ANALYSIS AND DESIGN OF VIRTUAL ENTERPRISES

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Abstract

Virtual Enterprise (VE) is an organizational business concept. Its key ingredients are collaboration among a set of member companies and integration of their competencies, which are needed for developing a new product or service. This concept is in response to the ever-increasing demand on the manufacturing enterprise to react quickly to changes in the market conditions and become agile enterprises.

This thesis presents a quantitative study on the life cycle of Virtual Enterprises. Specifically, it covers the design and management phases. These two phases are modeled using system engineering as a foundation. This has led to the development of two new methods for designing and managing Virtual Enterprises. The design method uses Axiomatic Design Theory and a methodology for complex large systems. The management method is based on Robust Design principles.

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Dedication

To my sister Georgina Mercedes Guerra Guerra. I am confident that wherever she is, she will enjoy this moment as much as I do.

To my parents Doña Georgina Guerra Guerra and Don Juan Manuel Pego Mendez. Mother thank you for inculcating in me the immense value of education. Father, I hope that those endless hours of curiosity and continuous questioning have served their purpose.

To sisters Zita, Patricia and Margarita and my extended family for its support over all these years.

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List of Notations

Acronyms

AG	Agility
AHP	Analytical Hierarchical Process
ANOVA	Analysis of Variance
ANOM	Analysis of Means
ASME	American Society of Mechanical Engineers
BT	Business Strength
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CAO	Computer Aided Outsourcing
CA	Customers' Attributes
CC	Cultural Compatibility
CD	Customer Domain
	Cost of Development
CF	Control Factors cluster
CI	Consistency Index
CR	Collaborative Record
	Consistency Ratio
DB	Disband scenario
df	degree of freedom
DP	Design Parameters
DS	Development Speed
FEM	Finite Element Methods
FD	Functional Domain
FS	Financial Security
FR	Functional Requirements
ISO	International Standard Organization
IT	Use of Information Technology
	Information Technology
ICT	Information and Communication Technology
IP	Improve scenario
LO	Location
MA	New Market Conditions
MB	Management Ability
NF	Noise Factors cluster
NP	Select New Partners scenario
PDP	Product Development Process
PhD	Physical Domain
PrD	Process domain
PS	Partners Selection vector
PV	Process variables
R&D	Research and Development

RFQ	Request For Quotations
RI	Random Index
SI	Size
SMSB	Small and Medium Size Business
SP	Strategic Position
S/N	Signal to Noise ratio
SQ	Status Quo scenario
TC	Technical Capabilities
VE	Virtual Enterprise
5W1H	'Ws' are: what, who, why, when 'H' is how

.

English Symbols

A	Design matrix between the customer and functional domains Set of activities related to a product
AC	Priority vectors matrix of the alternatives-criteria
B	Design matrix between the functional and the physical domains
C	Design matrix between the physical and the process domains Set of selection criteria for assigning activities to partner companies Control Factors
C_f	Control factors vector
CO	Priority vector matrix of the criteria-objectives
c	Selection criteria
e	Error
E	Factor's effect
F	Variance ratio
L	Orthogonal array
m	Overall mean of the experimental region
n	Order of the matrix.
N	Noise factors
n_F	Number of factors
n_f	Number of experiments
n_L	Number of levels
n_I	Number of interaction
t	Time Student t at 95% confidence level
S	Set of specifications for an activity Signal factors
s	a specification of an activity
O	Output or response
P	Set of prospective partner companies
p	A partner company
Pvo	Priority vector of objectives

r	Spearman's rank correlation coefficient
r_1	vector of the VE management
r_2	vector of the SQ cluster
r_3	vector of the IP cluster
r_4	vector of the NP cluster
r_5	vector of the DB cluster
r_6	vector of the CF cluster
r_7	vector of the NF cluster
{ }	Indicates a vector
[ ]	Indicates a matrix
$	Indicates satisfaction

Greek Symbols

∂	Partial derivative
χ^2	Chi-Square probability distribution
α	Statistical level of significance
γ	Partner selection problem
λ_{max}	Largest eigenvalue
μ	Mean
σ	Standard deviation
η	Signal-to-Noise ratio
$\eta(C_f)$:	Signal-to-Noise ratio of control factors

Subscripts

i	Row index
	Functional Requirement index
	Design parameters index
i	Factor index
j	Column index
j	Factor level index
	Experiment index
n	Time interval index
	Functional requirement index
m	Partner company index
h	Activity index
r	Criterion index
x	Time step index
$( )^T$	Transpose

1 Introduction

1.1 Background and Motivation

The following extract from Goldman et al. [1995] illustrates how the application of the Virtual Enterprise ideas has influenced our everyday life. It also shows how we, as customers, have benefited from these ideas, perhaps unknowingly.

> “A customer buys an Ambra computer, a Ford automobile, or a compact disk and is never made aware of the fact that the Ambra was produced by a network of cooperating companies extending from Southeast Asia to North Carolina, each of which devoted only a selected portion of its operations to that effort; that a virtual design studio, made up of designers pulled together electronically from Ford’s seven design centers literally around the world, was responsible for the automobile style; that musicians on the recording either played together in separate studios linked by fiber optic cable or played at different times in different places and their contributions where combined electronically into a single performance.”

A Virtual Enterprise is the temporary union of enterprises, business organizations, units, or individuals to provide a product or service [Zhang et al. 1997]. By focusing on what each member does best, members of Virtual Enterprises collaborate and take advantage of market opportunities that they cannot individually satisfy.

The term Virtual [Corporation] Enterprise was coined by Jan Hopland, a Digital Equipment Corp. (DEC) executive at the beginning of the 1990s [Byrne et al. 1993]. It is said that Hopland used the adjective “virtual” drawing an analogy from the early days of the Personal Computer industry when the term virtual memory was introduced. Virtual memory describes the behaviour that makes a computer use more memory capacity than what it actually has[1]. The memory architecture of a computer system can be used to explain the concept of Virtual Enterprises [Zimmermann 1997]. From a cost-benefit viewpoint, it is not useful to provide very large (infinite) memory resources to a computer system to satisfy the demands of a reduced number of programming applications. This decision is both practical and economical[2]. Virtual memory, uses the main memory and "borrows" extra or secondary memory from the storage device when needed. Similarly, in the enterprise world, companies "borrow" other companies' capabilities when they need them.

The concept and principles of Virtual Enterprises are applied everyday more often by industry leaders inside their own organizations and externally. Those applications confirm the findings of Wildeman [1998], who foresaw a substantial growth of this kind of organizations. For example, the development of the central processing chip PowerPC® was a collaborative project of Apple Computers® with IBM® and Motorola® [Goldman et al. 1995]. Apple Computer lacked the technical and financial resources to carry out the project by itself[3]. On the other hand, IBM and Motorola did not have the vision to develop the PowerPC. The combination of the knowledge, skills and resources from these enterprises resulted in a very successful product that started to ship massively in nearly two years. The development of Chrysler Concorde® sedan, the Dodge Intrepid® and Eagle Vision® are other examples [Goldman et al. 1995]. Through collaboration and integration of Chrysler Corp. with its suppliers, these vehicles were brought to market in a considerably shorter time and at a significant lower cost than other USA car manufacturers.

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[1]More precisely, virtual memory was invented in 1959 when the memory resources in computers were relatively limited in today's terms. Virtual memory hides the memory hierarchy and allows a substantial simplification of the programming effort. Virtual memory enlarges the set of memory addresses a program can use [pcwebopedia]

[2] The practical considerations relate to issues such as size, portability, and manageability of computer systems and the return on investment of such capabilities.

[3]It is interesting to note that at the time of this collaborative project, Apple Computers had lost a substantial portion of the Personal Computer market share because of its outsourcing and cloning policies. After the comeback of Steven Wozniak as Apple Computers CEO, the company has substantially improved its business operations.

There are also pieces of evidence of a successful use of principles of Virtual Enterprises inside many organizations. Texas Instruments® realized substantial savings by reorganizing their calculator unit according to processes rather than specific products. They reduced the time to market of new products by more than 50%, quadrupled the overall return on investment and achieved a leading position in the market [Hammer and Stanton 1999]. Similarly IBM, through a process orientation of its global operations, achieved cost savings of over US $9 billion, decreased the time to market of new products by 75% and substantially improved its delivery capabilities and customer satisfaction.

The previous examples illustrate that companies realize short and long term benefits by forming Virtual Enterprise. Companies improve their technical, logistic, financial and other areas of operations. Companies are able to grow and diversify their markets. They also spread the risk of their investments and are able to deal better with uncertainty. Operationally, they are able to focus on their core capabilities, reduce time to market of the products and services they offer and improve their first time capabilities. In addition, Virtual Enterprises allow companies to gain global access to knowledge and information.

1.2 Research Issues

Virtual Enterprises are market-oriented organizations. They are formed with the objective to take advantage of specific market opportunities. Once the opportunity has passed, the Virtual Enterprise disbands or disintegrates and its members form other Virtual Enterprises. The framework used in this thesis for analyzing the design of Virtual Enterprises includes the following four components:

1) Analyzing the current situation in the design of Virtual Enterprises.
2) Establishing a foundation for the design of Virtual Enterprises.
3) Analyzing the context in which the design of Virtual Enterprises takes place.

4) Analyzing the components or stages of the design process in Virtual Enterprises.

The analysis of the current situation identifies the limitations in the current design of Virtual Enterprises. Once the current situation is evaluated, it is possible to propose solutions targeted at the overall design process.

In this thesis, Virtual Enterprises and their design are analyzed as systems. Virtual Enterprises follow a life cycle composed of three phases: design, management and disbanding. The design of Virtual Enterprises takes place in the design phase. Virtual Enterprises operate in a market environment characterized by rapid changes in customer needs and trends. They can be considered as the way companies are reacting to the current market conditions

The analysis of the current situation shows a high disbanding rate or failure, with more than 60% of Virtual Enterprises disbanding prematurely [Wildeman 1998]. In addition, it was found that most Virtual Enterprises are designed following a ad-hoc approach [Franke 2001]. Current design approaches fail to evaluate the satisfaction of customers' needs, functional requirements, design parameters and process variables. They have ignored that the design of Virtual Enterprises needs to follow both a top-down and a bottom-up approach. A top-down approach identifies the required core capabilities needed and makes it possible the selection of partner companies. A bottom-up approach focuses on building the organization by integrating the core capabilities of partners. More importantly, the design process is static and ignores the market oriented and opportunistic nature of Virtual Enterprises.

1.3 Research Objectives and Scope

This thesis focuses on the analysis and design of Virtual Enterprises. To that end, the objectives are:

1) Establish a foundation for a systematic and consistent design process.
2) Provide a unified framework for the design of Virtual Enterprises.
3) Include time as a variable in the design of Virtual Enterprises.
4) Formulate a time-dependent partner selection problem to improve the success rate and to avoid a premature disbanding.
5) Identify the reasons for failure in collaborative relationships and outsourcing.
6) Identify the importance assigned to the selection criteria in the Partner Selection Process.
7) Develop a methodology for robust management of Virtual Enterprises.
8) Investigate the effects of selection criteria in the management of Virtual Enterprises.

Current research works in the design of Virtual Enterprises considered only some of the characteristics of systems. Virtual Enterprises can be analyzed as both systems and organizations. However, most of the research has focused solely on the design of Virtual Enterprises as organizations and ignored their design as systems. A time-dependent formulation that explains the evolution of Virtual Enterprises as an organizational form is developed in this thesis. The formulation is also extended to include the design of Virtual Enterprises as systems.

The design of Virtual Enterprises as organizations is inconsistent. It focuses on the isolated analysis of some of the design domains. It fails not only to establish relationships between domains, but also to evaluate the satisfaction of their requirements. This thesis presents a formulation of this design process aimed at overcoming these current limitations.

On the other hand, the design of specific instances of Virtual Enterprises does not seem to follow a structured approach. Virtual Enterprises need to, first, identify and later integrate the core capabilities of its members. However, the process throughout which core capabilities are identified and integrated is often ignored. This type of design can be based on 'make or buy' decision process, often used in outsourcing. A 'make or buy' decision-making process uses the system engineering and Product Realization Process to identify the points in the Product Development Process where partners are need.

Up to now the selection of partner companies has been considered a static process performed only during the design phase. However, it is a dynamic process which may take place during both the design and the management phase. This thesis introduces a time-dependent formulation of the partner selection process that takes into account the life cycle of both the Virtual Enterprise and of the product or service it delivers. By including time in the analysis, the formulation aims to reduce the disbanding rate in Virtual Enterprises. The disbanding rate can be reduced if instead of evaluating partners only at the beginning of the relationship, the evaluation process is performed regularly. The regular evaluation of partners identifies changes in the partners' performance that could lead to the disbanding of the Virtual Enterprise.

Only few studies have addressed the disbanding rate in Virtual Enterprises. The most important causes of disbanding are identified by conducting a survey in design and manufacturing companies. The survey also investigates the role of the selection criteria and their importance in the partner selection process. Traditionally, three criteria (cost, location and core capabilities) have been considered in the partner selection process. Advances in Information Technology have made location a less relevant criterion. On the other hand, the influence of cost has also changed. Customers are willing to pay more if value is added to the solutions offered to them.

This thesis re-examines the criteria used for the partner selection process in the light of the current market conditions.

The management of Virtual Enterprises is a complex issue. It includes the integration of core capabilities and other important issues such as the management style of the partner companies. Although design is the most important phase in the life cycle of Virtual Enterprises, the management phase plays a very important role in avoiding the premature disbanding of the organization. A robust management methodology aimed at reducing the disbanding rate in Virtual Enterprise is developed in this thesis. In addition, the effects of selection and evaluation criteria on the management of Virtual Enterprise are investigated.

1.4 General Research Methods

The proposed models for Virtual Enterprises incorporate previous research in the analysis and design of Virtual Enterprises. The analyses and formulations presented in the thesis are based on existing examples and theories for the design and analysis of Virtual Enterprises.

Objective 1 is achieved by using system engineering as a foundation. System engineering principles have been widely used in research for diverse purposes. In this research, they are used to establish the foundations for other analyses presented in this thesis. System engineering is used as a foundation to obtain a time-dependent of the design of Virtual Enterprises and partner selection process.

The unified framework for the design of Virtual Enterprises, stated in Objective 2, is based on Axiomatic Design. Axiomatic Design structures the design process by diving it into four domains: customers' needs, functional, physical and process domains.

Statistical methods such as the Analysis of Variance (ANOVA) and Spearman's rank correlation are used to fulfill Objectives 5 and 6. These methods identify the most important reasons for failure in collaborative and outsourcing relationships. They also make it possible to identify the most important selection criteria and their importance in the partner selection process.

To satisfy Objectives 7 and 8 principles of Robust Design are used. The proposed methodology divides the evaluation criteria into control and noise factors and explores the effects of these factors on the management of Virtual Enterprises.

1.5 Organization of Thesis

The outline of the thesis is as follows. A detailed review of the pertinent literature is presented in Chapter 2. Chapter 3 analyzes Virtual Enterprises as systems. This analysis links Virtual Enterprises to previous organizational forms and establishes the foundations for the analysis of specific instances of Virtual Enterprises. The chapter also develops a conceptual and control model of Virtual Enterprises and includes a time-dependent formulation of the design of Virtual Enterprises as both organizations and systems.

Chapter 4 presents the results of a survey on outsourcing practices in design and manufacturing enterprises. The chapter investigates the most important reasons for failure in outsourcing relationships. It also identifies the current partner selection practices, including the selection criteria and their importance.

Chapter 5 analyzes the design of Virtual Enterprises as organizations. Using Axiomatic Design, the chapter shows that the design of Virtual Enterprises is coupled and does not have a large probability of success.

Chapter 6 studies partner selection problems in Virtual Enterprises. It provides a time-dependent formulation of the problem, which can be used in the whole life cycle of Virtual Enterprises. The chapter also compares two decision-making methods: the Analytical Hierarchy Process and Axiom II from Axiomatic Design. These methods differ in the decision rules they use. The chapter concludes with a case study that compares the performance both methods.

Chapter 7 introduces a robust methodology for the management of Virtual Enterprises. The methodology aims to avoid a premature disbanding by evaluating partners regularly. This chapter also investigates the effects of selection criteria on the management of Virtual Enterprise using an experimental design. The conclusions and possible extension of the thesis are presented in Chapter 8.

2 Literature Review

2.1 Introduction

This chapter presents the analysis of previous research on the design of Virtual Enterprises. The goal of the analysis is to further demonstrate the need for the research objectives described in Chapter 1. The chapter is organized as follows. Section 2.2 introduces the definition of Virtual Enterprises, as well as the advantages and disadvantage of this type of organization. Section 2.3 analyzes the characteristics of Virtual Enterprises, agility, the current market conditions and corporate structure as well as the role of Information and Communication Technologies. Section 2.4 presents the classification of Virtual Enterprises. Section 2.5 establishes the foundations for analyzing Virtual Enterprises as systems. Section 2.6 studies the design phase in Virtual Enterprises. It shows that depending on the starting point of the design, two different design views can be obtained. This section also presents an analysis of the partner selection process, the selection criteria and the decision-making methods. Section 2.7 describes the management phase of Virtual Enterprises.

2.2 Definition

Virtual Enterprise is the temporary union of enterprises, business organizations, units, or individuals to provide a product or service [Zhang et al. 1997]. Members of the Virtual Enterprises collaborate and together take advantage of market opportunities that none of them could individually satisfy by focusing on what each member does best.

The concept of Virtual Enterprise has generated debates in both academic and industrial circles. Those debates are centered in whether or not Virtual Enterprises are a new business model [Campbell 1998]. One side of the debate argues that industry leaders have successfully applied principles of Virtual Enterprises for years. The opponents of this argument suggest that despite the use of a similar terminology, many of the concepts and activities associated with Virtual Enterprises gain a completely different meaning [Goldman et al. 1995].

Concepts such as marketing and customers' satisfaction are enhanced to satisfy and take into account individual customers. Other definitions such as supply chain management, collaboration and suppliers (partners) are completely redefined. Considering Virtual Enterprises as an evolution from earlier organizational forms seems to be the middle ground in this debate. Similarly to other cases of evolution, Virtual Enterprises have both common and differentiating elements from previous business models.

All the definitions of Virtual Enterprises found in literature [Davidow and Malone 1992, Goldman et al. 1995, Zhang et al. 1997, Campbell 1998, Chen et al. 1998, Jäger et al. 1998, Strausak, 1998, Franke 2001, Filos and Ouzounis 2003, Mowshowitz 2002, Tølle 2004] agree that:

1) Its objective is to take advantage of the market opportunity, improve competitiveness and make profits.
2) It is temporary.
3) It uses Information Technology and computer-mediated communication,
4) It links core competencies from different members, has value-added capabilities, and reaches across space, time and organizational boundaries.
5) the management style is egalitarian and the members create a loose network of independent but autonomous entities.
6) Human resources are critical to its success.

This thesis adopts the definition of Arnold et al. [1995] referenced in [Strausak, 1998]. Arnold et al. defined a Virtual Enterprise as:

> "a form of cooperation involving legally autonomous companies, institutions and individuals [that] delivers a product or service on the bases of a common business understanding. The cooperating units participate in the collaboration primarily with their core competencies and present themselves to third parties as a unified organization."

2.2.1 Advantages

Companies realize benefits in both the short and long-terms by forming Virtual Enterprises. These benefits extend to almost all their areas of operations, including areas such as the company's market strategy and management structure. Indeed, they improve their technical, logistic and financial operations. It is interesting to notice that these benefits have multidimensional effects. This means that the advantages derived from one or more of the benefits also contribute to improve the companies' performance in other areas of operations.

Strategically, by forming Virtual Enterprises, companies can concentrate in their areas of expertise and knowledge. This strategy releases the companies' financial and human resources that, in turn, can be used to improve or reinforce the company strategic position in the market place. At the same time, this strategy improves the knowledge and expertise of the company. Companies are, therefore, capable of increasing their technical capabilities in their areas of expertise. In addition, they can avoid fruitless efforts to develop technologies or products that are already available in the market place[1]. These strategic and technical benefits improve the companies' financial position.

From a financial perspective, the formation of a Virtual Enterprise allows companies to shorten their product development process and improves their time to market

[1]Motorola is one of the industry pioneers in the implementation of such approach by establishing a corporate policy of "do not create what already exists somewhere else." [Baines et al.1999].

capabilities[2]. By being the first in bringing a successful product to market, companies reinforce their strategic position. Furthermore, they realize financial and human resources savings that may be used to satisfy other company's needs.

In addition to the technical advantages related to the knowledge and expertise areas, Virtual Enterprises help companies to improve the quality of their products and services. Quality is improved by the collaborative efforts of the members or partners of the organization. Members contribute to the final quality of the product by excelling in their respective area of expertise[3]. In this way, better products are brought to market faster. The contribution of individual member companies to the final product of the Virtual Enterprise also results in better designs of product or services. Better quality contributes to improve customer satisfaction. As the customer satisfaction or customer loyalty increases, the possibility of repeating customers also increases. This, in fact, has a waterfall effect in which companies gain and control a larger portion of the market, strengthen their strategic position and obtain larger profits.

Companies can also take advantage of the organizational structure used in Virtual Enterprises. Virtual Enterprises operate in an almost flat and non-hierarchical structure. A flat hierarchical structure empowers the decision-making process at lower levels of the hierarchy, where problems are better understood. Ottaway and Burns [1997] pointed out that non-hierarchical structures allow the energy of the organization to flow horizontally instead of vertically. The efforts of the organizations hence are focus on the collaboration among different development teams rather than on satisfying the demands of the hierarchy. Furthermore, through a horizontal collaboration, only value-added activities are performed. This, in turn, results in a greater focus on customers and their satisfaction. Besides, a non-hierarchical structure improves the flexibility and capability of the organization to

[2]Time to market capabilities, refer to the time elapsed from the moment in which an idea of a new product (service or technology) is thought to the moment in which this product is introduced to the market.
[3]High technical capabilities of individual companies do not always provide superior products. However, in the case of Virtual Enterprise, companies are expected to collaborate to realize this goal.

adapt rapidly to new market conditions. Development teams are created and start to work faster, thus financial and strategic benefits are also realized.

Closely related to a non-hierarchical management structure is the concept of process enterprises. In a process enterprise, the company's resources are aligned according to the process rather than according to functions or products [Hammer and Stanton 1999]. Managing by processes allows companies to realize substantial saving. Companies are able to reduce their product development process, lead-time, turn around of inventories, administrative and logistic costs. Additionally, they improve their logistics performance and customers' satisfaction. For example, by implementing a process oriented management style, Duke Power, the electric subsidiary of the Duke Energy, has increased the satisfaction of its construction commitments from less than 50% to 98% [Hammer and Stanton 1999]. At the same time, they improved their warehouse operation with time saving of seven folds. Furthermore, their supervisory control has expanded from 1:10 to 1:30-40, while their management hierarchy was reduced from six to three levels of management between the front line workers and senior management.

Virtual Enterprises benefit both small and large organizations. Small enterprises join forces and compete together for larger sections of the market, sections that otherwise they would not be able to access. In addition, they gain access to capital and technological resources and achieve market recognition by conducting projects in collaboration with larger enterprises. For instance, the development of a pen-based computer device to facilitate user-computer interface, by Telepad® illustrates this point. Telepad ®was able to successfully introduce four products in 12 months, by taking IBM as the manufacturer of the device [Goldman et al. 1995]. Large enterprises on the other hand, gain access to existing technologies and improve the flexibility of their operations. Thus, they are able to speed up their development process by reacting more efficiently to changing trends in the market.

Collaboration and integration are two critical factors associated with the success and advantages of Virtual Enterprises. Collaboration is the ability of a company to exchange information, knowledge, and resources in order to achieve a common goal. It allows companies to share their technical, human, and financial resources. It is through collaboration that companies achieve shorter product life cycles, improve their time to market capabilities, satisfy customer demands, and realize the other benefits mentioned above. As companies collaborate with each other, they need to integrate their operations. In this way, companies interact with customers as monolithic enterprises that are in reality a conglomerate of independent companies.

The ongoing analysis has been based on a strategic viewpoint of collaboration and integration. It has shown that these two factors are advantageous to companies. However, these two factors also illustrate the disadvantages or threat faced by companies when joining Virtual Enterprises.

2.2.2 Disadvantages

Ironically, many of the disadvantages of Virtual Enterprises are also directly related to collaboration and integration. It could be said that in these two factors reside both the strength and weakness of the Virtual Enterprises. Collaboration and integration can have a negative impact in areas such as management and strategic position. Additionally, the integration of operations faces challenges as companies have usually seen themselves in isolation [Preiss 1997, Filos and Ouzounis 2003, Tølle 2004]. Issues such as information and communication exchange can damage the companies' performance and influence their profitability.

One of the most critical issues in Virtual Enterprise is the loss of independence [Campbell 1998, Wildeman 1998]. The loss of independence affects the company strategy and can have substantial financial consequences. Since companies are mainly focused on what they do best, they need to collaborate with other companies to bring new products or services to the markets. This means that companies do not have a complete control over the product development process. This loss of control creates a dependency on the performance, skills, and knowledge of their partners. This dependency could influence negatively essential areas of operations in companies. If one of the partner companies decides to leave the organization in the during the product development process, even if another partner is found, the impact on the Virtual Enterprise performance would be considerable. In addition, if no other partner is available, this may mean that the introduction of the new product will have to be abandoned.

The focus on collaboration may affect the companies' strategy and operations. Because companies are mutually dependent, they need to find a balance between prioritizing their own needs and the needs of the Virtual Enterprise. The interests of the Virtual Enterprise are the ones that should prevail. Taking the opposite approach and prioritizing individual needs can have a devastating effect on the existence of the Virtual Enterprise [Campbell 1998]. This is based on the long-term perspective that if the Virtual Enterprise is successful, its members will also be successful. Goldman et al. [1995] referred to Virtual Enterprises in which all the members, including the partners that are brought in for contingency purposes share the profits realized by the collaborative effort.

Companies may also find themselves being both partners and competitors [Campbell 1998]. The focus on core capabilities may lead companies to take part in different Virtual Enterprises concurrently. Instead of carrying out product development process on their own, companies collaborate in different Virtual Enterprises where their skills and knowledge are in demand. Thus, companies may get involved in different Virtual Enterprises that are competing for the same portion of the market. Although unusual in today's market practice, this situation might appear in the near future. Taking part in different Virtual Enterprises at the same time is a consequence of the focus on core capabilities. Companies see themselves more as services providers for other enterprises than isolated and independent companies [Preiss 1997].

Instrumental to the collaboration and integration efforts is the notion of trust among partners. Partners in a Virtual Enterprise can only succeed if they trust each other. The most secure way to achieve trust is through collaborative relationships that repeat over time. However, the market orientation of Virtual Enterprise may result in opportunistic and time-based relationships, in which trust among members have not been developed. It is trust or the lack of it that can damage significantly new Virtual Enterprise initiatives. For example, Campbell [1998] referred to the existence of law suits and incidents over intellectual property in the Silicon Valley in California. This statistics shows a lack of trust among collaborative partners.

Virtual Enterprises also face important integration challenges. It should be noticed that the mere integration of core capabilities does not guarantee the integration of other important and less visible partner characteristics such as management style and corporate culture. These "soft" or human-related issues are one of the critical factors in the success of Virtual Enterprises. They, in fact, are responsible for the low success rate in this type of organization. Wildeman [1998] pointed out that, in a vast majority of cases, the premature disbanding of Virtual Enterprises is due to human-related issues. Therefore, this type of organizations needs to implement creative integration strategies.

Another critical factor in the integration of Virtual Enterprises is the information sharing mechanism. Companies realize the strategic importance of having an efficient exchange of information and knowledge. However, they understand that their information sources are often in different formats. This situation becomes even more complicated when the semantic of the information is added to the analysis [Fox and Gruninger 1998]. Even though companies understand the importance of information exchange at a strategic level, they still spend vital human and financial resources in achieving this integration at a practical level. This is considered a distraction to the company's operations. In extreme cases, the investment can become so expensive that companies withdraw from the idea of integrating their information and knowledge sources. Therefore, the benefits associated with integration in Virtual Enterprises cannot be realized.

In summary, Virtual Enterprises have both advantages and disadvantages. The benefits of forming Virtual Enterprises expand to almost all the areas of operation, from management to finances. It was shown that collaboration and integration are the two most important that affect the formation of Virtual Enterprises. These two factors can have both positive and negative consequences on the companies' operations. Joining a Virtual Enterprise may negatively affect the performance and operations of the participating companies, especially in areas such as information sharing and integration, management, and competitive advantage.

2.3 Characteristics of Virtual Enterprises

The development of the Virtual Enterprise concept is seen as an evolutionary process influenced by several factors. Three main influences that have shaped this evolution: outsourcing, network organizations and agility. The analysis of this evolution, using the 5W1H methodology, is presented in Appendix A.

In one evolutionary path, the origins of Virtual Enterprises can be traced back to the development of outsourcing or subcontracting relationships [Fine and Whitney 1996]. Outsourcing decision-making allows companies to focus on their core capabilities by deciding whether to make or buy a given component.

A second path considers Virtual Enterprises as an evolution from network organizations [Jäger et al. 1998, NIIIP 1998, Wildeman 1998, Franke 2001, Tølle 2004, Camarinha-Matos and Afsarmanesh 2005]. Networks organizations are created by sharing the development process of products or services, with the purpose of achieving a competitive advantage. In addition, changes in the current market conditions have forced companies to adapt their strategies to be able react quickly to changing market conditions and achieve agility. In principle, it can be said that a Virtual Enterprise is the creative combination of attributes from outsourcing, strategic networks and agility.

The creation of a Virtual Enterprise has not been a “voluntary” decision. Indeed, Virtual Enterprises are the way in which companies are reacting to new market conditions. All the literature consulted acknowledge that Virtual Enterprises are operating in an environment substantially different from previous organizational forms [Byrne 1993, Goldman et al. 1995, Parunak 1997, Preiss 1997, Campbell 1998, Franke 2001, Tølle 2004, Camarinha-Matos and Afsarmanesh 2005]. The current situation in the market is influenced by social, political, economical, business, technical, and organizational as well as other factors dealing with the workforce.

This section introduces the most important characteristics of Virtual Enterprises. It also analyzes agility, current market conditions and management structure that have created the need for this kind of organization.

Wassenaar [1999] divides the research on the characteristics of Virtual Enterprises into intra-organizational and inter-organizational. Intra-organizational oriented studies deal with the creation of Virtual Enterprises within organizations. Inter-organizational studies, in contrast, consider the formation of Virtual Enterprises as a network organization. Most research is oriented towards the analysis of inter-organizational Virtual Enterprises because of the challenges they face.

Intra-organizational studies consider virtual teams as the basic building block of Virtual Enterprises [Wassenaar 1999]. Virtual teams are created to satisfy specific organizational goals and disbanded once the goals are met. These teams are dynamic, self-managed, and composed of a multidisciplinary expertise. Trust is critical to the success of virtual teams, since it protects team members from both geographical and organizational isolation.

