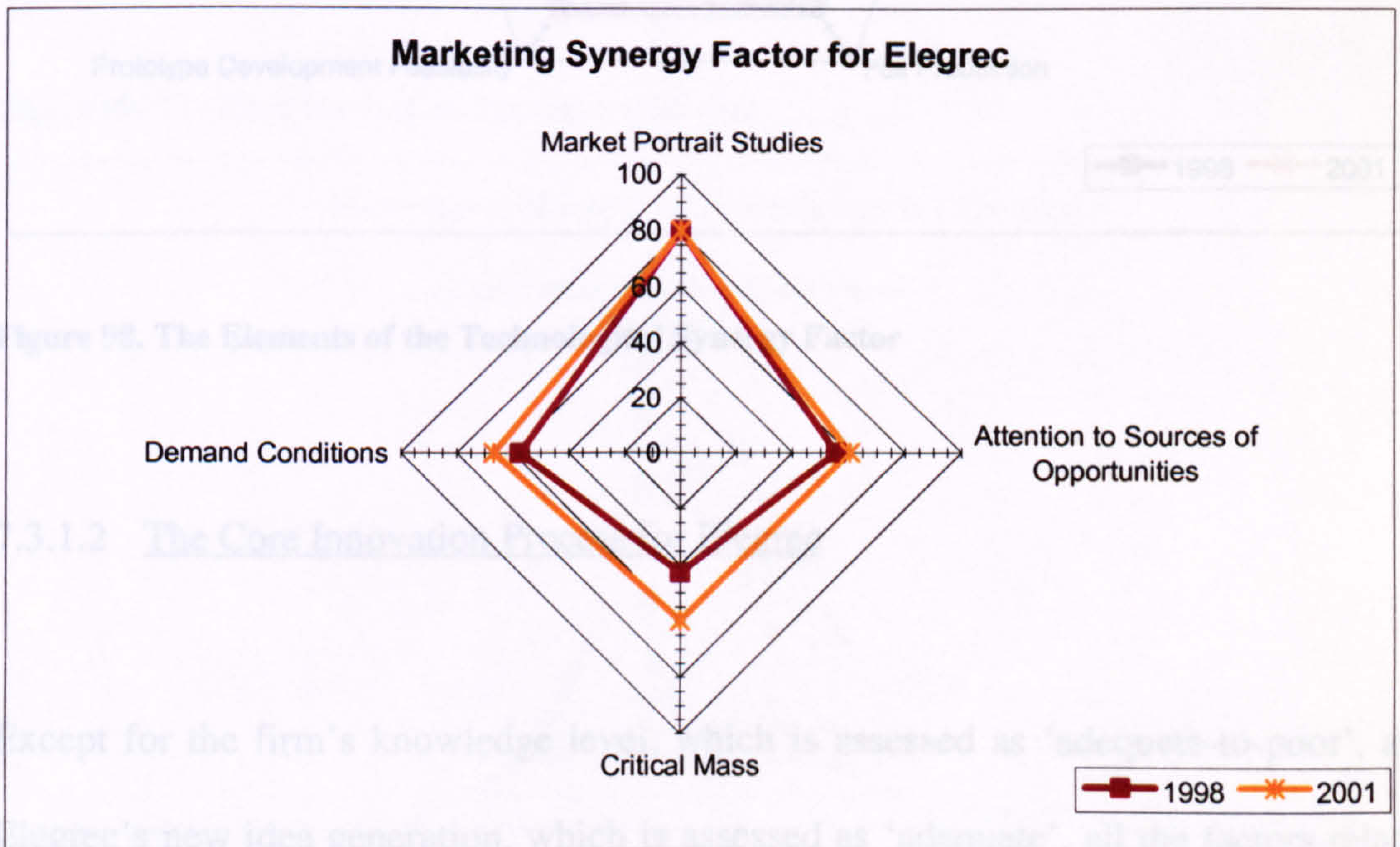


Figure 97. The Elements of the Marketing Synergy Factor

The Marketing Synergy factor, the only one that improves significantly, is affected by both internal and external elements (Figure 97). The improvement that has appeared in recent years has originated mainly from the significant improvement of the external elements, the demand conditions and the critical mass. On the other hand, a small decline is shown in the technological synergy because of the low level of the firm's knowledge and the decline of the core competencies (Figure 98).

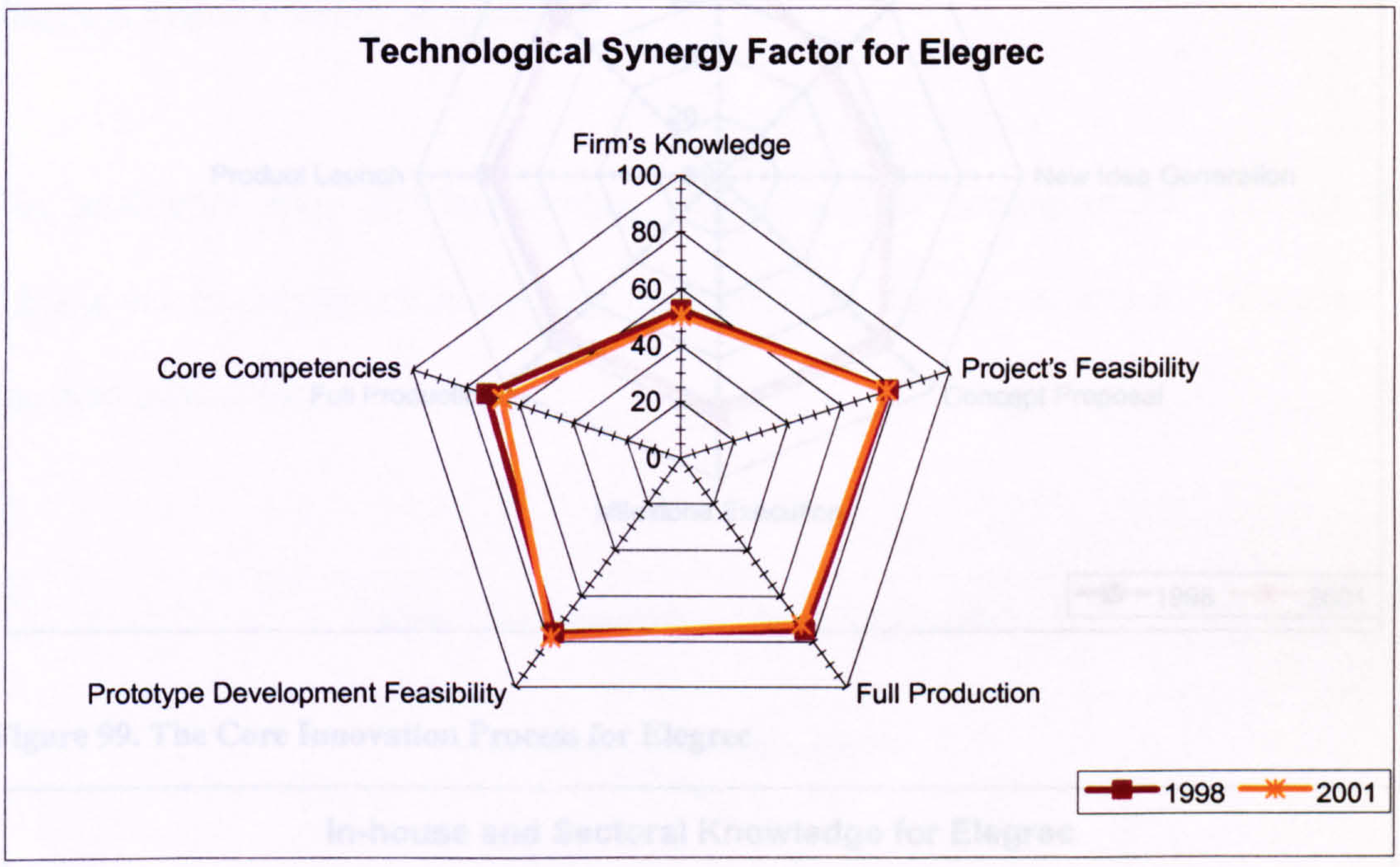


Figure 98. The Elements of the Technological Synergy Factor

7.3.1.2 The Core Innovation Process for Elegrec

Except for the firm's knowledge level, which is assessed as 'adequate-to-poor', and Elegrec's new idea generation, which is assessed as 'adequate', all the factors related to the core innovation process are assessed as 'good-to-very good' or 'very good-to-good' (Figure 99). The status of the firm's knowledge can be traced, mainly, to the status of the employees' creative activity (see Section 7.3.1.3). Furthermore the general level of knowledge of the electronics and telecommunication equipment sectors in Greece is limited, only evaluated at an 'adequate-to-poor' level (Figure 100), and affects the in-house generation of knowledge.

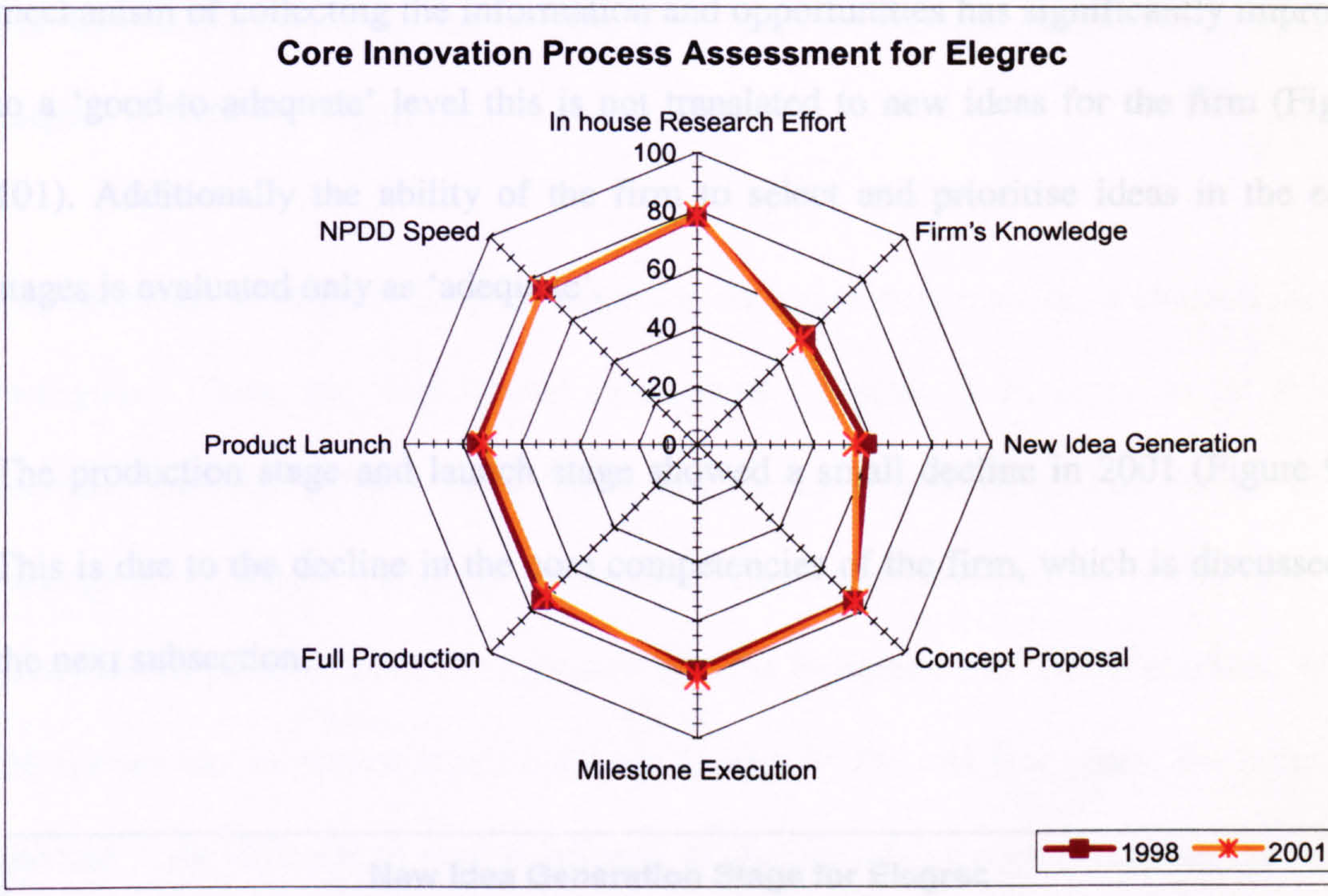


Figure 99. The Core Innovation Process for Elegrec

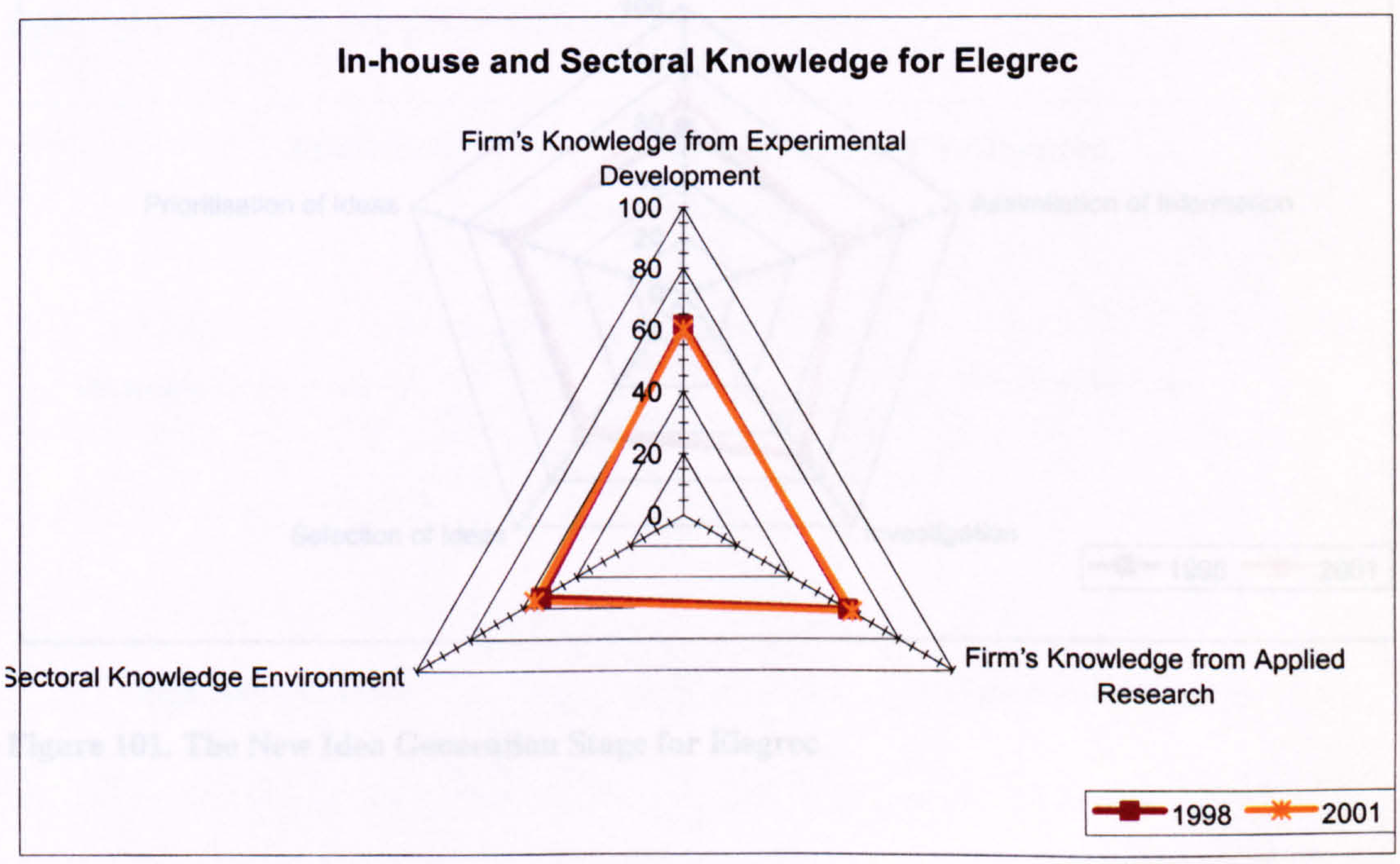


Figure 100. The In-house Knowledge and the Sector's Knowledge for Elegrec

The status of new idea generation is affected by the ability of the firm to assimilate the information and opportunities that are collected by the firm. Thus, although the mechanism of collecting the information and opportunities has significantly improved to a 'good-to-adequate' level this is not translated to new ideas for the firm (Figure 101). Additionally the ability of the firm to select and prioritise ideas in the early stages is evaluated only as 'adequate'.