Inter-organizational studies, on the other hand, consider Virtual Enterprises as an organization with a short and transitory lifespan. Some studies focus on the structure of functional units, while others consider value adding processes and capabilities in Virtual Enterprises [Campbell 1998]. The former focuses on identifying the functional requirements of the organization. The latter concentrates on the analysis of efficiency and effectiveness of the value-adding processes created while forming Virtual Enterprises. Fortunately, regardless of the focus of the analysis, both approaches identify similar characteristics in Virtual Enterprises.

Studies focused on structure of Virtual Enterprises have been very repetitive and characterized by the constant reintroduction of similar concept with different terminologies. Thus, only the most relevant research works are analyzed here.

Wigand et al. [1997] identified three characteristics and three design principles in Virtual Enterprises. The characteristics are: modularity, heterogeneity, as well as a time and space distribution. Complementation of core capabilities, open-closed and transparency, on the other hand, are the three design principles.

Modularity considers decentralization of the decision making process, and the size of the members or units of the organization. Heterogeneity takes into account the diversity of the membership. The membership in Virtual Enterprises is varied and based on core capabilities and strengths of partners. Time and space distribution considers the geographical distribution of partners, and the dynamic reconfiguration of the organization.

The complementarity's principle deals with the complementation of core capabilities of the members of the Virtual Enterprise. The open-closed principle makes it possible for a Virtual Enterprise to function as an integrated system. The transparency principle refers to the capability of the Virtual Enterprise of appearing to customers as a monolithic organization when it is, in fact, a conglomerate of companies. Customers recognize functions but neither time nor space distributions.

Goldman et al. [1995] identified five essential characteristics of Virtual Enterprises. They are:

1) opportunism,
2) excellence,
3) technology,
4) no borders, and
5) trust.

These characteristics apply to any Virtual Enterprise. Factors such as the size of the partner companies or the specific markets where the companies operate do not affect the generality of these characteristics.

Opportunism is the ability of the organization to identify existing market opportunities or create new ones. Once an opportunity is identified, the Virtual Enterprise should react quickly to take advantage of the opportunity. As explained earlier, companies need to collaborate and integrate their core competencies to provide solutions as fast as possible to their customers.

It will be shown during the analysis of the current market conditions that customers are demanding cost-effective solutions. To satisfy customers demands for cost-effective solutions, companies need to excel in their core capabilities. Goldman et al. [1995] referred to a Virtual Enterprise as an all-star team when stating: "imagine the power of an all-star team for every business opportunity, tailored to the challenge of the opportunity and that competitive situation." Virtual Enterprises are, thus, the integration of resources, skills and knowledge of organizations dedicated to excel in their core capabilities. It is through the integration of their core capabilities that companies provide high quality solutions to their customers.

The Technology characteristic has a dual meaning. On one side, technology refers to the ability of Virtual Enterprises to be market leaders in the creation of new technology. In this interpretation, the technology characteristic relates to core competencies and excellence. Technology also refers to the effective and creative use of technology to create value to customers. From this viewpoint, technology relates to the ability of the company to carry out global business and erase boundaries among enterprises using Information Technology. Virtual Enterprises concentrate on providing value and using the core competencies of partners, no matter where they are located. In this second interpretation, technology refers more to the no borders and trust attributes.

Virtual Enterprises focus on gaining access to a set of core competencies that are available globally. They, therefore, need to reach across other organizations that possess the core competencies needed to take advantage of new market opportunities. Definitely, Information Technology plays an important role in this approach, but it has been shown that the use of Information Technology in itself does not provide a significant competitive advantage. Closely associated with the no borders characteristic is the use of distributed facilities to carry out the product development process. Distributed facilities allow a concurrent development process. By working concurrently, instead of sequentially, companies shorten their product development processes and therefore can bring products or solutions to market faster.

Trust is the ability of the Virtual Enterprise to conduct business in an environment where both collective and individual interests are rewarded. Indeed, organizations are in need of a smooth flow of information and knowledge among them. Trust is one of the most challenging issues in Virtual Enterprises. It is through trust that companies can achieve a meaningful integration of their core capabilities. Trust is also the foundation for information sharing and collaboration.

Bultje and van Vijk [1998], as well as Sieber [1998] conducted surveys to identify the characteristics of Virtual Enterprises. Bultje and van Vijk [1998] reduced to 12 a set of 26 characteristics that have appeared in literature regarding Virtual Enterprises. Out of these 12 characteristics, seven were classified as primary and five as secondary characteristics. A primary characteristic is one that appeared in all the surveyed companies, while a secondary characteristic appeared in 80% or more of the cases. They concluded that primary characteristics of Virtual Enterprises were:

1) a partial mission overlap,
2) customer-centered and mass customization,
3) network of independent companies,
4) semi-stable relations,
5) geographical dispersion,
6) based on core competencies, and
7) dependent on innovation.

They also identified as secondary characteristics:

1) one identity,
2) based on trust,
3) shared loyalty,
4) based on the use of Information Technology, and
5) distinction between strategic and operational levels.

These findings have been confirmed by more recent research [Tølle 2004, Camarinha-Matos and Afsarmanesh 2005].

Most characteristics have been explained above. Thus, only the 'new' characteristics are analyzed below.

A partial mission overlap refers to the business focus of the partner companies in a Virtual Enterprise. Partners may participate in a Virtual enterprise with a complete or a partial mission overlap. Members with a complete mission overlap perform all their business activities within the Virtual Enterprise. In contrast, members with a partial mission overlap conduct only part of their business within a Virtual Enterprise.

Customer-oriented [based] and mass customization take into account the ability of the Virtual Enterprise to provide individualized products and services tailored to individual customer needs.

The semi-stable relations characteristic refers to the kind of relationship established among partners in Virtual Enterprises. Relationships in Virtual Enterprises are less formal and less permanents than in other types of organizational structures. Although these relationships create dependencies among partners, they can continue to operate without them.

Virtual Enterprises depend heavily on innovation since they are market-oriented organizations. As explained earlier, they need to react quickly and reconfigure to satisfy new market demands and customer trends. Innovation is not constrained only to technical innovation. It can include innovation in other functions such as management strategies that allow the organization to satisfy its objectives fully. This dependency on innovation is strongly related to the scope of the mass customization provided by the organization as well as its development as a learning organization.

The 'one identity' secondary characteristic refers to how a Virtual Enterprise presents and markets itself to customers and other organizations. Two well-defined types of Virtual Enterprises can be identified 'soft' and 'hard'. In the 'hard' form, Virtual Enterprise presents themselves to customers (or other companies) as a single and monolithic organization where only functions can be identified. Customers are unable to recognize either their space or time distributions. In 'soft' Virtual Enterprises, the identities of the members remain visible. This is the case, for instance, of service-oriented Virtual Enterprises. Each member of the organization has access to customers and “transfers” them to other organizations, for additional or complementary services. In this way, the Virtual Enterprise enhances the scope of the solution offered to customers.

Shared loyalty considers the dual position faced by individuals working or interacting in Virtual Organizations. It also extends to member companies themselves. Individuals are concurrently members of a Virtual Enterprise and members of their ‘source’ organizations. Therefore, individuals need to identify themselves with both their own organization and the Virtual Enterprise. Member companies also face this duality. They have to ‘protect’ their own interests and at the same time protect the interests of the Virtual Enterprise. The balance between individual and collective objective is delicate and it should be considered carefully. However, the interest of the Virtual Enterprise as a whole should prevail [Goldman et al. 1995, Campbell 1998, Franke 2001]. Failing to do so, often results first in conflicts and finally in the premature disbanding of the organization. This characteristic also is strongly related to trust among employees and partners.

The distinction between strategic and operational levels deals with separation of the abstract requirements of Virtual Enterprises (strategic level) from their satisfiers (operational level), as identified by Mowshowitz [1994, 1997a, 1997b, 1999, 2001]. This separation results in what is defined as the ‘switching principle’. The switching principle focuses on assigning satisfiers to the abstract requirements in such a way that the strategic goals of the Virtual Enterprise are met. Thus, if the strategic goals change, so will the satisfiers.

Sieber [1998] analyzes Virtual Enterprises based on their value adding processes, instead of studying the structure of functional units. The analysis of value-adding processes focuses on the efficiency and effectiveness of Virtual Enterprises. The survey identified the followings as the main characteristics of Virtual Enterprises:

1) temporary network of companies,
2) complementary core capabilities,
3) inter-organizational co-operation and integration,
4) flat hierarchies and changing of hierarchical positions,
5) formulation of a common network strategy, and
6) trust.

In this survey, Internet was identified as an enabling technology rather than as a characteristic.

Flat hierarchies and changing hierarchical position are consequences of the market orientation in Virtual Enterprises. It was explained earlier that the market orientation of Virtual Enterprises causes a constant redefinition of the organization membership. The reorganization occurs at both intra-organizational as well as inter-organizational scale. Internally, team members are assigned according to their core capabilities (skills and knowledge) and according to the value-adding chain that the company decides to join. On the other hand, the role of a company in the value-adding chain may change according to the market opportunity. In Virtual Enterprises, partners can be either leaders or contributing members depending on the need for their core capabilities in the value chain. In the context of a constant adaptation to market conditions, hierarchical structures loose usefulness.

The analysis presented above has identified the most important characteristics of Virtual Enterprises. It should be noted that similar characteristics are identified, regardless whether the analyses focused on the structure of the functional units or the efficiency and effectiveness of value-adding process in Virtual Enterprises. It is also interesting to notice, the proliferation of terms referring to similar concepts. For example, no borders has been also referred to as geographical dispersion, time and space distribution of the Virtual Enterprise (or the core capabilities), boundary crossing, sharing of skills and resources.

Table 2.1 Summary of the Characteristics of Virtual Enterprises.

Golman et al. [1995]	Concepts or characteristics with similar meanings
Opportunism	• goal oriented • open-closed • temporality • flexibility • changing participants • semi-estable relations • temporary networks • common network strategy
Excellence	• customer-centered • mass customization
Technology	• dependent on innovation • information and communication technologies • electronic communication • information exchange
No borders	• multidisciplinary expertise • modularity • heterogeneity • time and space distribution • network organizations • sharing of skills and resources • boundary crossing • geographical dispersion • inter-organizational co-operation and integration
Trust	• equity's of participants • shared loyalty
One identity	• transparency

Table 2.1 organizes the characteristics identified by all the sources into a common framework taking as a reference those characteristics identified by Goldman et al. [1995]. Although some of the characteristics put together may refer to slightly different concepts, in general, they match the meaning of the definition of the characteristics taken as references. An excellent review of the varied terminologies used in describing to Virtual Enterprises and related concepts can be found in Camarinha-Matos and Afsarmanesh [2005].

In summary, nine characteristics of Virtual Enterprises are considered in this thesis. These characteristics are:

1) opportunism,
2) excellence,
3) technology,
4) no borders,
5) trust,
6) one identity,
7) partial mission overlapping,
8) distinction between strategic and operational levels, and
9) flat hierarchies and changing hierarchical positions.

The list above shows that in addition to the characteristics identified by Goldman et al. [1995], four other characteristics were identified while surveying companies that have implemented Virtual Enterprises.

2.3.1 Agility

Companies have used both outsourcing and network organizations for years. After all, the origins of outsourcing can be traced back to mid 1930s when Toyota started to develop a management system capable of dealing with variety and the economy of scale production at the same time [Schlie and Goldhar 1989, Halley 2001]. Network organizations have perhaps followed a similar development path. To a certain extent, companies always have had the need to collaborate, even though; collaboration has not been at the scope and scale seen today. This understanding leads to inquiring on the causes of why companies are changing their strategies and the way in which they operate. The element significantly different is the environment in which companies currently operate. That is, companies are operating in market conditions that are substantially different from the mass production era.

Virtual Enterprise is the way in which companies are reacting to new market conditions. More important than the changes per se is, however, the inclusion of time as an important variable influencing these changes. Current market conditions have forced companies to shorten their product life cycle, to reduce cost and concept to cash time, as well as to provide solutions instead of isolated products to their customers.

According to Goldman et al. [1995], agility is the capability to react rapidly to accommodate new needs of the market place. Becoming agile enterprises enables companies to enhance their performance in complex and continuously changing markets. Due to the market conditions, companies need to focus on maintaining their competitiveness not only at local or national levels but globally. Agile organizations need to quickly detect changing market conditions and learn to take advantage of market changes [Davidow and Malone 1992, Reich et al. 1999, Ip et al. 2003].

Yusuf et al. [1999] suggested a more complete definition. They define agility as "the successful exploration of competitive bases (speed, flexibility, innovation, proactivity, quality and profitability) through the integration of reconfigurable resources and best practices in a knowledge-rich environment to provide customer-driven products and services in a fast changing market environment."

It can be shown that the analysis of this definition in terms of inputs, processes or transforming operations, and outputs shows that agility satisfies the nine major characteristics of a system. This analysis also coincides with Goranson's [1999] findings, which consider agility as set of capabilities reaching all the functions of company. The nine characteristics of systems will be introduced in Chapter 3.

Yusuf et al. [1999] summarized the main characteristics of agility as follows:

1) High quality and highly customized products,
2) Products and services with high information and value-added content,
3) Mobilization of core competencies,

4) Synthesis of diverse technologies,
5) Response to change and uncertainty,
6) Intra-enterprise and inter-enterprise integration, and
7) Responsiveness to social and environmental issues.

2.3.2 Market Conditions and Corporate Structure

The analysis of the current conditions in the market place shows that Virtual Enterprises are operating in an environment substantially different from previous business models [Goldman et al. 1995, Camarinha-Matos and Afsarmanesh 1998, Filos and Ouzounis 2003, Tølle 2004]. The current market conditions are influenced by social, political, economical, and technical factors. Factors such as globalization, deregulation of international law and businesses, rapid advances in Information Technology, product complexity and mass customization are some of the most visible trends.

During the mass production era ideas such as "in house" development or "if not invented here is not good" gained ground in many enterprises [Goldman et al. 1995]. This way of thinking led many businesses to develop technologies that were available in the market place. For example, in mid-1970 the three major car manufacturers in USA independently developed catalytic converters. The cost of these Research and Development (R&D) projects is estimated at US $250 million for each of the manufacturer [Goldman et al 1995]. This approach consumed considerable human and financial resources from these manufacturers. However, none of the manufacturers could realize any substantial competitive advantage out of this investment. In contrast, if they were carried out the development project together, these enterprises could have freed some of their resources and use them to their competitive advantages in other areas.

There was, moreover, the tendency to believe that the markets were infinite and that all manufactured products could be sold, if the prices were low enough [Gardiner

1996]. At the same time, markets have been traditionally considered predictable and based on transactional relationships between suppliers and customers [Hirsh et al. 1998]. Nowadays, in the environment in which Virtual Enterprises operate, there is a clear understanding that markets are finite. Therefore, companies need to find new ways to compete for customers and market shares. Indeed, markets are more oriented to a mutually beneficial approach between suppliers and customers and are considerably less predictable [Hirsh et al. 1998].

Product performance and variety improvements are consequences of the markets being finite and a customer-centered market place. Manufacturers and service providers need to differentiate themselves. Manufactures also need to show that their products are those that better address customers' needs and have more value. Customers are demanding products and services that fully satisfy their specific needs rather than accepting offers that provide incomplete solutions. This is why customers have been identified as the "manufacturing driving force" [Ham and Kumara 1997].

Product performance and variety should not result in a significant increase in the overall cost. Customers are not asking only for solutions, but for innovative and cost-effective solutions to their problems. Companies need to focus in cost reduction since competition is based more everyday on price. They need to provide similar or better products or services at a lower price than their competitor do to succeed. Examples of the so-called "price war" are abundant, for instance, Wal-Mart and its competitors such as Zellers®, Kmart®[4] and ByWay®[5], courier companies, such as United Parcel Service® (UPS) and Federal Express® (FedEx) as well as computer manufacturer such as Dell®, IBM® and Hewlett-Packard-Compaq®. In these three cases, the leading position of those companies in the market is due to an overall cost reduction with respect to their competitors. These companies have been able to reduce cost through better logistics and other innovative business strategies [Gardiner 1996].

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[4]The Kmart store chain went out of the Canadian market in 1996
[5]ByWay store chain had a similar story as Kmart, it went out of the Canadian market early in 2001. However, Kmart and ByWay still operate in USA.

Presently, products are so complex that enterprises do not have the time or the capabilities to develop all the related components and technologies "in house". The automobile industry is one illustrative example of this complexity. A modern automobile is the combination of knowledge of diverse disciplines such mechanical, chemical, and electronic engineering. Improvements in today's automobiles, such as Anti-lock Brake System (ABS) and microprocessor applications, as for instance, fuel injection systems illustrate this complexity.

The personal computer (PC) is another interesting example. Producing a computer involves, among others, electronic, mechanical, and material engineering knowledge. As products become more complex, more information (knowledge) is required to design and manufacture them. Ottaway and Burns [1997] identified the information content as one of the most influential factors affecting a company's productivity. Information content ranks even higher than any other critical factor such as labour and cost.

Globalization and the deregulation of international laws and businesses have also influenced the current market conditions. The globalization of the economy is the open flow of capital and commerce across international boundaries. It enables companies to extend their presence all over the world and to compete for markets at a multinational scale. Because of the deregulation of international commerce, protective barriers, and regulations are disappearing. Those regulations have been keeping less-efficient domestic manufacturers afloat. They were also giving a competitive edge to domestic industries. For example, after more than 20 years of existence, the car manufacturing agreement between Canada and USA expired, early in the year 2000. This was an initiative lead by Japanese car manufacturers at the World Trade Organization (WTO). Japanese manufacturers argued that this agreement was a barrier to an open competition in the North-American automobile market and gave a competitive edge to the USA car manufacturers. Currently, the North-American automobile market is definitely more competitive because car buyers have now access to Japanese car at lower prices.

Globalization and deregulation have also increased the competition among enterprises. They have influenced the migration from a closed to an open market society where centralized facilities are no longer needed [Ham and Kamura 1997]. Meanwhile, these conditions have presented new opportunities and challenges in the use and application of Information and Communication Technologies [Hirsh et al.1998]. Currently, companies need to coordinate and integrate their operations from literally every corner of the world. These global operations could affect the effectiveness of the companies' decision-making process. The ability of globally distributed companies to bring a product to market depends on a large number of interdependent decisions taken by many individuals [Ottaway and Burns 1997]. Therefore, as the information content increases, it could significantly influence the ability to take the right decision. The problems of early version of Windows 95 are is still fresh in the mind of many users. Many of the problems resulted from poorly coordinated development efforts of the Microsoft subsidiaries. To avoid subsequent problems and improve customer satisfaction, Microsoft decided to develop the core of the Windows operating system at its headquarters in Seattle, and leave mainly the internationalization (or language related) issues to its subsidiaries.

The advances in technology Information Technology (IT) are felt in market. Information Technology is a term used to describe a wide range of microprocessor-based technologies including both software and hardware [Laundon and Laundon 1998]. These technologies provide better ways to manipulate, process, collect, and distribute information. The advances in Information Technology have been fuelled by a rapid growth in the microprocessor computing power, the development of networking and communication related technologies and the appearance and growth of the World Wide Web (WWW) and Internet [Ham and Kumura 1997, King 1996]. A more powerful microprocessor process more information and does it faster. Networking and communication related technologies simplify accessing and distributing information. They allow companies to work concurrently with their partners and be more productive. The doubling of the number of web-servers in use every 18 months has increased the sources and amount of information to unmanageable numbers [King 1996, Gardiner 1996].

This section has analyzed the most important changes in the marketplace that are forcing companies to change their way of operations. Indeed, companies are changing the nature of their relationship with customer, including how they interact with them. In summary, it is the combination of social, political, and technological factors what has radically changed the situation in the market place. To understand the concept of Virtual Enterprises, the management structure of the companies doing business in the market needs to be analyzed.

The majority of the organizations operating in today's market place have a deep hierarchical structure. This management structure has been in use for many years with both positive and negative results. Hierarchies are characterized by a high level of centralization. This centralization expands to many areas of the operations of the enterprise from decision-making to resources allocation. Hierarchical organizations tend to focus on their functions rather than on the underlying process of the product they produce [Hammer and Stanton 1999]. Specifically, much of the efforts in these organizations are focused on the satisfaction of the requirements of higher-level management. This approach reinforces the isolation of internal units as they are seen as discrete and unrelated to one another.

Hatvany [1985] pointed out that organizations with high degree of centralization are rigid and constrained. Many hierarchical organizations suffer from stagnation and bureaucracy. Therefore, their ability to react fast to the market conditions and trends is undermined. Hierarchical organizations are unable to compete in a dynamic market place, since they lack the flexibility and responsiveness needed to succeed in such environment [Hammer and Champy 1993].

To operate successfully in the new market conditions, organizations need to overcome the limitations associated with hierarchical organizations. This is hardly a new discovery, but still not much has been done to correct the situation. Hammer and Stanton [1999] argued this is not an easy transformation, since senior functional managers run their units as if they were their own businesses. They expect resources from higher-level management and provide results according to that allocation. Middle and low-level managers, in contrast, have been focused on executing "instructions from above" and assuring that the deadlines are met. This behaviour damages the ability of the companies to establish an effective flow of information along the hierarchical structure. Those managers have become transmitters of instruction with little decision-making capabilities instead of sources of information for their teams. The overall result is an organization in which many non value-added activities are performed only to fuel the engine of the hierarchy.

However, it should be noted that in stable markets with scalar economies, where customer needs do not change so often, hierarchical structures are still very effective forms of organization [Dembski 1998, Tøller 2004]. Companies such as Boeing and Bombardier operate in this kind of market. The former operates in the aeronautical market, while the latter competes in the same market and the public transportation.

Hirsh et al. [1998] noted that hierarchical organizations with a strong functional orientation are being replaced by open and flexible organizational structures with extended responsibilities (especially for employees at lower hierarchical levels). Reithofer and Naeger [1997] described as the fundamental element of the factory of the future, the substitution of the centralized hierarchies by flatter organizational structures. This new kind of enterprises will be managed according to flexibility, product variety, and development times [Schile and Goldhar 1989]. To succeed companies need to apply these principles to all functions of business, including Research and Development, engineering, marketing, and distribution.

Non-hierarchical organizations switch their focus from the hierarchical structure to the customer. The flow of energy in the organization is horizontally rather than vertically [Ottaway and Burns 1997]. In a horizontally focused organization, the flows of information and work extend across (instead of along) different business units. This new focus results in the elimination of non-value added activities and a better customer satisfaction [Ottaway and Burns 1997, Hammer and Stanton 1999].

Reengineering the organization according to processes rather than its functional units overcomes the limitations of hierarchical organization. In a process-oriented enterprise, financial resources are assigned according to projects, neither departments nor functional units. The process owners are the ones that are responsible for the design, control, and providing resources to the activities. This change orients management to the underlying process or product instead of fulfilling the demands of the hierarchy. The transformation of the Calculators Unit of Texas Instruments [Hammer and Stanton 1999] explained earlier, illustrate this trend.

The previous analysis shows a mismatch between the current market conditions and the organizational structures of the enterprises that operate in it. Companies are reengineering themselves in a way that they can meet these new market demands. More importantly, companies are starting to recognize that the only viable option is to be able to react fast to market changes. Indeed, they realize that to compete effectively, they need to change their organizational structures. One of the possible solutions to the new challenges from the market place is for the companies to become an agile enterprise and to form Virtual Enterprises.

2.3.3 The Role of Information Technology

The current understanding about the characteristics of Virtual Enterprises and its causes (the current market conditions) has not been without controversy and passionate debates. In addition to the debate whether Virtual Enterprises are a new type of organizational, the role of Information and Communication Technologies has been argued extensively.

The role of Information Technology in Virtual Enterprises has divided researchers into two opposite groups. One group argues that Information Technology is a central component in achieving agility and forming Virtual Enterprises. The second group leans towards recognizing the role of Information Technology, but acknowledges that technology in itself will not solve all the problems. Finding a middle ground in this debate seems to be the most reasonable approach

The advocates of the critical role state that Information Technology is essential to achieving agility and forming Virtual Enterprises [Upton and McAfee 1996, Sandhoff 1999, Camahainha-Matos et al. 1998, Jägers et al. 1998, Eversheim et al. 1998, Ott and Natansky 1999, Wassenaar 1999, Franke and Hickmann 2001, Dembski 1998]. They have gone, as far as, to question the very objective of achieving agility, if Information Technology is not used. They argue that Virtual Enterprises depend heavily on Information Technology. Information Technology is presented as the solution to many of the collaboration, integration, and concurrent development problems that companies face nowadays.

On the other hand, the researchers that see the supportive or enabling role argue that Information Technology is only a tool [Goldman et al. 1995, Ranta 1997, Parunak 1997, Campbell 1998, NIIP 1998, Reich et al. 1999, Ashuri and Rouse 2004, Tølle 2004]. Information Technology is not the only way of achieving agility. Companies achieve agility by rapidly adapting to new market conditions. Agility, as strategy, can even be attained even without the use of Information Technology [Goldman et al. 1995]. Jägers et al. [1998] indicated that Information Technology does not solve all problems. They used as an example the case of a company with communication problems. The availability of new and more sophisticated information exchange tools (such as e-mail, newsgroups, workgroups, etc.) will not solve these problems. It will rather emphasize them, as the use of these tools relay more on asynchronous communication and less face-to-face contacts.

Reich et al. [1999] and Tøller [2004] pointed out that Information and Communication Technology alone is only a necessary but not a sufficient condition to succeed under the current market conditions. Any company, assuming it has the financial resources available, can acquire the technology. Thus, the possession of the technology does not guarantee an improvement in a company's competitive advantage. If this were the case, the adoption of the technology would create generic corporate strategies for success applicable to all enterprises. This, in fact, would eliminate any competitive advantage gained by the use of the technology [Campbell, 1998].

Palmer and Speier [1999] conducted a survey on the usage of communication technologies in Virtual Enterprises. They found large differences, depending on the form of virtual organizing (virtual team, a virtual project, a temporary or permanent Virtual Enterprise). Fax and e-mail were identified as the most common means of communication, regardless of the form of virtual organizing. Seventy five percent of the companies surveyed, ranked fax and e-mail, as the most used way of communication. The usage of groupware and the World Wide Web (www) ranked tied at the third place while EDI ranked always as the least used technology. In addition, they found that virtual teams rely more on mature technologies whereas Virtual Enterprises use Internet more often than mature technologies.

Although a more recent study on the same factors was not found and time might have made some these findings obsolete, they point out to a critical role of communication in Virtual Enterprises. These findings suggest that the most proven (or older) technologies are used more often than the newer ones. The usage of newer technologies should increase as they mature and become more reliable.

The way in which technology contributes to a company's competitive advantage is by creating and managing the enterprise knowledge. It is the effectiveness of the company in the use of the technology to support its global (or geographically distributed) operations what differentiates companies in the market [Hirsh et al.

1998]. The examples of Hewlett-Packard-Compaq and Dell Computers can be mentioned again. The competitive advantage attained by these companies is not only a result of the introduction of the new technology in itself, but the use of technology together with innovative business strategies. Therefore, the creative utilization of technology is one of the essential factors – perhaps the most important one – in bringing new products and sustaining a profitable presence in to market place.

The characteristics identified in this section are used as the starting point for the analysis of Virtual Enterprises as a design problem (Chapter 5), the Partner Selection Process (Chapter 6), and the management of Virtual Enterprises (Chapter 7).

2.4 Classification of Virtual Enterprises

Many attempts have been made to classify the way Virtual Enterprises are formed [Wigan et al. 1997, Camarinha-Matos et al. 1998, Campbell 1998, Wassenaar 1999, Tølle 2004, Camarinha-Matos and Afsarmanesh 2005]. Larsen [1999] reported that more than 40 different terms and classifications have appeared in the business and scientific literature. Some of the most common terms used are: extended enterprise, network of enterprises, and cross border enterprises. In most of the cases, the differences among terms are more syntactical than conceptual, since many of them refer to equal or closely related concepts.

Camarinha-Matos et al. [1998] classified Virtual Enterprises according to three dimensions:

1) Time.
2) Topology.
3) Structure.

The time dimension refers to the duration or lifespan of the organization. Virtual Enterprises are created for both short and long term purposes. The formation of short-term enterprises is oriented to take advantage of time-dependent market opportunities that appear for a short period or a single business cycle. In long-term Virtual Enterprises, the life of the enterprise extends for several business cycles. In this case, the Virtual Enterprise focuses on establishing strategic ties within its members. Even if the initial market opportunity has disappeared, the relationships among members survive. They can reassemble their core capabilities to satisfy new market opportunities in different projects [Jäger et al. 1998].

The topology dimension considers the membership of the Virtual Enterprise. A Virtual Enterprise can be either open or closed. Closed memberships are static since partner companies remain in the Virtual Enterprise for several business cycles. Open memberships, on the other hand, are dynamic since there is a constant renewal of the members. Partner companies join or leave the Virtual Enterprise based on factors such as the need for core capabilities, the stage of the business cycle and economy of scale [Wildeman 1998, Tølle 2004]. For example, it is possible to bring into the Virtual Enterprise a member for its research and development core competencies. Once the research and development phase is completed, the enterprise may not need these core competencies anymore. At the same time, the Virtual Enterprise may require the core capabilities of another member to manufacture the product at a large scale. In this dynamic process, each member shares both risks and benefits regardless of the stage of the product development process where its core competencies are needed.

The structural dimension deals with the different management structures of Virtual Enterprises. The three most common forms are: star-like, democratic alliances and federations. The distinguishing factor of these structures is the partners' level of independence with respect to the operation of the Virtual Enterprise. The star-like structure is characterized by the dominant role of one of the members. Usually, the most powerful member establishes the protocols for information and communication exchange within the organization. Automobile and agribusiness alliances usually manage their supply chains in this way [Camarinha-Matos et al. 1998, Tølle 2004, Camarinha-Matos and Afsarmanesh 2005]. Star-like structures are the most common implementations because of the impetus and funding provided by the strongest member [Upton and McAfee 1996].

The democratic alliances, on the other hand, work in a more collaborative and egalitarian environment where each member keeps its autonomy. The decision making process is based more on consensus than on the relative power the member enterprises. Members are brought into the alliance because of the mutual complementation of their core capabilities. Federated alliances are an expansion of collaborative alliances based on the need for a common management of resources and skills. This structure is more likely to be implemented, after member enterprises have been successful in democratic alliance. This kind of alliance is seldom seen in industry.

It is worth noting that the above analysis has been focused on extreme cases in each dimension. Many of the combinations of these three dimensions will result in viable Virtual Enterprises. According to this classification, the most challenging combination is the one characterized by a short duration, an open membership, and a federated management structure. In this case, the partners are constantly joining and leaving the Virtual Enterprise. In addition, all of them equally influence the management of the organization. Therefore, the role of collaboration and integration becomes even more critical to the success of the Virtual Enterprise. This combination is what is considered a Virtual Enterprise in its purest form [Byrne 1993]. Thus, it is understandable this configuration of Virtual Enterprise would have a poor success rate. Wildeman [1998] found out that even in less complex configuration, 60 to 70% of Virtual Enterprises disband prematurely.

To improve this poor success rate Virtual Enterprises may migrate from an open to a closed membership and create what is defined as a web of Virtual Enterprises [Goldman et al. 1995, Eversheim et al. 1999, Franke 2001]or breeding environments [Camarinha-Matos and Cardoso 1999, Tøller 2004]. The web serves as a pre-qualifying stage where the "fit" among the partners is developed and their compatibility is evaluated. The web is used also to solve collaboration and integration issues, before partners start to work in a Virtual Enterprise. Then, when an opportunity is identified, some members of the web form a Virtual Enterprise according to the required core capabilities.

The network broker is central to the web of Virtual Enterprises [Upton and McAfee 1996, Eversheim et al. 1999, Franke and Hickmann 2001, Nayak et al. 2004, Tølle 2004]. The broker is the coordinator of the web and its functions and responsibilities are varied. The role of the broker can either be taken by one of the members of the web or by a company whose core capabilities are to perform this role.

2.5 Virtual Enterprises as Systems

Virtual Enterprises can be analyzed as systems; however, judging from the analysis of the literature, this is often assumed and seldom proved. Many papers start by simply acknowledging that Virtual Enterprises are considered as systems without supporting such a statement. Others only analyze some of characteristics of systems. The most used characteristics have been goal seeking, holism and hierarchy.

Grenier and Metes [1995] and Tølle [2004] characterized Virtual Enterprises as holistic systems. A holistic system is one in which the analysis of its components cannot be completely isolated without a lost of generality. The system is considered as an inseparable entity, where the analysis of its subsystems or components always has to include the analysis of the whole system. Furthermore, Merchant [1997] pointed out that the manufacturing factory of the future would be an integrated holonic system. This feature is considered critical to the achievement of the common goals of the Virtual Enterprise, since it makes possible for partners to cooperate and communicate.

Klüber [1998] provided a more comprehensive study of Virtual Enterprises as holistic systems. He used strategy, process, structure, knowledge, and culture as dimensions for the analysis. The strategy dimension focuses on the objectives and core competencies required in Virtual Enterprises. It combines a market and resource based thinking as well as material and immaterial assets. The combination of strategic management and use of Information Technology are seen as central to this dimension. In addition to core capabilities, this dimension includes human competencies and the capability to cooperate.

The process dimension takes into account the underlying process in the formation of Virtual Enterprises. Processes are restricted to interfaces and the exchange of information for the management of the whole system. The two most important components of this dimension are the management of the life cycle, and the information and communication mechanisms of the Virtual Enterprise. The life cycle of the cooperation is divided into macro and micro processes. The macro process considers the contribution of each member at general or high level. It is used to describe the initiation, bargaining and contracting phases of Virtual Enterprises. The micro process on the other hand, deals with the individual contributions of the partners to the macro process. It takes into account the details of the operational processes among cooperating units such as the interfaces used by partners to collaborate and integrate their core capabilities and resources.

The structural dimension deals with autonomy, recursion, and viability of the Virtual Enterprise. This dimension focuses on the functional perspective of the governance structures, and the information flow between different functional units. The optimization of the Virtual Enterprise as a system has to be addressed not only globally, but also locally. Globally, the optimization should focus on the capability of the system to develop, while the locally it should consider the interest of individual operating units or partners.

The knowledge dimension considers the critical role of knowledge as a source of innovation and competitive advantage. The management of knowledge includes tools to share and capture the organization's knowledge, as well as supporting and nurturing a culture of collaboration.

The cultural dimension considers the organizational culture of the partners, as well as their cultural fit in terms of management styles and corporate culture. Culture extends to all the function of organization, and hence, it supports all the other dimensions. Culture is also essential in the development of a collaborative environment that binds partners companies, nurtures trust and therefore reduces potential for conflicts.

Zhang et al. [1997] and Chen et al. [1998] considered Virtual Enterprises as systems composed of independent and geographically distributed members. Using the General System Theory and the product architecture, the authors proposed as the system main goal, the achievement of a particular configuration in a Virtual Enterprise. Such a configuration has to satisfy the product requirements as well as a set of design constraints.

To the best of our knowledge, no research has demonstrated how Virtual Enterprises satisfy the characteristics of a system. O'Sullivan [1994] identified as the nine most important characteristics of any system: goal seeking, holism, hierarchy, inputs and outputs, transformation, energy, entropy, equifinality, feedback. A detailed analysis of Virtual Enterprises as systems is presented in Chapter 3.

2.5.1 Life Cycle of Virtual Enterprises

A Virtual Enterprise, similarly to life systems, follows a life cycle of creation, development, reproduction, and disappearance. Virtual Enterprises are created to take advantage of a market opportunity. Next, they develop by linking the core competencies of their members to provide products or services. Virtual Enterprises may reproduce depending on the market conditions. Reproduction deals with the repetition of the product or services by other organizations with a better economy of scale [Bronder and Pritzl 1992, Wildeman 1998]. Finally, after the market opportunity is satisfied, Virtual Enterprises disband and the same process starts all over again.

More precisely, the life cycle of a Virtual Enterprise is divided into three phases [Parunak 1997]:

1) Design or creation.
2) Management or operation.
3) Disbanding or dissolution.

The design phase is equivalent to the creation (birth) of a life system. This phase establishes the goal and the objectives of the future Virtual Enterprise, according to the market conditions. It also identifies the functional requirements that organization needs to fulfill. After the functional requirements are known, the Virtual Enterprise determines the core capabilities it needs. Several companies may have these core capabilities, but only few of them are selected as members of the organization. This process is defined as the partner selection process.

Once the partner selection process is finished, the Virtual Enterprise enters in its management phase. The management phase focuses on how to achieve the goals and objectives of the Virtual Enterprise. This phase is equivalent to the development phase in life systems. In the management phase, members collaborate and integrate their core competencies to satisfy the functional requirements, identified in the design phase.

Finally, once the market opportunity has passed, the Virtual Enterprise disbands, and its members find other value-adding chains, where their core capabilities can be used. The disbanding phase deals with ending the relationship among partners and eventually the evaluation of the results of the collaborative work. The disbanding phase is similar to the extinction or disappearance phase of life systems.

More recently Tølle [2004] has expanded the understanding of the life cycle of Virtual Enterprises using the IFIP-IFAC Task Force reference architecture [IFIP-IFAC Task Force 2000]. In this approach the design phase is subdivided into five sub phases: identification, concept, requirements, preliminary design and detailed design. In addition the management phase is divided into implementation and operation. The disbanding phase is referred to as dissolution.

2.6 Design Phase

This thesis focuses mainly in the design phase of Virtual Enterprise, since it is considered the most important phase. Studies in mechanical design have identified that design strongly influences the cost of a product [Dowlatshahi 1992, Albano and Suh 1998]. By the time design is finished, 70 to 85% of the product's cost is already determined, by decisions taken during its design. Design also allows companies to gain a competitive advantage by designing rather than manufacturing low cost products [Campbell 1998].

Making an analogy between the design of products and of Virtual Enterprises, it is argued that by the time the design phase of a Virtual Enterprise finished, more than 70% of its success rate is already determined. This leads to the understanding that the success of a Virtual Enterprise depends more on its design than in its implementation or management. However, the best designed Virtual Enterprise could disband, if it is not managed properly.

The design of Virtual Enterprises, at least as reported in literature, has followed an ad-hoc approach [Camarinha-Matos et al. 1998, Frank 2001, Tølle 2004, Camarinha-Matos and Afsarmanesh 2005]. Industry leaders have taken the initiative and started to search for answers to the challenges posed by the new market conditions [Grenier and Metes 1995]. Steep learning curves, company and industry oriented solutions are some of the distinguishing characteristics of this trend. Unfortunately, this approach does not provide general design principles or guidelines to be followed. The lack of a general design model of Virtual Enterprises is undoubtedly one of the major reasons for the high failure rate of implementations of Virtual Enterprises [Camarinha-Matos et al. 1998]

The current situation in the design of Virtual Enterprises is characterized by:

- a high premature disbanding rate or dissolution,
- an incomplete and inconsistent analysis of the functional requirements and the design parameters of the design,
- the lack of a structured approach and guiding principles for designing the organization and integrating the core capabilities of the partners, and
- a static design process that does not consider the market orientation and opportunistic nature of Virtual Enterprises.

Considering Virtual Enterprises as systems makes it possible to analyze their design, using the design of product or process as a reference. The design of a product starts by identifying the customers' needs it tries to satisfy. Based on these needs, the product's functional requirements are established. These functional requirements are, then, translated or mapped into design parameters. These design parameters, in turn, are translated into process variables. Process variables are used to manufacture the product. High-level functional requirements are decomposed into sub-functional requirements and the translation or mapping process starts all over again. The decomposition process finishes when the design reaches the desired level of detail. The design process of products has been formalized in Axiomatic Design Theory [Suh 1990, Suh 1995]. Axiomatic Design decomposes the design process in four domains: customer, functional, physical and process. The customer domain contains the customer needs, while the functional domain is characterized by the functional requirements of the design. In addition, the physical domain contains the design parameters and the process domains the process variables.

Virtual Enterprises aim to satisfy both current market conditions and specific customers' needs. Depending on the needs Virtual Enterprises aim to satisfy, two high level elements can be identified in the customer domain. This identification results in two design views: one general and one specific. The general view considers the needs of the market. Taking the needs of the market (or market conditions) as starting point makes it possible to identify the functional needs of the organization, its design parameters and process variables. This view explains the development of Virtual Enterprises as an organizational form. The specific view, on the other hand, takes into account specific customers' needs. This design process is similar to the one in products or processes.

Although the design of products or process can be used as a reference for designing Virtual Enterprise, there are differences between them. The most important difference is in the way the design process is carried out. The design of products follows a different approach depending on the architecture of the product being developed [Fine and Whitney 1996]. Products with a modular architecture are designed following a bottom-up approach, while products with an integral architecture are designed following a top-down approach.

In the design of Virtual Enterprises, two designs take place concurrently: the design of the product or service and the design of the organization. The design of the product follows a top-down approach, while the design of the organization follows a bottom-up approach. These two processes are illustrated in Fig. 2.1, in what is defined as the rhombus model.

Fig. 2.1 shows that the identification of functional requirements of the solution provided follows the identification of a market opportunity. These functional requirements are decomposed until they reach the level of core capabilities. It should be noted that core capabilities are more than just technical capabilities. Virtual Enterprise may need other capabilities such as marketing. These non-technical capabilities should be included in the analysis. At this point, the Virtual Enterprise selects partners capable of providing those capabilities. After the selection of partners, the design of the organization begins. Partners, then integrate their core capabilities to perform the different functions of the organizations.

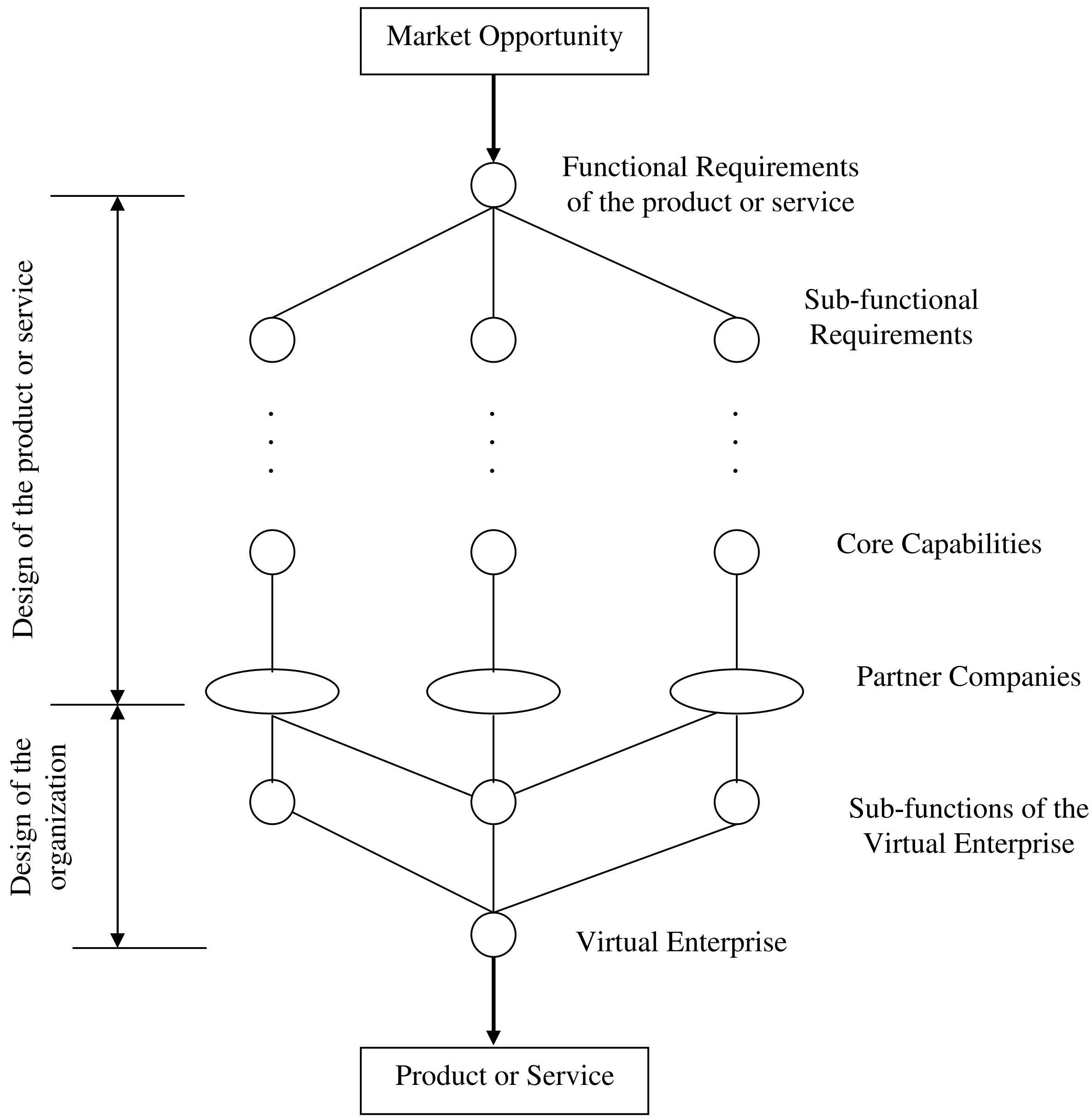

Figure 2.1 Rhombus Model of the Design of Virtual Enterprises.

2.6.1 General Design View

It was explained earlier that in the general view, the customer domain is characterized by the market conditions where Virtual Enterprises operate. The functional requirements are the functions that Virtual Enterprises, as organizations, aim to fulfill. Virtual Enterprises are focused on meeting the demands of agility; therefore, the characteristics of agility become the functional requirements. The physical domain contains the characteristics of Virtual Enterprises, since the formation of Virtual Enterprises is one way of satisfying the requirements of agility. The process domain is composed of the partner companies. These partner companies are the ones that form instances of Virtual Enterprise and hence needs to adapt their operations to meet the new market conditions, the requirements of agility and the demands of Virtual Enterprises.

The design of Virtual Enterprise as organizations, as conducted today, is both incomplete and inconsistent. It has been incomplete because research efforts have only been focused on the isolated analysis of some of the domains. Moreover, it is inconsistent since no analysis has been conducted to identify how the elements in one of the domains are satisfied by the elements in the neighbouring domain. That is, for example, how agility meets the requirements of the current market conditions or how the demands of agility are met by the formation of Virtual Enterprises.

Most of the literature reviewed is focused on the identification of the current market conditions and the analysis of the characteristics of Virtual Enterprises [Goldman et al. 1995, Jäger et al.1998, Sieber 1998, Wildeman 1998, Dembski 1998, Franke 2001, Filos and Ouzounis 2003, Tøller 2004]. These research have two major limitations: (1) they ignore that Virtual Enterprises are expected to satisfy the needs of agility and (2) they do not analyze how the characteristics of Virtual Enterprises meet the requirements of the market conditions.

On the other hand, Davidow and Malone [1992], Goldman et al. [1995], Goranson [1999] and Yusuf et al. [1999] provide a very detailed study of agility; nonetheless, they do not analyze the relationship between agility and the current market conditions.

No research work has been found dealing with the attributes of partners in the design of Virtual Enterprises as organizations. However, several studies have been conducted to identify the selection criteria being used in industry in the partner selection process [Zhang et al. 1997, Bailey et al. 1998, Wildeman 1998, Camarinha-Matos and Cardoso 1999, Chu et al. 2002, Tøller 2004]. These studies do not provide any analysis about how the selection criteria satisfy the needs of Virtual Enterprises.

Chapter 5 analyzes the design of Virtual Enterprises as organizations. It takes into account the elements of each design domain and their relationships. This analysis will identify whether the design of Virtual Enterprises is a good design or not according to Axiomatic Design.

2.6.2 Specific Design View

The specific view takes as starting point the customers' needs for specific products or services. The high-level element in the functional domain is the core capabilities required to produce the product or deliver the service. The physical domain is characterized by the partner companies forming the Virtual Enterprise, and the process domain is represented by the management phase.

The design process of Virtual Enterprises can be described as follows. Once the market opportunity is identified, a Virtual Enterprise is formed quickly to take advantage of the opportunity. Forming a Virtual Enterprise requires, first, the identification of the required core competencies, and second, the selection of partners that have those core competencies. After the partners are selected, the Virtual Enterprise starts to work. However, the integration of partners' core competencies in Virtual Enterprises has been proven difficult. Integration is challenging, since partner need to integrate not only core competencies, but also management styles and corporate cultures.

The market orientation, the need to react quickly and the challenges faced during integration of collaborative work have caused Virtual Enterprises to have a poor success rate. Wildeman [1998] reported that in 60-70% of the cases, Virtual Enterprises disband prematurely. O'Sullivan [1994] indicated that 50-75% of the new manufacturing systems fail to meet cost, start-up dates and performance expectations. Tøller [2004] identified trust, cultural differences, and different levels in the use of Information Technology as some of the challenges faced by Virtual Enterprises. To cope with this problem solutions such as webs of Virtual Enterprise [Goldman et al. 1995, Eversheim et al. 1999, Franke 2001] and Breeding Environments [Camarinha-Matos and Cardoso 1999, Tøller 2004] have been proposed.

The design process as described above is followed fairly well by the initial design of Virtual Enterprises. However, once the design phase is finished, and the Virtual Enterprises starts to operate, unpredictable changes in the design parameters or partners companies may occur. The most common changes mentioned in literature are a shift in focus of the partner companies, incompatible corporate cultures as well as difficulties in the integration of core capabilities and collaborative work [Sieber 1998, Wildeman 1998, Wassenar 1999, Tøller 2004]. Partner performance as measured by the selection criteria may remain constant, increase, or decrease. The most challenging situation is when the performance decreases, since it results in the dissatisfaction of the functional requirements of the Virtual Enterprise.

This dissatisfaction of the functional requirements leaves the Virtual Enterprise only two choices: either disband or substitute the partner. Disbanding is always the last choice, because it means not only the dissolution of the organization, but also failing to achieve the objectives of the Virtual Enterprise.

The substitution of a partner is more complicated than it seems at first. Changes in the partners often impact not only the management of the Virtual Enterprise, but also the functional requirements of the organization. This happens because neither the core capabilities of two companies nor the components supplied by them are the same. These changes in the design parameters should be followed by, at least, a re-evaluation of the functional requirements. However, this is usually not done, and the overall performance of the Virtual Enterprises suffers.

Critical to this analysis is the tracking of the changes of the design parameters to avoid both the substitution of partners and the premature disbanding of the Virtual Enterprise. The solution of this problem demands changes in the frequency of evaluation of the partners' performance in Virtual Enterprises. Therefore, instead of evaluating the partners only during the selection process at the beginning of the design process, the evaluation of the partners also has to be extended to the management phase.

The most significant limitation of the current design practice of Virtual Enterprises is the consideration of the design as static and time-invariant process. However, it is, in reality, a very dynamic and time dependent process. The market orientation of Virtual Enterprises points out to a time dependency of the design process. Virtual Enterprises, as market oriented organization, need to change according to the customers' needs they aim to satisfy. Variations in the customers' needs change the functional requirements of the Virtual Enterprise. The most common variation in the functional requirements is a change of customers. Since no two customers have equal needs, a change of customers usually means that the solution provided by the Virtual Enterprise needs to change accordingly. In principle, a change in functional requirements should trigger a new design process. Such a design process aims to identify a new set of design parameters that satisfy the functional requirements in a solution neutral environment [Suh 1990].

The design phase of a Virtual Enterprise can be divided in four stages or steps. These steps are:

1) identification of the market opportunity,
2) identification of the core competencies required for taking advantage of the market opportunity,
3) the selection of the partner companies capable of delivering the required core capabilities, and
4) the formation of the Virtual Enterprise by integrating the core capabilities of the partners and carrying out the collaborative work.

This thesis deals with the last three steps of the design phase. The first step is market and solution specific.

The design phase identifies the functional requirements of the Virtual Enterprise and deals with two important issues: (1) the identification of the required core competencies and (2) the partner selection process. These two issues are analyzed in the following sections.

2.6.2.1 Identification of the Required Core Competencies

All the literature reviewed acknowledge that the formation and deployment of a Virtual Enterprise should take advantage of the core competencies of each member of the organization [Byrne 1993, Goldman et al. 1995, Campbell 1998, Sieber 1998, Wildeman 1998, Tølle 2004]. However, only few studies consider how these core competencies should be assembled to form a Virtual Enterprise.

The formation of a Virtual Enterprise should be process oriented [Goldman et al. 1995, Chen et al. 1998, Nayak et al. 2004] and based on critical business processes [Fox et al. 1998, Eversheim et al. 1999]. Goldman et al. [1995] also emphasized the need for a redefinition of the design process in Virtual Enterprises. Design has to become a concurrent and holistic process that includes the participation of the complete supply chain, from suppliers to customers.

Two critical business processes have been identified for designing of Virtual Enterprises: (1) the company's business strategy Wildeman [1998] and (2) the product development process of the product being produce [Reithofer and Naeger 1997, Zhang et al. 1997, Chen et al. 1998, Eversheim et al. 1999, Chu et al. 2000].

The company's business strategy uses the cost/performance ratio as the prevailing factor in determining whether a vertical, horizontal or diagonal alliance should be implemented. This approach is derived from the analysis of strategic alliances. Although useful, it ignores the relationship between the solution provided by a Virtual Enterprise and its design.

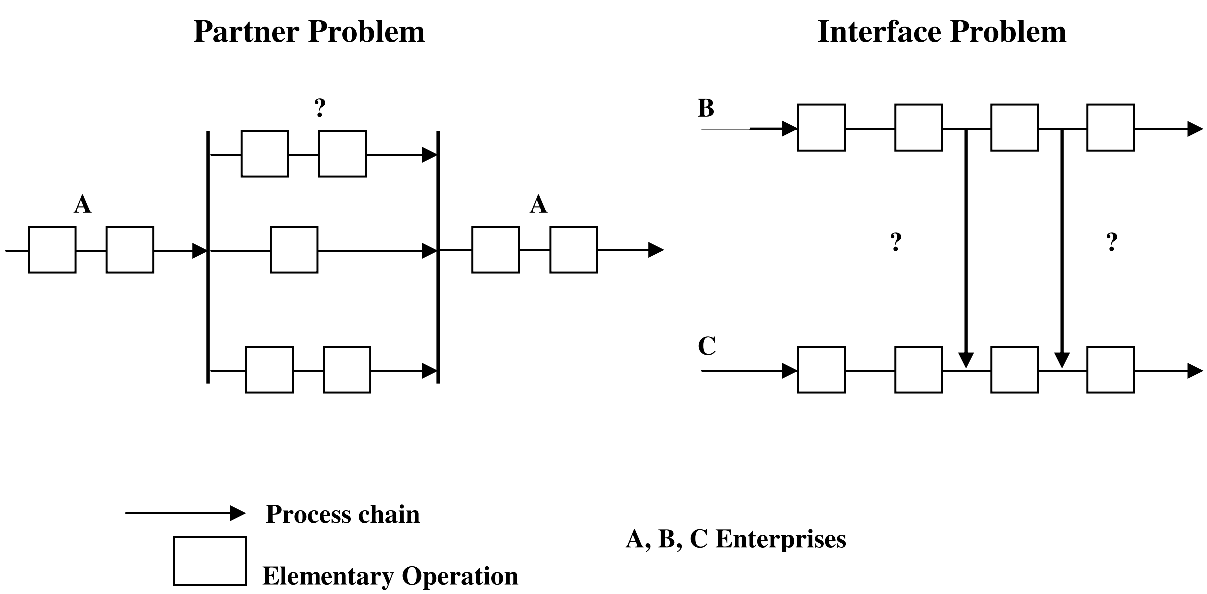

Figure 2.2. Partner and Interface Problems [after Reithofer and Naeger 1997].

Reithofer and Naeger [1997] suggested a process chain guided approach. In this case, the formation of a Virtual Enterprise is analyzed according to the interaction of two (or more) parallel process chains. The interaction between process chains results in two kinds of problems: (1) the partner selection problem and (2) the interface problem. Figure 2.2 illustrates these two problems.

Fig.2.2 (left) depicts the partner selection problem This problem appears when the interfaces between activities in the process chain are well defined, and company lacks the capabilities for performing the activity. Then, the company needs a partner to perform the activity. The gap between the two interfaces is the function that the partner company must fulfill.

The interface problem appears when process chains from two (or more) companies interact as shown in Fig. 2.2 (right). In this case, process chains are well defined. Companies, therefore, interact to produce the product concurrently. This problem addresses the communication and information exchange mechanisms among companies.

Chu et al. [2000] proposed an integrated product design and partner selection process model. Based on the General Design Theory the model integrates the product design activities to the partner selection process. Design activities of the product are divided in four phases:

1) Product Requirement Analysis
2) Product Function Design
3) Product Layout Design, and
4) Components Selection.

The analysis of the product requirements defines the requirements that the final design has to fulfill. The Product Function Design decomposes the functions of the products into sub-functions. It expresses the relationship between the functions and the sub-functions in the functional structure of the product. Once the functions of the products are identified, the layout design searches for design solutions and design principles that satisfy the functions of the product. The output of this phase is the product layout that details the components of the product and their interfaces. The component selection phase identifies the area of specialization of the potential partners, and selects the partners that can produce the components.

Fine and Whitney [1996] proposed the use of the Product Realization Process as the guiding principle in taking make or buy decisions. 'Making or buying' decisions is used in outsourcing decision-making to decide if a component should be produced "in-house" or acquired from the supply chain. The Product Realization Process allows identifying where in the process chain of the Virtual Enterprise the core capabilities of the members are needed. Once these points are identified, the next issue is to select partners, capable of providing these core capabilities and how they should be chosen. On the other hand, Zhang et al. [1997] proposed the Product Architecture as guiding principle for designing Virtual Enterprises. The product architecture identifies the product variants and the core capabilities required to produce it.

2.6.2.2 Partner Selection

The selection of partner companies to engage in any type of collaborative relationship has been usually based on factors such as location, cost associated with the provided services, or habits [Grenier and Metes 1995]. Due to the new market conditions in which Virtual Enterprises operate, this selection process becomes critical for the success of the organization.

Despite being critical to the success of the Virtual Enterprise, the partner selection problem has not received much attention. Most authors acknowledge the importance of the partner selection, but quietly avoid dealing with the problem. More importantly, those addressing this problem concentrate on the initial selection process and ignore a more challenging issue: how to make the relationship work.

Making the relationship work means focusing on the robust management of the organization to avoid its premature disbanding.

The literature review found only a few research works dealing with this subject. Wildeman [1998] divides the selection process into the partner and the partnership phases. Each phase focuses on different aspect of the prospective partners. The partner phase concentrates on the analysis of the partner as an individual and autonomous unit. The partnership phase, on the other hand, centers on the analysis of the relationship with the partner. Each phase uses a different set of selection criteria. In an initial stage the consideration of the partner's credentials receives 70% of the attention, leaving the rest to the analysis of the partnership. Once the preliminary assessment of the partner has been performed, the focus is shifted to the evaluation of the potential of the partnership. At this point analysis of the partnership gets 70% of the attention.

Chu et al. [2002] proposed an integrated product design and partner selection process model. The model divides the selection of partners in two phases: partner type and partner instance. Partner type deals with the selection of core capabilities required and a pool of partners for the manufacturing of the product. Partner instance, on the other hand, chooses the best possible partner among the partners identified in the partner type phase.

Using Plug and Play (PnP) principles, Gosain [1998] proposed a partners integration scheme that can be used to deal with the variable membership of Virtual Enterprises. Plug and Play defines three major protocols: cool, warm, and hot [PnP 1994, Fisher 1995]. The cool protocol means that the computer needs to be turned off before inserting the hardware. In Virtual Enterprises, a cool protocol is similar to an initial stage or start-up phase where the members are starting to integrate. The warm protocol deals with situations, in which the main system can remain working, but the majority of the software, including the operating system and all the applications should be closed. In Virtual Enterprises, the warm protocol occurs when the partners have been working together and the Virtual Enterprise is in the improving performance and reducing cost the phase [Wildeman 1998]. The hot protocol allows for the computer to remain on and the software open. This corresponds to the case in the deployment of Virtual Enterprises where the members have been working together for a certain period and have a close understanding of each other. Furthermore, the Virtual Enterprise is now in the phase of trying to reduce cost through a better economy of scale [Wildeman 1998].

Research works on partner selection have considered the partner selection as a static process. Partner selection is performed only as one of the initial steps in the design of Virtual Enterprises. However, they do not consider that Virtual Enterprises as market driven organizations, may need a changing membership with partners entering and leaving the organization opportunistically. Therefore, the selection process has to be performed systematically during the life cycle of the Virtual Enterprise.

A more realistic approach is to consider the partner selection as a dynamic process subject to the product development cycle, the degree of maturity of the relationship among partners, and the life cycle of the Virtual Enterprise.

2.6.2.2.1 Selection Criteria

Only few research have tried to identify selection criteria specific to Virtual Enterprises. Zhang et al. [1997], Chen et al. [1998], and Camarinha-Matos and Cardoso [1999] used cost, quality, capacity, and delivery time as selection criteria for partner companies. Chu et al. [2002] added customer services and financial stability to the previous list. Wildeman [1998] identified a more comprehensive set of criteria that consider the management and partnership issues in Virtual Enterprises.

Fortunately, the selection of partners in collaborative and outsourcing relationships has been addressed by other researcher works [Brendon and Przilf 1992, Meade and Liles 1997, Bailey et al. 1998, Huang and Mak 2000]. Due to the lack of previous research work about the criteria for selecting partners, an analysis of the selection criteria used in outsourcing and strategic alliances is presented below.