The production stage and launch stage showed a small decline in 2001 (Figure 99). This is due to the decline in the core competencies of the firm, which is discussed in the next subsection.

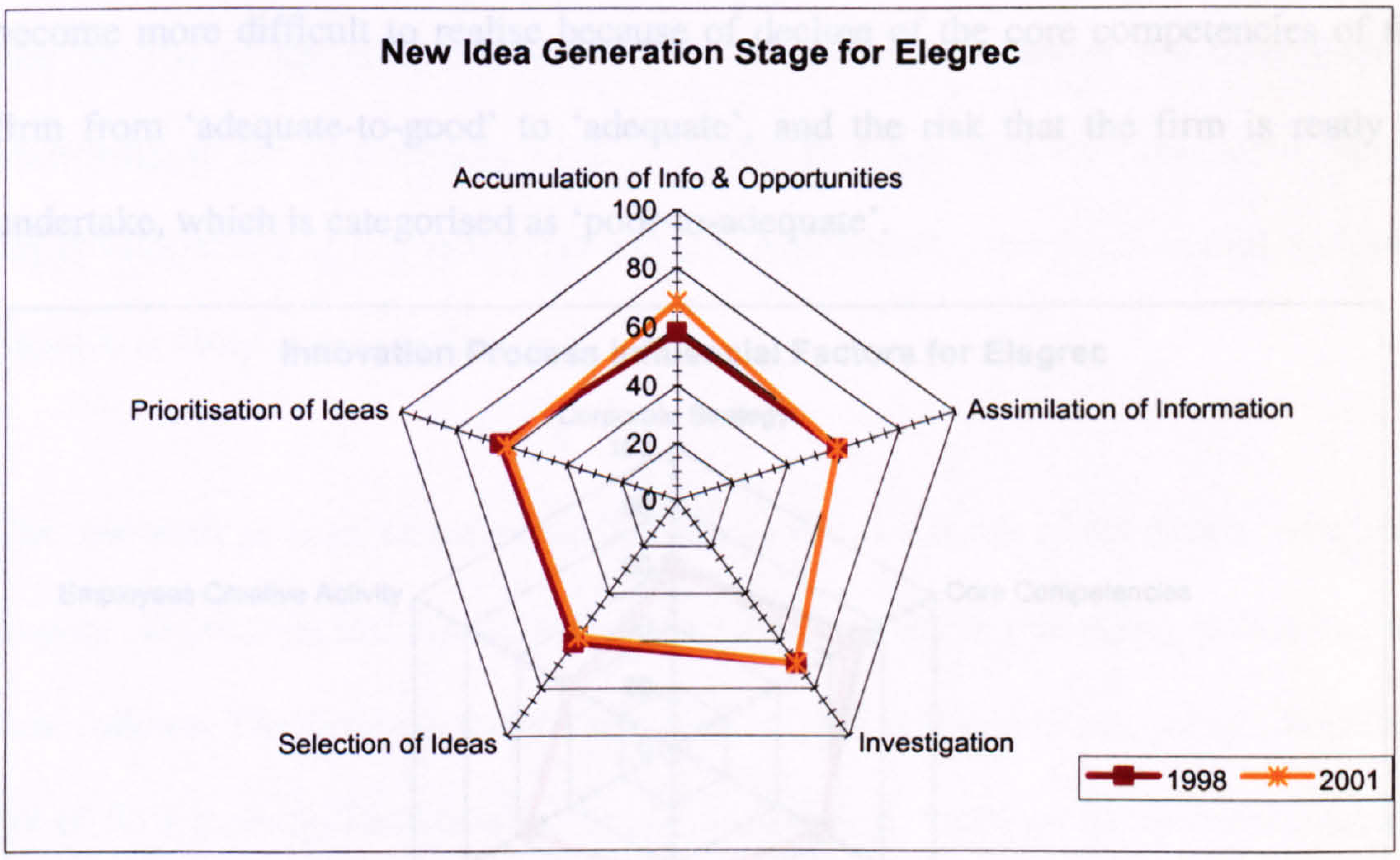


Figure 101. The New Idea Generation Stage for Elegrec

7.3.1.3 The Factors that Influence the Core Innovation Process for Elegrec

The assessment of the six factors that directly affect the core innovation process for Elegrec is shown in Figure 102.

The corporate strategy of Elegrec, regarding its innovation activity, is characterised as 'adequate'. Thus, the firm should re-examine its strategy in order to be able to maintain the high growth rates that it has managed until now. The design of the strategy is influenced partly by the national innovation environment of the firm, and partly by the need to consider expansion into the European and Global markets. While the former has improved significantly in Greece in the last few years, the latter has become more difficult to realise because of decline of the core competencies of the firm from 'adequate-to-good' to 'adequate', and the risk that the firm is ready to undertake, which is categorised as 'poor-to-adequate'.

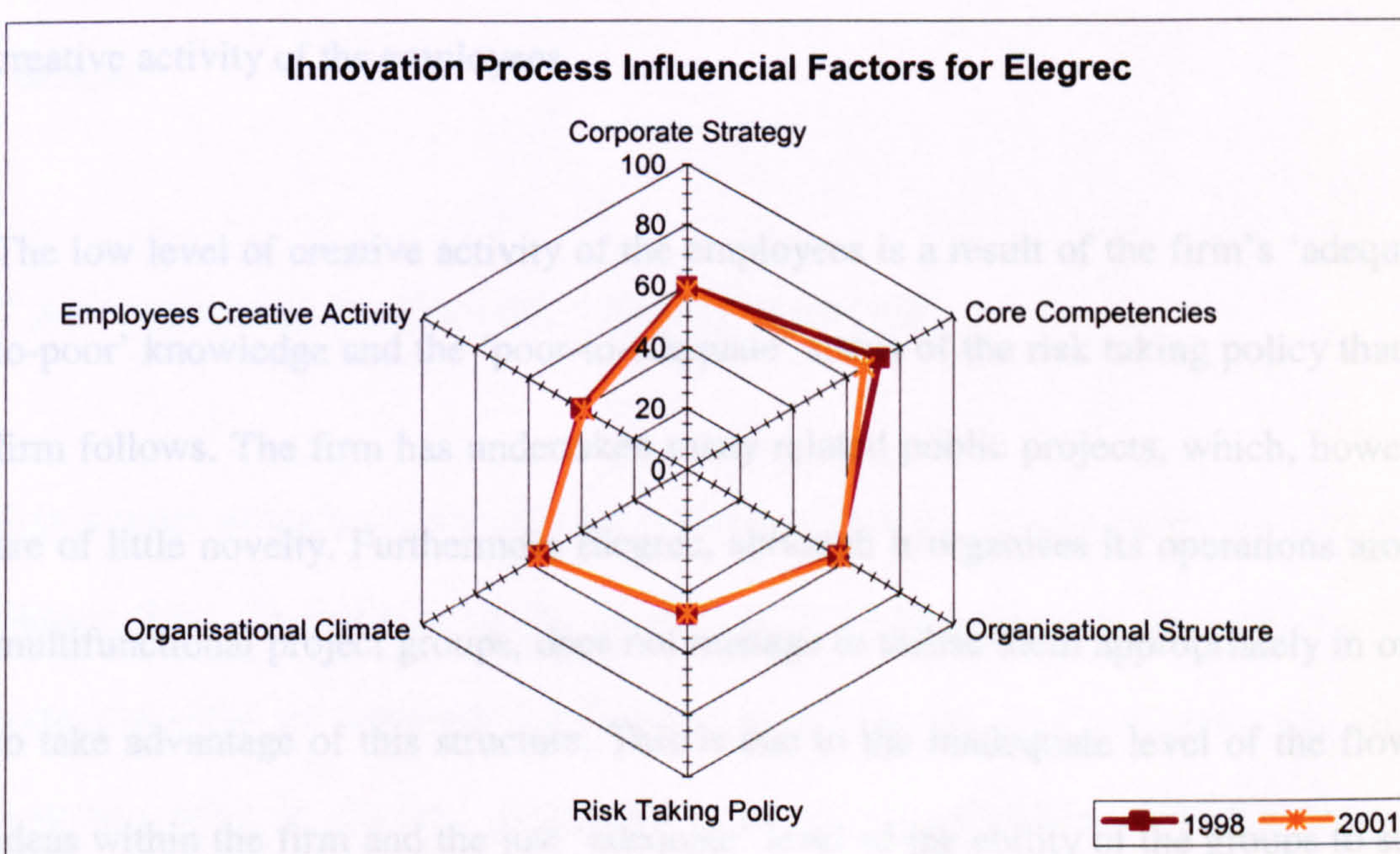


Figure 102. The Factors that Influence the Core Innovation Process for Elegrec

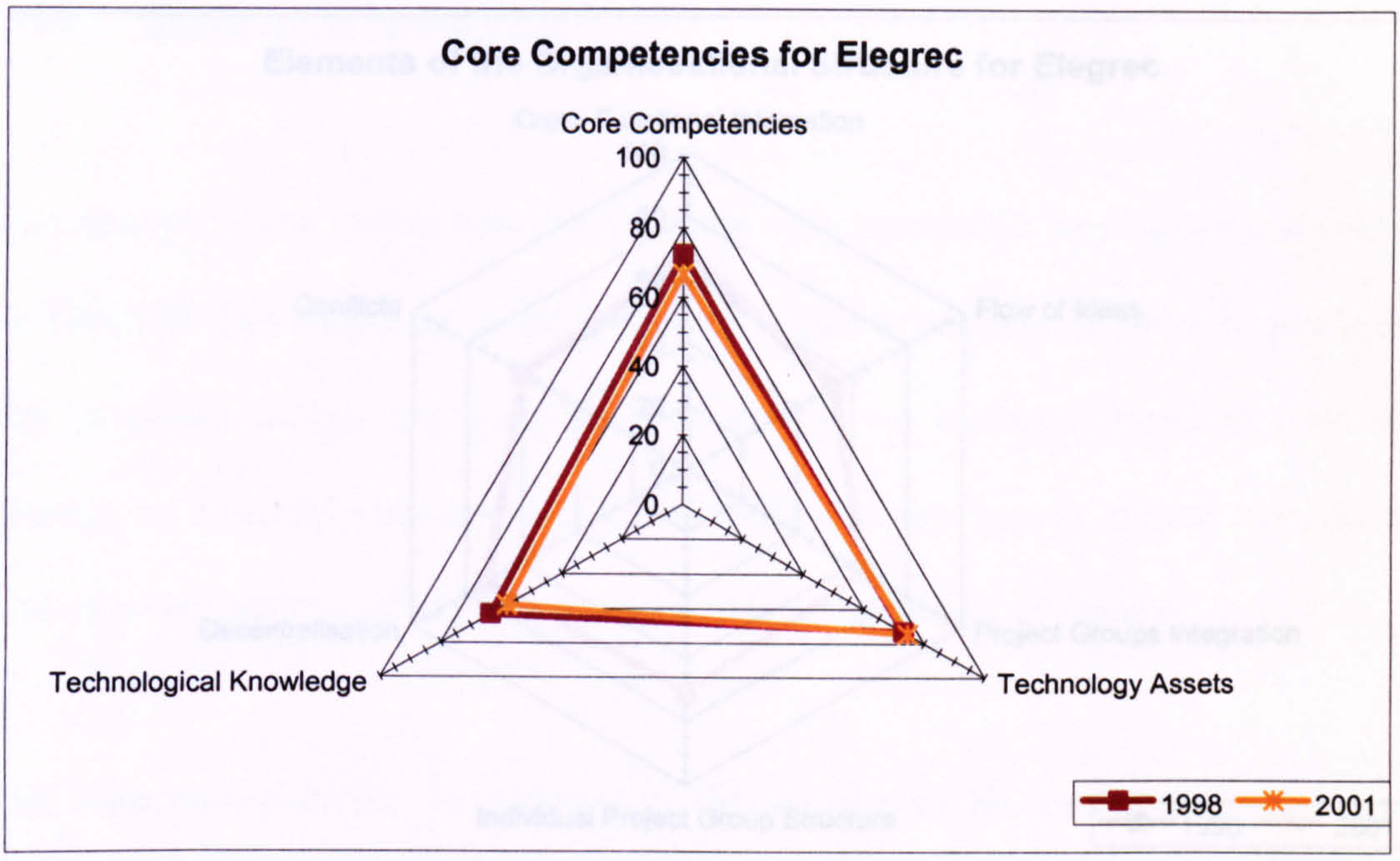


Figure 103. The Core Competencies for Elegrec

The decline of the core competencies is due to the decline of the technological knowledge of the firm (Figure 103). This may be a sign that the firm cannot follow the developments of the sector fast enough. Additionally, this is connected with low creative activity of the employees.

The low level of creative activity of the employees is a result of the firm's 'adequate-to-poor' knowledge and the 'poor-to-adequate' status of the risk taking policy that the firm follows. The firm has undertaken many related public projects, which, however, are of little novelty. Furthermore Elegrec, although it organises its operations around multifunctional project groups, does not manage to utilise them appropriately in order to take advantage of this structure. This is due to the inadequate level of the flow of ideas within the firm and the just 'adequate' level of the ability of the groups to solve problems which arise during a project (Figure 104).