Bailey et al. [1998] conducted a survey to identify the parameters used by companies in different industrial fields in order to select partners. They identify as the most important criteria: technical capabilities, matching aims, cultural compatibility, development speed, strategic position, management ability, security, collaborative record, business strength and cost of the development. These criteria were also ranked according to how managers consider them during the selection process. In this case, it seems that the size of the partner company was not considered important.

Huang and Mak [2000] proposed a set of selection criteria to be used during the early involvement of suppliers in the development process of new products. The selection criteria consider financial, business and technical factors. Financial factors evaluate the financial position of the partners. The technical factors take into account quality, price, reliability, as well as process and design capabilities. The business factors deal with the flexibility of the partner, its reputation, communication mechanism, and the closeness of relationship between partners.

Wildeman [1998] identified the criteria used in the partner selection and partnership phases. The partner selection phase considers the following criteria: complementary skills, market position, financial position, management philosophy, and size. The partnership phase evaluates the "chemistry" between managers, complementarity, culture, trust, commitment, financial position, and openness. This study also provides the relative importance of each criterion. This model fails to link the selection criteria to the maturity of the relationship among partners or the Virtual

Enterprise itself. Furthermore, it does not analyze how partners interact concurrently in several Virtual Enterprises.

The American Society of Mechanical Engineers (ASME) [ASME 1997] and Accenture [Accenture 2001] conducted surveys to identify the selection criteria used in outsourcing. The ASME's survey found commitment to quality and reputation as the two most important criteria used in the partner selection process. The factor considered least important was the matching of corporate cultures. Other factors considered in between these two extremes are the previous collaborative record, the resources of the subcontracting company, price, confidentiality, as well as general and value-adding capabilities.

Accenture [Accenture 2001] on the other hand, identified technical capabilities and the ability to work as a team, as the two most important attributes sought in partners. Other factors considered important were the understanding of business objectives, previous outsourcing experience, flexibility, and knowledge transfer.

Brendon and Przilf [1992] proposed to select partners in strategic alliances according to complementarity, strategic and cultural compatibility. The complementarity criteria should evaluate, among other factors, the complementation in core capabilities, the potential for increasing shareholders value, risks, and mutual gains. The strategic compatibility takes into account the strategic goals, the configuration, and the lifespan of the alliance. A cultural profile of the partners can be used to evaluate their cultural compatibility. The profile considers, the attitude of the partners towards the workforce and issues such as quality, cost, innovation, technology and customer orientation.

Meade and Liles [1996] linked the strategy and the partner selection in strategic alliances. They proposed to use a different set of selection criteria for each strategy. The five main strategies analyzed are: (1) Penetration of new markets, (2) sharing the development cost of new products, (3) fill product line gaps, (4) cost improvement and (5) implementation of the Just In Time (JIT) suppliers programs. The penetration of new market strategies, for example, uses criteria such as the number of distribution channel, the number of new products, the cultural compatibility, product recognition and market intelligence. Sharing the development cost of new products evaluates potential partners according to their net present value, return on investment and cost. The strategies also take into account the stage in the product life cycle (introduction, growth, maturation and declining).

In summary, the selection criteria considered in the Virtual Enterprise oriented literature seems to be focused on the outsourcing side of Virtual Enterprise. They, therefore, have ignored some of the strategic factors of Virtual Enterprises. On the other hand, the selection criteria used in strategic alliances do not consider the selection criteria used in outsourcing decision-making.

None of literature reviewed address the frequency of evaluation of neither the partners nor the partnership. It seems that companies are concerned with the selection of partners as a stand-alone process. The evaluation of partners is performed at the beginning, as part of the bidding process and hopefully once the relationship ends. This approach does not allow identifying small variations in the partners' satisfaction of the selection criteria. The cumulative effect of such variations over time could result in the failure of the relationship.

In Chapter 4, a survey of the outsourcing practices in Canada is presented. The survey identifies the most important selection criteria currently used in industry. It also presents the most relevant determinants for success and failure in outsourcing relationships.

2.6.2.2.2 Decision Making Methods

The partner selection process is a multi-criteria decision-making (MCDM) process characterized by a substantial degree of risk, uncertainty and subjectivity. Several methods have been proposed for selecting partners, once the evaluation of the partner credential is performed. Zhang et al. [1997] considered a weighted sum algorithm for the selection of partners. On the other hand, Chen et al. [1998] and Nayak et al. [2004] used the Analytical Hierarchy Process (AHP) as a selection algorithm.

Huang and Mak [2000] utilized several indices for selecting partners. They proposed four types of indices: satisfaction, flexibility, risk, and confidence. The satisfaction index measures the satisfaction of the customer requirements by the supplier capabilities. A larger value of this index indicates a better satisfaction of the customer requirements. The flexibility index measures the ability of the supplier to be flexible and satisfy changing customer requirements. This index should also be as large as possible. The risk index takes into account the risks involved in satisfying the customer requirements by the supplier. A small value of this index indicates a smaller risk that the supplier will not satisfy the customer requirements. The confidence index evaluates the trustworthiness of the partners in meeting the customer requirements. This index should be as large as possible.

Ip et al. [2003, 2004] and Sha and Che [2005] used more elaborated approaches for the selection of partners. The former utilized a 0-1 integer programming with a non-analytical function and a branch and bound algorithm. The latter implemented Genetic Algorithms. However, these approaches used only cost, time and quality as selection criteria.

The major limitation of the decision-making methods analyzed above is that all of them use an optimizing rule for performing the selection. Although they do rank all the available alternatives, they are unable to take into account the requirements of the Virtual Enterprise as a whole. Given a pool of partners companies, these methods rank the partners according to their satisfaction of the selection criteria without considering what the needs of the Virtual Enterprise are. These methods implicitly assume that the better the satisfaction of the partners of the selection criteria, the better the Virtual Enterprise will be. However, an overqualified partner can be as bad as an under qualified one.

Chapter 6 presents a time dependent formulation of the partner selection process. It also compares the Analytical Hierarchy Process, the weighted sum and Axiom II from Axiomatic Design. Axiom II allows the probabilistic treatment of the design parameters, selection criteria, which makes it possible to take into consideration risk and uncertainty. One major advantage of the utilization of Axiom II is its ability to consider independently, the contributions of the prospective partners and the needs of the Virtual Enterprise during the selection process for each criterion.

2.6.2.3 Summary

The analysis of the research works on the design of Virtual Enterprises shows that instead of an ad-hoc approach, either the business strategy or the product development process can be used as guiding principle for their design. It was also found that the design-oriented literature has only been focused on the identification of the elements of the design domains. No analysis of the relationships between domains has been found.

The set of selection criteria used in the partner selection process has dealt only with outsourcing decision-making factors and ignored the strategic factors in the design of Virtual Enterprises. Besides, the focus of the decision-making methods has been on choosing partners with the best qualification without considering the needs of the Virtual Enterprise. Such an approach may lead to selecting overqualified partners and therefore cause problems in the operation of the organization.

2.7 Management Phase

The management phase deals with how to achieve the objectives and how to satisfy the functional requirements identified in the design phase. Partners integrate their core competencies, management style, corporate culture, and business practices to work as one monolithic organization.

During its operation, a Virtual Enterprise faces internal and external influences. Changes in management of the partners companies or in the market place are just two of the many examples. These changes affect the satisfaction of the initial goals and objectives of the Virtual Enterprise.

Mowshowitz [1997a,b and 1999] proposed the switching principle to manage Virtual Enterprises. Fundamental to this principle is the separation of the need from the "need fulfillment" or satisfaction. The implementation of a goal-oriented activity is achieved by the assignment and reassignment of concrete "satisfier" to the abstract requirements of the task. This process of assignment and reassignment is defined as switching. The switching principle is discussed in details in Chapter 6.

The abstract requirements are defined as the logically defined needs of the talks. They should be specified independently of the "satisfier". Concrete "satisfiers", on the other hand, are the resources used to meet the needs of the task. Switching provides flexibility and make possible to change satisfiers due to changes in the abstract requirements. The optimization criterion for applying the switching principle is cost. Switching is only justified if the cost of replacing a satisfier is lower than the cost of the replacement.

Mowshowitz was the only research work found dealing with the management of Virtual Enterprises. Chapter 7 presents a management methodology aimed to improve the success rate in Virtual Enterprise. The objective of the robust management of Virtual Enterprises is to achieve the best possible performance of the organization by considering the influence of these internal and external factors. It should make possible for Virtual Enterprises to live their full life cycle and succeed even when the initial conditions in which they were formed change.

2.8 Summary

This chapter has reviewed previous research work in Virtual Enterprises. It analyzed the advantages and disadvantages of Virtual Enterprises, the market conditions that have created the need for this kind of organizations, as well as their most important characteristics. These characteristics are:

1. opportunism,
2. excellence,
3. technology,
4. no borders,
5. trust,
6. one identity,
7. partial mission overlapping,
8. distinction between strategic and operational level, and
9. flat hierarchies and changing hierarchical positions.

Virtual Enterprises can be classified according to three dimensions: time, topology, and structure. The time dimension refers to the duration or lifespan of the organization. The topology dimension considers the membership of the Virtual Enterprise. The structural dimension deals with the different management structures of Virtual Enterprises.

Virtual Enterprises have a short or a long-term lifespan, depending on the market opportunity they target. The topology dimension considers an open or closed membership in the Virtual Enterprise. A Virtual Enterprise may assume a star-like, democratic alliances or federation managerial structure. The distinguishing factor of these structures is the partners' level of independence with respect to the operation of the Virtual Enterprise. Star-like is the structure used more often.

Virtual Enterprises follow a life cycle similar to life system. The three phases of the cycle are: design, management and disbanding. Design is considered the most important phase of the life cycle.

Considering Virtual Enterprises as systems makes it possible, to analyze the design of Virtual Enterprises based on methodologies used in the design of products and process. The design methodology used for this analysis is Axiomatic Design. The chapter also presented two design views that can be used to design Virtual Enterprises. The general design view focuses on the design of Virtual Enterprises as organizations. The specific view considers the design of specific instances of Virtual Enterprises.

3 Virtual Enterprises as Systems

3.1 Introduction

Core competencies, collaboration, and integration are the three most important characteristics that guide the analysis of agility and Virtual Enterprises. These characteristics were first introduced, during the analysis of advantages and disadvantages of Virtual Enterprises. It was shown then, that collaboration and integration are the foundation of Virtual Enterprises. Most of the challenges in Virtual Enterprises relate to the ability of the partners to satisfy these two traits.

This chapter focuses on the analysis of Virtual Enterprises as systems. It is not a coincidence that collaboration and integration are also two of the most important characteristics of a system.

The main objective of the chapter is to establish the theoretical foundations for other analyses presented in the thesis. The foundations established here are the starting point for developing a conceptual and control models of Virtual Enterprises, studying Virtual Enterprises as a design problem, the partner selection process, and the management of Virtual Enterprises. In order to establish the theoretical foundations the chapter focuses on:

1) Demonstrating that Virtual Enterprises satisfy the nine most important characteristics of systems.
2) Defining a conceptual and control models for Virtual Enterprises.
3) Introducing Axiomatic Design as the methodology used for the analyzing Virtual Enterprises.
4) Analyzing Virtual Enterprises as large systems.
5) Providing a time dependent formulation of the design of Virtual Enterprises as organizations and as systems.

3.2 Virtual Enterprises as Systems

Chapter 2 mentioned that although many authors characterize Virtual Enterprises as systems, their characterizations were incomplete. They were incomplete because authors only analyzed some of the characteristics of systems, ignoring others. This limitation should become obvious later, when the nine characteristics of systems are analyzed.

Some authors such as Grenier and Metes [1995], Merchant [1997], and Klüber [1998] focused on the holistic characteristic. Others like Zhang et al. [1997] concentrated on the components and goals of the system. Chen et al. [1998] centred their characterization on the hierarchy structure and pointed out that it shows the distributed, cooperative, and dynamic nature of Virtual Enterprises.

System Theory has been used for analyzing diverse problems in a variety of fields. It has become one of the most widely used methods for analyzing designs. This approach has as an advantage, the use of well-established methodologies that have been proven useful in dealing with complex analysis at different levels of details.

O'Sullivan [1994] defines a system as "an identifiable, complex dynamic entity composed of discernibly different parts or subsystems that are interrelated to and interdependent on each other and the whole entity with an overall capacity to maintain stability, and to adapt its behaviour in response to external influences."

Using Virtual Enterprises as the object of the O'Sullivan's definition shows, that Virtual Enterprises, in fact, are systems. A Virtual Enterprise is an identifiable entity that exists by itself as an independent unit. It is composed of different units or subsystem (partners) that dynamically interact to achieve the goal of the Virtual Enterprise. Partners need to collaborate and integrate their operations to succeed in satisfying the organization's goals. By linking core capabilities, partners in a Virtual Enterprise become interdependent and interact with each other. Two types of relationships are established in a Virtual Enterprise: relationships among members and the relationships between the members and the Virtual Enterprise as a whole. Moreover, Virtual Enterprises are forced to maintain stability and to adapt their behaviour in response to external influences, in this case the market. This behaviour results from their opportunistic and non-deterministic natures [Goldman et al. 1995, Parunak 1997].

O'Sullivan [1994] identifies the nine major characteristics of any system, regardless of their field of study. These characteristics are:

1. goal seeking,
2. holism,
3. hierarchy,
4. inputs and outputs,
5. transformation,
6. energy,
7. entropy,
8. equifinality, and
9. feedback.

Systems are oriented to achieve a certain goal such as satisfying a market need or producing a product. Holism refers to the needs of the integration of functions in a system. A holistic system is one in which the analysis of its components, cannot be completely isolated from the analysis of the system, without a lost of generality. The system constitutes an inseparable entity. The analysis of subsystems always has to include the analysis of the whole system. Being holistic allows a system to attain goals that none of the components can achieve independently, i.e. emergent properties.

Hierarchy deals with the relationships among the components of the system as well as their decomposition. Ordered relationships among the elements of the system are often represented in a hierarchical structure. In hierarchical structures, the overall system is represented as the root of a tree. Subsystems obtained as the decomposition of the overall system, are represented as nodes in the second level of the hierarchy. The decomposition process lasts until it reaches primitive components or the desired level of detail. The hierarchical decomposition of a system reduces complexity and helps to analyze and to rank the component in the system. Hierarchical structures are recursive since they allow considering subsystems or components as systems, according to the requirements of the analysis.

Inputs are the stimuli that make the system react and perform its functions. Outputs, in contrast, are the result of the system performing its functions. A system influences and is influenced by its environment. The inputs influence the system and the system's outputs influence the environment. The inputs and outputs of a system are determined by artificial barriers or boundaries imposed on the system. Imposing boundaries has two objectives: simplification and isolation. Boundaries simplify or reduce the analysis to a specific area of interest. Isolation, on the other hand, makes it possible to consider the system mostly unaffected by the external influences in its environment. Isolation, in some cases, also contributes to the viability of the system since it allows controlling the system within its boundaries.

Transformation refers to how a system consumes and generates energy during the transformation of inputs are into outputs. Entropy considers level of order and the consumption of energy of the system. As in thermodynamics, a system always tries to reach a certain level of stability and does so by consuming energy. However, if the supply of energy stops, the system will consume its own energy and then it will disappear. These cycles of organization-disorganization and energy consumption keep a system alive.

Functionality considers the function of the system. A system must have a function to exist. In the process of performing its functions, a system takes inputs or stimulus from its environment and produces outputs or responses.

Equifinality refers to the flexibility of a system to change the paths used to reach its goals. This flexibility allows a system to select different ways to transform the inputs into outputs and to use energy.

Feedback considers how systems change or adjust their operations. By generating and using feedback, systems are controlled or steered towards achieving their goals. In general, systems will tend towards increasing their entropy in absence of control. The control of the system relies on communication to guide the system towards its state of equilibrium.

Virtual Enterprises satisfy these nine characteristics and therefore they can be considered as systems. They are goal seekers as they are formed to take advantage of a market opportunity.

A Virtual Enterprise is a holistic system since, as a whole, it becomes a monolithic and inseparable unit working towards a set of goals. At the same time, it is not possible to analyze a Virtual Enterprise without analyzing the role of individual partners and vice versa.

O'Sullivan [1994] references Friedrich Hegel as stating: "The whole is more important than the sum of the parts, the whole determines the nature of the parts", the role of the parts is only understood when considered in relation to the whole, and "the parts are dynamically interrelated and interdependent".

Virtual Enterprises realize all these statements of Hegel. By linking the core capabilities of its members, a Virtual Enterprise achieves objectives that none of the members could obtain independently. That is, a Virtual Enterprise has emergent properties. Indeed, the core capabilities brought to the Virtual Enterprise are oriented to satisfy the specific goals of the organization. This means, that the objectives and opportunities the organization seeks to fulfill determine the membership of a Virtual Enterprise. The role of each member company (or subsystem) has to be analyzed in relation to its contribution to the goals of the Virtual Enterprise. The members of a Virtual Enterprise are interrelated and interdependent on the performance of each other and the performance of the Virtual Enterprise as a whole.

The hierarchy characteristic addresses complexity and organization of Virtual Enterprises. It ranks the contribution of each member according to the goals of the enterprise. Each member company is an autonomous subsystem regardless of their size, core capabilities, etc. The hierarchy makes it possible to analyze Virtual Enterprises in a broader organizational environment. A Virtual Enterprise seen as a system in one context can become a subsystem, in another wider context or higher-level system.

The inputs are resources and core competencies that each member brings to the organization. The outputs, on the other hand, are the product or services that a Virtual Enterprise offers to its customers. By working as a system, Virtual Enterprises transform their resources and core competencies into product or services. In this transformation, Virtual Enterprises consume and generate energy. This energy is both physical and mental. Mental energy comes from the contribution of knowledge and human resources of each member.

Entropy refers to the ability of the Virtual Enterprises to have a supply of energy that makes the enterprise meet its market goals and objectives. In Virtual Enterprises, the energy supply disappears once the market opportunity is met. At that point, the organization either disbands or finds new sources of energies to keep itself alive.

At a given point in time, many Virtual Enterprises can be working toward satisfying the same need of the market place. Each of these Virtual Enterprises may attain its goals in different ways, either more efficiently or faster than others do.

The market and a Virtual Enterprise influence each other dynamically. The market creates the need for a Virtual Enterprise. The Virtual Enterprise, on the other hand, influences the market where it operates. Therefore, a Virtual Enterprise receives and generates feedback based on the influences of the market in which they operate. Feedback allows the management of the organization and adapting its strategies according to the market and customers' demands. Furthermore, feedback makes it possible to identify when the market opportunity has been met and to start the disbanding of the organization.

Several classification of system can be found in literature. Winstanley [1991] used the classification proposed by Checkland [1981]. This classification considers the nature of the system. In relation to their nature, systems are classified as: natural systems, designed systems, human activity systems as well as social and cultural systems.

Open systems are those that interact dynamically with their environments. Their outputs are neither predictable nor deterministic. The dynamic interaction with the environment does not allow predicting the outputs based on the inputs. Closed systems, on the other hand, consider systems mostly isolated from their environments. Commonly in these systems, the inputs are explicitly mapped to the outputs.

Natural systems represent the physical universe. Biological and ecological systems belong to this group. Designed systems are man-made systems such as computers and automobiles. Human activity systems are those used to represent situations that include human activities. Management and political systems are instances of human activity systems. Social and cultural systems are a combination of human activity system and natural systems.

According to the classification presented above, it can be concluded that Virtual Enterprises are both open and human activity systems. They are open systems because they interact dynamically with their environments and their outputs cannot be predicted. It is not possible to take the market conditions as an input and to predict the response of a Virtual Enterprise, as it would be the case, for example, of an electric circuit. On the other hand, Virtual Enterprises are systems where companies interact and exchange resources with the purpose of satisfying specific goals. Although the term company is used here, it should be noticed that companies are created by humans . Humans are the basic and most important components of companies. They are the ones that plan, manage, execute, and verify all the activities of the entity, generically referred to as a company. There is not such a thing as a company without human activity.

The foregoing analysis has shown that a Virtual Enterprise can be studied as a system. Initially, the analysis focused on showing how a Virtual Enterprise satisfies the definition of a system. Later, it was shown how Virtual Enterprises satisfy the nine characteristics of a system.

Over the years, tools and techniques have been developed for the study and design of systems. The three most common tools and techniques are: models, languages, and methodologies [Winstanley 1991]. Models are used for representing the system and its boundaries. Languages, on the other hand, are utilized in building and manipulating the models. Methodologies make it possible the analysis and synthesis of systems.

This thesis uses only models and methodologies to study Virtual Enterprises. Therefore, only these two tools will be analyzed.

3.3 Models and Methodology

According to Wilson [1984], a model is "an explicit interpretation of one's understanding of the situation. […] It essentially describes the entities and relationships among them." The three basic types of models are: iconic, analogic, and analytic. In this thesis, only the analytic type is presented.

Analytic models employ logic or mathematics to demonstrate the physical behaviour of the system. This class of models is further decomposed into deterministic and non-deterministic models. Deterministic models are determined by physical laws. Non-deterministic models, in contrast, are based on statistical distributions. Each of these two types of models can be either dynamic or static. Dynamic models are time dependent while static models are not.

Both conceptual and control models are analytic model. Winstanley [1991] defines a conceptual model as "an intuitive representation of a situation to a maximum level of abstraction consistent with associated meaning". A conceptual model should represent the qualitative aspects of the system. This model is best used at the initial stages of the system development. Control models, in contrast, are non-deterministic and dynamic models commonly used to represent situations, where the transformation function of the system is uncertain.

3.3.1 A Conceptual Model of Virtual Enterprises

Winstanley [1991] proposed a model building-approach that takes into account nine characteristics of system explained earlier. The approach uses the following steps:

1. Choosing the boundaries,
2. Identification of the system components,
3. Identification of the relationships among the components of the system,
4. Analysis of the effects across the boundaries of the systems,
5. Communication and
6. Control.

The components of the conceptual model are the phases of the life cycle of a Virtual Enterprise. Chapter 2 analyzed these phases. The three phases of the life cycle of Virtual Enterprise were identified as: design (or creation), management (or operation) and disbanding (or dissolution).

The application of these six steps results in the conceptual model of Virtual Enterprises shown in Fig. 3.1. The customers' needs that create the needs for a Virtual Enterprise are the inputs to the model. The output is the product or service that the Virtual Enterprise delivers to the market.

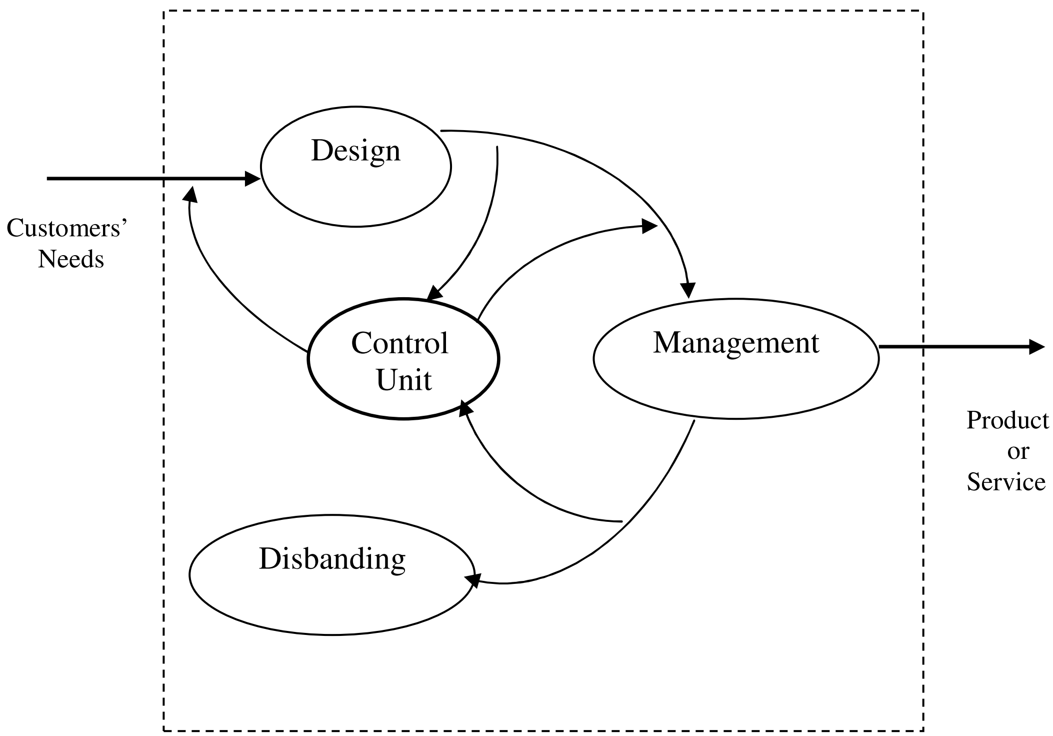

Figure 3.1. A Conceptual Model of Virtual Enterprises.

The model has also a control unit. The control unit deals with the control of the design and management phases. For the design phase, the control unit ultimately checks the selection of the components of the systems or partners in a Virtual Enterprise. Furthermore, this unit verifies other subsystems within the design phase such as identification of core capabilities, internal preparation, and the partner selection process.

For the management phase, the control unit primarily checks the operation of the Virtual Enterprise, in the management phase. Control in this phase verifies the collaboration and integration among the members of the Virtual Enterprise. Its main objective is to avoid a premature disbanding of the organization and to solve operational issues. In addition, the control unit serves two other functions. First, it checks that the product or service delivered by the Virtual Enterprise satisfies the market needs. Second, it evaluates the need of the Virtual Enterprise to continue its operations. If the product or service is not meeting the market's needs, the control unit should adapt the output of the Virtual Enterprise. By evaluating the need for continuation of operation, the control unit triggers the disbanding of the organization, once it is recognized the market opportunity has passed.

3.3.2 A Control Model of Virtual Enterprises

The six-steps of model building were also used to develop a possible control model for Virtual Enterprises. This model is shown in Figure 3.2.

Similarly to the conceptual model, the control model represents the design and management phases of Virtual Enterprises. The model has three feedback loops. These loops make it possible for the organization to achieve the desired level of response and tend towards minimum entropy.

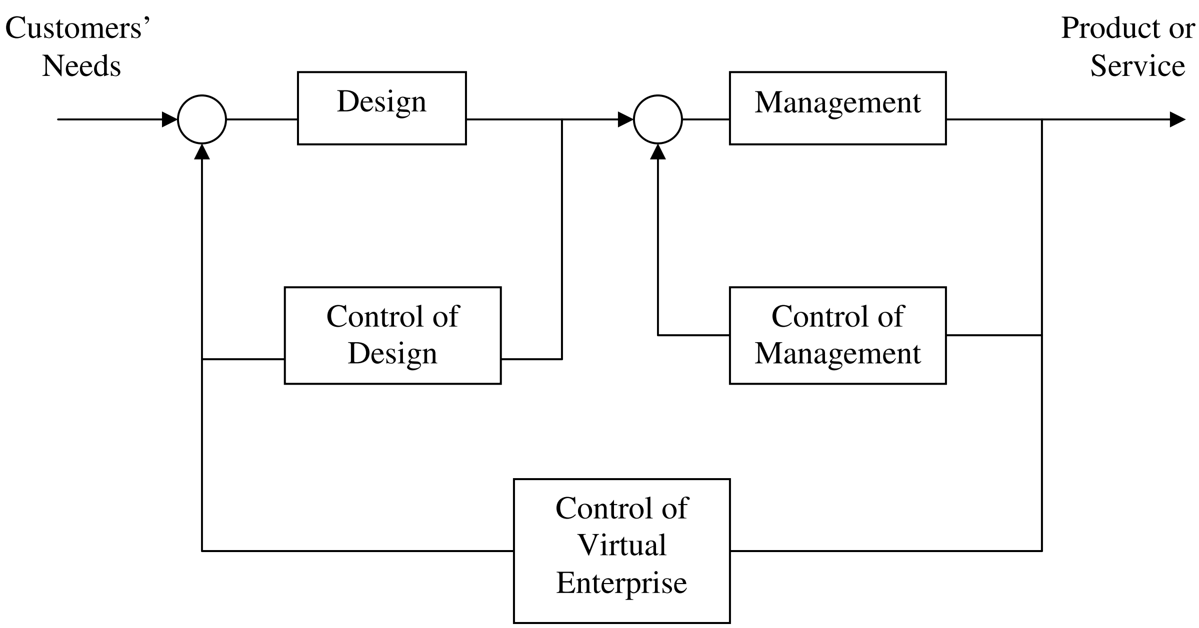

Figure 3.2. A Control Model for Virtual Enterprises.

Each feedback loop verifies a different component of the model. The control unit of design, checks the outputs of all the components of the design phase. The control of the management unit performs a similar function, but for the management component. The control of the Virtual Enterprise verifies the operation of the Virtual Enterprise as a whole. This last control unit is the one responsible for evaluating the need of the Virtual Enterprise of continuing its operations. Therefore, it triggers the disbanding component once the market opportunity has passed. In addition, this unit uses the output of the management phase to decide if a new design phase is needed. That situation arises when one or more partners leave the Virtual Enterprise or have to be substituted, due to problems in the management phase.

3.3.3 Methodology

Winstanley [1991] defines a methodology as "[a tool that] provides means of conducting the analysis and design of a system in a structured way". Axiomatic Design [Suh 1990, Suh 1995] is the methodology used in this thesis.

Axiomatic Design is an approach that considers the design as an activity based on a set of governing axioms that characterize all good designs [Suh 1990]. It provides the theoretical foundations for logical and rational designs [Albano and Suh 1998].

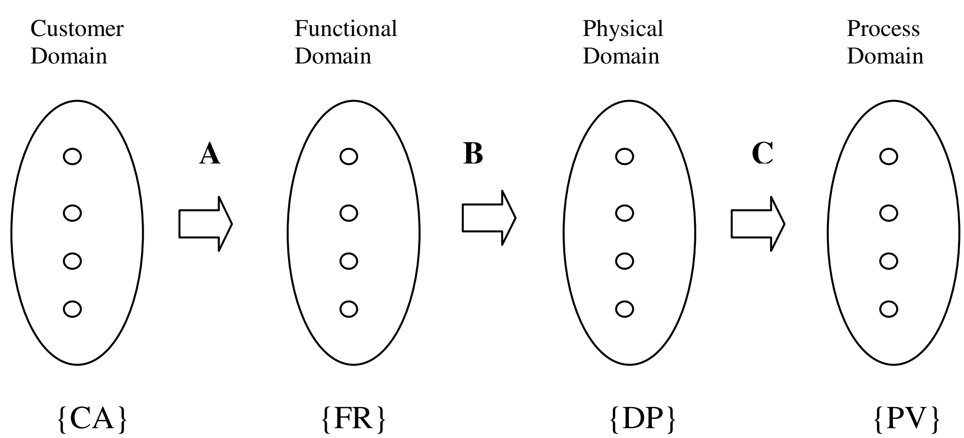

Figure 3.3. Representation of the Design Process through Axiomatic Design.

Fig. 3.3 shows the four domains of the design process, according to Axiomatic Design. These domains represent the high level of the design process. They are:

1) the customer domain (CD) which characterizes the capabilities or attributes expected from the product, systems or process,
2) the functional domain (FD) which represents the translation of the customer requirements into design terms (functional requirements, FRs),
3) the physical domain (PhD) where the materialization of FRs as design parameters (DPs) takes place, and
4) the process domain (PrD) where the DPs are translated into process variables (PVs) used in the production process.

The design process is carried out as mappings between two contiguous domains. Always in the design process, the domain located on the left, represents the goals or "*what*" the designer wants to achieve. The domain on the right denotes how goals are satisfied or the "*how*". In general, the mapping between two contiguous domains can be reduced to the mapping between the functional requirements (domain on the left) and the design parameters (domain on the right) regardless of the domain under study.

It should be noticed that mappings between any two contiguous domains are not unique. In principle, many mappings can be obtained. The quality of these mappings depends on the designer's knowledge, experience, and creativity. Therefore, the satisfaction of customers' requirements could vary considerably.

High-level elements in each domain are often decomposed in a hierarchy. The design hierarchy is created by alternating or zigzagging between the functional and physical domains. That is, once the design parameters are obtained, the designer must return to the functional domain. Then, decompose the elements of this domain, before decomposing the elements of the physical domain. This zigzagging process allows the evolution of the design in a solution neutral environment. A solution neutral environment is an environment in which the design parameters are set according to the satisfaction of the functional requirements.

Axiomatic Design has two axioms. These axioms are:

1) Independent Axiom (or Axiom I), and
2) Information Axiom (or Axiom II).

A good design should satisfy both axioms. Based on these two axioms, other theorems and corollaries have been derived. They can be found in [Suh 1990].

Axiom I states that the independence of the functional requirements (FRs) must be always maintained. The set of functional requirements should be minimal. That is, it should contain the minimum number of requirements needed to describe design goals. Axiom II, on the other hand, states that amongst all the designs that satisfy Axiom I, the design with a highest probability of success is the one with the minimum information content.

Mathematically, the design process shown in Fig. 3.3 is represented by Equations 3.1, 3.2 and 3.3.

$$\{CA\}= [A]\ \{FR\} \tag{3.1}$$

$$\{FR\}= [B]\ \{DP\} \tag{3.2}$$

$$\{DP\}= [C]\ \{PV\} \tag{3.3}$$

where:

{CA}: vector in the customer domain,

{FR}: vector in the functional domain,

{DP}: vector in the physical domain,

{PV}: vector in the process domain,

[A]: design matrix between the customer and functional domains, $A_{ij} = \partial CA_i/\partial FR_j$,

[B]: design matrix between the functional and the physical domains, $B_{ij} = \partial FR_i/\partial DP_j$, and

[C]: design matrix between the physical and the process domains, $C_{ij} = \partial DP_i/\partial PV_j$.

The evaluation of the design according to Axiom I, might result in one of the three following situations:

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \\ FR4 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 & 0 \\ 0 & X & 0 & 0 \\ 0 & 0 & X & 0 \\ 0 & 0 & 0 & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \\ DP4 \end{Bmatrix} \qquad \begin{Bmatrix} FR1 \\ FR2 \\ FR3 \\ FR4 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 & 0 \\ 0 & X & X & X \\ X & 0 & X & 0 \\ 0 & X & X & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \\ DP4 \end{Bmatrix} \qquad \begin{Bmatrix} FR1 \\ FR2 \\ FR3 \\ FR4 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 & 0 \\ X & X & 0 & 0 \\ X & 0 & X & 0 \\ X & X & X & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \\ DP4 \end{Bmatrix}$$

Uncoupled Coupled Decoupled

Uncoupled designs are those in which the functional requirements are satisfied by one, and only one design parameter. A diagonal matrix represents these designs. A triangular matrix, on the other hand, represents decoupled or quasi-coupled designs. In these designs, the independence of the functional requirements is achieved only if the design parameters are changed in the sequence suggested by the matrix. Coupled designs are those in which it is not possible to change a design parameter, without affecting two or more functional requirements. These designs do not satisfy Axiom I and they are the worst design cases.

Table 3.1. Elements of the Domains for Designing Systems and Organizations.

Domain	Elements of the domain	
	Systems	Organizations
Customer	Attributes desired of the overall system	Customers' [satisfaction] needs
Functional	Functional requirements of the system	Functions of the organization
Physical	Machines or components, subcomponents	Programs or offices
Process	Resources (human, financial, material, etc.)	People or other resources that can support the programs.

Axiomatic Design can be used in diverse field such as manufacturing, material, software, organizations, and systems [Suh 1990, Suh 1995]. Table 3.1 shows the elements of the domains for the design of organizations and systems.

These two applications are chosen because Virtual Enterprises are seen as both systems and organizations. It should be noticed that, each organization is a system; however, no every system is an organization. Therefore, the design of Virtual Enterprises as organizations uses the definitions of the domains in the organizational design. On the other hand, the design of Virtual Enterprises as systems, utilizes the definitions of the domains in the system design.

In both cases, designs aim to satisfy the elements in the customer's domain. However, these needs are different, depending on what is being designed. In the organizational design, the customers' attributes are the market conditions. In the design as systems, the attributes are the specific customers' needs of a product or service. Market conditions and customers' needs should not be confused. Market conditions are the combined effects of political, economic, business, technological, and human factors that create a concrete situation in the market. These conditions were analyzed in Chapter 2. Definitely, customers' needs are one of the elements of the market conditions. This understanding emerges from the recognition of the role of the market in society. Later, during the analysis of Virtual Enterprises as large system, it is shown that each time the market conditions have changed; new organizational forms have been created to satisfy them.

Traditionally, the design organizations and products have been done sequentially. First, the organization was designed and then it produced products or delivered services. Several products were produced with the same organizational design during several business cycles. The challenge of Virtual Enterprises is that these two designs are used concurrently. The organization and the product it delivers are designed at the same time. The former is to satisfy market conditions and the latter to satisfy customers needs (one element of market conditions). Once the opportunity has passed, the organization disbands and the design processes of both the organization and the product have to start all over again.

Other domains also are redefined in the context of Virtual Enterprises. In the design of an organization, the functions of the organizations (or functional requirements) are established in such a way that the market conditions are met. Suh [1995] identified the programs and offices of the organization as the elements of the physical domain (design parameters). This definition, although useful, only applies to single organizations. Virtual Enterprises still require 'programs and offices'. However, instead of a single organization, programs and offices are scattered among partners according to their core competencies.

The elements in the process domain (process variables) are human and other resources that make the organization work. Nonetheless, significant changes take place because of the membership in the Virtual Enterprises. Virtual Enterprises do not have a centralized structure for assigning resources. Instead, each partner contributes with its resources to the Virtual Enterprise. This change influences the nature of the relationships established in the organization. Chapter 2 explained that in Virtual Enterprises, relationships are based on factors such as trust, mutual benefits, and information sharing rather than on authority and power as in hierarchical structures.

The design of Virtual Enterprises as organizations is explained in more detail in Chapter 5, during the analysis of Virtual Enterprises as a design problem.

In the design of Virtual Enterprises as systems, the elements of the customer domain are the customers' needs that the product or service aims to satisfy. The functional domain is composed of the core capabilities required for producing the product. The components of the systems in the physical domain are the partners companies (or teams) capable of providing the required core capabilities. The resources of the systems are those contributed by each partner to the Virtual Enterprise. Similarly to organizational design, the assignment of resources and the nature of the relationships established in the Virtual Enterprise are changed.

The design of Virtual Enterprises as systems is the foundation for the analysis of the partner selection process and the management of Virtual Enterprises. These analyses are presented in Chapters 6 and 7, respectively.

3.4 Virtual Enterprises as Large Systems

Axiomatic Design also can be used for analysis and design of large systems. Suh [1995] defines large systems as:

> "A system is a large system if the total number of the highest level of functional requirements that the system must satisfy during its lifetime is large and if at different times the system is required to satisfy many different subsets of functional requirements."

This definition mentions two important characteristics of large systems. First, large systems have a large number of functional requirements. Second, the functional requirements are time dependent.

Suh [1995] did not provide an explicit account of what a large number of functional requirements is. However, he stated that systems such as government bureaucracy, an assembly plants for automobiles, and airplanes, such as a Boeing 747 are considered large systems.

Functional requirements are time dependent because the set of functional requirements changes over the system's life cycle. At a given time, the system may need to satisfy one set of functional requirements. Later, a different set will have to be satisfied. These new sets may not be known a priory or when the system is designed for a first time.

The time dependency of functional requirements radically changes the formulation of the design process. It makes it impossible to obtain design parameters that always will satisfy the functional requirements of the system over its life cycle. Axiomatic Design states that design parameters should satisfy the functional requirements. Therefore, if the functional requirements change, so should do the design parameters. Furthermore, the changes need to be propagated to all the other domains, to keep the design consistent.

In general, changes as a function of time of the design process can be represented as:

$$CAs(t) \rightarrow FRs(t) \rightarrow DPs(t) \rightarrow PVs(t), \quad \forall\, t = t_1, t_2, t_3 \ldots\, t_n \tag{3.5}$$

Specifically, Suh [1995] formulated the design problem of large systems as follows:

$$\begin{aligned} &FR1 \; \$ \; \{DP1^a, DP1^b, \ldots, \; DP1^m\} \\ &FR2 \; \$ \; \{DP2^a, DP2^b, \ldots, \; DP2^q\} \\ &FR3 \; \$ \; \{DP3^a, DP3^b, \ldots, \; DP3^w\} \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ &FRn \; \$ \; \{DPn^a, DPn^b, \ldots\ldots DPn^s\} \end{aligned} \tag{3.6}$$

where:

FRi, $\forall$ i, i = 1 …n, are the functional requirements of the design,

{DPi}, $\forall$ i, i = 1 …n, are the sets of design parameters that may satisfy FRi, and

$: indicates satisfaction.

Eq. 3.6 means that, for example, the first functional requirement, FR1, can be satisfied by one of the element of the design parameters set, {DP1} = ($DP1^a$, $DP1^b$, …, $DP1^m$). However, it is not known which element of the design parameters set is the one that satisfies the functional requirement FR1. That occurs because at a given time $t = t_x$, other functional requirements may also need to be satisfied. The selection of an element in {DP1}, depends on how other functional requirements are satisfied by elements of other design parameter sets. Therefore, the final choice from the {DP1} set may differ depending on the number of functional requirements to be satisfied.

Table 3.2 shows an example of possible changes with time of the functional requirements and design parameters. This example could be extended to other domains, if required.

At time $t = t_0$, when the system is initially designed, the set of functional requirements was $\{FR\}_0$. Applying Axiom I and II, the design parameters set $\{DP\}_0$ was found.

Table 3.2. A Scenario of Changes in Functional Requirements and Design Parameters.

Time (t)	Functional Requirements FR(t)	Design Parameters DP(t)
$t = t_0$	$\{FR\}_0 = \{FR1, FR5, FR7, FRn\}$	$\{DP\}_0 = \{DP1^1, DP5^3, DP7^2, DPn^4\}$
$t = t_1$	$\{FR\}_1 = \{FR3, FR5, FR8, FRm\}^*$	$\{DP\}_1 = \{DP3^2, DP5^1, DP8^4, DPm^2\}^*$
$t = t_2$	$\{FR\}_2 = \{FR4, FR9, FR10, FRn\}^*$	$\{DP\}_0 = \{DP4^3, DP9^2, DP10^1, DPn^3\}^*$

*These sets are not known a priori.

Then, at time, $t = t_1$, the system reconfigures and the functional requirements change from $\{FR\}_0$ to $\{FR\}_1$. This new set of functional requirements is not satisfied by $\{DP\}_0$. Therefore, a new set of design parameters, $\{DP\}_1$, that satisfied $\{FR\}_1$, has to be identified. A similar situation occurs when the functional requirements change from $\{FR\}_1$ to $\{FR\}_2$.

Based on this formulation, Suh [1995] derived (9) nine theorems for the best design of large systems. These theorems address the importance of high-level decisions, the selection of the best design, the need for a better design, the completeness of the design, the adaptability and completeness of the design, as well as its complexity and quality.

Suh [1995] also pointed out the challenge of organizational design: the design of flexible organizations. These organizations should react quickly to changes in their functional requirements. Furthermore, he argued that in organizational design, redundant systems are not a solution due to cost. A redundant system means that the organization would have a large set of process variables (human and material resources) to satisfy unforeseeable changes in the functional requirements.

Two theorems are particularly important for this thesis: Theorems 8 and 9. Theorem 8 deals with the design of organizations and Theorem 9 deals with the need for modularity. These two theorems are stated as follows:

Theorem 8 (Design of Organizations):

> In the design of large organizations with finite resources, the most efficient organizational design is the one that specifically allows reconfiguration by changing the organizational structure and by having a flexible personnel policy when a new set of functional requirements must be satisfied.

Theorem 9 (The Need for Modularity):

> When a large system consists of several subunits, each unit must satisfy independent subsets of functional requirements as to eliminate the possibility of creating a resource-intensive system or coupled design for the entire system.

In Theorem 8, the two important elements to be noticed are: ‘reconfiguration by changing the organizational structure’ and ‘flexible personnel policies’. Reconfiguration (or reorganization) is considered by Suh [1995] a change in the design parameters of the organization. On the other hand, a flexible personnel policy means that the organization should only keep resources that satisfy the design parameters. A flexible personnel policy is similar to changing process variables. The policy applies to both human and other types of resources. Some human resources are eliminated, others are trained and new ones may be acquired to satisfy the design parameters.

Although, this theorem deals with single organizations, it is readily applicable to Virtual Enterprises. It should be noted that it captures the two most important elements of a Virtual Enterprises: the need of reacting quickly to changes in market conditions as well as the collaboration and integration of core capabilities. The need to react quickly is referred by the theorem as ‘reconfiguration’. That is, the design of a Virtual Enterprise capable of taking advantage of a specific market opportunity. A flexible personnel policy is associated to collaboration and integration. Nevertheless, Virtual Enterprises are formed by integrating the core capabilities of partners. Thus, a Virtual Enterprise as a whole does not need to keep redundant resources or to train its human resources within the organization. In principle, a Virtual Enterprise uses only resources required to satisfy the market opportunity and the goals of the organization.

Theorem 9 guides the design process and warns about the consequences of violating the modularity principle. It can be used in the selection of partner companies during the design of Virtual Enterprises as systems. The theorem is interpreted as the need for each partner (subunit) to satisfy independent subsets of functional requirements. This condition is readily met by the focus on core capabilities of Virtual Enterprises. Each partner contributes with specific core capabilities and resources to the organization. A Virtual Enterprise first identifies the required core capabilities and only then selects the partners capable of delivering those capabilities.

Using the definition of large systems and Axiomatic Design, the design of Virtual Enterprises can be analyzed as a function of time. The analyses consider both the design of Virtual Enterprises as organizations and as systems. The analysis of organizational design explains the evolution of organizational forms. The analysis of system design focuses on the design of specific Virtual Enterprises, including the web of Virtual Enterprises.

3.4.1 Evolution of Virtual Enterprises as Organizational Form

The evolutionary formulation is based on Eqs. 3.5 and 3.6. As explained earlier, the elements of the customer domain, {CA}, are the market conditions that have created the need for a different organizational form. Changes in market conditions generate changes in the functional requirements, {FR}, or functions of the organization.

Since new functions need to be satisfied, the organization reconfigures or reorganizes to satisfy those functions. This reconfiguration is achieved by changing the programs and offices (or design parameters) of the organization. These new programs and offices are satisfied by the human and material resources capable of supporting those changes. This design process is represented in the upper section of Fig. 3.4.

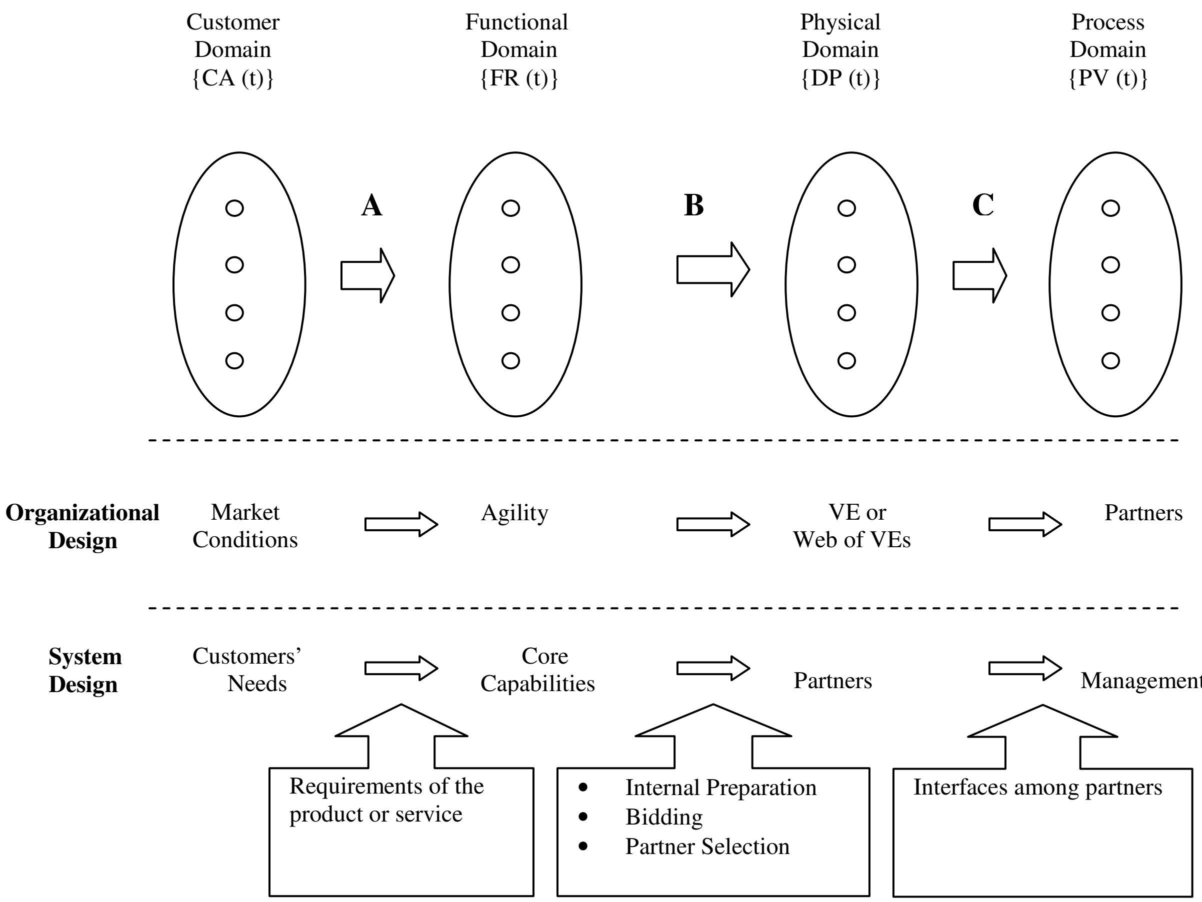

Figure 3.4. Design of Virtual Enterprises as Organizations and as Systems.

Table 3.3 shows the recent evolution in organizational design. It is not the purpose of this example to provide a detailed analysis of the evolution of organizational forms. It only aims to illustrate the main points of the formulation. Definitely, a more complete and concise formulation of this evolution can be done using a similar approach. Such a formulation might start from the time of industrial revolution or perhaps earlier and finish with the analysis of current organizational forms.

Table 3.3. Three Stages in the Evolution of Organizations.

	Time (t)	Customer Attributes {CA (t)}	Functional Requirements {FR (t)}	Design Parameters {DP (t)}	Process Variables {PV (t)}
Past	$t = t_0$	Mass production (stable market conditions)	Pre-agility • Outsourcing • Network Organizations • Process Enterprises	Corporate Structure (Programs and Offices)	People or other resources
Present	$t = t_1$	Mass customization (dynamic market conditions)	Agility	Virtual Enterprises and Web of Virtual Enterprises	People or other resources (Partner Companies)
Future	$t = t_2$	Post-mass customization (? market conditions)	Post-agility ?	?	People or other resources ?

In Table 3.3, the (recent) past is considered the mass production era and it is set at $t = t_0$. At that time, a set of market conditions was identified. These market conditions were satisfied by pre-agility functional requirements. These pre-agility functional requirements, in turn, were satisfied by programs and offices organized in a hierarchical corporate structure. The organization utilized people and other resources capable of supporting (satisfy the need of) the offices and programs. As time went by, market conditions changed. These changes caused changes in the functional requirements of the organization. Approaches such as outsourcing, network organizations, and process enterprises are seen as evolutionary changes within the mass production era.

Changes in the functional requirements have resulted in many changes in the programs and offices of the organizations. This happened even though the hierarchical corporate structure remained as the linking element of the design parameters. As the results of changes in the programs and offices, human and other resources were also changed. Layoffs, downsizing, rightsizing, and other buzzwords as well as spin-offs**,** reduction of management levels, and other organizational changes can all be seen as changes in the resources of the organization or process variables. These changes represent the way in which organizations tried to satisfy changing design parameters.

As changes in the market domain continued, there was a point in which a substantially different set of market conditions was identified. This new set of market conditions is represent by $t = t_1$ and it is considered the present. These changes were not episodic. They were rather small changes that over time resulted in the current market conditions.

Nowadays, these new market conditions need to be satisfied by new functional requirements of the organization. These new functional requirements are widely known as agility, or the need to react quickly to market changes. The requirements of agility can be satisfied in the physical domain by different organizational designs.

Some of these designs keep the hierarchical corporate structure as liking element. That is, for example, the case of concurrent engineering and process enterprises. Other designs, such as Virtual Enterprises, cannot exist within the rigid boundaries of a hierarchical structure. Once more, changes in the design parameters of the organization led to changes in the resources that support the programs. Those resources are the partner companies that form the Virtual Enterprise. The utilization of people and resources, then, takes the form of virtual teams that support the operation of the Virtual Enterprise.

The middle section of Fig. 3.4 shows the present stage in the evolution of organizational design. A more detailed analysis of this current situation is presented in Chapter 5, during the analysis of Virtual Enterprises as a design problem.

The foregoing analysis provides strong reasons to believe that market conditions will continue to change, as they have done for centuries. In the future, at some point in time (designated here by $t = t_2$), a new set of market conditions will be identified. These new conditions are called, for a lack of a better term, post-mass customization. These conditions will be satisfied by a set of (post-agility) functional requirements. Some sort of organizational form will then satisfy these functional requirements. Such an organizational form still will need to be supported by people and other resources.

This futuristic analysis is simple. It did not identify new organizational forms or predict future developments. However, it does demonstrate that organizational design can be explained as a function of time, in terms of Axiomatic Design and the design of large systems.

3.4.2 Design of Virtual Enterprises as Systems

Eq. 3.5 and 3.6 can also be used to represent the design process of Virtual Enterprises as a system. The focus here is the product or service delivered by the organization. It was already explained, that the inputs to the system are customers' needs and the output is the product or service delivered by the Virtual Enterprise. Therefore, the design of Virtual Enterprises as systems deals with the transformation of inputs into outputs. It should be recalled that two designs are taking place concurrently: the design of the organization and the design of the product or service delivered by the Virtual Enterprise. The lower section of Fig. 3.4 shows this design.

Once the customers' needs are known, the Virtual Enterprise identifies the functional requirements, {FR}, required to satisfy those needs. The functional requirements are the core capabilities needed to produce the product. This transformation or mapping between these domains is achieved by analyzing the requirements of the product or service.

After the core capabilities are identified, the Virtual Enterprise needs to find partners capable of delivering those capabilities. Partners are the design parameters, {DP}. The mapping from the core capabilities to the partners' selection includes the following steps: internal preparation, bidding, and partner selection.

Following the partners' selection, the organization is formed by setting the interfaces that allow partners to work together. In addition, the control variables for managing the organization are identified. At this point, the Virtual Enterprise starts operating and delivers a product or service that satisfies the customers' needs.

The operation of the organization needs to be managed to achieve the desired results. In other words, a Virtual Enterprise (the system) needs to be controlled to minimize its entropy. Management also deals with triggering the disbanding of the organization, once the market opportunity has passed. This function was explained earlier during the analysis of the control and conceptual models.

As the customers' needs change with time, a new (or different) set of core capabilities, $\{FR\}_1$, will be required. These capabilities will be satisfied by a new set of partners, $\{DP\}_1$ or a new Virtual Enterprise. Hence, the operation of the Virtual Enterprise will have to change accordingly.

3.4.3 Design of Virtual Enterprises in a Web

Chapter 2 mentioned that the management of a Virtual Enterprise is one of its greatest challenges. The integration of operations requires partners to establish interfaces, interact, and behave as a single organization. Unfortunately, this is not an easy task and often Virtual Enterprises disband. This failure is mainly due to the inability of the partners to integrate and work together successfully. The reasons for failing are analyzed in more details in Chapter 5.

Chapter 2 also explained that a web of Virtual Enterprises has been used to cope with the challenges of managing Virtual Enterprises [Goldman et. al 1995, Franke 2001]. The web is a meta-organization (meta-Virtual Enterprise) that acts as a pre-qualifying step in the formation of Virtual Enterprises. It requires a network-broker or coordinator to deal with the management of the web. The broker is responsible for addressing collaboration, coordination, integration, and other management issues inside the web.

The main function of the web is to prepare partners for working in a "real" Virtual Enterprise. Management issues are dealt with before the Virtual Enterprise is formed. In the web, partners establish and improve interfaces to be ready to operate in a Virtual Enterprise. The network broker mediates this process.

Fig. 3.5 shows the design of a Virtual Enterprise starting from a web. The upper section of the figure depicts a general view of the design. The customer needs are identified either by the web as a whole or one of its members. Then, the web selects some of its partners to form a Virtual Enterprise. Each Virtual Enterprise, once it is created, needs to be managed to delivery its product or service.

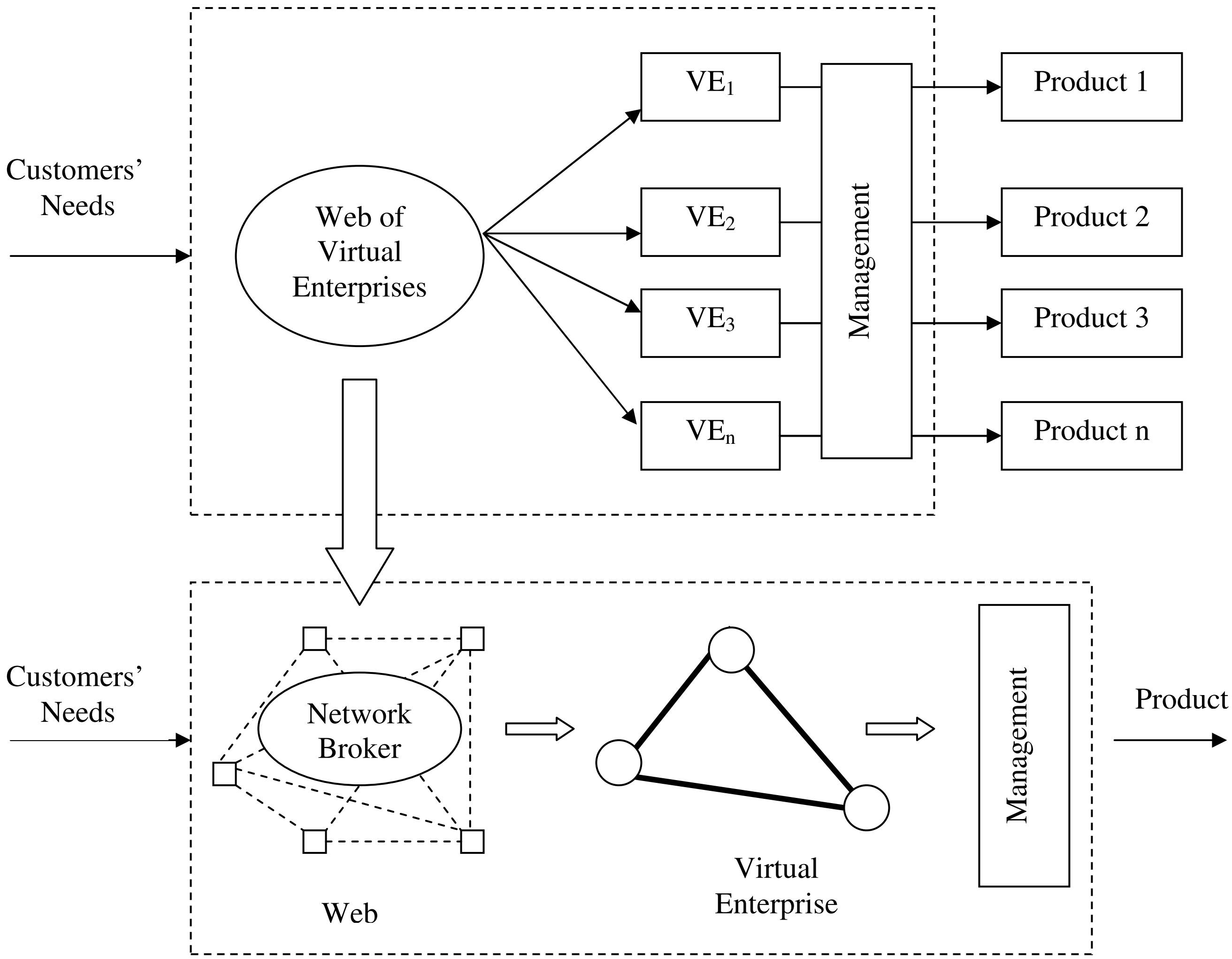

Figure 3.5. Web of Virtual Enterprises.

The lower section of the figure shows a more detailed view of the process. The web of Virtual Enterprises is formed by partners (squares) and coordinated by the network broker. In the web, the partners establish and improve the interfaces (broken lines). The interfaces are used later during the operation of a Virtual Enterprise. Once the market opportunity is identified, some of the partners form a Virtual Enterprise. Then, the organization starts to deliver a product or service to the market and goes through its management and disbanding phases. The lower section of the figure is somehow similar to the model proposed by Zhang et al. [1997]. However, it is not based on a type-instance model as suggested by the authors.

In system terms, the addition of the web transforms the design of Virtual Enterprises into a closed system. This transformation contributes to the control of the system (the management of the Virtual Enterprise) by isolating the system from its external environment [Winstanley 1991]. The web "isolates" or constrains the design process and management of the Virtual Enterprise, making them more predictable and controllable.

As in the case of the design of Virtual Enterprise as systems, the organization formed by the web changes, as the customers' needs change with time. Each time that a new set of customers' needs is identified, a new organization is formed.

The designs of a Virtual Enterprise with and without a web are very similar. Both systems have the same inputs and outputs. In addition, regardless of how the Virtual Enterprise is formed, it has to be managed and a product has to be delivered.