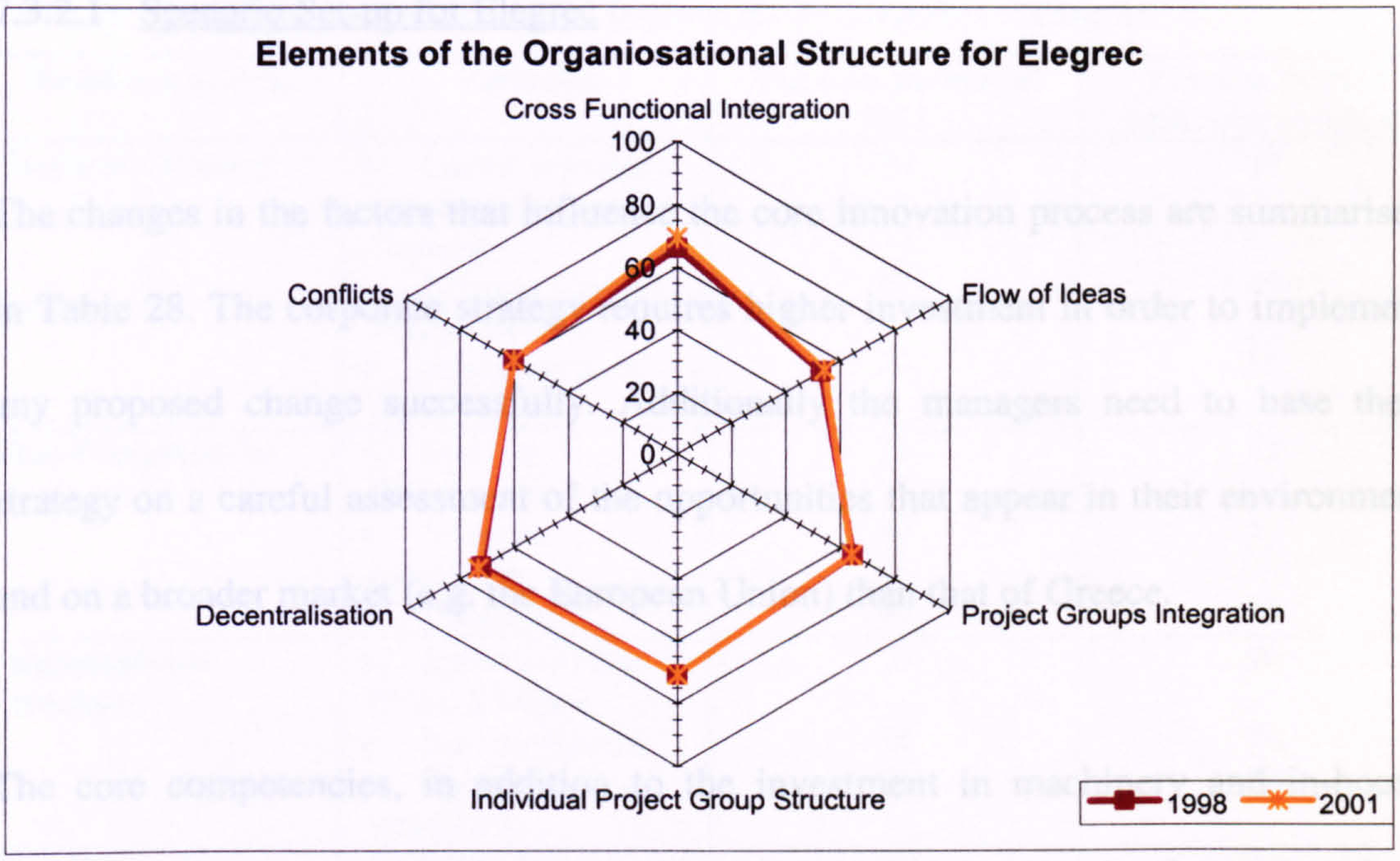


Figure 104. The Elements of the Organisational Structure for Elegrec

Finally, the organisational climate is evaluated as 'adequate' (Figure 102). This factor is influenced by the corporate strategy, the organisational culture, the official risk taking policy, the tolerance to mistakes, the flow of ideas and the ability to solve conflicts.

7.3.2 Improving the Innovation Activity of Elegrec

This section offers a simulation of a scenario based on the assessment of Elegrec in Section 7.3.1. In that section the factors that influence the core innovation process were evaluated as 'adequate' or 'poor', except for the core competencies, which, however, were in decline. Additionally the firm's knowledge and the new idea generation stage were identified as weak.

7.3.2.1 Scenario Set-up for Elegrec

The changes in the factors that influence the core innovation process are summarised in Table 28. The corporate strategy requires higher investment in order to implement any proposed change successfully. Additionally the managers need to base their strategy on a careful assessment of the opportunities that appear in their environment and on a broader market (e.g. the European Union) than that of Greece.

The core competencies, in addition to the investment in machinery and in-house development, need to identify cooperative schemes with companies from abroad, in order to import into the firm technological knowledge and knowledge about other markets. The structure of the firm, however, needs to be improved and adapted on a cross functional basis. In particular, this is true of the timing of the interaction between the teams and the internal structure of the teams.. The organisational climate also needs to be improved, starting with a higher acceptance of risk in new product development, and then the acceptance of mistakes and the recognition of success. These changes together with better financing of creativity promotion programmes would improve the creative activity of the employees.

The scenario considers the possibility of radical innovations – a creative destruction – in the market. Because the life cycle of products in this sector is only three years the creative destruction is programmed to take place with this frequency.

Table 28. Variables that were changed to Improve the Performance of Elegrec

Model Sub-system	Variables	Value on the end of 2001	Value on 2001+5 years of simulation
Corporate Strategy	• Capital Adequacy to Implement Strategy Changes	70	95
	• Effect of Strategy because of NIE	60	95
	• Identification of Opportunities	70	95
Core Competencies	• Invest in Development	75	95
	• Invest in Machinery	70	95
	• Cooperation	40	95
Organisational Structure	• Individual Project Group Structure	70	90
	• Decentralisation	75	90
	• Project Groups Integration	65	90
Risk Taking Policy	• Management Decision for Risk Acceptance	70	95
Organisational Climate	• Tolerance to Mistakes	50	95
	• Recognition of Success	60	95
	• Senior Management Culture	70	95
Employees Availability	• Capital Adequacy for Creativity	70	95

7.3.2.2 Simulation Results of the Scenario for Elegrec

Simulating these changes, the factors that were assessed as weak, earlier, are now shown to have 'good' or 'very good' status (Figure 105).

The firm's knowledge, the idea generation stage and the employees' creative activity, although they have been improved, are still only at the 'adequate' level. Although this is due to a programmed creative destruction which takes place at the moment of the measurement, further improvement can be achieved. Thus three more changes need to take place in the scenario. First, the firm needs to invest further in applied research and experimental development, to a level that is considered 'very good'. Second, the research needs to be directed to world market developments and not only to the Greek market and to use resources from the international pool of knowledge and personnel. Third, the new idea generation process needs to collect information from all the available resources and to identify opportunities from all possible sources. The new assessment of the firm's factors is shown in Figure 106.

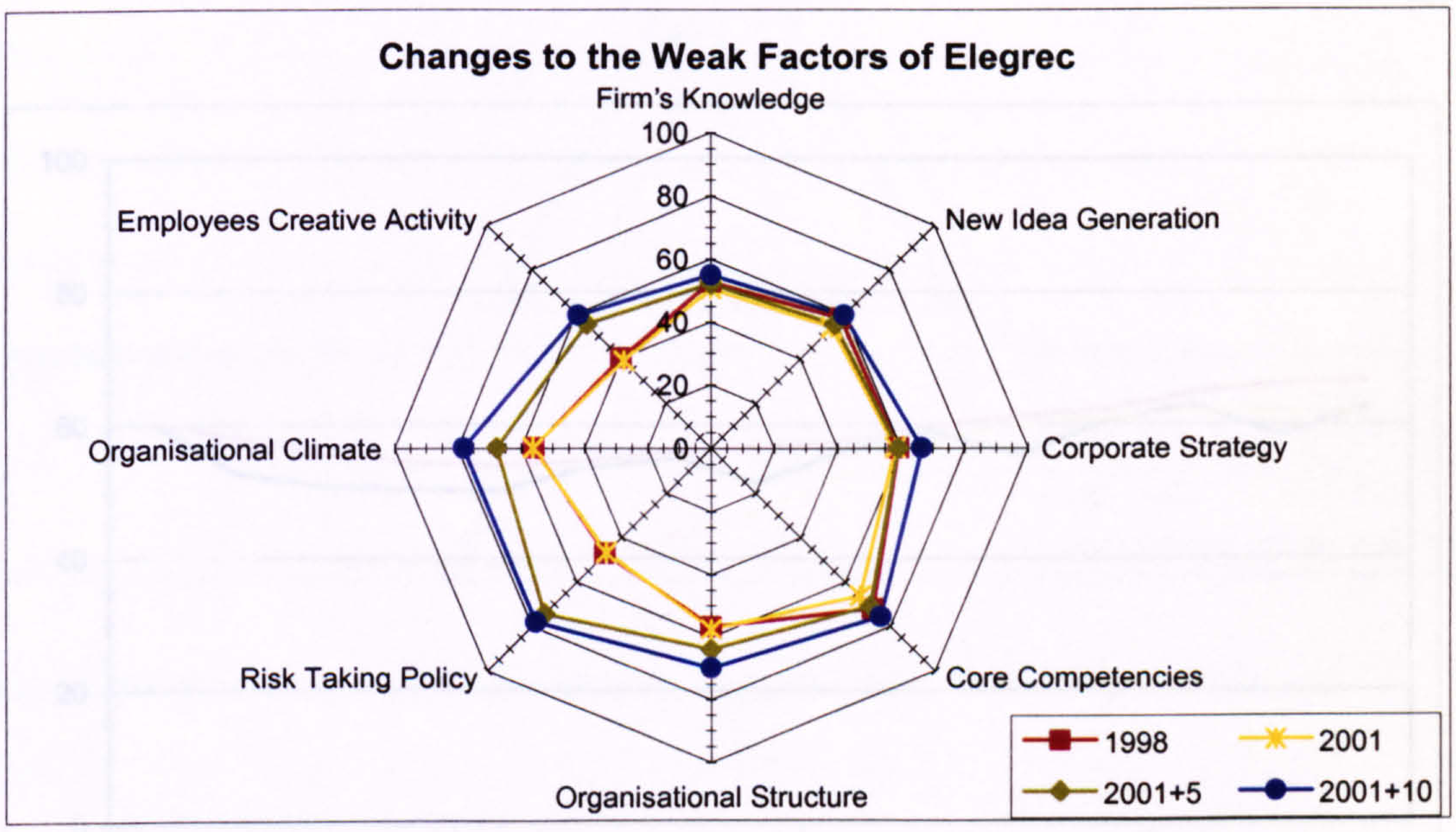


Figure 105. Assessment of the Weak Factors for Elegrec after the scenario

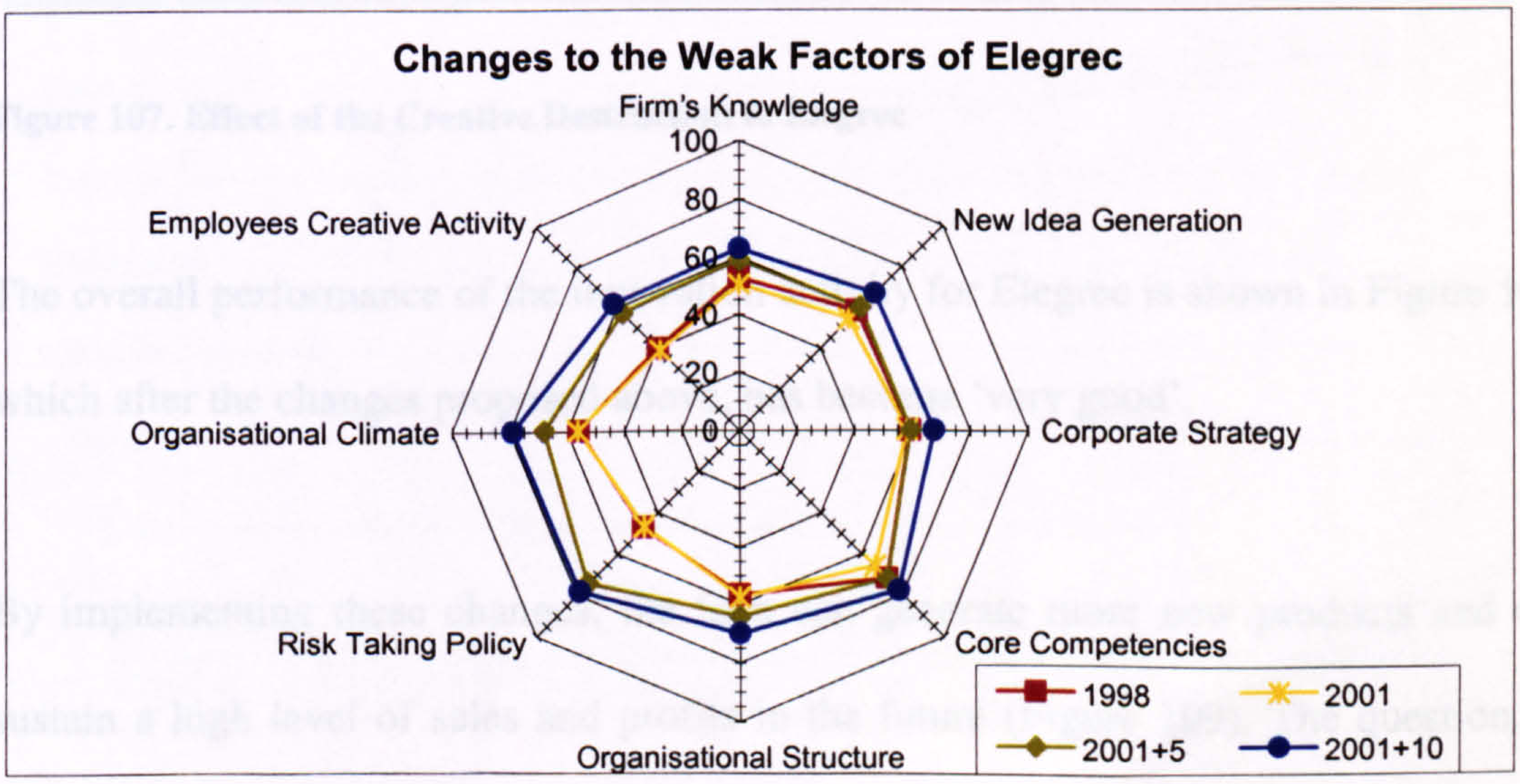


Figure 106. Assessment of the Elegrec after the changes in Firm's Knowledge and New Idea Generation

The firm's knowledge now, is given an 'adequate-to-good' status. Figure 107 shows that the firm's knowledge and the new idea generation continue to improve even after a series of creative destructions have taken place. The employees' creative activity however, is reaching its limits and the firm needs to expand into the international market in order to overtake the restriction imposed by the home market.

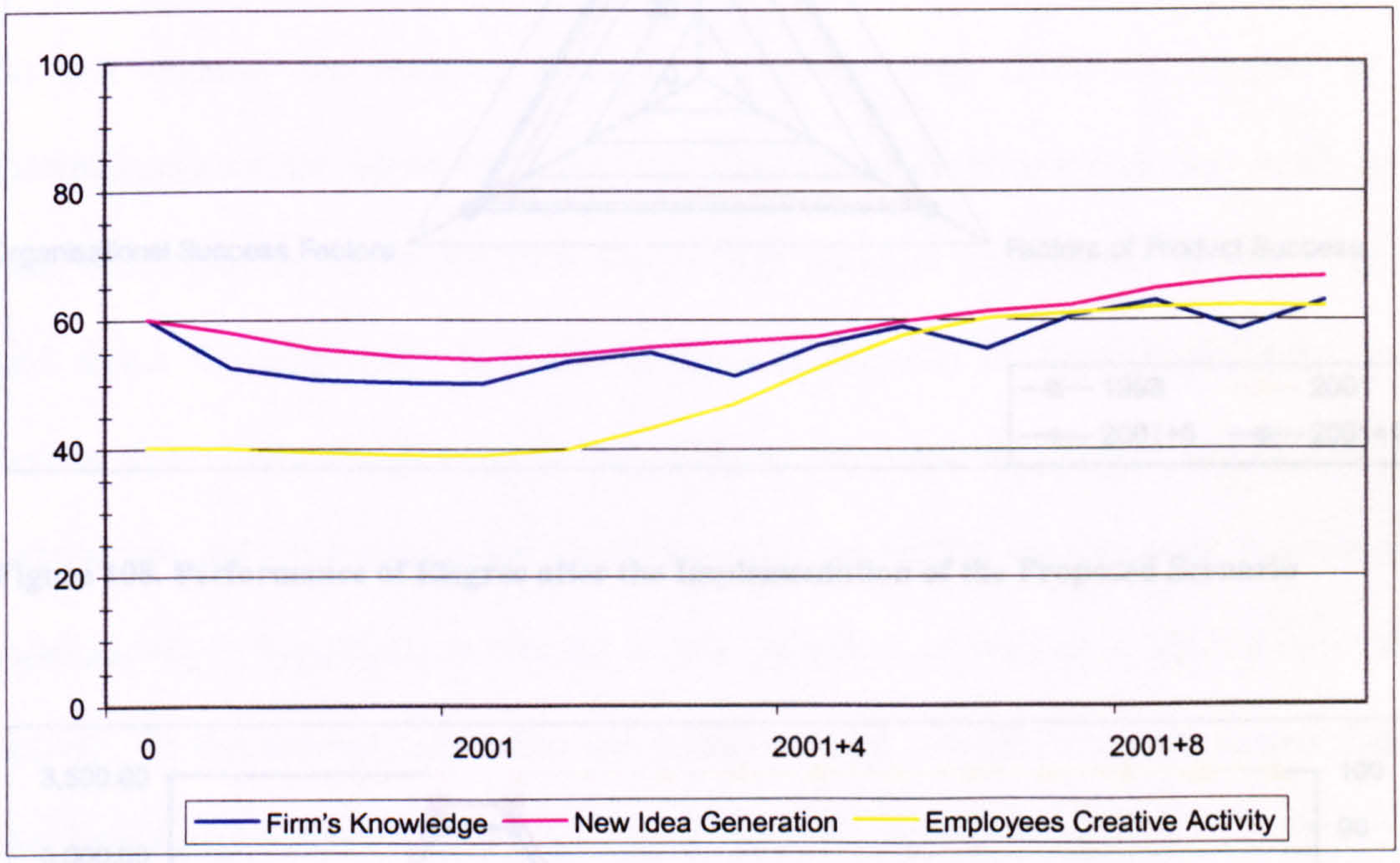


Figure 107. Effect of the Creative Destruction to Elegrec

The overall performance of the innovation activity for Elegrec is shown in Figure 108, which after the changes proposed above, has become 'very good'.