However, there are differences between both approaches. The most marked difference is the scope of the market opportunity that the web can pursue. In principle, a Virtual Enterprise (without a web) could pursue any market opportunity. All that is needed is to find partners capable of delivering the required core capabilities. The web, on the other hand, can mainly pursue opportunities within the scope of the core capabilities of its members. This difference can be seen as a trade-off between success and scope. Surely, the mediation of the web improves the success rate, reduces start-up times, and improves the management of Virtual Enterprises. However, these benefits come with a price: a limited number of market opportunities.

Internal differences also can be identified. The bidding process is moved and the partner selection and the interface setting processes are simplified. The bidding process is now performed during the formation or expansion of the web. Partners do not bid to form the Virtual Enterprise but to enter the web. The web as a meta-organization allows some redundancy in the core capabilities of the partners. This can be very useful if a Virtual Enterprise needs to substitute some of its members, after starting to operate.

The partner selection process is constrained to the best possible partners within the membership of the web. This is a considerably easier process than the one performed in a Virtual Enterprise. Setting the interfaces becomes also easier. The partners have already established the interfaces and only need to strengthen (or reactive) them for the operation of the Virtual Enterprise.

3.5 Summary

The chapter analyzed Virtual Enterprises as systems. It was shown that Virtual Enterprises satisfy the nine most important characteristics of a system.

Based on this analysis, a conceptual and a control model of Virtual Enterprises were developed. These models consider the three phases of the life cycle of a Virtual Enterprises: design, management and disbanding. Both models included a control unit for managing the organization.

It was also shown that Axiomatic Design allows analyzing and designing Virtual Enterprises as both systems and as organization. The design of Virtual Enterprises as organizations takes as inputs the market conditions that have created the need for forming this type of organizations. It has as output the partner companies capable of forming a Virtual Enterprise. The design as systems takes as inputs the customers' needs for specific products or services. Its output is the product or service delivered by the organization.

The chapter also presented a time dependent formulation of these designs, using the design of large system as a foundation. The inclusion of time in the design of the organization, explained the evolution of organizations forms. Considering time in the design of Virtual Enterprises as systems provided a general and unified view of the design inside and outside a web. The web of Virtual Enterprises is a particular case of the design of Virtual Enterprises as systems. It can be seen as a trade-off between success and scope.

3.6 Current Stage of the Analysis

Fig. 3.4 guides the analyses presented throughout the thesis. It helps to identify what have already been done and what remains to be done. Let us first analyze organizational design. The Partners domain and the mapping between domains have not been analyzed yet. All other domains (Market Conditions, Agility and Virtual Enterprises) were analyzed in Chapter 2. The next two chapters study these two missing elements. Chapter 4 identifies the elements of the Partners domain and their importance. This was achieved by conducting a survey about outsourcing practices in Canada. Chapter 5, on the other hand, identifies and analyzes possible mappings between domains. It also evaluates the design, according to Axiomatic Design.

For the design of Virtual Enterprises as systems, only the high-level elements in each domain have been presented. The first two domains of the design – Customers' Needs and Core Capabilities – are specific for each application. The other two domains – Partners and Management – are general or independent of specific instances of Virtual Enterprises. The former are specific since each Virtual Enterprise will have to identify the customers' needs it wants to satisfy, and the required core capabilities. The latter are general, because regardless of the required core capabilities, a Virtual Enterprise always needs to select partner companies capable of providing these capabilities. Furthermore, partners need to work together during the management phase to deliver a product or service.

Since Customers' Needs and Core Capabilities domains are application specific, they are not analyzed in the thesis. The Partners and Management domains are studied in Chapter 6 and 7, respectively. Chapter 6 covers the Partner Selection Process, while Chapter 7 deals with the management of Virtual Enterprises.

4 Survey on Outsourcing Practices in Canada

4.1 Introduction

Chapter 2 explained that outsourcing or subcontracting has been one of the three main influences shaping the development of Virtual Enterprises. Often outsourcing is only seen as a cost-saving strategy [Taylor 1999, Halley 2000] without considering many other implications it may have.

The study presented in this chapter, was designed to gain a better understanding about how outsourcing is being used in the Canadian industrial practice nowadays. The chapter focuses on two of the most important research questions covered by the survey. Hence the objectives chapter are:

1) To identify the importance of the criteria used for partner selection, and
2) To identify the reasons for success and failure in outsourcing relationships.

The survey focused on outsourcing practices rather than on Virtual Enterprises because, despite many reports of successful implementation of Virtual Enterprises, only industry leaders seem to be currently applying this concept. Therefore, not many "ordinary" design and manufacturing companies are currently applying these principles in their everyday operations.

The organization of the chapter is as follows. First, the chapter introduces its two research questions and their relevance. Second, it introduces the methodology used for answering the research questions. The chapter finalizes with the analysis of the most important findings of the survey and their comparison to previous research.

4.2 Research Questions

This chapter seeks to answer two of the most critical questions about current outsourcing practices in Canada. The first question deals with the importance assigned to the selection criteria during the partner selection process. The second question addresses the determinants of success and failure in outsourcing relationships. The research focused on outsourcing relationships that took place in the last three to five years.

The importance assigned to the selection criteria addresses two important issues. First, it analyzes outsourcing in a Canadian perspective and second it seeks to identify the new trends in the perceived importance of the selection criteria. New demands posed by agility as well as the advances and extensive use of Information Technology in design and manufacturing have changed the relative importance of the criteria used outsourcing decision-making. Location, for example, once considered a critical factor, has become a less important factor due to the use of electronic communication and exchange of information. The relative importance of cost has also changed. The increasing focus on satisfying customer needs and providing them with solutions (rather that isolated products) has made it possible to increase the price of the product or service offered. Delivery time is perhaps the only factor that may have become more important, since companies are consistently trying to be first in the market as a way to increase their competitive advantage.

The identification of the determinants of success and failure seeks to provide insights on the most important reasons for both success and failure in outsourcing relationships. It is natural to assume that changes in the roles of selection criteria affect the success of outsourcing relationships. Therefore, these determinants need to be re-evaluated according to the current situation. Identifying these determinants should help decision-makers to focus on areas or issues in which problems are more likely to happen.

Unfortunately, determinants of success have received more attention than those of failure. This extensive focus on success might be associated with the companies' unwillingness to refer to failures. Although, determinants of success can be used to draw conclusions about failure, it is far more beneficial to study failure in itself and to identify its causes.

Bailey et al. [1998] found that technical capabilities, financial security, business strengths, development speed and matching aims were positively correlated with success in collaborative relationship. In addition, this study identified a negative correlation between success and cost as well as success and collaborative record. That is, those companies that chose partners according to cost and collaborative record were less successful. This study also found wide variations in the accuracy of the evaluation of the selection criteria. Criteria such as management ability, technical capabilities and development speed were often underestimated. In contrast, criteria such as cultural compatibility and collaborative record were overestimated.

Wildeman [1998] suggested that cultural compatibility between companies can affect negatively the success of the relationship. This study also found lack of commitment, complementation of core capabilities and cultural compatibility as the most important causes of failure. Lack of attention to relational aspect of the relationship, lack of communication and changing circumstances were identified as issues that required a careful attention.

4.3 Research Methodology

To answer the research questions, a four steps methodology was implemented[1]. The methodology is explained in Appendix B. First, the research objectives were established. These objectives were used to identify the research questions presented in Section 4.2. Second, a theoretical framework for the study was developed. During the development of the framework the hypotheses and propositions of the research were established. The third step identifies research variables based on hypotheses and propositions. It also included the design of the questionnaire (Appendix C). The design of the questionnaire

[1] I am thankful of Prof. Long for his invaluable help in the development of the methodology and the design of the survey.

was based on the "Total Design Method" proposed by [Dillman 1978]. Several case studies in local design and manufacturing companies were conducted to evaluate both the relevance the issues covered by the research and the terminology used in the survey. The final step dealt with the distribution of the questionnaires and the collection and analysis of the data.

4.4 Analysis of Results

The questionnaires were mailed to managers and outsourcing decision-makers of 300 design and manufacturing companies. These companies were selected from the Dun and Bradstreet database. Eighty-four companies provided useful responses, for a response rate of 28%. Taking into consideration the length and complexity of the questionnaire, this response rate compares well with other surveys such as ASME [1997], Bailey et al. [1998], and Culley et al. [1999]. These studies obtained a response rate of 17%, 31%, and 22.6%, respectively.

Thirty-two per cent of the respondents were small companies, 53.6% were medium sized companies, and 14.3% were large companies. Regarding annual revenue, 28.6% of the respondents have annual revenue of less than $10 million, while 35.7% have revenues between $10 and $50 million and 32.2% have revenue of more than $50 million. Sixty-eight (68) percent of the respondents were fully ISO certified. The remainder of the respondents were at different stages of the certification with 21.5% being ISO compliant in more than 50%.

Section C and D of the survey addressed the research questions analyzed in this chapter. Section C inquired about the role of the selection criteria in general outsourcing policies. Section D was divided into two subsections; focused on successful and unsuccessful outsourcing relationships. Successful relationships were defined as those in which 50% or more of the objectives set before starting the relationships were met. Unsuccessful relationships were considered those where less than 50% of the initial objectives were met.

It was not clear whether the data followed a normal distribution or not. Therefore, parametric and non-parametric tests of the selection criteria for the three outsourcing situations were conducted. The parametric test conducted was the Analysis of Variance (ANOVA) and the nonparametric test was the Friedman-R test. Follow-up tests were conducted to identify the differing means. The follow up test for the Analysis of Variance was the Bonferroni comparisons, while the Wilcoxon signed rank test was used after Friedman-R tests.

4.4.1 Importance of the Selection Criteria

Table 4.1 summarizes the findings on the importance of the selection criteria in outsourcing decision-making. The first column shows the importance assigned to the selection criteria in a 1 to 9 scale, with 1 being not at all important and 9 being extremely important. It can be seen that delivery and technical capabilities are the most important criteria. On the other hand, size and cultural compatibility were found to be the least important criteria.

Table 4.1 Importance, ANOVA and Bonferroni comparison of Selection Criteria.

	Importance	ANOVA	Bonferroni	
Criterion	(1-9)	(F)	G vs. U	S vs. U
Delivery Capabilities	8.5	9.61*	x	x
Technical Capabilities	8.1	9.42*	x	x
Collaborative Record	7.7	6.42*	x	
Management Ability	7.4	0.62		
Financial Security	6.9	3.54*	x	
Cost of Development	6.9	0.07		
Business Strength	6.7	2.02		
Strategic Position	6.3	0.38		
Development Speed	6.3	2.07		
Location	6.2	5.30*		x
Information Technology	6.1	0.37		
Cultural Compatibility	5.8	2.26		
Size	5.3	2.46		

(*) indicates statistical significance at 5%.
G: (G)eneral outsourcing policies S: (S)uccessful relationships U: Unsuccessful relationships

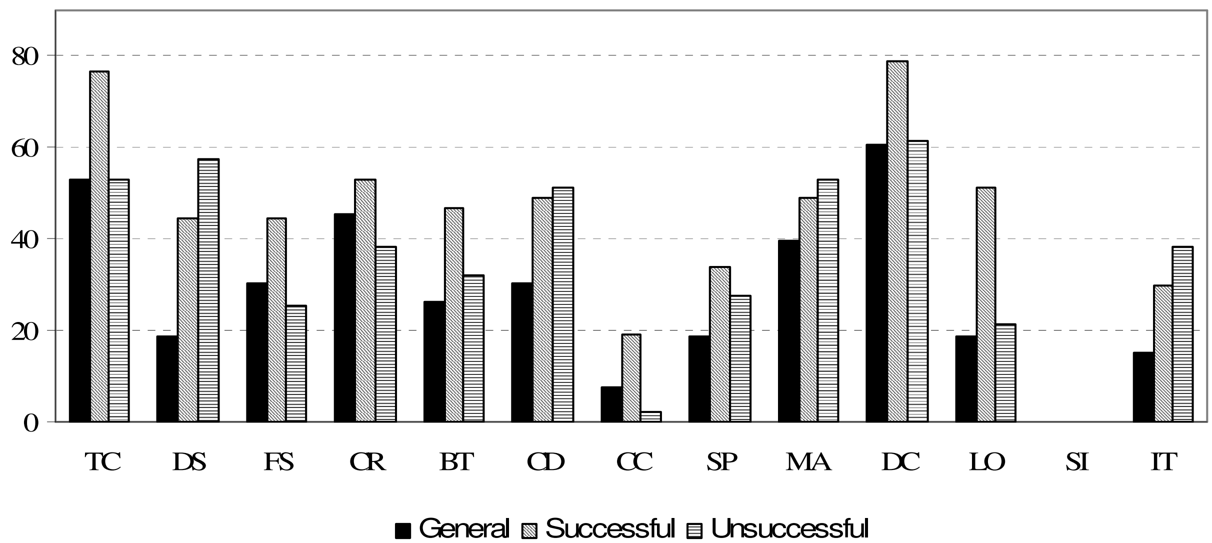

Figure 4.1. Importance of the Selection Criteria in General, Successful, and Unsuccessful Outsourcing.

Figure 4.1 shows a comparison of the importance of each criterion for the three outsourcing situations. For each outsourcing situation, the criterion with the lowest ranking was taken as reference for calculating the percentage of variation for the other criteria. In all the case, the size of the subcontractor (SI) is the least important criterion. Therefore, no bars are shown in the figure.

It can be noticed that delivery capabilities (DC) consistently ranks first regardless of the outsourcing situation, although its importance seems to be more critical for success than for failure. However, it still seems to be the most important factor in causing the failure of outsourcing relationships. In addition, technical capabilities (TC) ranks second in general and successful outsourcing situations. This position is exceeded only in unsuccessful outsourcing by development speed (DS). On the other hand, the size of the subcontractor (SI) ranks consistently as the least important criteria for all outsourcing situation. These rankings illustrate the challenges faced in the selection of subcontractors, since two of the highest ranked criteria play a very important role in both success and failure of subcontracting relationships.

In summary, it can be seen that for each triad, Fig. 4.1 shows that technical capabilities (TC), financial security (FS), collaborative record (CR), business strengths (BT), cultural compatibility (CC), strategic position (SP), delivery capabilities (DC), and location (LO) are the most important criteria in successful outsourcing. On the other hand, development speed (DS), cost of development (CD), management ability (MA), and the use of Information Technology (IT) appear to be the most influential criteria in unsuccessful relationship.

It should be noticed that the roles assigned to the criteria in general outsourcing, are never the largest value in the triad. This pattern indicates that decision makers are consistently underestimating the roles of the criteria in setting general outsourcing policies.

The second column in Table 4.1 shows the results of the Analysis of Variance (ANOVA). ANOVA compared the means of the importance of the selection criteria for general outsourcing policies as well as successful and unsuccessful relationships. It can be seen that means differ for the technical capabilities, financial security, collaborative record, delivery capabilities, and location criteria.

The last two columns in Table 4.1 show the Bonferroni comparisons for the selection criteria in the two of the outsourcing situations. These comparisons identify the means causing the differences in the analysis of variance. Three comparisons were performed ($c = 3$) at 1% significance and a t-value $t_{0.01,\infty} = 2.326$. The comparison between the importance of the criteria in general outsourcing policies and successful outsourcing was omitted since it no differences in means were found.

The differences in the means always appear in the comparisons between the general outsourcing policies and unsuccessful outsourcing as well as between successful and unsuccessful relationships. For the technical capabilities criterion the means differ in the comparison of general vs. unsuccessful outsourcing and successful and unsuccessful outsourcing.

In the case of the financial security and collaborative record criteria, the means differ only in the comparison between the general and successful outsourcing. The means of the delivery capability criterion differ in both general vs. unsuccessful and successful vs. unsuccessful outsourcing. The means of the location, on the other hand, differ only in the comparison between the successful and unsuccessful outsourcing.

The analysis of variance indicates that the most important criteria (in order of importance) are delivery and technical capabilities, collaborative record, location and financial security. These results have both similarities and differences with other reseach. The technical capabilities and financial security criteria have always been identified as an important criterion in outsourcing, strategic alliances, and collaborative relationships [Wildeman 1998, Bailey et al. 1998]. The findings related to the delivery capabilities, location and collaborative record are different. Delivery capabilities and location were not considered as selection criteria in other research. Collaborative record is perhaps the most controversial of these findings. Previous surveys have identified a negative role of this criterion in either collaborative relationships or strategic alliances.

One possible explanation for this difference is the characteristics of sample used. This survey focused on design and manufacturing companies involved in outsourcing relationships while the other survey targeted collaborative relationship or strategic alliances.

The Friedman-R test for the means of the three outsourcing situations shows that the probability distribution among these means differ at $\chi^2 = 0.05$. The Wilcoxon signed rank tests indicate that the means of general outsourcing policies and unsuccessful relationships differ at the 0.025 significance level ($\alpha = 0.025$), while the means of successful and unsuccessful outsourcing are different at the 0.01 significance level. ($\alpha = 0.01$).

4.4.2 Determinants of Success and Failure in Outsourcing

To determine the role of the selection criteria in the success or failure of the outsourcing relationships, the weightings given to each criterion were correlated with the level of success of the relationship. Table 4.3 shows the Spearman's rank correlation coefficient (r) for each criterion in success and unsuccessful relationships.

Table 4.2. Relationship between Weighting of Criteria and Success and Failure.

	Correlation Coefficient (r)	
Criterion	Successful	Unsuccessful
Delivery Capabilities	0.66*	0.24
Technical Capabilities	0.59*	0.12
Development Speed	0.53*	0.66*
Financial Security	0.53*	0.63*
Location	0.53*	0.28
Collaborative Record	0.53*	0.03
Management Ability	0.53*	0.66*
Business Strength	0.52*	0.54*
Cost of Development	0.52*	0.32
Size	0.51*	0.41
Cultural Compatibility	0.51*	0.16
Strategic Position	0.51*	0.29
Information Technology	0.51*	0.47*

(*) indicates statistical significant at 5%

The first column in Table 4.3 shows that all the criteria are positively rank correlated with the success of the relationships. These values should be interpreted with caution. All the respondents identified a level of success of 75% or more. This in fact may have affected these results. Still, it can be seen from the table that the same criteria identified by the analysis of variance as significant have a larger rank correlation.

The second column shows the Spearman's rank correlation coefficients in unsuccessful relationships. These values seem to indicate that management ability, development speed, financial security, business strength and the use of information technology are positively rank correlated with failure. It should be noted that the 'traditional' selection criteria: cost, location and delivery capabilities do not seem to have a positive rank correlation with failure. Still another interesting result to notice is that collaborative record ranks last.

This result can be interpreted as collaborative record having almost no effect in the failure of the outsourcing relationships.

4.5 Summary of Findings

It can be noticed from the analysis shown above that some criteria are consistently identified as important, regardless of which method is used to evaluate their importance. In order of importance, the criteria that belong to this group are: technical capabilities, delivery capability, collaborative record, location, and financial security.

Other criteria were identified as important by only one of the tests. Business strength and the use of Information Technology, for example, ranked relative high in the analysis of frequencies and they were found significant by Spearman's rank correlation in both success and failure of outsourcing relationships. However, the analysis of variance did not identify these criteria as important.

Notably in this analysis is the fact that cost of development, size, and cultural compatibility were identified as important, only once. Despite that cost of development ranks relatively high in the analysis of frequencies, it was identified important in neither the Analysis of Variance nor Spearman rank correlation (with the exception of success where it ranks the second last). Size and cultural compatibility were found important only by the Spearman correlation with success.

The cost of development was found by Bailey et al. [1998] as the least important criteria and negatively rank correlated with success. In this research, the authors argued that it was possible that the respondents may have been unwilling to acknowledge the importance of cost in their decision-making process. The finding of the survey with respect to cost of development may be used to reinforce this understanding. However, the opposite approach also may be valid. The similarity of findings might suggest that, in fact, a shift in the importance of cost is taking place.

5 Virtual Enterprises as a Design Problem

5.1 Introduction

Chapter 2 mentioned that 60 - 70% of Virtual Enterprises disband prematurely [Wildeman 1998]. This finding establishes as one of the objectives of the thesis; to study Virtual Enterprises as a design problem.

Chapter 2 and 3 showed that the life cycle of a Virtual Enterprise could be divided in three phases: (1) design; (2) management; and (3) disbanding. Design is considered the most important phase. The selection of partners or members is critical to the success of the organization. Once a Virtual Enterprise starts to operate, the substitution of one or more of the members becomes a very difficult and sensitive issue. More importantly, the substitution of one of the members may result in the disbanding of the organization.

Chapter 3 also analyzed that the success of a Virtual Enterprise depends more on its design than on its implementation or management. Unfortunately, quantitative evaluations of the impact of the design phase on the success rate of Virtual Enterprises are not available.

The objectives of the study of the Virtual Enterprise as a design problem are:

1. To provide a unified and consistent view of the relationships among the current market condition, agility, Virtual Enterprises and the selection of partner companies in these organizations.
2. To contribute to understanding of the reasons for the disbanding.
3. To identify possible solutions to reduce the statistics, presented at the beginning of the chapter.
4. To determine how the selection criteria satisfy the needs of Virtual Enterprises.

Chapter 2 identified as one of the characteristics of Virtual Enterprises the distinction between strategic and operational levels. The strategic level considers the abstract requirements of Virtual Enterprises. The operational level takes into account the satisfiers of abstract requirements. This separation results in what is defined as the 'switching principle' [Mowshowitz 1999].

The switching principle separates the 'needs' from the 'need fulfillment' or satisfaction. Based on this principle, the implementation of a goal-oriented activity is achieved by the assignment and reassignment of concrete 'satisfiers' to the abstract requirements of a task. This process of assignment and reassignment is defined as switching.

The application of the switching principle requires the following five steps:

1. Analysis of the 'abstract requirements'.
2. Identification of possible 'satisfiers'.
3. Switching and tracking of the allocation of 'satisfiers' to 'requirements'.
4. Maintaining and possibly revising the procedure for allocating 'satisfiers' to 'requirements'.
5. Reviewing and adjusting the optimality of the allocation procedure.

Abstract requirements are the logically defined needs of the tasks. They should be specified independently of the 'satisfiers'. Concrete 'satisfiers', on the other hand, are the resources used to meet the needs of the task. Switching provides flexibility and makes it possible to change satisfiers due to changes in the abstract requirements. Cost is the optimization criterion applied to the switching principle. Switching is only justified if the cost of replacing a satisfier is lower than the cost of the replacement.

The switching principle was originally proposed to deal with the management of virtual tasks. Although it is a sound principle, it does not provide all the capabilities, required for analyzing Virtual Enterprises as a design problem.

Fortunately, between the switching principle and Axiomatic Design a relationship can be established. The former is a subset of the latter (i.e., switching principle $\subseteq$ Axiomatic Design). Axiomatic Design was introduced in Chapter 3. According to Axiomatic Design, the switching principle considers only the functional and the physical domains, as well as the mapping between them.

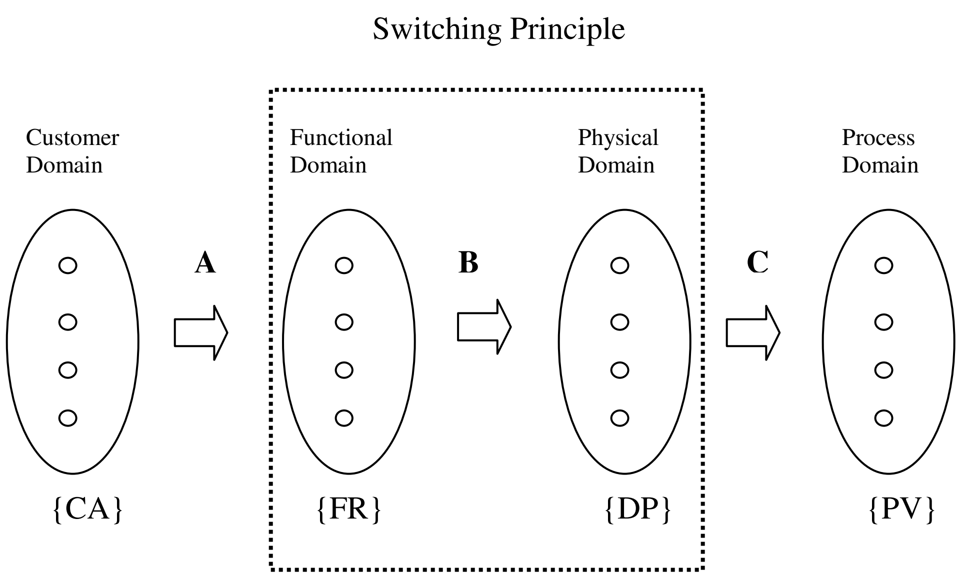

Figure 5.1. Relationship between the Switching Principle and Axiomatic Design.

Fig. 5.1 shows the location of the switching principle within the design process. In the figure, the switching principle is represented by the rectangle in broken lines. It can be seen that the switching does not consider either the customer or the process domains of Axiomatic Design. In addition, the switching principle does not deal with the decomposition of neither the abstract requirements nor the satisfiers.

A comparison between the switching principle and Axiomatic Design shows both similarities and differences. The abstract requirements are similar to the elements of the functional domain. Satisfiers, on the other hand, are equivalent to the elements in the physical domain. Besides, the allocation procedure (switching and maintenance) between requirements and satisfiers is similar to the mapping, in Axiomatic Design.

The revision and adjusting of the optimality criteria of the allocation procedure is matched by the applications of Axiom I and II. The main difference between these two methods, is the optimization criterion. The optimization in the switching principle is based on costs, while Axiomatic Design achieves the same goal by using the information content of the design.

The analysis of Virtual Enterprises as a design problem begins with the definition of the domains used in the design Virtual Enterprises. Next, the high level components for each domain are introduced. Using Axiomatic Design as a guide, the elements in each domain are decomposed. This decomposition expands the design hierarchy up to three levels. Each time the elements of the domain are decomposed, the analysis of their relationships is performed. Afterwards, the mapping between two neighbouring domains is carried out. The mappings are performed from the domain on the left to the domain on the right. The chapter finishes with an overall analysis of the design.

Chapter 3 showed that mathematically, Eq. 3.1, 3.2 and 3.3 represented the design process. These equations are reintroduced here as Eq. 5.1, 5.2 and 5.3. They can also be used to guide the design process.

$$\{CA\} = [A]\,\{FR\} \tag{5.1}$$

$$\{FR\} = [B]\,\{DP\} \tag{5.2}$$

$$\{DP\} = [C]\,\{PV\} \tag{5.3}$$

where:
{CA}: vector in the customer domain,
{FR}: vector in the functional domain,
{DP}: vector in the physical domain,
{PV}: vector in the process domain,
[A]: design matrix between the customer and functional domains, $A_{ij} = \partial CA_i/\partial FR_j$,
[B]: design matrix between the functional and the physical domains, $B_{ij} = \partial FR_i/\partial DP_j$, and
[C]: design matrix between the physical and the process domains, $C_{ij} = \partial DP_i/\partial PV_j$.

Basically, the analyses presented below identify the terms for each equation. Once the domains are introduced, the analysis identifies the terms in Eq. 5.1. First, the vectors {CA} and {FR} are identified. Later, the matrix [A] is determined. Eqs. 5.2 and 5.3 are used in a similar way. The process continues until it reaches the third level of the design hierarchy.

The analyses that follow are mainly qualitative, since many of the factors under study are difficult to quantify due to their qualitative nature. Examples from the industrial practice are used, as much as possible, for illustrating the concepts presented.

5.2 Domains

The study of Axiomatic Design in Chapter 3 explained the high-level elements of the domains for the design of organizations. In the customer domain, the highest level element was the customers' needs. In the functional domain, the highest element was the functions of the organization. In the physical domain, programs and offices were located at the highest level of the design hierarchy. People and resources occupy a similar position in the process domain.

Also in Chapter 3, during the study of Virtual Enterprises as organizations and large systems, it was analyzed each time the market conditions have changed; a new type of organization has been designed. This analysis led to the conclusion that the current market conditions have created the need for new functional requirements (agility). Agility, in turn, needs of a new set of design parameters. Virtual Enterprises represent the new set of design parameters in the context of organizational design. Furthermore, the partner companies represent the new process variables. Partners have the human and material resources required to implement a Virtual Enterprise.

Using this analysis as starting point, the four domains of the design were established. These domains are: Market, Agility, Virtual Enterprise and Partners domains. In Mowshowitz's terms, the market domain has the abstract requirements to be satisfied. According to the Axiomatic Design, the customer domain is characterized by the attributes customers want in a product being designed. These attributes are the "whats" of the design. Therefore, they are the attributes that a Virtual Enterprise, as organization needs to fulfill. In the context of current analysis, the relationship between the Market and an agile enterprise can be interpreted as a relationship between a customer and a product. The product (the Virtual Enterprise) aims to satisfy the requirements of the customer (the Market).

Agility was introduced in Chapter 2, during the analysis of the characteristics of Virtual Enterprises. There, agility was introduced as the capability to react quickly, to accommodate new needs of the market place. Agility is open-ended and dynamic, since companies should always keep improving their agile capabilities [Campbell 1998]. Companies are constantly adapting their internal operations and their external relationships, to satisfy new customers' demands. It is understandable that companies aim to satisfy the current situation in the market by transforming themselves into agile organizations. They, therefore, take a new and revised function in the market, oriented to meet the demands of market [Parunak 1997].

In Mowshowitz's terms, the Agility domain represents the "satisfiers" of the abstract requirements of the Market domain. In Axiomatic Design terms, the Agility domain is similar to the functional domain. This domain represents the functional requirements that the design needs to satisfy. The components of this domain can also be seen as the "*how*s", that satisfy the "*what*s" in the Market domain.

It should be noticed that, in principle, agility is the only one of the possible solutions. Other ways to deal with the ever-changing market requirements can be found in the future.

The Virtual Enterprise domain is the next domain to the right of the Agility domain. The Agility domain now becomes a "what" domain with respect to the Virtual Enterprise domain. This domain is equivalent to the physical domain in Axiomatic Design Theory. The Virtual Enterprise domain seeks to answer the question about how the functional requirements of agility can be satisfied. According to Parunak [1997], companies aim to satisfy these requirements by establishing a distinctive business strategy. As Campbell [1998] suggested, changes taking place in the commercial environment demand new forms of enterprises. Leaving differences and specific issues aside, other approaches are being used not only to achieve agility, but also a distinctive business strategy. Concurrent Engineering, Lean Manufacturing and Flexible Manufacturing Systems are some of the examples. However, for the purpose of current analysis, the focus is on how the requirements of agility are met by forming Virtual Enterprises.

The Partners domain is the last domain, located in the far right of the design process. The equivalent domain in Axiomatic Design is the Process domain. As in the previous cases, the elements in the Virtual Enterprise domain now become the set of functional requirements that this domain needs to satisfy. Chapter 2 explained that Virtual Enterprises are created by assembling core capabilities of competent partners. Partners are the actors or enablers in these organizations. Virtual Enterprises create (or add) value, succeed, and ultimately satisfy the requirements of the Market domain through cooperation, integration the management of the relationships among partners. Thus, for the purpose of this application, partners or members in a Virtual Enterprise are considered the "satisfiers" of the requirements of the Virtual Enterprise domain.

The equivalence between the domains in Axiomatic Design and those used in this chapter is summarized as follows:

Domains	Axiomatic Design		Design of Virtual Enterprises
Customers Attributes	Customers' needs	→	Market
Functional	Functions of the organization	→	Agility
Physical	Programs and offices	→	Virtual Enterprises or Web of Virtual Enterprises
Process	Human and material resources	→	Partners

The current market conditions were chosen as the starting point of the analysis for three reasons. First, the market is the environment in which Virtual Enterprises operate. This environment, according to Gardiner [1996] exits, and hence, cannot be ignored. It can only be acted upon. Second, the creation of Virtual Enterprise, as explained in Chapter 2, has not been a "voluntary" decision. Virtual Enterprises are, indeed, the way in which companies are reacting to new market conditions. Third, Virtual Enterprises are both market and profit-driven organizations. They are market-driven organizations since they are created with the purpose of taking advantage of a market opportunity [Goldman et al. 1995]. They are profit-driven because one of their main purposes is to generate a profit or value for both their member organizations and shareholders [Goldman et al. 1995, Parunak 1997].

The study of Virtual Enterprises by dividing the analysis into these four domains differs from those commonly found in literature; and presented, for example, in Campbell [1998], Jägers et al. [1998], Sieber [1998], Wildeman [1998], Franke [2001]. In those analyses all the market conditions, the need for achieving agility, forming Virtual Enterprises and selecting partners are presented together. These studies do not differentiate about their specific relationships. Therefore, cause-effect analyses cannot be carried out and the satisfaction of the market attributes in Virtual Enterprises cannot be evaluated. The approach adopted in this chapter aims at overcoming these limitations. It contributes also to a better understanding of Virtual Enterprises.

5.3 First Level of the Design Hierarchy

During the definitions of the domains, the elements of the first level of the hierarchy were also introduced. Starting from the Market domain, the high level or abstract requirements in this domain are the new market conditions. Companies deal with these conditions by transforming themselves into agile enterprises. Thus, new market conditions are mapped to agility or the adoption of a new and revised market strategy.

Virtual Enterprises are one of the possible ways in which companies satisfy the requirements of agility. For this reason, agility is mapped to the formation of a Virtual Enterprise or a web of Virtual Enterprises. The selection of partners companies is how the requirements of the Virtual Enterprise domain are satisfied, since Virtual Enterprises are formed by joining resources and core capabilities from different partners.

The elements of the first level of the hierarchy for the four domains are summarized in Table 5.1.

Equations 5.1, 5.2, and 5.3 are written as Eqs. 5.4, 5.5 and 5.6, respectively. These latter equations represent the elements at the highest level of the hierarchy in all the domains.

$$\{MA\} = [A]\ \{AG\} \tag{5.4}$$

$$\{AG\} = [B]\ \{VE\} \tag{5.5}$$

$$\{VE\} = [C]\ \{PS\} \tag{5.6}$$

where:

{MA}: New Market Conditions vector,

{AG}: Agility vector,

{VE}: Virtual Enterprise vector,

{PS}: Partners Selection vector,

[A] =[1] design matrix of the mapping between Market and Agility domains,

[B] = [1] design matrix of the mapping between the Agility and the Virtual Enterprise domains, and

[C] = [1] design matrix of the mapping between the Virtual Enterprise and the Partners domains.

Table 5.1. Domains and Elements at the First Level of the Design Hierarchy.

Domains			
Market	Agility	Virtual Enterprises	Partners
MA: New market conditions	FR: Agility (Flexibility)	DP: Virtual Enterprises (VE) or webs of VEs	PV: Partner Companies

In Eqs 5.4, 5.5 and 5.6 all vectors and matrices are 1x1, since there is only one element and one mapping between each two neighbouring domains.

The analysis of the design for the first level of the hierarchy is relatively simple, since each domain has only one element. All of the mappings are therefore one-to-one (1:1) because each element in the domain on the left is satisfied by (or mapped to) only one element in the domain on the right. For this first level of the hierarchy, the elements of the domains are independent and the design satisfies the Independent Axiom (Axiom I). Changing an element in one of the domains, affects one and only one element in the domain of the next right.

According to Axiomatic Design and because of these one-to-one (1:1) correspondences, there is no need to further analyze these elements at this level. In general, these correspondences have two interpretations. First, they mean that the design is correct up to this point, since one and only one element in each domain on the right is used to satisfy the requirement of the respective domain on the left. Second, the mappings imply that if changes occur in one of the domains, the mappings can be adjusted accordingly to represent those changes in other domains.

For example, if market conditions change, companies react to those changes by meeting these new requirements. These new requirements in the Agility domain cause a reassessment of the company's business strategy (Virtual Enterprise domain). The reassessment may lead to the selection of new partners. Alternatively, the Virtual Enterprise may put in place a different managerial strategy to deal with the new requirements, or do both. Although, the previous scenario was started in the Market domain (first domain on the far left), this does not have to be always the case. Changes may appear in any domain. However, the new design must perform a new mapping from the domain in question to the last domain in the far right. That is, changes must be propagated accordingly. In this way, the integrity and correctness of the design are preserved.

5.4 Second Level of the Design Hierarchy

Once the elements of the first level of the hierarchy have been analyzed, they need to be decomposed. This decomposition identifies the elements of the second level of the hierarchy for each domain. Elements at the second levels can be interpreted as sub-elements of those on the first level.

Specifically, the analysis presented in this section seeks to identify the vectors, {NM} and {AG} and the matrix [A] in Eq. 5.4. First, the elements of the second level of the Market domain, {MA}, are identified. Second, the analysis of the relationships among these elements is presented. Third, the elements of the Agility domain, {AG}, are identified and their relationships analyzed. Fourth, the mapping between the Market and Agility domains is performed and the elements of the design matrix, [A], are identified. The design matrix, [A], allows classifying the design according to Axiomatic Design, and understanding its implications.

The procedure described above, differs from common applications of Axiomatic Design. The main difference is found in the analysis of the relationships among the elements of each domain. This is commonly not required, because the designer has the freedom of choosing the elements in all the domains, except for the Customer domain. Thus, designers can avoid choosing interdependent elements. In the current analysis, it is not possible to choose freely the sub-elements in the Agility, Virtual Enterprise, and Partners domains. Choosing the elements in these domains freely means ignoring previous research efforts, in the study of agility and Virtual Enterprises. These elements should only be identified from the analysis of agility, the formation of Virtual Enterprises and the Partner Selection process. Therefore, analysis of the relationships among elements is required to verify the independence of the elements in each domain.

5.4.1 The Market Domain

To identify the elements of the Market domain, the market conditions that have created the need for agility and flexibility need to be analyzed. The current market conditions were introduced in Chapter 2. The market conditions considered in this analysis are:

1. Increased competition (due to globalization, and deregulation of international law).
2. Uncertainty and risk.
3. Rapid technological advances.
4. Product complexity.
5. Emergence of a knowledge-based economy.
6. Product variety or so-called mass customization.

These factors are divided in two clusters to facilitate their analysis. The factors are assigned to either the business or technological cluster, according to their meanings. Increased competition, as well as uncertainty and risk are assigned to the business cluster. Rapid technological advances, product complexity, product variety and the knowledge-based economy are allocated to the technological cluster.

Social and political factors are beyond the scope of this thesis and they will not be considered here. This exclusion neither diminishes nor underestimates the importance of these factors. Nonetheless, it simplifies the analysis. The factors excluded are only considered if a clear consequence on any of the clusters can be identified.

The most important and visible consequence of globalization and deregulation is an increase in competition among enterprises [Phrahalad 1990, Parunak 1997, Solow 1997, Preiss 1997, Campbell 1998, Wildeman 1998, Shen 2000, Franke 2001]. Globalization allows companies to extend their presence all over the world and to compete for markets at a multinational scale. This open flow of capital and commerce across international boundaries eases both the access and penetration into new markets. It facilitates also a market diversification for companies. Companies are always looking for means of increasing their competitiveness and producing value for their stakeholders [Parunak 1997]. This goal is achieved by either growing or diversifying the market presence, while reducing their operating expenses. On the other hand, the appearance of new players in a given market, results in its fragmentation. Fragmentation extends not only the variety of the offers, but also forces companies to use creative ways to attract new customers. To succeed in attracting new customers, companies need to rapidly change their offers according to customers' needs and preferences [Campbell 1998]. This in turn, results in a ferocious battle for gaining new customers, thereby increasing the competition in that market.

In addition, globalization and deregulation make possible the internationalization of business [Franke 2001]. Smaller companies join to increase their apparent size and their market presence, adding even more players to a given market [Goldman et al.1995]. This is particularly important for Small and Medium Size Businesses (SMSB), which traditionally have had difficulties operating beyond national borders.

Uncertainty is the inability to predict accurately market developments and consumer trends. The decision-making process for future opportunities, leads companies to forecast and make assumptions that may be proven inaccurate. However, the constant change in the market, often in unpredictable directions, creates uncertainty and forces companies to take risks [Barnet et al. 1994 and Preiss 1997]. Issues such as, variability in the product requirements and volume illustrate this point [Chen et al. 1999].

Also, uncertainty and information are related [Jägers et al. 1998]. Lack of information is one of the main reasons for uncertainty. Companies may need to take decisions when information is incomplete, inaccurate, or unavailable. They may lack information about, for example, the market, consumer trends, sustainability, and workability of the technology, timing of the market, volume, and variety of offers.

Uncertainty and risk may also appear when companies run new or difficult projects [Jägers et al. 1998]. In addition to the lack of information, Campbell [1998] explained that companies do not have the time to engage in long and extensive strategic analyses. Hence, they are in a constant revision, reassessment, and implementation of their business strategies.

Rapid advances in the development of technology have substantially influenced the current market conditions [Goldman et al. 1995, Preiss 1997, Campbell 1998, and Wildeman 1998]. The effects of these factors have been felt in the market in two distinctive manners. First, technological advances have increased the complexity of the products and services. This is a general view that acknowledges how technology has permeated the very fabric of our everyday life. Second; advances in Information and Communication Technology (ICT) have increased the variety, capabilities, and complexity of many products and services. This is a particular or specific view where a single technological advance has spread – perhaps "invaded" – almost all the other industrial fields. Nowadays, it is difficult to find a field that Information and Communication Technologies have not touched. Because of this ubiquitous presence, this particular view of technological advances is analyzed independently. The effects of all other technological advances are studied under the product complexity factor.

Developments in Information and Communication Technologies have spread knowledge and competencies all over the world [Preiss 1997]. These developments have also eliminated most of the space and time constraints. Companies and employers can communicate and exchange information efficiently, regardless of their geographical location. This, in fact, makes it possible for companies to access the competencies they required from anywhere. It also reduces the time required to bring a product to market, in two ways: first; by reducing the product development process time; and second, by avoiding duplication as they can use the technology developed elsewhere in the world.

Jägers et al. [1998] reported that Microsoft has reduced the development time of its products by distributing the work between two times zones in U.S.A and India. Each day, as the work finishes in one geographic location, developers start to work in the second location where the working day is just starting. This distribution of work results in at least a 50% reduction in developing time of the software.

The current knowledge-based economy is characterized by the integration of information and knowledge from different disciplines. Technological advances have caused the migration from a labour-intensive to knowledge-intensive economy [Drucker 1992]. Presently, products are both complex and rich in knowledge and information [Parunak 1990, Rayport and Sviokla 1995, Ottaway and Burns 1997]. Companies do not have the time or the capabilities to develop all the related components and technologies "in house" or all by themselves [Prahad 1990, Byrne 1993, Goldman et al. 1995]. As Byrne [1993] puts it, "technology is changing so fast that nobody can do it all alone anymore". However, even in the case that a company has all the resources and capabilities to carry out a given project, it is possible that by the time the development process is finished, the market opportunity would also have disappeared.

As products become more complex, more information and knowledge are required to design and manufacture them. Information content is one the most influential factors affecting a company's productivity [Ottaway and Burns 1997]. It ranks even higher than any other critical factor such as labour and cost.

Ranta [1997] provides an analysis of the relationship between product complexity and the migration of a technology from one industry to another. He argues that product complexity is a consequence of a technology transfer from fast moving industries to others where changes occur more slowly. Two important reasons are responsible for this migration: (1) the need for recuperating the investment made in developing the technology and (2) shorter delivery and production times.

To recuperate their investments companies are forced to prolong the life cycle of a production technology beyond the life cycle of the product technology. As the product life cycle approaches decline in one industry, the technology is "transferred" to another sector. The return on investment of production technology is therefore spread over a longer time. In this way, companies can shorten product life cycles and time-based competition within one industry and obtain reasonable returns for their investments.

One example is the migration of microprocessor applications from the computer to other industries. Intel spends $4 billions in developing a technology knowing that it will become obsolete for the microprocessor and computer industry, in probably three or four years. To recuperate this investment, the technology is transferred to slower changing industries such as the automotive. In the automotive industry, the technology is introduced gradually, by developing microprocessor-based applications as the ones found in modern automobiles. This technology transfer benefits both companies and customers. Intel can extend its return on investments for several more years rather than three or four years. Customers, on the other hand, get relatively lower prices, otherwise impossible to offer due to higher investment costs.

Increased product performance and variety improvements (or product variety) are consequences of the markets being finite and a shift towards a customer-centered market place [Barnett et al. 1994, Goldman et al. 1995, Campbell 1998]. Manufacturers and service providers need to constantly differentiate themselves in the market. Differentiation forces them to persuade customers about the capabilities and benefits of their products. This transformation from "one size fits all" to "individual fitting" increases the range of products that companies have to develop and produce [Mew 1997 (ref. in Franke [2001]), Chen, Liao, and Prasad 1999].

Customers are demanding products and services that fully satisfy their specific needs rather than accepting offers that provide incomplete solutions [Goldman et al. 1995, Mew 1997]. They are asking for one-stop shopping and comprehensive total solutions [Dembski 1998]. This is perhaps why customers have been identified as the “manufacturing driving force” [Ham and Kumara 1997] or terms such as “customer-driven market” and “mass customization” have been coined [Pine II, 1993, Gilmore and Pine II 1997].

Product variety should not result in a significantly higher overall cost. Customers are not only asking for solutions, but also for innovative cost-effective solutions to their problems (or needs). Therefore, companies have been forced to provide similar or better products at a lower price than their competitor to succeed. Gardiner [1996] analyzed how the leading market position of companies such as Hewlett-Packard and Dell is due to an overall cost reduction with respect to their competitors. These companies have been able to reduce costs through better logistics and other innovative business strategies.

The development of catalytic converters by the three major U.S.A car manufacturers in mid-1970’s [Goldman et al. 1995], can be compared to the Japanese electronic industry. Japanese manufacturers routinely conduct collective research and development (R&D) initiatives. Nonetheless, they compete in the market under different brand names. In this way, critical financial and human resources are used more efficiently.

Once the components of the Market domain have been introduced, the next step would be to map these components into the Agility domain. However, before this is done, the relationships among the elements of the Market domain have to be analyzed. This analysis identifies whether or not these components are independent of each other.

Table 5.2 shows the reorganized matrix of the relationships among the elements of the Market domain. This matrix is obtained by transforming the original matrix into a triangular matrix. A lower or upper triangular matrix indicates that although the elements are related, they can be changed independently. In principle, this may not be always possible. In those cases, the objective of the transformation is to obtain a transformed matrix as close as possible to a lower (or upper) triangular matrix.

Since this analysis is internal to the Market domain, the matrix of the relationship is square. Both rows and columns contain the same elements. In this matrix, an (x) represents a relationship between elements intersecting at the cell. For the few cases in which relationships might exist but their appearance are rare, unlikely or unusual, the symbol x^* is used. An empty cell means that elements of the row and column of the cell are not related.

Table 5.2.Reorganization of the Elements in the Market Domain at the Second Level.

	Product Complexity	Knowledge based Econ.	Product Variety	Uncertainty and risk	Technological Advances	Increased competition
Uncertainty and risk						
Product Variety	x*					
Product Complexity		x				
Technological Advances	x	x	x*			
Increased Competition		x	x	x		
Knowledge based Econ.	x				x	x

x: relationship x*: conditional, rare, unlike or unusual relationship

Increased competition in the market place is seen as related to uncertainty and risk, product variety, and knowledge-based economy. The relationship between increased competition and uncertainty was explained earlier. The fact that companies are facing increased competition in the market, forces them to operate under uncertain conditions. They aim to be first in the market or introduce their product or services as early as possible. As companies make assumptions and try to predict new customer trends, they may lack accurate and timely information about the markets, and hence incur risks.

Increased competition also affects product variety since companies try to differentiate themselves by offering products and services that satisfy customers' needs better.

Uncertainty and risk do not influence any other elements in the domain. This is represented by an empty row in Table 5.2.

Product complexity is related to knowledge-based economy. Product development and innovation are heavily based on the company's knowledge [Campbell 1998]. Knowledge and skills allow the company to increase the complexity of its products through technology transfer or by creating new knowledge.

In general, product variety should not influence other elements in the domain. Varied offers can be made without increasing the complexity of the products. The variety offered by Personal Computer manufacturers clearly illustrates how this can be achieved. Dell, Hewlett-Packard-Compaq, and IBM allow the customization of their computers without increasing the complexity of the product. Customers can select within a variety of hard drives, motherboards, sound cards, monitor size and resolution, etc. and satisfy their specific needs without variety resulting in a more complex product. However, a relationship between the product complexity and product variety may appear in certain cases. For example, Ranta [1997] explained that offering customer engines with nine types of pistons could significantly influence the complexity of manufacturing the engine. In those cases, as the variety of the offer increases, so does the complexity of the product or service.

Technological advances influence product variety and complexity, as well as the knowledge-based economy. As technology gets transferred from one industrial sector to another, the complexity of the product in the new sector usually increases because of the new technology.

Advances in Information and Communication Technology allow companies to offer a larger variety of products or services. The airlines reservation system is a good example. Others such as bank and financial industries have also taken advantages of the current networking capabilities, to offer their customers solutions that, only a few years ago, seemed impossible.

The link between advances in technology and knowledge-based economy can be found in the capabilities of the companies to access the knowledge and skills required regardless of space and time constraints. Again, the developments in Information and Communication Technology in particular, have eased the access to knowledge and technology, developed elsewhere in the world. The global distribution of knowledge is a result of the technological advances [Preiss 1997]. In addition, the knowledge makes it possible, the development of new products or services and therefore creates new technology or finds creative uses to a technology that already exists.

The analysis of the elements in Market domain shows dependencies or relationships among them. This should have been an empty matrix. Such a matrix would have indicated the absence of relationships among the elements of the domain.

To change the elements, all that is required is, to change the elements in the order suggested by the triangular matrix.

Table 5.2 shows that at least in principle, it is possible to change the elements in the Market domain without affecting others. It is said in principle, since some of the orderly changes may be impractical, or unlikely to occur as suggested by the matrix.

Let us analyze, for example, the relationships among technological advances, knowledge based economy as well as product complexity and variety. A possible chain of events could be as follow. New knowledge leads to the creation of a new technology. Then, the technology is introduced in new products. This introduction may result in products that perform more functions than their predecessors, increasing product variety. Satellite radio illustrates this scenario.

This concludes the analysis of the market characteristics for the second level of the design hierarchy. The next step would have been to map these characteristics to the Agility domain by answering the question: "How are these characteristics satisfied in the Agility domain?" However, the observation of the industrial practice shows that somehow this mapping has already been "done". Companies are already engaged in the process of dealing with current market conditions. Therefore, instead of performing a new mapping, the current mapping has to be identified.

The identification of the current mappings requires the study of elements or characteristics in the Agility domain. These characteristics represent how in practice companies are trying to satisfy the current market requirements.

In terms of Eq. 5.4, the next step deals with the identification of the elements of the {AG} vector. The analysis proceeds in the following order. First, the characteristics of the Agility domain are introduced. Second, as in the analysis of the Market domain, the relationships among the characteristics of the Agility domain are identified. Third, the study of how these characteristics satisfy the market needs is presented. This last step identifies the mapping between the Market and Agility domains. The elements of the design matrix, [A], in Equation 5.4, represent the mapping.

5.4.2 Agility Domain

The decision domains of agility were chosen as the elements of the Agility domain at the second level of the hierarchy. The decision domains of an agile enterprise were introduced in Chapter 2. It was shown that, according to Yusuf et al. [1999], these domains were:

1) Market and competence.
2) Change.
3) Technology.
4) Integration.
5) Quality.

6) Education.
7) Partnership.
8) Team building and welfare.

'Market and competence' deal with the behaviour of the company in the market. They take into account the introduction of new products, multi-venturing capabilities, and the need to shorten the development life cycle of the products introduced to the market.

'Change' deals with the responsiveness or the ability of agile enterprises to react fast to changing market conditions. It also considers continuous improvements on the company operations and offers, as well as the development and nurturing of a culture of change.

'Technology' is seen in light of the use of Information and Communication Technologies. It considers making the information accessible to employees, the use of skills and knowledge enhancing technologies.

'Integration' takes into account issues related to both technology, in general, and of Information and Communication technologies, in particular. It focuses on leadership in the use of current technology, the concurrent execution of activities, enterprise integration and development of business practices and products difficult to reproduce.

'Quality' considers the customer-driven approach of agile enterprises, as well as the offerings of products and services with substantial value addition. It also considers the development of first time capabilities. First time capability is the ability of a company to deliver a high quality product (or a defect free product) in its first try.

'Education' takes into account the development of learning organizations, the need for multi-skilled and flexible human resources as well as their continuous training and development.

‘Partnership’ takes into account the need for creating partnerships quickly, a decentralized decision-making process and the establishment of both strategic and trust based relationships with suppliers and customers.

‘Team building and welfare’ deals with the human resources related issues of integration. It includes the empowering of individual working in teams, the creation of both cross functional, and across company borders teams as well as the satisfaction of employees.

It can be noted that two of the elements of ‘Education’ and all the elements of ‘Team building and welfare’ take into account human resources issues. These issues are dealt with separately, during the analysis of the structure of Virtual Enterprises and their workforces.

The relationships among these characteristics are shown in Table 5.4 in a lower triangular matrix. ‘Market and competence’ is seen as related with change, integration, quality, and partnership. A variation in the market conditions forces the companies to adapt to these new conditions. For example, changes in customers’ needs and wishes, may force a company to introduce products that use a new technology. If none of the existing partners has the technology, this change triggers the formation of a new partnership. This new partnership results in the integration of operations with other organizations, with whom the company might not have worked before. The technology provided by the new partner, may add value to the company’s products. On the other hand, if the new technology belongs to a current partner, a new strategic relationship could be established according to the relevance of the technology for the agile enterprise.

‘Change’ is related to market and competence, integration, education, and partnership. Being able to respond quickly to market changes is directly related to the ability of agile enterprises to integrate their core capabilities and carry out activities concurrently.

The enterprise integration relies on the establishment of strategic and trust based relationships among partners. Companies also deal with change by developing learning organizations. As explained earlier, these organizations are able to both integrate existing and create new knowledge.

Table 5.3. Reorganization of the Elements of the Agility Domain at the Second Level.

	Integration	Quality	Change	Market and Competence	Partnership	Education	Technology
Education	x						
Technology	x	x*					
Quality	x		x				x*
Partnership	x	x	x	x			
Market and Competence	x	x	x		x		
Change	x			x	x	x	
Integration		x	x	x	x	x	x

x: relationship x*: conditional, rare, unlike or unusual relationship

'Technology' is related to integration and quality. Changes in Information and Communication technologies may affect the integration of the enterprises and concurrent execution of activities. For example, the introduction of a new information system may facilitate the access and distribution of information among partners. This introduction may contribute to a more efficient exchange of information. In the services industry, changes in technology may increase the value in offers. The example of the airline reservation system can be used once more to illustrate this relationship. Surely, changes in technology may also negatively affect the performance of agile partners.

'Integration' is connected with market and competence, change, technology, quality, education, and partnership. The relationships among integration, change, and technology have been already explained. Integration is related to quality, since it allows increasing the value added content of offers. This strong relationship becomes evident, when it is realized that companies are unable to carry a full development process 'in house', because of rapid technological advances and growth in the complexity of products. The relationship between integration and education can be found in the development of learning organizations. The integration of existing knowledge or the creation of new knowledge is directly related to leadership in the use of current technologies. Integration also affects strategic and trust-based relationships with customers and suppliers. Members in agile enterprises become dependent on each other performance and develop strategic relationships based on trust. That is what Byrne [1993] referred to as 'co-destiny'.

'Quality' has a strong relationship with change and integration. In some cases, quality may also be related to technology. Changes in the market have forced companies to increase their responsiveness and to adopt a customer-driven approach for satisfying changing customers' need. Integration allows companies to increase their value-adding capabilities by combining development efforts. The use of technology may result in highly customized products that meet specific customer needs. The earlier example of IBM®, Dell®, and Hewlett-Packard-Compaq® computer illustrates how companies achieve highly customized products, with the use of Information Technology.

'Education' is seen related to change and integration. In addition, market and competence, change, integration, and quality may affect partnership. These relationships were explained above.

Table 5.4 should have been an empty matrix as in the Market domain, this matrix. It can be seen that, except for one conditional relation, it is possible to change the elements in the Agility domain, without affecting more than one element.

Once the characteristics in the Agility domain and their relationships are analyzed, it is possible to perform the mapping between the Market and Agility domains. This mapping will determine the elements of the matrix [A] in Equation 5.4.

5.4.3 Mapping between Market and Agility Domains

The reorganized mapping between the Market and Agility domains is shown in Table 5.6. In this table, the elements of the Market domain are located in rows, while the elements of the Agility domain occupy the columns. The question being answered for this mapping is how companies realize or deal with each of the elements of the Market domain. For example, to determine which element in the Agility domain maps increased competition (in the Market domain), the following question has to be answered; “How can companies deal with the increased market competition?”

Dealing with the increased competition is perhaps one of the most important challenges for agile companies. Increased competition is mapped to all the elements in the Agility domain.

To deal with the increased competitive pressures, companies introduce new products and form new venturing partnerships. They also aim to shorten the product development cycle times. It has already been explained that companies have been forced to react quickly to market changes and need to strive in continuous improvements in their products and operation. Technology facilitates access and dissemination of information and knowledge. Information and knowledge are critical factors in the success of the company in the market, since they are used to provide customized solutions to customers. They also help to track advances in technology as well as changing customers’ trends and demands.

Highly customized solutions to customer problems are obtained by the integration of the capabilities of partners. Integration and quality also allow company to reduce the product development cycle time by pooling core capabilities of partners and performing activities concurrently. In addition, they contribute to develop business practices that are hard to reproduce. Education makes it possible for companies to develop as learning organizations and providing better products and services to its customers.

Rapid formation of partnership as well as strategic and trust-based relationships with customers and partners are also used to deal with market competitive pressures. Being able to form partnership faster than competitors, results in products and services being brought to market faster and thus, increase market shares. In addition, strategic and trust-based relationships with customers and partners allow companies to increase the information and value added content of their products. They make it possible to involve customers earlier in the product development process and foster customer loyalty.

Table 5.4 Reorganized Design Matrix of the Market and Agility Domains at the Second Level.

Market Domain	**Agility Domain**						
	Partnership	Integration	Education	Change	Technology	Quality	Market and Competence
Product complexity	x	x	x				
Uncertainty and risk	x	x		x			
Knowledge based economy	x	x	x				
Technological advantages	x	x	x	x	x		
Product variety	x	x			x*	x	
Increased competition	x	x	x	x	x	x	x

x: relationship x*: conditional, rare, unlike or unusual relationship

Uncertainty and risks is mapped to change, integration, and partnership. Companies deal with uncertainty and risk by reacting fast to changes and taking advantage of market opportunities. Often uncertainty and risks are dealt with by sharing resources and risk (risk-spreading). Integration and partnership are some of the alternatives commonly used. Enterprise integration allows companies to use resources from their partners, instead of investing in acquiring those resources. Integration is supported by the development of strategic and trust-based relationships with partners.

Companies become better poised to deal with the risk and uncertainty by sharing risks, rewards, infrastructure, knowledge, and resources. For example, design expertise or manufacturing facilities of one company may be used to speed up the development phase of the product or production, respectively. This is mutually beneficial. One company does need to invest in building and equipping manufacturing facilities, while the other uses the facilities it has already built. Similar benefits are derived from sharing the design. One of the companies does not need to invest time, money, or both in developing parts of the design. The other company finds a useful application of the expertise it already has.

It also possible for companies to share the financial risk related to the introduction or development of new technologies by investing collectively [Jägers et al. 1998]. Thus, they spread the risk associated with the investment.

Product complexity is mapped to integration, education, and partnership. Integration and partnership allow an agile enterprise to focus on its core capabilities and integrate those core capabilities with partners. This integration results in the concurrent execution of activities and the development of business practices that are hard to reproduce. In addition, companies deal with product complexity by developing learning organizations that either integrate existing knowledge or create new knowledge and technologies. As explained above, critical to enterprise integration is the development of strategic and trust-based relationships with customers and partners.

Product variety is mapped to quality, technology, integration, and partnership. Product variety is achieved by providing products with substantial value addition capable of satisfying individual customers' needs. It has been explained earlier that in some cases, the use of technology may contribute to a better product variety. For example, that is the case of the airlines reservation systems, the Personal Computer industry, and service-oriented enterprises. Enterprise integration makes it possible to provide comprehensive solutions by pooling resources and knowledge from several organizations. Such solutions are high in information content.

The technological advances market condition is mapped to change, technology, integration, education and partnerships. Technological advances are changes or breakthroughs in technology. Companies, therefore, need to response to those changes. They respond to changes in technology by either integrating the technology into their products or creating new product using the new technology. As explained earlier, this integration of diverse technologies results in the inter-enterprise integration. This integration is supported by strategic and trust-based relationships. In this integrative process, learning organizations may develop. For example, a technological advance in one industry may open new opportunities in the application of technologies from other industries. An example of this scenario is the development of intelligent workshop machines. Technological advances in the microprocessor and computer industry facilitated the development of a new type of machine whose operation could be programmed. These machines are the integration of two diverse technologies and industries: manufacturing and microprocessor.

The knowledge-based economy characteristic is mapped to education, integration, and partnership. Integration and creation of knowledge are achieved by developing learning organizations, where technologies and knowledge from different partners are combined. The formation of learning organizations relies on the development of strategic and trust-based relationship among partners.

Table 5.4 shows that partnership and integration are the characteristics most used by the mapping. This should not come as a surprise, since agile organizations and Virtual Enterprises are both based on the use of these characteristics. The high frequency of these characteristics reinforces the understanding that agile enterprises are based on collaboration and integration among different enterprises or partners.

Also, it should be noticed that the design is coupled because the number of elements in each domain is different. This difference renders impossible to obtain a decouple design, even in a case of only 1to1 (1:1) mappings between these domains.