By implementing these changes, the firm can generate more new products and can sustain a high level of sales and profits in the future (Figure 109). The question, of course, which remains for Elegrec, is whether it will manage to expand into European and International markets in order to bring within its organisation the knowledge and the employee expertise that are necessary for this expansion.

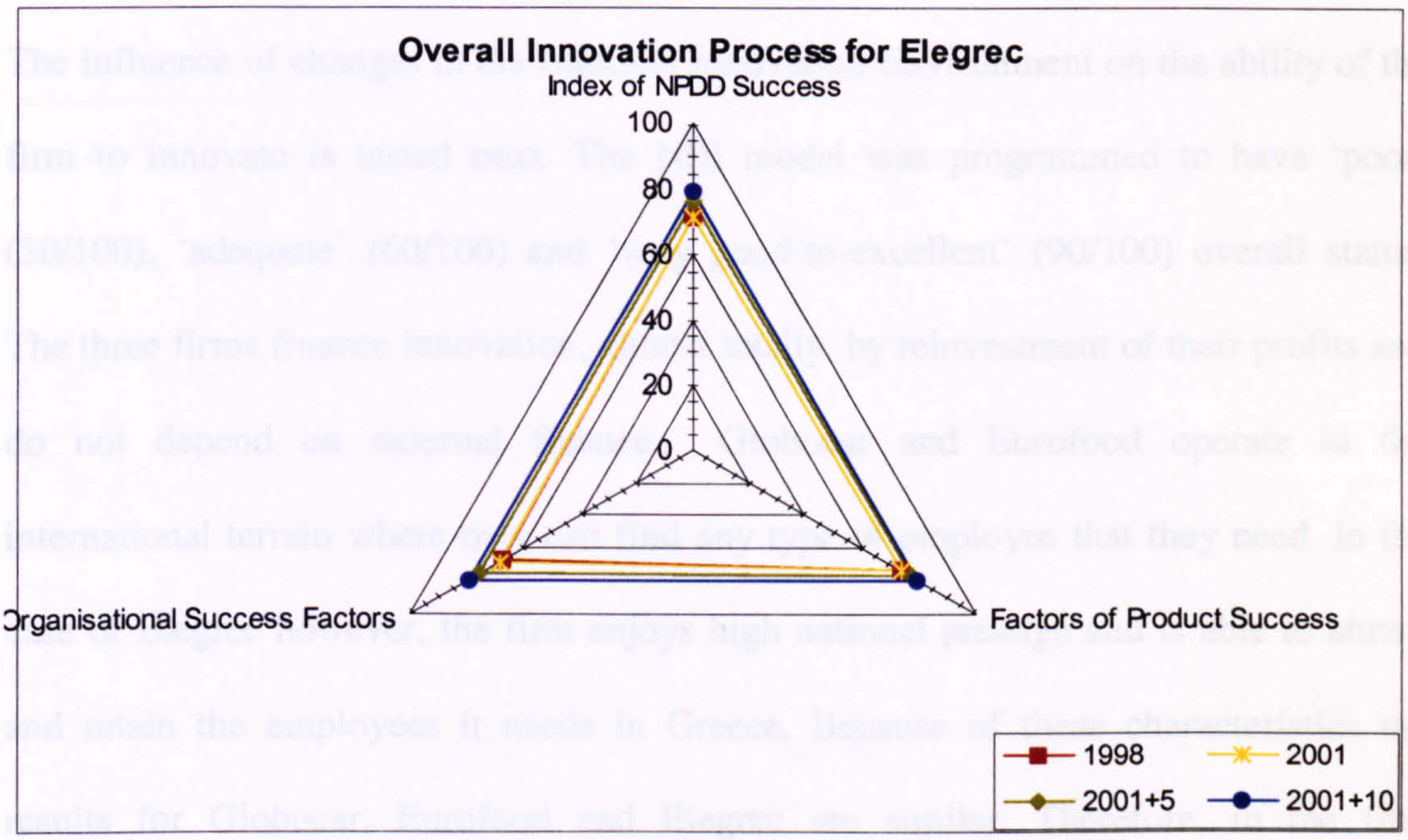


Figure 108. Performance of Elegrec after the Implementation of the Proposed Scenario

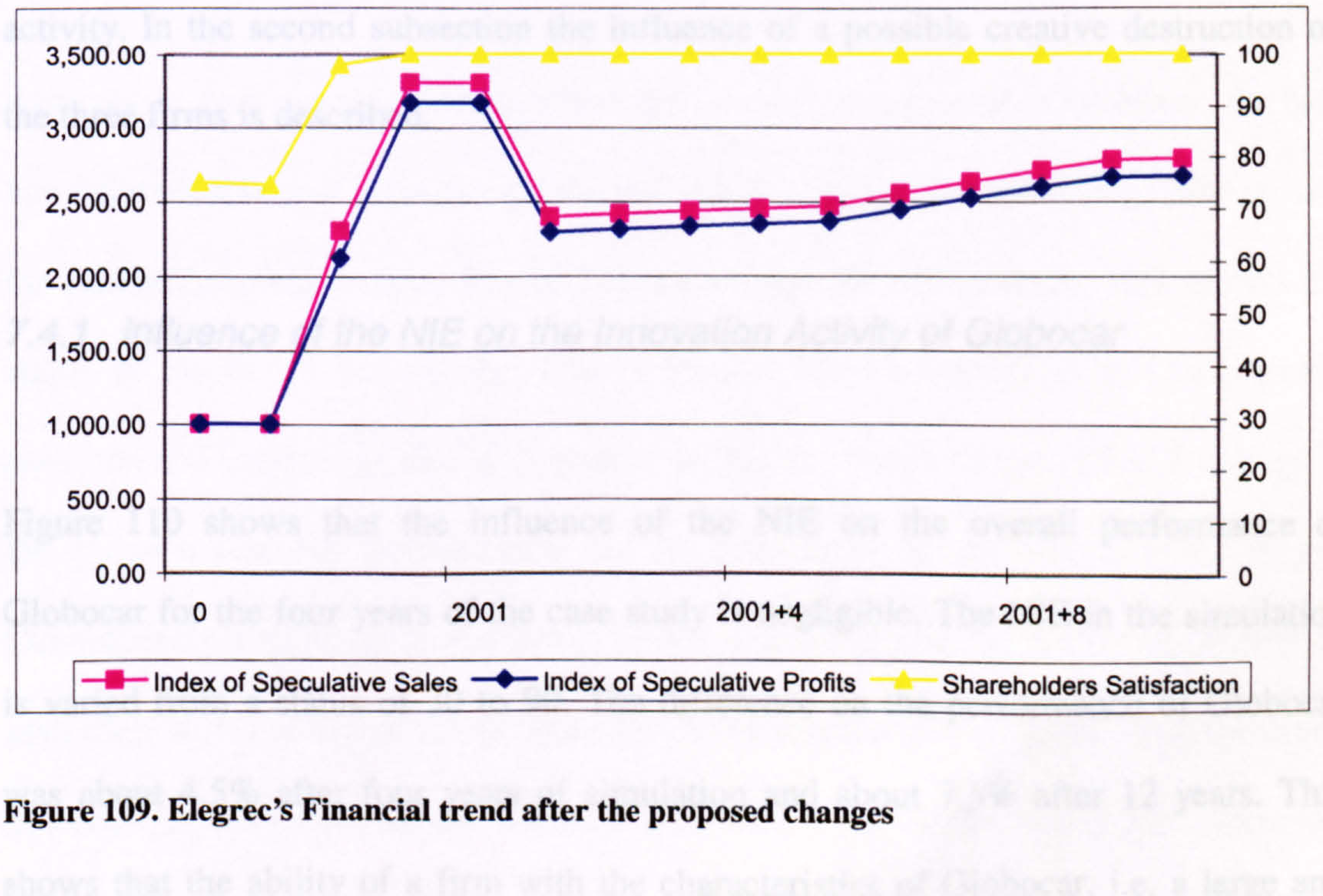


Figure 109. Elegrec's Financial trend after the proposed changes

7.4 The Influence of the National Innovation Environment on the Innovation Activity of a Firm

The influence of changes in the National Innovation Environment on the ability of the firm to innovate is tested next. The NIE model was programmed to have 'poor' (30/100), 'adequate' (60/100) and 'very good-to-excellent' (90/100) overall status. The three firms finance innovation, almost totally, by reinvestment of their profits and do not depend on external finance. Globocar and Eurofood operate in the international terrain where they can find any type of employee that they need. In the case of Elegrec however, the firm enjoys high national prestige and is able to attract and retain the employees it needs in Greece. Because of these characteristics the results for Globocar, Eurofood and Elegrec are similar. Therefore, in the first subsection, only the simulation of Globocar's innovation performance is presented. Additionally a hypothesis is created to test the effect of NIE on a SME's innovation activity. In the second subsection the influence of a possible creative destruction on the three firms is described.

7.4.1 Influence of the NIE on the Innovation Activity of Globocar

Figure 110 shows that the influence of the NIE on the overall performance of Globocar for the four years of the case study is negligible. The NIE in the simulation is varied from a status of 30 to 90. The difference on the performance of Globocar was about 4.5% after four years of simulation and about 7.5% after 12 years. This shows that the ability of a firm with the characteristics of Globocar, i.e. a large and long established firm with a large amount of cash for internal investment in its innovation process, and with a relatively 'good' innovation performance, is not substantially affected by changes in the NIE.

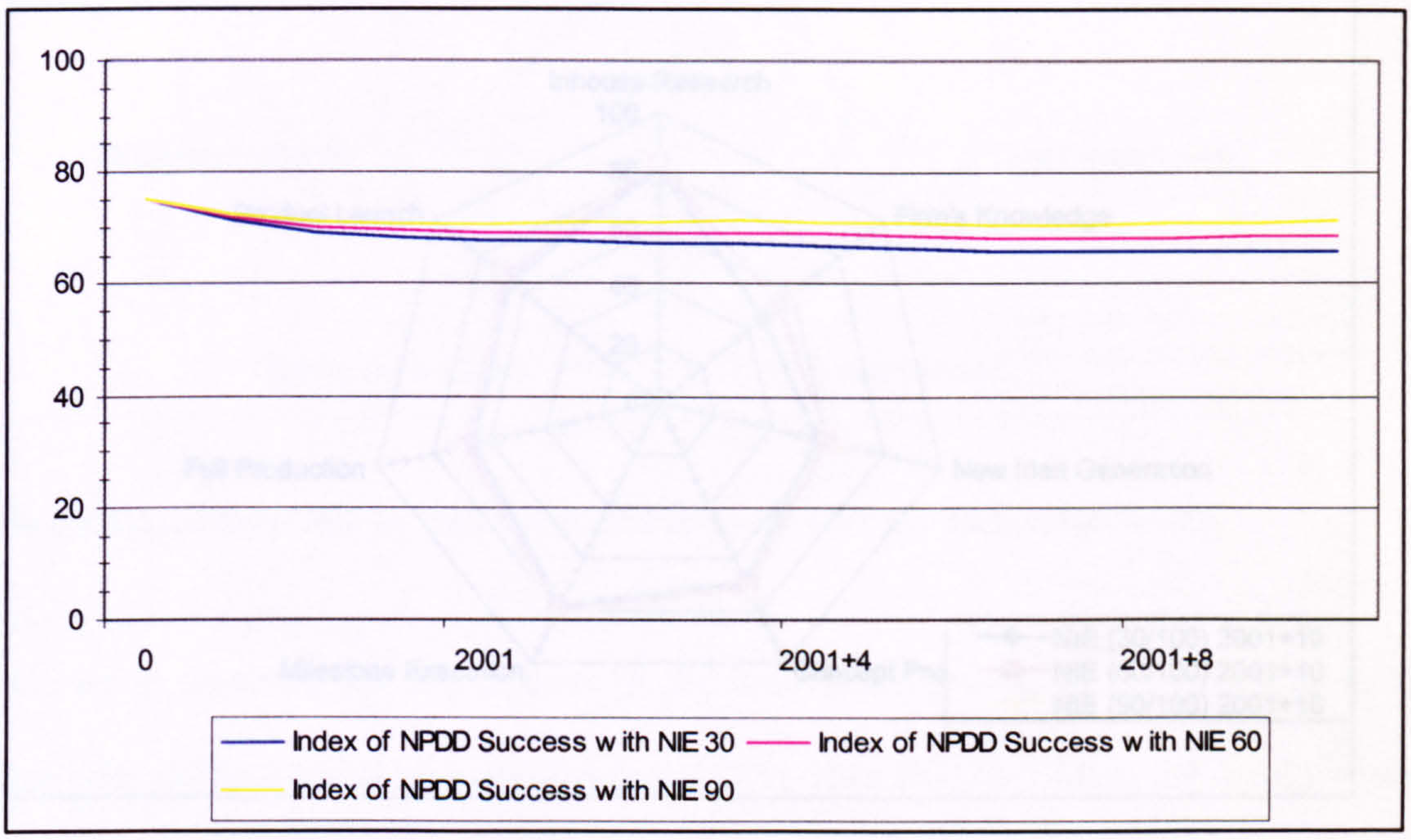


Figure 110. Influence of the NIE differences on the Overall Ability of Globocar to Innovate

Although it does not significantly affect the overall performance of Globocar, the NIE has different levels of influence on the individual stages of the innovation process and the related business factors. Figure 111 shows that the NIE substantially affects the status of the firm's knowledge. This is because the knowledge of a firm depends partly on the knowledge that is generated within the firm's sector. Thus, a change in the sector's research performance can be transferred to the firm's performance. Consequently the change in the firm's knowledge influences the ability of the firm to assimilate and investigate information for the generation of new ideas. This influence has been demonstrated in the scenario test for Elegrec in Section 7.3.2. However, once a firm manages to sustain a high standard in the selection and prioritisation process for these ideas, the following stages of the process are not influenced significantly by changes in the NIE.

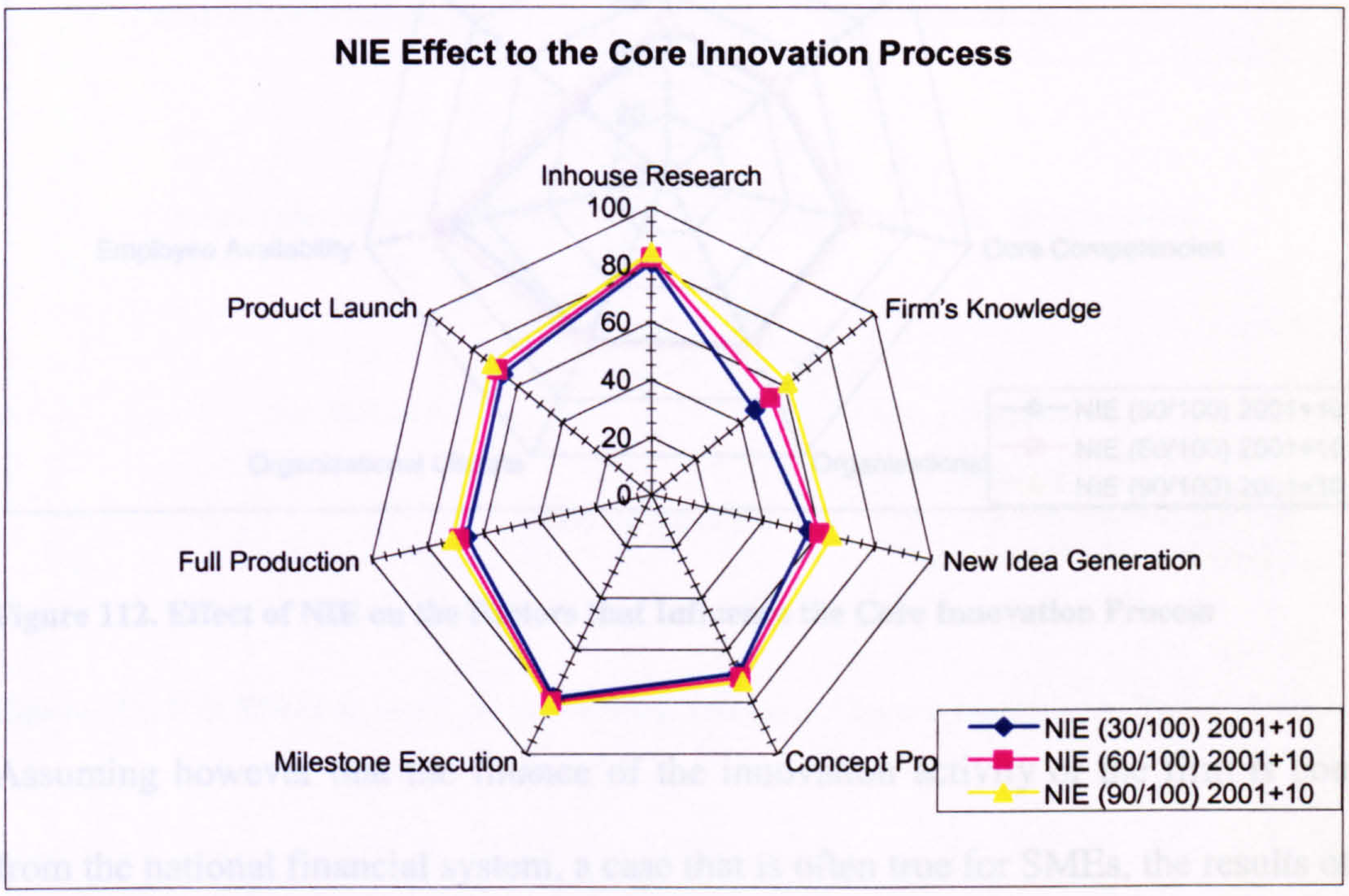


Figure 111 Effect of the NIE on the Core Innovation Process Elements

Furthermore Figure 112 shows that the business factor that is affected most by the NIE is employee availability. This influence however can be overtaken by the prestige, training and the employment scheme that the firm offers.

It is important however to notice that the factors that tended to decline because of internal factors (firm's knowledge; corporate strategy; risk taking policy and core competencies (see Sections 7.1.1.2 and 7.1.1.3)), decline further, independently of the status of the NIE, if the inputs that influence them do not improve. The case of the firm's knowledge however, shows that the NIE may accelerate this decline.

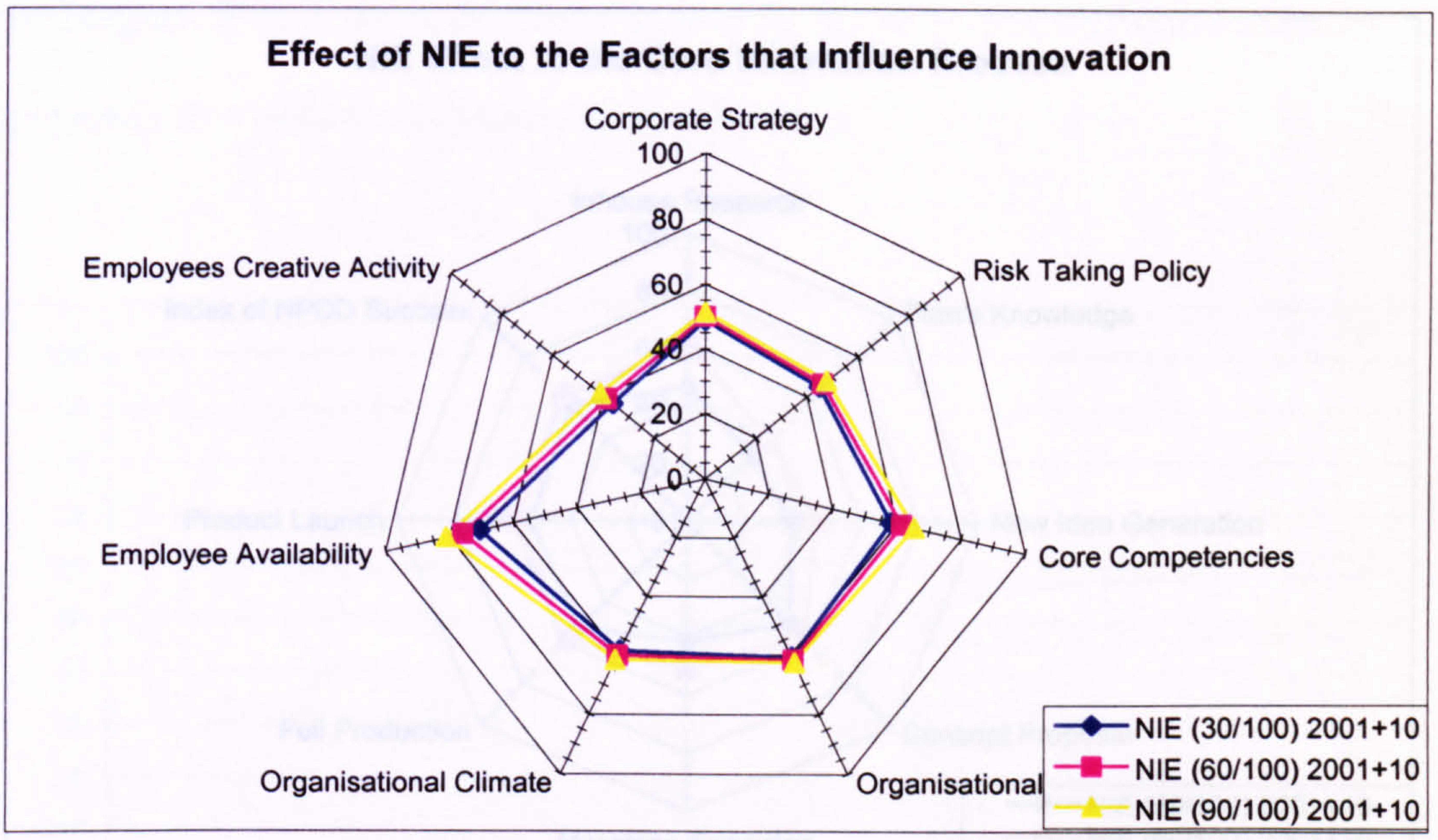


Figure 112. Effect of NIE on the Factors that Influence the Core Innovation Process

Assuming however that the finance of the innovation activity of the firm is coming from the national financial system, a case that is often true for SMEs, the results of the effect of the NIE on the core innovation process is totally different (Figure 113) from that where innovation is financed from internal investment. In this case the performance of each stage of the innovation process is directly correlated with the national innovation environment and especially with the financial system of the nation in which the firm operates. Thus, the overall innovation performance of the firm would be affected significantly by the NIE status.

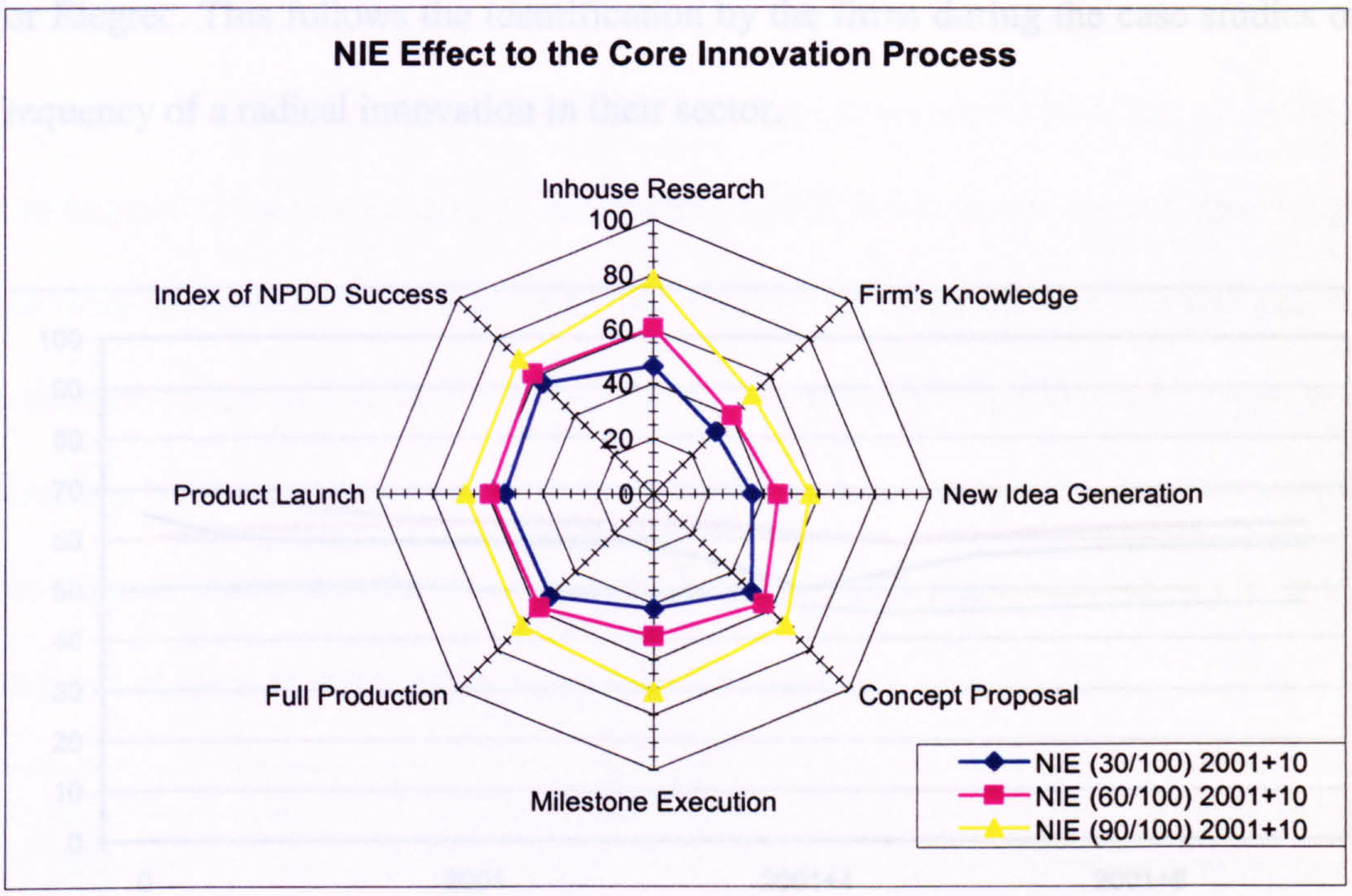


Figure 113. NIE Effect on the Core Innovation Process if Finance comes from External Sources

7.4.2 The Influence of a Creative Destruction on the three Firms

The only stages of the core innovation process that seem to be affected directly by a possible radical innovation – creative destruction – are the firm's knowledge and the new idea generation. These two stages that are at the front end of the process are affected temporarily and the extent of the effect depends on the ability of the firm to realise what is happening and adapt to the new environment. From the moment, however, that the firm adapts to the new situation, the process can respond to the new needs. Other factors that are influenced are the corporate strategy, the risk taking policy and the core competencies. The creative destruction[12] has been programmed to take place once for Globocar and Eurofood during the simulation time and three times

[12] The creative destruction has been programmed to appear as a sine function.

for Elegrec. This follows the identification by the firms during the case studies of the frequency of a radical innovation in their sector.

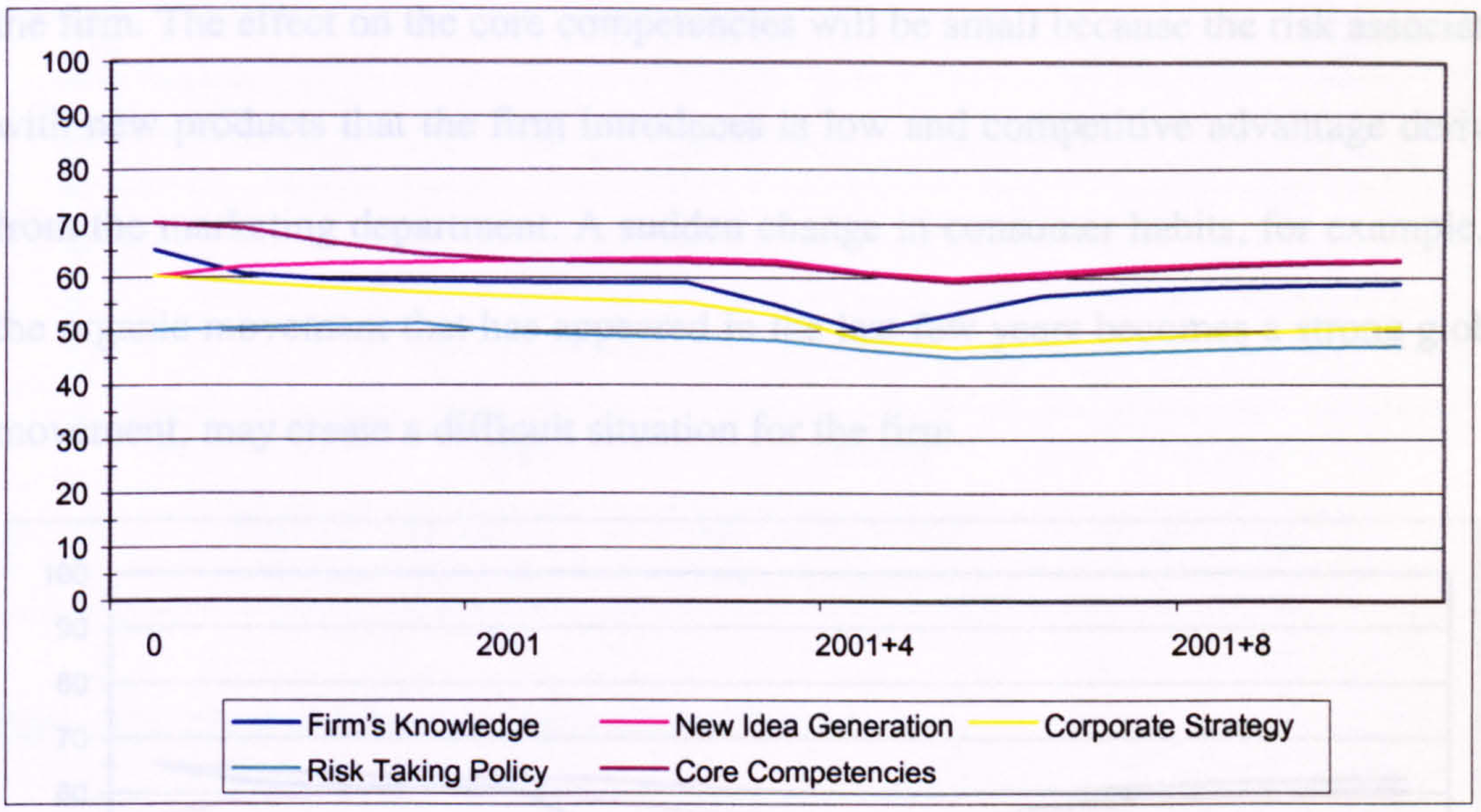


Figure 114. Effect of a Creative Destruction on Globocar

In the case of Globocar (Figure 114) the recovery of the first stages of the innovation process may take up to three years, because the ability of the firm to change has not been evaluated as strong. Additionally, because of the strong in-house research the firm is very reluctant to abandon its own ideas, which have been developed under the direction of its corporate strategy and have been built under the core competencies of the firm. The corporate strategy, risk taking policy and core competencies are in danger of taking an even longer period of time to recover, because the firm does not seem open to a sudden external radical change in technology. In particular the corporate strategy has been characterised during the case studies, as 'adequate-to-poor' in ability to change and the firm needs to be ready to react to technological changes.

In the case of Eurofood (Figure 115) the firm may take even longer than Globocar to recover from a creative destruction. The firm has concentrated its effort on marketing, and neglected the early stages of innovation, which build technological knowledge for the firm. The effect on the core competencies will be small because the risk associated with new products that the firm introduces is low and competitive advantage derives from the marketing department. A sudden change in consumer habits, for example, if the organic movement that has appeared in the last few years becomes a strong global movement, may create a difficult situation for the firm.

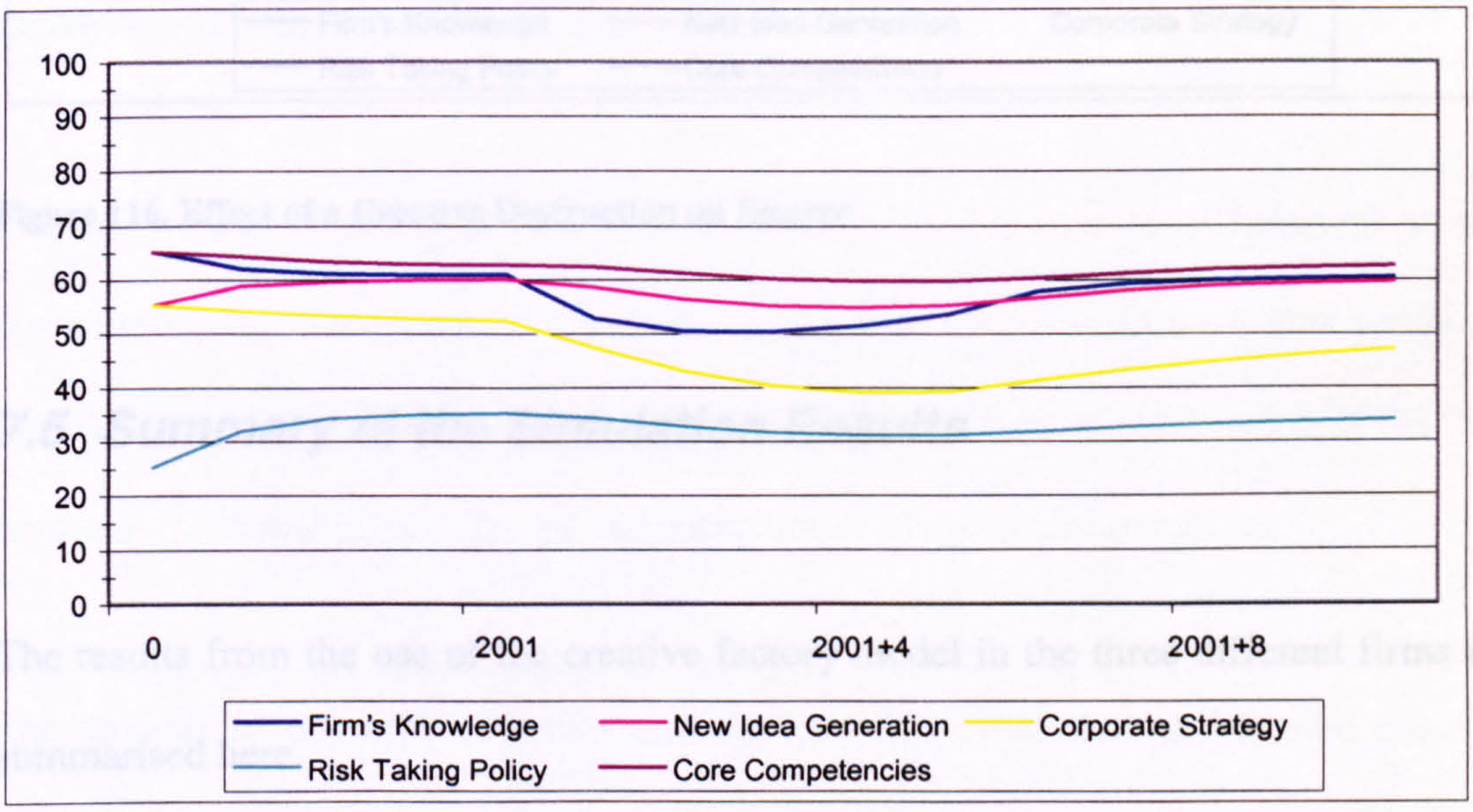


Figure 115. Effect of a Creative Destruction on Eurofood

In the case of Elegrec the effect of a creative destruction, which has a frequency of three years, could be overcome quite rapidly (Figure 116). The sector is moving very fast and the firm has learned to use changes in order to improve its position. The status of the firm's knowledge however is at an 'adequate-to-poor' level, which turns temporarily to a 'poor' level, after the shock. Thus, if the firm wants to become world class, it should focus on improving the level of its knowledge.

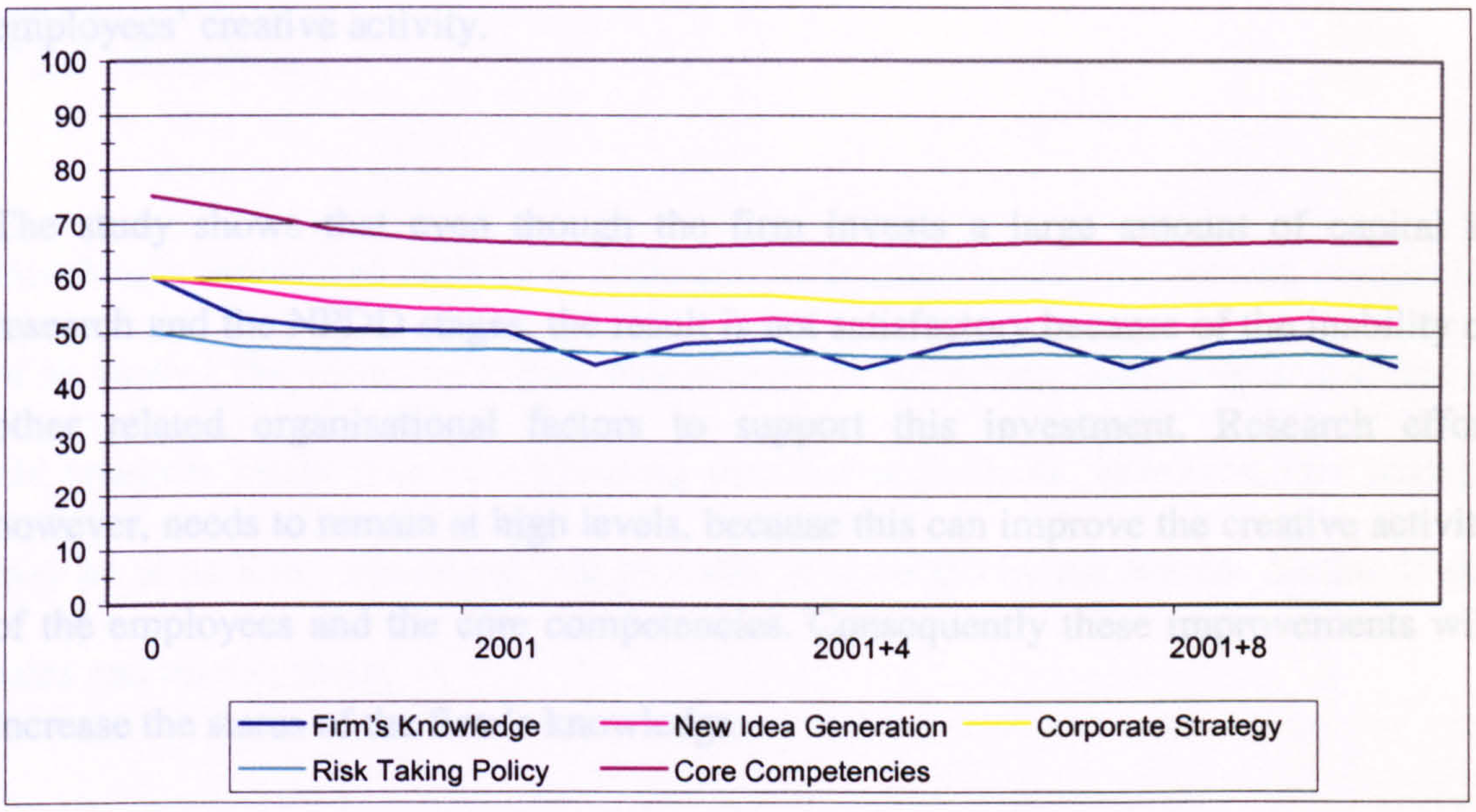


Figure 116. Effect of a Creative Destruction on Elegrec

7.5 Summary of the Simulation Results

The results from the use of the creative factory model in the three different firms are summarised here.

7.5.1 Globocar

Using the creative factory model to assess Globocar, the following factors related to the innovation activity of the firm which need attention have been identified: the firm's knowledge; the new idea generation, selection and prioritisation; the full production and launch of new products; the corporate strategy; the core competencies;

the organisational structure; the risk taking policy; the organisational climate and the employees' creative activity.

The study shows that even though the firm invests a large amount of capital in research and the NPDD stages, the result is not satisfactory because of the inability of other related organisational factors to support this investment. Research effort however, needs to remain at high levels, because this can improve the creative activity of the employees and the core competencies. Consequently these improvements will increase the status of the firm's knowledge.

The early stage of idea generation lacks diversity in the sources of information and opportunities on which the firm focuses, in order to identify ideas for new products. The late stages of the NPDD however, are expected to be developed further if the firm continues to invest directly in the improvement of the core competencies.

The strategy of the firm concerning its technological direction and market position should be re-examined and the acceptance of risk needs to be increased. The firm needs to create a structure, which will help continuous change and which will be flexible in the case of a radical innovation in the firm's environment. The creativity of the employees would be improved as a result of the development of knowledge and risk acceptance but also an improvement is required in the recruitment procedures used to identify highly skilled and creative people.

Overall Globocar has 'good' innovation activity, which if it improves further will bring back profitability and satisfaction for its shareholders.

7.5.2 Eurofood

Eurofood's innovation activity is evaluated as average among the leading companies of its sector. The company's sales rely heavily on the strong marketing investment in old products rather than on promoting new novel products. However, this strategy may be at its limit, something that probably is signalled by the current decline in the sales and market share.

The stages of the firm's NPDD process, except for the launch stage that involves the marketing activities, are assessed as weak. This is due to low capital investment in these stages; the limited diversity of the sources of information and opportunities to what the firm pays attention in order to identify new ideas; the inability of the firm to assimilate the collected information into the whole organisation and the very low risk acceptance accorded to new projects that is tolerated by the firm.

The research activity does not always seem to be connected with the rest of the firm because of the very hierarchical organisational structure. Additionally, research funding does not translate to knowledge for the firm because of the low status both of core competencies and employees' creativity. In addition to this the technology related activities are evaluated as being weaker than the very strong marketing related activities, an imbalance which, creates inadequacies in product development. Another characteristic of the weak NPDD process is that the process is conducted in serial mode. Thus, the teams engaged in the later stages are involved in the process late and the problems which may identify have to be solved at a higher cost than would be necessary if the stages were conducted concurrently.

The simulation of the creative factory in the case of Eurofood shows, once more, that capital investment alone, although it is a necessity for a strong innovation process, has only limited effect. A combination of organisational changes is necessary in order to support this investment.

The author has suggested that the key elements which need to change are: the corporate strategy and risk taking policy, which would give the signal to the employees to increase their creative activity; the core competencies, where the firm needs to invest directly in technological assets, improve the employees training and support their creative activities; the restructuring of the organisation in a cross functional mode, which would help the interaction of people, the parallel processing of projects and the decentralisation of decision making about a particular project. Through their interrelation these elements would affect, the whole innovation process and would bring it to a 'very good' status. As a result, the firm would generate more and higher innovative products which would increase sales and profit margins for the firm.

7.5.3 Elegrec

The overall innovation activity of Elegrec is evaluated as 'good'. The firm has managed to take advantage of the improvements in its national innovation environment and has grown dramatically the last few years. However, the knowledge of the firm and the early stage of innovation and the new idea generation and selection, are characterised as weak. This however, is a result of the status of the organisational factors that affect the core innovation process. These factors: the corporate strategy; the organisational structure; the risk taking policy; the organisational climate and the employees creative activity are characterised as 'adequate' or 'poor' and the core competencies have declined in recent years to an 'adequate-to-good' level.

The organisational factors that affect innovation are interconnected and need to be considered by the firm in parallel, in order to provide a sustainable improvement in the innovation process. Thus, its corporate strategy should target the international markets and expansion into them. In addition, the international markets would provide the firm with new sources of knowledge and employees with a high level of expertise, which would improve the firm's knowledge, new idea generation and employees creativity. At the same time, the risk taking policy of the firm should be more positive, a factor that would allow the development of the creative activity of the employees and the realisation of a more ambitious strategy.

The expansion in the international terrain and the employees' activities together with continuous direct investment in machinery and in-house research would improve the core competencies of the firm. The restructuring of the firm under a cross-functional integration would allow the easy flow of ideas inside the firm, the resolution of conflicts, which subsequently would improve the organisational climate, and reduce the time that a new product takes to be designed and developed.

Thus, with these changes Elegrec would be able to develop novel products faster than currently and be able to compete in more competitive markets than Greece.

7.5.4 National Innovation Environment

The simulation of the scenario that illustrates the effect of the NIE on the innovation activity of a firm showed that large firms that do not depend on external finance for their activities, have a multinational base of operations and can easily employ the necessary people, are not significantly affected by the differences in the NIE. A firm's knowledge can be adversely affected by an inadequate NIE, because it is partly formed by the available knowledge in the sector, but this effect is filtered from the moment that the firm introduces a strong NPDD process with strong selection and prioritisation gates.

SMEs or start-ups that operate locally and depend for their finance on the financial system of a nation are greatly affected by differences in the status of their NIE.

Simulation showed that a creative destruction can more heavily affect those firms that traditionally move slowly. Additionally, it can affect a firm when its strategy has taken different routes from those dictated by the creative destruction i.e. radical innovation. Firms however, who are used to change and whose products have short life cycles, can recover quickly from such destructions even if their strategy is directed along different paths.

8 Discussion of the Creative Factory Project

A study of the innovation related literature gave rise to the development of the Creative Factory model. This literature was reviewed in Chapters 3 to 5. A system dynamics methodology was applied in order to transform the creative factory from a theoretical concept to a dynamic model that could be used to simulate firms' innovation activities. Using this approach a study was conducted in three multinational firms from different home nations and industrial sectors in order to build confidence in the validity of the model (Chapter 6). The use of the model was then illustrated by applying it to the study of these firms (Chapter 7).

In the following section the methodology that was used during this project and its strengths and limitations are discussed. Subsequently, a discussion of the theory that was used to construct the creative factory model, its overall design and its potential uses is presented. In Section 3 the cases to which the creative factory model has been applied are reviewed and finally, in Section 4 proposals for further research are made.

8.1 Modelling Methodology

The complexity of innovation systems (identified in the literature, for example: Rothwell, 1994b; Porter, 1990; OECD, 1997a) has been revealed using system dynamics modelling methodology. The analysis of the theory led to the construction of influence diagrams. The verification of these diagrams however, took place in parallel by building the computer-based model, and simulating them in a hypothetical model (described in the theory of using system dynamics, Coyle, 1996). Thus a test was conducted to verify whether the resulting model behaved as expected from the literature. Additionally, this provided a simultaneous test for the logic and the equations of the model.

The ability of the system dynamics methodology to generate sub-models of different levels of detail is an important characteristic that has been used in the construction of the model (Coyle, 1996). Thus, wherever it has been judged necessary, sub-models were created in detail. The purpose of this was to identify areas that managers usually neglect and to try to present to them all their available options. Such examples are shown in the sources of information and opportunities for new ideas sub-models and the selection and prioritisation criteria for ideas, concepts and prototypes. In other areas however, a more general model has been designed in order to demonstrate the overall activity of the firm. Such examples are the NPDD success index and the firm's sales and profits speculation. The latter level of detail targets the shareholders and senior managers who are not interested in the details of the innovation process but only in its outcome.

The model was transformed from a theoretical one to a practical one, by the collection of data through the designated case studies. The necessary data was identified by the analysis of the literature rather than by the data available in each case. This was necessary because the creative factory model needed to cover best practice rather that a firm's current practice. Thus, often the industrialists who were interviewed did not have, or they did not want to give, some of the information. In particular, the data relevant to the finance of each activity were, most of the time, unavailable. This however has been overcome by hypothesising that, because the changes to each factor in the four years of the study had been planned by the firm, the capital had been committed and thus, the important factor was the adequacy of this capital in order to implement the plan. Thus, the assessment of each firm was possible. Taking this limitation into account however, the changes in the action-scenarios have been defined so as to take place over a five-year period, a period that was considered as likely to enable the firms to invest in such changes.

Another limitation of the method employed in the study of the cases is that the data set was not obtained directly but via a manager who either gave a personal view or collected the information from other managers and transferred it. Therefore, the information employed could have been biased to present a better picture of the firm or, various activities of the firm could have been presented differently depending on the managers' personal involvement in these activities. An attempt has been made to overcome this limitation by creating questions that identify such contradictions and by using as much published information about the firm as possible.

8.2 The Theory of the Creative Factory Concept

The theoretical study of the innovation process and the factors that affect this process have been used to define the creative factory (Chapters 3 to 5).

8.2.1 The Core Innovation Process

The 'Core Innovation Process' concept has the following stages: knowledge creation; product design and development and product success.

8.2.1.1 Knowledge Creation

In a particular sector, a firm can take advantage not only of knowledge that its own research creates, but also, of knowledge that is accumulated by public research or by the research that other firms have developed. Additionally, as technologies merge, knowledge from other industrial sectors may become relevant and useful for a firm (Ganguly, 1999). Thus, part of the in-house research role is the integration of this external knowledge into the firm.

The public sector (universities and public research centres) usually conducts basic research and to a lesser degree applied research and experimental development (OECD, 1996b). On the other hand, industries usually invest in applied research or experimental development with more interest in the latter. Section 4.1 has shown that a balance between public and industrial research is necessary in order for a sector to generate new products of low, medium or high novelty.

Section 4.1 shows that it is important for a nation and enterprises to invest in basic and applied research. Even though these do not necessarily have a direct and short-term visible outcome. Often radical innovations in areas such as telecommunications, information technology or drug discovery have emerged through research that has been conducted in the public or private sector many years before a company has managed to transform the research outcomes to a useful product for its customers. These radical innovations would have never been developed if such research had not taken place (Freeman and Soete, 1997).

The public sector has the responsibility however, to promote basic research in areas where the private sector either cannot afford to invest, because of the heavy investment that is required, or is not interested in doing so. The latter is very often because managers cannot justify by simple accounting methods to their shareholders, the benefits that research investment can bring to their firm (Pavitt and Patel, 1999). To do so they need to identify other benefits that often are person embodied such as the knowledge that the firm is gaining, or organisation embodied such as the improvement in the management or production techniques.

Furthermore, research activity is the most important tool by which a firm can protect itself and be prepared against radical innovations that come from other firms (Burgelman et al., 1996). This is because of the knowledge that the firm accumulates through its research. The most important defence against radical innovations from elsewhere however, seems to be the generation of the radical innovations by the firm itself and its ability to direct the developments in the sector.

8.2.1.2 Product Design and Development

Often firms show great attention to the development, production and launch stages, neglecting the early stages of idea generation and concept development (Cooper, 1993). Sections 3.3 and 3.4 however have shown that these early stages are very important for the success of a project. The idea generation stage requires the identification and use of as many sources of information and opportunities as possible. This is necessary for a firm in order to identify the directions that the market, technology and competitors have taken. Additionally, in these early stages, any changes that are identified in the proposed product are easy to make and cheaper than if they are identified later (Cooper, 1999). Thus, the involvement of the customers as early as possible into the NPDD process is important in order to identify their real requirements and test the desirability of the product under its functionality and proposed price.

The optimisation and acceleration of the NPDD process is required for a firm to take the maximum advantage that a new product may offer (Stalk and Hout, 1990). Thus, firms need to operate the NPDD stages in a concurrent manner and involve stages that traditionally come later in the process as early as possible in order to identify and solve possible problems as early as possible. Such acceleration however should not take place at the expense of quality, which needs to be high and to the expectations of the customers.

The proper organisational structure is considered as a necessity to accelerate the NPDD process (Wheelwright and Clark, 1992). Thus, a cross-functional structure is considered as the most appropriate to reduce the development time of a product and to help knowledge and information to flow easily and effectively inside the firm. Additionally, strong selection and prioritisation processes are required in order to invest efforts and resources only in those projects that can be justified as worthy and are compatible with the firm's strategy and competencies.

8.2.1.3 Product Success

The success factors of a new product in the market are grouped under the titles of the product's function competencies and the organisation's competencies. These two groups of factors need to be balanced and to support one another, or else the weaker creates barriers to the product success and consequently to the firm's success.

The most important success factor for a new product, as identified in Section 4.2, is the unique benefits that it offers to the users. The rest of the success factors can be considered to derive from this main one and also the need to:

- identify these unique benefits, for example, the early definition and justification of the project and the high quality of execution of predevelopment activity success factors;
- execute the project in a quality manner, for example, the high quality of new product process success factor or the high quality of execution of technological and marketing activities success factors;
- deliver these benefits, for example, the necessary resources in place success factor;
- bring these benefits first in the marketplace, for example, the strategy to accelerate the NPDD process.

8.2.2 Factors that Influence the Core Innovation Process

The stages of the core innovation process operate in parallel and affect one another. Additionally they are being affected by the rest of the firm's operations and the national innovation environment.

8.2.2.1 Organisational Factors

The corporate strategy; the risk taking policy; the technological capabilities of the firm; its structure; the organisational culture and the creativity of the employees have all been identified as playing a significant role in determining the nature of the outcome and the success of the process (Sections 5.1 to 5.6).

New projects need to be compatible with the firm's strategy, risk taking policy and core competencies (Tidd et al., 1997). These elements however need to be assessed continually and modified according to the needs of the firm's environment. Thus, the firm needs to identify and modify its technological paths, market position and organisational processes continually in order to be proactive to changes in its environment. Additionally, a firm needs to follow a risk taking policy that will allow higher risk projects to be developed and exploit the creativity of its employees. Projects that are characterised as highly novel, however, might not be as risky as is generally believed, because they usually offer more benefits to the customers, are more successful and bring a higher return on investment for the developer (Cooper, 1993).

The organisational factors are affected by each other. For example, the employees' creativity is affected by the organisational climate and the risk taking policy. The creativity may generate new knowledge that influences the technological capabilities of the firm, which subsequently influence the corporate strategy to use these new capabilities and identify a new risk taking policy for developing new products. When one of these factors is neglected then, this will be a barrier to the firm's improvement of its innovation activity, given that it will influence the rest of the factors negatively.

8.2.2.2 National Innovation Environment

Innovation, as a long-term activity, involves the consideration not only of the firm's internal factors but factors that are external to the firm which may reduce or increase the uncertainty of such activity. These external factors – the National Innovation Environment (NIE) – are: the financial system of a nation; the infrastructure; the demand conditions; the critical mass of industries and the existence of physical resources; the knowledge and human resource availability and the regulations that create or reduce barriers in the marketplace (Porter, 1990; Lundvall, 1992; Freeman and Soete, 1997; Edquist, 1997a).

A large firm may feel protected from changes in the NIE because of its size and the capital that it can reinvest. The NIE however, needs to be considered for new investments in a new market as it can make such an investment more expensive. The corporate strategy in any case should be designed taking into consideration the NIE or else the firm may face 'unexpected' events that otherwise would have been identified.

SMEs need to consider the NIE because their operations are usually local and their finance is often dependent on the national financial system. Thus, when a firm has to face an inadequate NIE, it should consider its expansion to other markets and nations in order to cover this disadvantage.

The study of the NIE moreover can be a source of ideas for new products for a firm, for example, because of new environmental regulations, or a source for new processes, for example, to economise on resources and improve management techniques.

8.2.3 The Overall 'Creative Factory'

This new innovation concept, the creative factory, integrates the ideas of the later generations of innovation theory as identified by Rothwell (1994b) with the theories of the national innovation systems (such as Porter, 1990; Lundvall, 1992; Freeman and Soete, 1997), in order to create a complete system of the innovation process and the factors that affect it.

8.2.3.1 Designing the Model

The creative factory's design starts from a top-down analysis of the innovation process, which led to a step-by-step exploration of all the elements that constitute the model. The two different modelling tools – the influence diagrams and the computer-modelling package – use these elements to build the model from bottom-to-top. The centre however of the creative factory is the firm that uses new or existing knowledge, transforms it to a novel product and benefits from its success.

The design of sub-models with different levels of detail has been used to address different audiences. Thus a generic high-level model is directed at senior managers and shareholders in order to present to them the effect of innovation activity on the firm's financial outcomes. A more detailed model is directed at academics and managers because they need to know which elements separate best practice from runners up and which are needed to study the innovation process.

Each section of the theory has been transformed as a separate sub-model. Using the ability of the software to 'freeze' particular sections and 'run' others, a user could simulate only these sub-models on which s/he wishes to focus. The user then could design a sub-model with further details, to study and improve its performance.

The model has been designed using the observations in the literature which refer to the operation of large firms. Thus, it may be the case that some questions and sections of the model cannot be applied to a small or medium enterprise. This limitation has been identified and the case studies directed to large and very large firms. Further work could be done (see Section 8.4) in order to cover, also, the case of SMEs.

8.2.3.2 Potential Applications of the Creative Factory

The influence diagrams and the computerised model can be used to explain in generic terms, the logic of the innovation process and the relationships of the different factors.

The detailed diagrams of each factor and stage of the process could be employed as teaching material for academia and managers in order to identify all the elements that are involved in the innovation process. In addition the simulation of the creative factory can illustrate for academics and industrialists, how changes in one area of a business can influence innovation performance and/or other business factors. These simulation results could be used as an argument to convince an audience of the theory of these factors and of the necessity of innovation activity for the good performance of a firm

Together with the designed questionnaire, the model can present to industrialists aspects of the process to which they have not previously given great attention, either because they did not have the knowledge or training or because these aspects are outside their personal experience. Furthermore the questionnaire can show which areas of a business need to be measured, in order to be used as indicators for the performance of the firm's innovation activity.

A firm is not able to influence the factors of the national innovation environment and the sector's research directions and knowledge creation directly, but it can control its own internal factors; in-house research effort; product design and development process and new product's marketing related activities. Thus, a firm should optimise these factors within the limitations or opportunities that the external environment provides in order to obtain the best results. The first step in order to optimise them is to assess their current status. The simulation of the model gives an opportunity to managers to assess the performance of their firm, to identify in which areas there are shortcomings and which factors should be changed in order to rectify them.

The creative factory however goes a step further than other assessment tools that are usually used by firms (for example, Cooper, 1993; McGrath, 1996). The simulation of the creative factory can be employed to demonstrate the effect of changes in the financial outcome of a firm, an angle that is of great interest to the shareholders of a firm, or the detailed elements of the innovation system. The simulation can be used either to design the changes, to try different combinations of which changes bring the best results in the most efficient way, or to demonstrate the misconception of proposals that lead to only short-term results and neglect the long-term growth. Thus, the creative factory is a strategy-planning tool in addition to an assessment one. The simulation of the scenarios is not a forecast for the financial, or sale performance of a firm. It can evaluate, however, whether proposed changes can influence the innovation performance positively and, under the hypothesis that the costs of running the business will be similar for subsequent years, can illustrate the direction of the financial performance of the firm.

Moreover, the model's National Innovation Environment can illustrate the effect of changes in the external factors on the innovation activity of a firm. This can prepare a firm to react appropriately to a sudden change in the environment, to plan a recovery strategy from an unexpected event or just to recognise the level of influence that these external factors have on its activities.

Studying the creative factory however provides a guideline for policy-making bodies and policies can be designed which will enhance industrial innovation activity. By building theoretical models, the public sector can study how regulation and legislation can change the environment so as to encourage, positively, innovation in the enterprises of the nation. Thus, implementing these changes can enhance innovation activity and improve and sustain the economic growth of the nation.

8.3 The Case Studies of the Creative Factory

To verify whether the creative factory can represent the innovation activity of a firm, three case studies were carried out in different multinational firms. The data collected was used as inputs to the model. The results from the simulation for each factor of the model were then compared to the status that had been identified from the case studies or other published information. Given the level of confidence that gained from this comparison, the creative factory can then be used as an assessment tool and a strategy-planning tool by simulating action-scenarios to improve the innovation activity in those three firms.

8.3.1 Quantification of the Data

The creative factory studies the innovation process and the factors that affect it in a qualitative mode rather than the quantitative one. In order to quantify each element that was under study the questionnaire that was used in the case studies was designed in such a way that the industrialists could mark the performance of their firm in a '1-10' scale with the average to be on the '5'. The best practice for each factor was a '10' grade. The information for the NIE and the firms' sector research activity were quantified with the same logic using published information. The collected information was used in the model as input for each sub-system, they were transformed however on the scale '0-100' in order to avoid decimal points. This quantification method provided a canonisation for each factor in order to make it comparative between the different firms and the best practices.

The simulation results kept this quantification logic. The status of the outputs however where characterised as: 'very poor'; 'poor'; 'adequate'; 'good'; 'very good' and 'excellent'. The two lower labels cover the '0-50' part of the scale and the rest divided to the other four, with the range: '50-65'; '65-75'; '75-90' and '90-100' respectively. When the status of a factor was close to the border of two levels, it was characterised with the combination of these two levels. For example, 'good-to-very good' indicated that although the value of this factor was inside the limits of the 'good' index, it was very close to the 'very good' index. These combinations of indices gave ten possible levels between the average and the best practice for the status of each factor.

8.3.2 Accuracy of the Data and Level of Confidence

The accuracy of the results cannot be analysed statistically to indicate an error element. They can however, be judged as to whether the quantified indices represent the real status of the factors in each case. To do this, the assessment results of the three firms were confirmed by discussion with the industrialists during and after the case studies, as well as by comparison with published information about the firms.

The analysis of the results of the case studies (Chapter 6) and the 'open-box' validation, which took place during the literature review and the parallel construction of the model, indicate that the creative factory:

- gives a good representation of the innovation theory;
- generates successfully the status of the innovation process and the related factors of the firms in the case studies; and that
- can model other large firms using the same theoretical concept by using the questionnaire; adjusting the model to the findings and modifying the equations.

The scenarios cannot be tested in a real situation to validate the results of the simulation of the firm's outputs because of the time that is involved between the changes and their outcome and because firms are not prepared to invest in such a test. However, because of the confidence that has been gained that the creative factory can accurately generate the status of the three firms, it can be assumed that the scenarios are leading to correct conclusions.

8.3.3 Simulation Results

A problem common to the three firms is that, although they invest significant capital and effort in research, this does not necessarily improve their knowledge base. This inadequacy can be traced to the degree that the firms expand their core competencies to follow developments in technology and markets and to use the creative activity of their employees. The latter is weak, either because the firms do not promote creativity by their attitude to risk taking and corporate strategy, or because they just do not have the knowledge necessary to generate creative ideas. The study of the model's logic shows that the relationship between creative activity and a firm's knowledge is defined as a reinforcing loop. Thus, it is necessary for a firm to sustain both factors at a high level, or else both will decline. For the case of Elegrec in particular, an extra factor that reduces the firm's knowledge is that in Greece, the sector is not very advanced compared with the USA or the EU. The situation at Elegrec suggests that firms from small nations need to be more active in the international field, to bring in highly skilled employees to their organisations from the more advanced nations and to create co-operation with other firms from their nation and/or abroad to share risks, knowledge and markets.

A second important observation that derives from the simulations in Globocar and Eurofood, and supports previous studies (see for example Tidd et al., 1997; Dodgson and Rothwell, 1994), is that capital adequacy alone does not guarantee a highly innovative performance. Capital investment seems to be a requirement but if it is not followed by organisational changes it has limited effect.

The simulation in Elegrec's case shows that a firm needs to study its processes holistically and to make improvements in the core innovation process as well as in the business factors that affect this process. Often improvements made only in the core innovation process can be cancelled by inadequacies elsewhere, such as when a high degree of research effort is affected by shortcomings in the core competencies and in the employees' creative activity. Additionally, firms often neglect the early stages of the NPDD process. Even if they invest a large amount of capital in the later stages, neglect of the early stages will limit the performance of the process.

The simulation scenarios for Eurofood illustrates that improvements in sales and profits by marketing efforts alone or by reducing costs, have only a limited effect. Long-term improvement is obtained by the creation of successful new products that will replace old ones and expand the range of activities of a firm.

The effect that the NIE has on the innovation activity of a firm is particularly significant for small or medium size firms that operate locally and are financed by the national financial market. A large firm, with multinational operations and a large internal cash flow that is reinvested in innovation, is not significantly affected by differences in the NIE. Additionally unexpected and radical events, such as a creative destruction, have a greater effect on firms that are not prepared to change and sectors that traditionally have long life cycles. The firms that operate within fast changing sectors have to change every few years so that they can react more effectively to such unexpected events.

8.4 Further Research

In many nations, SMEs are the firms that generate a high degree of innovation and novelty in order to meet the challenge of their large competitors. Thus, a closer study of the innovation process in these firms would identify practices that large firms could adopt in order to improve their own innovation activity and vice versa. The creative factory then would need to be modified using these findings to create a new version that would refer to the characteristics of the activities of a SME.

It would be useful to compare the findings from the assessment of a firm using the creative factory with those using other assessment tools, in order to identify differences or to demonstrate the ease of use of the creative factory model. Additionally such a comparison could demonstrate further the additional use of the creative factory model, as a strategy-planning tool as well as for assessment.

The study in the same three firms, or in others, could continue with researchers positioned inside the firms under study, able to collect directly the necessary information for the adjustment of the creative factory model. It would be possible then for a firm to implement an action-scenario and the progress of the firm as it implemented the scenario could be monitored and the results could be compared with the simulation. This would build even higher confidence in the creative factory, not only as a theoretical and assessment tool but also, as a strategy-planning tool.

Furthermore, more industrial sectors could be covered, in order to identify approaches used in different innovation processes and to test the validity of the creative factory in a broader range of industrial sectors. The successful application of the creative factory in different sectors could help the transfer of best practices from one industrial sector to another, creating a competitive advantage for all. Eventually however, the plurality of the studies could lead to different versions of the creative factory that would be targeted at different industrial sectors and firm sizes. A stand-alone version then, could possibly be provided for managers, academics and policy makers in order to study innovation and evaluate different action-scenarios without the intervention of the author or other researchers.

9 Summary and Conclusions

During this project the author has designed, developed and applied a new Innovation Systems concept – the Creative Factory. The creative factory integrates five generations of innovation theories together with national innovation system theories using a common perspective in order to communicate innovation theory to academics, managers and policy makers, who may have different experiences and knowledge expertise.

9.1 Summary of the Creative Factory Concept

The concept of the creative factory (Figure 117) has at its centre the firm, which is the generator and promoter of innovations in the market, the industrial sector and the nation. The model's main focus is the Core Innovation Process which is constructed from Knowledge Creation from public or industrial research; the New Product Design and Development process, which transforms knowledge into a new product, and the Product Success in the market, which depends on the product's functional competencies and the organisational competencies of the firm to produce it at a reasonable price and quality and place it adequately in the market. This process is affected by other internal factors of the firm as well as by external factors, in the National Innovation Environment. The internal factors refer to the Corporate Strategy; the Risk Taking Policy; the Technological Capabilities of the firm; the Organisational Structure; the Organisational Climate and the Creativity of the firm's employees. The

National Innovation Environment is constructed from the Financial System of a Nation; the Infrastructure; the Demand Conditions; the Critical Mass and Physical Resources available in the nation; the Knowledge and Human Resources available and the Regulations relevant to the activities of a firm.

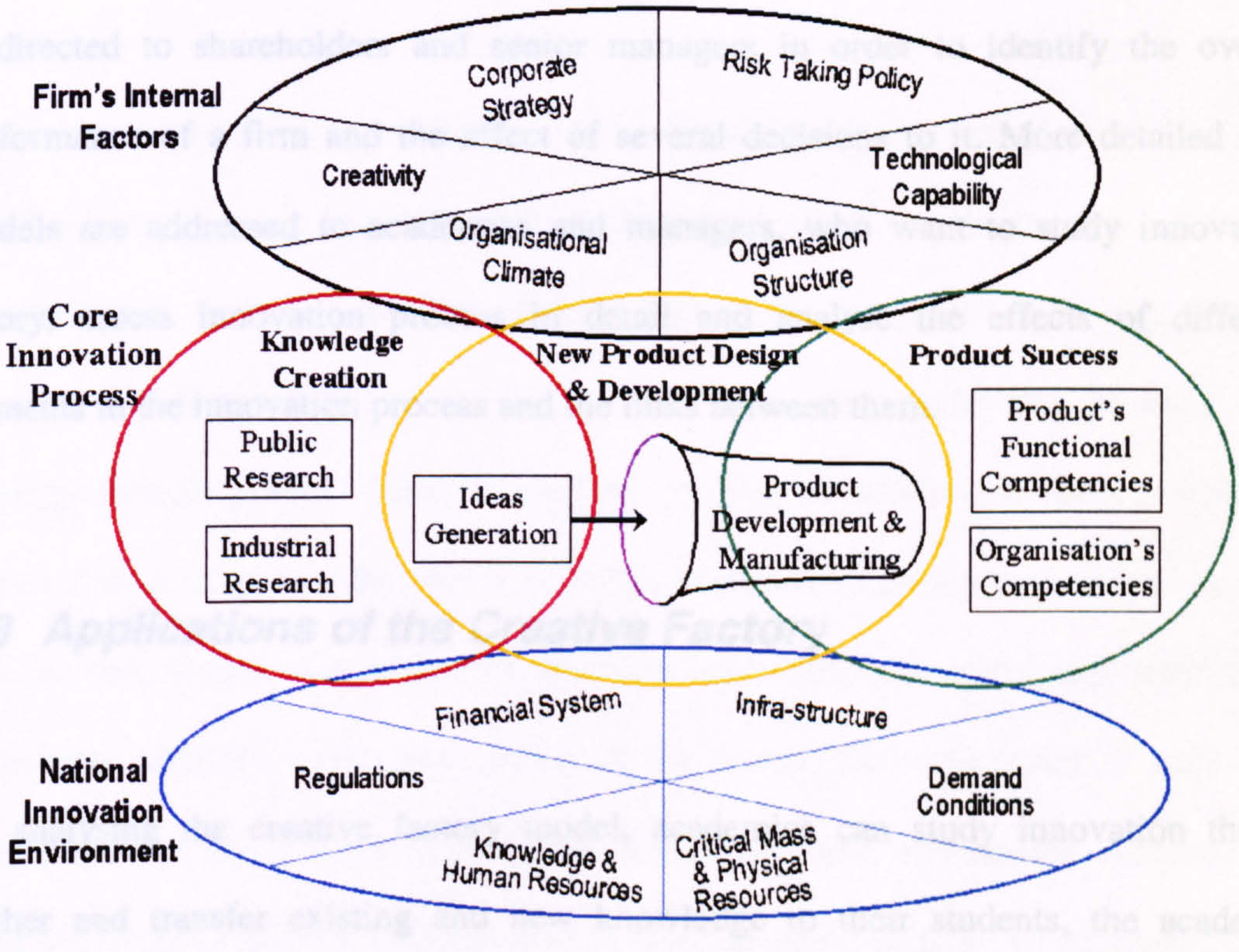


Figure 117. The Creative Factory Concept

9.2 System Dynamics Methodology

The complexity of this innovation system has been revealed by using System Dynamics methodology in order to transform the concept to a computer-based model, using the ithink business-modelling package. Although the System Dynamics methodology has its roots in Control Engineering theory, the method is commonly used in business administration and public policy making. Thus, the creative factory provides a common perspective for innovation theory, the factors that affect the outcome of the innovation process and how the innovation process can be improved.

Different levels of detail in the several sub-models of the system have been used to match the specific needs of different types of audience. Thus, a high-level sub-model is directed to shareholders and senior managers in order to identify the overall performance of a firm and the effect of several decisions to it. More detailed sub-models are addressed to academics and managers, who want to study innovation theory, assess innovation process in detail and analyse the effects of different elements in the innovation process and the links between them.

9.3 Applications of the Creative Factory

By analysing the creative factory model, academics can study innovation theory further and transfer existing and new knowledge to their students, the academic community and the public. Managers can consider their decisions according to the effect of these discussions on their firm's innovation activity. They can identify the elements that influence innovation and correlate these with the effects on different areas of the firm. Additionally, policy-making bodies can identify how the National Innovation Environment affects innovation activity of a firm and how obstacles that this environment may create for the firms of their nation may be minimised.

The creative factory model has been used in this project as an **assessment tool** in three different firms. The assessment tool with its different levels of detail shows either, at a generic level, the overall financial performance of the firm according to its innovation activity, or, at a detailed level, the condition of each of the elements that constitute the innovation process and the factors that affect this process. The assessment provided an evaluation of the current status of the firms' innovation process and of the factors that affect innovation compared with best practices that have been identified in the literature.

Assessment tools provide a snapshot of the firms that they are used to analyse. The creative factory goes a step further. It illustrates the **short and long-term influences of managers' decisions and/or external factors** on the innovation outcomes and between the different factors in the system. Thus, the model can be used as a **strategy-planning tool.** This is realised by the simulation of action-scenarios designed to demonstrate the effects of different decisions on the innovation outcome and on the factors that influence innovation in both the short and long term. Moreover, using the assessment ability of the model, the weaknesses of each firm were identified and a scenario proposed to improve these weaknesses. Additionally, using the creative factory model scenarios were designed in order to demonstrate the effects of external influences on the innovation activity of the firms and to show how the simulation results could be used either to minimise the negative influence or to maximise the opportunities that the National Innovation Environment offers.

9.4 Results from the Use of the Creative Factory

From the use of the creative factory in three different firms the following results have been found:

- The several stages and factors that construct an innovation system are interconnected and they need to be developed in parallel in order that a firm's innovation process be highly successful.
- Many elements of an innovation system are not considered relevant by managers and thus, they do not correlate their status with the innovation performance of their firm.
- Cost reductions and heavy marketing make only limited improvements to sales and profits. The long-term success of a firm is generated through innovative products.
- A balance between basic research, applied research and experimental development is necessary in order for firms to be able to generate not only incremental innovations but also radical ones.
- Capital adequacy, although a necessity for high innovation activity, requires support from the organisational elements of the system in order to be translated to highly innovative performance.
- Firms often neglect the early stages of the innovation process, although this can make the difference between success and failure.
- Employee availability is not necessarily transformed to creative activity from these employees when the firm does not have the right strategy, risk taking policy and creative support programs.
- Often, a high in-house research effort cannot be transferred as new knowledge to the firm because of the low level of employees' creative activity and the inadequacy of the firm's core competencies in following the developments of the research. Additionally this inability is based on the inadequacy of the

organisational structure available to transfer ideas and information throughout the organisation.

- Changes to the NIE do not significantly affect a large and well established multinational firm, but can affect SMEs, start-ups which are often the sources of radical innovation, that operate locally and depend on the national financial system for the finance of their activities.
- A firm that is based in a small or developing nation faces limitations because of the size and the expertise available in that nation. Such firms need to develop products targeting the global competition and to implement a strategy that will allow them to expand in the international market, in order to take advantage of the larger sizes of markets and to import the necessary expertise.
- A creative destruction can negatively affect a firm that is not prepared or operates in a sector with very long product life cycles. Firms however, that are used to continual changes in the marketplace can overcome such destructions relatively faster.

9.5 Epilogue

This project presents a new innovation system concept, the creative factory. This concept integrates the management innovation theories with theories about other organisational factors that are related to innovation process of a large firm and the national innovation environment of this firm. This complex innovation system has been codified for the first time, under a system dynamics approach, to create a model that includes all the aspects that academia, a firm or the policy making bodies need to consider around innovation activity.

The creative factory model is a theoretical tool for academics that can be used to study and communicate innovation theory. Additionally, it can help to improve the decision making of managers when innovation is concerned, through the analysis of the innovation process and its related factors, the assessment of a firm's processes and the simulation of scenarios aimed at improving the work of the system in the short- and the long-term. Thus, the creative factory improves the understanding of innovation theories and the control of the innovation process by managers. Its use can enhance the innovation activity of firms, which could improve the welfare and economic growth of a nation.