This coupling may explain the challenges faced by agile enterprises. The design matrix helps to understand why variations in a single element of the Market domain can have devastating consequences for the agile enterprise. For example, the introduction of a new technology may increase the complexity of the products. This variation in complexity may result in the need for forming a new partnership and the integration of different complementary core capabilities. However, the introduction and integration of the new technology may be proven difficult, if the company is not capable of integrating the technology in existing products.

On the other hand, it is known that even if the design is coupled, many agile enterprises succeed. The reasons for their success can be found probably in the careful design of the organization and the strong commitment of the members to remain in the organization. This can be achieved if no changes take place, after the organization is formed. This coupling reinforces the importance of a reliable partner selection process.

Equation 5.4 can be rewritten as Equation 5.7. In this equation, the matrix [A] is similar to Table 5.4.

$$\begin{Bmatrix} MA_3 \\ MA_2 \\ MA_6 \\ MA_5 \\ MA_4 \\ MA_1 \end{Bmatrix} = \begin{bmatrix} x & x & x & & & & \\ x & x & & x & & & \\ x & x & x & & & & \\ x & x & x & x & x & & \\ x & x & & & x & x & \\ x & x & x & x & x & x & x \end{bmatrix} \begin{Bmatrix} AG_7 \\ AG_4 \\ AG_6 \\ AG_2 \\ AG_3 \\ AG_5 \\ AG_1 \end{Bmatrix} \tag{5.7}$$

where:

MA_1: Increased competition
MA_2: Uncertainty and risks
MA_3: Product complexity
MA_4: Product variety
MA_5: Technological advances
MA_6: Knowledge-based economy

AG_1: Market and competence
AG_2: Change
AG_3: Technology
AG_4: Integration
AG_5: Quality
AG_6: Education
AG_7: Partnership

Once the mapping between the Market and Agility domains is performed, the analysis continues with the study of the next domain to the right; the Virtual Enterprise domain. As in the previous mapping, the elements in the domain and their relationships are examined first. Afterwards, the mapping between the Agility and the Virtual Enterprise domain and the analysis of the design matrix are presented. These two analyses determine the vector, {VE}, and the design matrix, [B], in Equation 5.5, respectively.

5.4.4 Virtual Enterprise Domain

It was shown in Chapter 2 that the most important characteristics of Virtual Enterprises are:

1. Opportunism.
2. Excellence.
3. No borders.
4. Technology.
5. Trust.
6. One identity.
7. Partial mission overlapping.
8. Distinction between strategic and operational levels.
9. Flat hierarchies and changing hierarchical positions.

Only the first five characteristics are used in this analysis. One identity, is not considered here, since it takes into account the way a Virtual Enterprise interact with customers and other enterprises. Partial mission overlapping take into account the duality of the ability of partners companies in a Virtual Enterprise to conduct business inside and outside the organization. This is irrelevant for the purpose of the design of Virtual Enterprises as organizations. The distinction between the strategic and operational levels is already being used as a foundation for the design of Virtual Enterprises as organizations. The 'flat hierarchy' characteristic deals with the way the programs and offices (or partners in Virtual Enterprises) are organized. This characteristic is considered separately, during the structure of Virtual Enterprises and their workforces.

Chapter 2 explained that these characteristics apply to any Virtual Enterprise. Other characteristics such as the size of the companies or the specific markets where the companies operate do not affect the generality of these characteristics. Let us first examine these characteristics independently.

‘Opportunism’ in agile enterprises refers to the ability of the Virtual Enterprises to react quickly to market opportunities [Goldman et al. 1995, Franke and Hickhamn 1999]. Companies either identify these opportunities or create them [Bremer et al. 1999]. To take advantage of a market opportunity, a company may reorganize itself either internally or externally. The internal reorganization occurs in the case of process-oriented enterprises [Hammer and Stanton 1999]. Often, however, a company lacks either the time or the expertise, to fully take advantage of an opportunity individually. In such cases, companies reach across organizational boundaries in search for the core competencies of others [Goldman et al. 1995, Preiss 1997]. Companies join their core capabilities to take advantage of specific market opportunities and they usually disperse once the opportunity has passed [Byrne et al. 1993].

The fast changing nature of the opportunities pursued makes the cooperation both highly dynamic and opportunistic [Dembski 1998]. The cooperation lasts as long as the opportunity exists, or until companies meet the objectives that brought them into cooperation. In addition, companies usually remain in the Virtual Enterprise as long as the cooperation is more profitable than being on its own [Odenbahl et al. 1997].

Companies are opportunistic because it helps them to stay competitive [Campbell 1998]. By using each partner’s expertise only when required, a Virtual Enterprise becomes flexible and can adapt to different market conditions. This, in turn, increases their market responsiveness, as companies do not have to develop all the competencies and technologies “in-house”.

Virtual Enterprises achieve excellence by providing superior solutions for their customers. As explained above, customers are demanding cost-effective solutions to their problem rather than products that partially satisfy their needs. To satisfy these demands, companies need to collaborate and integrate in such a way that they enrich their customer with total and individualized solutions [Preiss 1997]. Goldman et al. [1995] compared a Virtual Enterprise with an all-star team. In addition, Dembski [1998] referred to it as *la crème de la crème*. An all-start team where core capabilities, resources, and expertise are assembled with the purpose of providing the best solution that satisfies the customers' needs. Collaboration as well as the integration of core capabilities and resources are expected to result in what Byrne et al. [1993] referred to as the "best of everything" or "best of its class" organizations. These organizations form a highly coordinated system in which value-adding chains work together as processes, and the outputs of one activity becomes the inputs for the next [Preiss 1997].

The 'no borders' characteristic refers to the focus of agile enterprises on gaining access to core competencies regardless of their geographical location. Therefore, they need to have the ability to reach across other organizations that possess the core competencies required to take advantage of new market opportunities [Preiss 1997]. Davidow and Malone [1992] identified the inclusion of external parties [partners] in the planning and execution steps of the production process, as one of the most important features of agile enterprises and therefore of Virtual Enterprises.

Traditionally, companies have seen themselves as stand-alone organizations from both a legal and an operational perspective [Preiss 1997]. They have operated independently, guided by static or time-invariant plans and forecasts. The growth in competition and the demands for efficiency have led companies to consider themselves as part of value-adding chains in which companies contribute according to their area of expertise. As Jäger et al. [1998] stated, reaching out for the help of other organizations allows companies to provide the desired product quality and performance, as well as keep pace with market demands.

Closely associated with the 'no borders' characteristic is the use of distributed facilities to carry out the product development process. Distributed facilities allow a concurrent development process. Partners in Virtual Enterprises deal with projects and tasks regardless of their location in space or time [Sandhoff, 1999, Wigand et al. 1997]. By working concurrently instead of sequentially, companies shorten their product development processes. Hence, they can bring products or solutions to market faster [Chen, Liao, and Prasad 1999]. Definitely, Information Technology may play an important role in concurrent development. However, as explained in Chapter 2, the use of Information Technology in itself does not provide a significant competitive advantage.

The ‘no border’ characteristic also helps smaller enterprises to increase their apparent size [Goldman et al. 1995, Dembski 1998, Franke 2001]. To their customers, they appear as one entity that provides complete solutions. However, in reality, these organizations are a group of companies, where each partner provides a portion of the whole solution. Therefore, for outsiders, Virtual Enterprises are seen as larger and more powerful organizations than what they really are [Dembski 1998].

Chapter 2 explained that the technology characteristic has a dual meaning. One meaning refers to the leadership of the in the development of new technology. From this viewpoint, technology provides a framework for the division of labour [Sandhoff 1999]. As companies specialize in the application of specific technologies, they are able to integrate these competencies with others. Jägers et al. [1998] explained that market difficulties and demands could not be solved by individual organizations. Thus, the addition of the partners’ complementary capabilities is instrumental to carrying out new projects. In this interpretation, technology was related to core competencies, and excellence. Companies add value to the solution offered, not only by using the technology but also by expanding the scope of the solution.

In its second meaning, technology refers to the effective and creative use of technology to add value to market offers. From this perspective, technology relates to the ability of a company to carry out global business and erase boundaries among enterprises using Information and Communication Technology. Virtual Enterprises concentrate on providing value and using the core competencies of partners regardless of their geographical location. In this second interpretation, technology refers more to the ‘no borders’ characteristic.

‘Trust’ was referred in Chapter 2, as the ability of an agile enterprise to conduct business in in such a way that both collective and individual interests are rewarded. It is both critical and challenging. Trust is the foundation of collaboration [Goldman et al. 1995, Campbell 1998, Dembski 1998, Sieber 1998, Franke 2001]. It is through trust that companies can share and achieve a meaningful integration of their core capabilities. Thus, trust makes possible a smooth flow of resources, information, and knowledge. Since collaboration and integration are at the heart of a Virtual Enterprise, it can only succeed if partners trust each other. One of the ways in which trust is developed is by appropriately rewarding partners for their efforts [Goldman et al. 1995 and Campbell 1998].

Ranta [1997] observed that collaboration in Virtual Enterprises is deep and based on mutual trust. As the relationships formed aim at reciprocal benefits, Virtual Enterprises can only succeed if their internal and external relationships are based on a mutual understanding. He also explained that, in economic terms, there are costs associated with building trust and shared values in this type of organization. Consequently, companies will only remain in the organization if they realize benefits that surpass those costs.

The challenge comes from the fact that trust, as in human relationships, is difficult to build but easy to break. The most secure way to achieve trust is through repetitive collaborative relationships. However, in many cases, this may not be possible and companies may be ‘forced’ to establish new collaborative relationships. For example, strategies such as trying to be first in the market or gaining access to new technologies may occasionally contribute to weaken the importance of trust. It is trust or the lack of it that can significantly damage Virtual Enterprise initiatives [Sieber 1998, Wassenaar 1999].

Table 5.5 shows the relationships among the element of the Virtual Enterprise domain in a quasi lower triangular matrix. The 'technology' characteristic has been divided into two elements: Information Technology (IT) and others. This division considers the dual character of this characteristic. As in previous cases, relationships are indicated by an (x); and conditional, unlikely or unusual relationships are represented by x*.

Opportunism relates to the 'technology' and 'no borders' characteristics. The relationship with technology can be found in the need of a Virtual Enterprise to provide complete solutions to its customers, as a member of value-adding chains. If a given technology could not be added to an offer, the quality of the final solution may suffer. Consequently, the agile enterprise might not fully take advantage of the market opportunity. The relationship with the 'no borders' element comes from the focus on core competencies and the need for collaboration with other organizations, to provide complete solutions.

Table 5.5. Reorganized Relationships Matrix in the Agility Domain at the Second Level.

	Technology Others	No Borders	Technology IT	Excellence	Opportunism	Trust
Opportunism	x	x				
Excellence	x	x	x*			x*
Trust	x	x	x	x*		
Technology IT	x	x		x*		
Technology Others		x	x	x	x	x
No Borders	x		x*	x	x	x

x: relationship x*: conditional, rare, unlike or unusual relationship

'Trust' and 'opportunism' are not seen as related. In very dynamic markets, companies collaborate with the sole purpose of providing a comprehensive solution to customers, and mutually benefiting from the opportunity [Dembski 1998]. In addition, it is possible to buy the technology and take advantage of the market opportunity rather than establishing collaborative relationships. For example, in 2001, Abode bought Acelio an

Ottawa-based company. Based partially on Adobe's technology, Acelio has developed a technology for processing forms electronically. Adobe considered this new technology both complementary and critical to its market and business objectives. However, rather than establishing a collaborative relationship with Acelio, it decided to buy the company. From an outsider viewpoint, one possible justification for this decision can be the unwillingness of Adobe to develop collaborative ties with Acelio and dealing with issues related to trust.

'Excellence' is seen as related to both aspects of 'technology', 'no borders' and 'trust'. In many instances, excellence is achieved by offering customers solutions that involve the use of a given technology. Such technologies add value to the offer and increase customers' satisfaction. Besides, Information Technology (IT) can be used to achieve excellence. This is, for example, the case of the airline reservation system explained earlier. Information Technology is also used in service-oriented enterprises to link services from different enterprises. However, achieving excellence may not require the use IT. In essence excellence is trying to satisfy customer needs by any means possible. Technology is not the only way to achieve excellence. Companies achieve excellence by other means, such as providing superior customer services, after sale support, updates, and a high degree of customization to their products.

'Excellence' and 'no borders' are related because one of the ways to satisfy increasing customers' needs is to provide complete solutions. Due to the lack of internal expertise beyond their core competencies, companies need to reach to other organizations (no borders) and collaborate, in order to provide comprehensive solutions to customer demands.

The relationship between 'excellence' and 'trust' is very strong in cases in which customers are brought into Virtual Enterprises by one of their members, and then referred to other partners for additional services. In these situations, the trust element is very important, since the partners are transferring customers with the expectation that a similar level of excellence will be provided.

Both aspects of technology are considered as related to the ‘no borders’ characteristic. It is through reaching beyond the organization’s borders that companies gain access to technologies developed elsewhere. These “external technologies” are used to offer customers complete solutions to their needs. On the other hand, the use of Information Technology, contributes to blur boundaries among organizations when dealing with customers. In addition, it helps to provide better solutions to customers’ needs. Technology is also related to trust. Companies collaborate and share information based on trust. They need to have access to each other’s information. Moreover, when companies collaborate they assume that the information is accurate and that confidential or proprietary information will not be disclosed to third parties. These assumptions rest on trust that partners have for each other.

Table 5.5 should have been an empty matrix, with no relationships among the elements of the domain. The fact that the matrix is not empty means that the elements are related and a change in one of the elements can cause a change in other elements in the domain.

Once the characteristics in the Virtual Enterprise domain and their relationships are analyzed, it is possible to perform the mapping between the Agility and Virtual Enterprises domains. This mapping will determine the elements of the matrix [B] in Equation 5.5.

5.4.5 Mapping between Agility and Virtual Enterprise Domains

Once more, it is important to note, that the objective of the mapping between Agility and Virtual Enterprises domains is to answer the questions on how the elements of the Agility domain are satisfied by the elements in the Virtual Enterprise domain. To meet this objective, the mapping seeks to answer the following questions with respect to agile enterprises:

- How companies deal with market and competition?
- How companies deal with change?

- How companies deal with technological advances?
- How companies integrate?
- How companies achieve quality?
- How companies deal with the education? and
- How companies implement partnerships?

The mapping is shown in Table 5.6 in a transformed quasi-lower triangular matrix. In the table, the elements of the Agility domain are located in the rows and the elements of the Virtual Enterprise domain occupy the columns. This is only one of the possible mappings between these two domains. Other mappings could be found and they do not necessarily have to be similar to the one presented here.

In the mapping from the Agility to the Virtual Enterprise domains, market and competence is mapped to 'opportunism', 'excellence', 'technology' (others) and 'no borders'. 'Opportunism' allow companies to react quickly and take advantage of market opportunities. 'Excellence' makes it possible to provide comprehensive solutions to individual customer needs. Achieving excellence may require the integration of diverse technologies for increasing the information and value-added content of market offers. In such cases, companies need to collaborate with their partners in order to bring the solution to the market. Collaboration also reduces the time required for bringing an offer to the market.

'Changes' in the market are also dealt with 'opportunism', 'excellence', 'technology', 'no borders' and 'trust'. Opportunism allows companies to react to changing in market trends and customer needs. Excellence is the way companies aim to meet changing customers' needs by providing solutions rather than isolated products. As explained earlier, companies may achieve excellence by incorporating different technologies into their products. The use of diverse technologies requires the collaboration of the company with other organizations ('no borders'). This collaboration has to be based on trust. The critical role of trust for collaborating and dealing with uncertainty was analyzed above.

‘Technology’ is mapped to the use of Information and communication technologies (IT), ‘no borders’ and trust. The use of IT makes it possible for faster access and distribution of information to employees and partners. Information and knowledge exchange among partners is based on trust.

Table 5.6.Reorganized Design Matrix between the Agility and Virtual Enterprise Domains at the Second Level.

Agility Domain	Virtual Enterprise Domain					
	No borders	Trust	Technology Others	Technology IT	Opportunism	Excellence
Technology	x	x		x		
Partnership	x	x			x	
Integration	x	x	x	x		x
Education	x	x	x	x		x
Change	x	x	x		x	x
Quality	x	x	x	x*		x
Market and Competence	x*		x*		x	x

x: relationship x*: conditional, rare, unlike or unusual relationship

‘Integration’ is mapped to ‘excellence’, ‘technology’ (IT and Others), ‘no borders’ and trust. Enterprise integration results from the focus on core capabilities. This focus makes it almost impossible to fully conduct a development process “in-house”. Therefore, companies need to reach beyond their borders for the expertise of others. This collaboration is based on trust. Trust allows establishing strategic and trust-based relationships with both customers and partners. Technology (IT) plays a very important role in achieving both intra-enterprise and inter-enterprise integration.

‘Quality’ is mapped to ‘excellence’, ‘technology’, ‘no borders’ and ‘trust’. Excellence makes it possible for companies to provide complete solutions to customer problems. Quality can also be satisfied with the ‘technology’ and ‘no border’ characteristics. This happens in cases in which a high level of customization is achieved by providing products of high information and value-added content.

'Education' is mapped to 'excellence', 'technology', 'no borders' and 'trust'. Learning organizations create new knowledge or new applications for existing technologies. This new knowledge and applications of technologies could not be individually achieved by any of the companies involved. To success in creating learning organizations, companies need to collaborate with others ('no borders') and this collaboration requires trust. Technology (IT) allows achieving a more meaningful integration by making it possible to have access to the core capabilities required, regardless of their geographical location.

'Partnership' is mapped to opportunism, 'no borders' and trust. Partnership needs to be formed quickly because companies want to take advantage of market opportunities. By reacting quickly and adapting its offer to the market requirements, a company can satisfy customer needs ahead of its competitors. The formation of partnerships relies on trust among partners.

Table 5.6 shows three interesting facts. First, the Agility and Virtual Enterprise domains have different cardinality or number of elements. The former has eight elements while the latter has only six elements. That means that even in the case that all mappings would have been 1 to 1 (1:1); the design still would have been incorrect since according to Axiomatic Design, both domains must have the same cardinality.

Second; the 'no border', and 'trust' characteristics are used often in the mapping. The extensive use of these characteristics in the Virtual Enterprise domain, illustrates their importance in the formation of Virtual Enterprises. Third, the design remains coupled even after the reorganization of the matrix. A coupled design means that it is not possible to change one of the elements in the Agility domain without changing more than one element in the Virtual Enterprise domain.

Equation 5.5 can be rewritten as Equation 5.8. In this equation, the matrix [B] is similar to Table 5.6.

$$\begin{Bmatrix} AG_3 \\ AG_7 \\ AG_4 \\ AG_6 \\ AG_2 \\ AG_5 \\ AG_1 \end{Bmatrix} = \begin{bmatrix} x & x & & x & & \\ x & x & & & x & \\ x & x & x & x & & x \\ x & x & x & x & & x \\ x & x & x & & x & x \\ x & x & x & x & & x \\ x & & x & & x & x \end{bmatrix} \begin{Bmatrix} VE_3 \\ VE_5 \\ VE_{2\_2} \\ VE_{2\_1} \\ VE_1 \\ VE_4 \end{Bmatrix} \quad (5.8)$$

where:

AG_1: Market and competence
AG_2: Change
AG_3: Technology
AG_4: Integration
AG_5: Quality
AG_6: Education
AG_7: Partnership

VE_1: Opportunism
VE_{2_1}: Technology (IT)
VE_{2_2}: Technology (Others)
VE_3: No borders
VE_4: Excellence
VE_5: Trust

Once the mapping between the Agility and Virtual Enterprise domains is performed, the analysis continues with the study of the Partners domain. This is the last mapping on the second level of the design hierarchy. As in the previous mapping, the elements in the domain and their relationships are examined first. Afterward, the mapping between the Virtual Enterprise and the Partner domains is performed. This is followed by the analysis of the design matrix. These two analyses determine the vector, {PS}, and the design matrix, [C], in Equation 5.6, respectively.

5.4.6 Partners Domain

Klüber [1998] proposed a holistic model for virtual organizing. In the model, five (5) dimensions are used for the analysis of Virtual Enterprises. These dimensions can be used as general design principles for the partner selection process in the Partners domain. The dimensions are:

1) Strategy.

2) Processes.
3) Knowledge.
4) Culture.
5) Structure.

'Structure' is considered separately, since it deals with the way members of Virtual Enterprise organized internally. These configurations were analyzed in Chapter 2. It was shown then, that Virtual Enterprises could adopt several structural configurations depending on the strength and size of their members, as well as the objective of the partnership.

The Oxford English dictionary [Oxford 2002] defines strategy as a plan oriented to achieve particular long-term goal(s). The 'strategy' of a Virtual Enterprise deals with the objectives of forming the organization. It addresses what are the needs or market requirements that a Virtual Enterprise aims to fulfill. In Virtual Enterprises, partners share strategies and their implementations but they do not try forecasting future market conditions [Campbell 1998].

'Strategy' can be both external and internal. The external strategy considers the long-term goals for the survival of an organization in the market. The internal strategy, in contrast, establishes plans within the organization to materialize the external goals. These two views influence each other dynamically. Internal strategies are tailored to meet the requirements of the external strategy. Therefore, if the external strategy changes, the internal strategy should also change.

In the case of a single organization, there should be no contradiction between these two strategies. In Virtual Enterprises, internal and external strategies may conflict, if they are not managed properly. These conflicts arise from the heterogeneous membership of the organization. The external strategy is often clear, as it is the main reason for forming a Virtual Enterprise. However, internal strategies need to consider both the Virtual Enterprise as whole and the strategies of each member. For example, if the external goal is to penetrate a given market, either the Virtual Enterprise may decide to have a partner that has the knowledge about that market, or it is already operating in it. If, for instance, the strategy is to gain access into a niche and profitable market with a specialized solution, the Virtual Enterprise will need at least one partner capable of providing the required core technical competencies.

Failure to consider the individual strategies of partners leads, initially, to conflicts among members and later, it may result in the disbanding of the organization prematurely. Partners join a Virtual Enterprise for two important reasons: (1) it benefits them and (2) it matches their organization's individual strategies. If, at any point, they fail to be satisfied, companies usually see no reason to continue working in the Virtual Enterprise.

The 'process' dimension considers the core process implemented by a Virtual Enterprise. To offer a service or a solution to its customers, members of a Virtual Enterprise collaborate and integrate their core competencies. They form a value-adding chain where each member contributes to the final solution in its area of expertise. This value-adding chain becomes the core process of the Virtual Enterprise as a whole. That means that the organization, as a whole, specializes in providing a given solution to the market.

Klüber [1998] divides this dimension into macro and micro processes. The macro process is the process of forming the Virtual Enterprise by integrating the core capabilities of the members into the core process of the organization. It considers the contribution of each member at a general or high level. The micro process, on the other hand, deals with the individual contributions of the partners to the macro process. This more detailed view considers the contributions of each member to the Virtual Enterprise to the macro process. It also takes into the account, the interfaces used by partners to collaborate and integrate their core capabilities and resources.

Macro and micro processes can be understood through the analogy of a cooking recipe. Cooking recipes are usually composed of two sections. The first section details the required ingredients while the second provides instructions about how they should be mixed. In this example, the selection of the ingredients of the recipe is the macro process and the mixing while cooking of the ingredients is the micro process. In Virtual Enterprises, the organization needs the core competencies of each member to bring the product to market. However, having the right ingredients in a recipe is only the first step. The cook needs to carefully follow the instructions to succeed. The micro process in Virtual Enterprise deals with the same requirements. Members of a Virtual Enterprise (as the ingredients in the recipe) need to collaborate and carefully integrate their core capabilities to satisfy the market requirements. As in the recipe, failure to either use the right ingredients or mixing them properly results in a final product of a lower quality.

The ‘knowledge’ dimension deals with one of the major assets of today’s organization: skills and knowledge. A knowledgeable and empowered workforce with the capacity to use its initiative is one of the greatest assets of any organization, including a Virtual Enterprise [Campbell 1998]. As explained during the analysis of the Market domain, knowledge is critical to organizations operating in a knowledge-based economy and the information age. Skills and knowledge are both individual and collective. Individual skills and knowledge refers to the skills of individual members in the Virtual Enterprise. Similarly, collective skills refer to knowledge of the Virtual Enterprise as a whole. These two types of skills and knowledge influence each other dynamically. Not only do partners contribute to the knowledge of the organization, but also the organization contributes to the knowledge of partner companies.

Skills and knowledge are certainly immaterial assets. However, they manifest themselves in all the functions of the organization. They are one of the most important sources in the company innovation and competitive advantage.

The ‘culture’ dimension refers to the organizational culture of the partners and their organizational fit. The culture of the organization extends to all its functions [Klüber 1998]. The development of an organizational culture is, foremost, an internal process that transpires to the external behaviour of the Virtual Enterprise and its partners. Davenport et al. [1992] stated that a business culture that nurtures participation and collaboration positively influences all the other functions of the company. They also suggested the need of an open organizational culture to succeed in collaborative relationships internally and externally. Culture also reinforces collaborative links among partners and reduces the potential for conflicts [Klüber 1998]. The need for similar organization cultures comes from what is referred to as "co-destiny" [Byrne 1993]. Partners in a Virtual Enterprise understand that their "destinies" are tied and they depend on each other to succeed. Destinies become tied as companies begin to see each other as members of an interrelated value adding chain [Preiss 1997].

During the analysis of Virtual Enterprise domain, the fundamental role of trust was explained. All of what has been said earlier about trust applies to the culture dimension. According to Franke [2001], trust accelerates both collaboration and integration of core capabilities and influences other business factors such as concept to cash time and transaction costs in Virtual Enterprises. Moreover, both organizational culture and trust strongly influence the relationship between the Virtual Enterprise and its customers. It is by a continuous effort to fully satisfy customer expectation that a culture of customer satisfaction is built.

The relationships among elements in the Partner domain are shown in Table 5.7 in a lower triangular matrix. In this table, the strategy element is divided into the internal and external to account for the two types of strategies introduced earlier. Furthermore, the process dimension was divided into macro and micro processes.

The 'internal strategy' is related to the 'external strategy', 'core process', 'knowledge', and the cultural dimensions of a Virtual Enterprise. The internal and external strategies are related since they influence each other dynamically; as two sides of the same coin. It was explained earlier, that the external strategy determines the internal strategy, in Virtual Enterprises. The market opportunity that the Virtual Enterprise aims to take advantage of, is the one that determines what internal strategy the organization will follow. The internal strategy, on the other hand, affects the external strategy. The long-term planning of partners may influence the external approach of the Virtual Enterprise.

Table 5.7. Reorganized Relationships among the Elements of the Partners Domain at the Second Level.

	Culture	Strategy External	Processes Micro	Knowledge	Processes Macro	Strategy Internal
Strategy External	x				x	x
Process Macro	x	x	x			x
Strategy Internal	x	x	x	x		
Culture		x	x	x	x	x
Knowledge	x	x	x		x	
Process Micro	x			x	x	x

x: relationship x*: conditional, rare, unlike or unusual relationship

The relationship between the ‘internal strategy’ and ‘core process’ in Virtual Enterprises considers that core processes results from the integration of the core capabilities of partners. A variation in the internal strategy of a Virtual Enterprise may trigger a change in its macro and micro processes. A similar outcome is obtained if the strategy of one or more of its members changes. These relationships are consequences of the integration of the core capabilities of partners that produces the core process of the organization. A change in one of the activities affects other activities in the process, since activities are highly interrelated.

There is also a relationship between the ‘internal strategy’ and ‘knowledge’ dimensions in Virtual Enterprises. Virtual Enterprises offer solutions to their clients in the area of expertise. Skills and knowledge are one of the core competencies that the organization provides collectively. At the same time, this collective knowledge is obtained by the creative integration of expertise of individual partners. The long-term internal goals of the Virtual Enterprise, therefore, are influenced by the capabilities of each member.
‘Culture’ relates to the ‘internal strategy’ since trust among members – an important component of culture – is critical for the success of the Virtual Enterprise.

The 'external strategy' of a Virtual Enterprise relates to the 'internal strategy', 'macro process', 'knowledge', and 'culture' dimensions. The relationship between 'internal' and 'external' strategies was already explained. The 'external strategy' of Virtual Enterprises and the 'macro process' of its formation, influence each other. The external goals that a Virtual Enterprise seeks to achieve determine its core process and hence, the membership of the Virtual Enterprise. For instance, it is useless to have a member whose core competencies are not required for satisfying the market goals of the Virtual Enterprise. A Virtual Enterprise should use only the core competencies that contribute to the external goals of the organization and add value to the core process [Goldman et al. 1995]. Knowledge and skills, in themselves, have limited value, if they cannot be put to work towards achieving the long-term plans of the Virtual Enterprise.

The relationship between 'external strategy' and 'culture' results from the fact that Virtual Enterprises are seen as monolithic organizations. As a monolithic organization, a Virtual Enterprise has to show a unified external strategy to other enterprises and its customers. This unified view comes from the individual performance of partners acting as a single entity. Partners need to "merge" organizational cultures to form the culture of the Virtual Enterprise. For example, if one partner decides unilaterally to deviate from agreed strategy in dealing with customer services, the overall performance of the Virtual Enterprise may suffer.

The relationship between 'macro' and 'micro' processes was explained earlier. They are related to the 'internal' and 'external' strategies, 'knowledge' and 'culture' dimensions. 'Knowledge' is strongly related to both 'micro' and 'macro' processes. Collaboration and integration of core capabilities cannot happen without the knowledge and skills of the member companies. For instance, if member is less skilled than others are, and no replacement can be found, the core process of the Virtual Enterprise might be lower than required. A lower quality core process may negatively influence the quality and the scope of the solution provided by Virtual Enterprise.

It is only through an organizational culture of trust, sharing, and collaboration that the formation of the core process and therefore the integration of core capabilities take place [Sieber 1998, Wassenaar 1999]. Let us take for example the case of a member company trying to hide information from other members. Both the 'macro' and 'micro' processes are affected by this situation since withholding information conspires against a meaningful integration of the Virtual Enterprise core capabilities. On the other hand, let us consider now the case of a member trying to unfairly put its interests ahead of the interest of the Virtual Enterprise. This behaviour does not contribute to a free exchange of information. Others companies may see it as if the partner is unfairly taking advantage and they may start to behave accordingly. Ultimately, it is the integration of the core capabilities that suffers and by extension the Virtual Enterprise and its offers to customers.

'Knowledge' and 'culture' dimensions are closely related. This relationship was analyzed previously during the analysis of 'core processes' and 'knowledge'. Organizational culture and trust are the foundations on which the exchange of information and knowledge is based. The creation of new collective knowledge (by the combination of partners' knowledge) is barely possible without a common organizational culture and mutual trust. The lack of trust among members negatively influences the exchange of information among them. This, in turn, affects the collaboration and integration of their core capabilities and the satisfaction of the goals and objectives of the Virtual Enterprises. A mismatched or incongruent organizational culture usually leads to the premature disbanding of the Virtual Enterprise.

It can be seen in Table 5.7 that it is not possible to change some elements in the Partners domain without affecting other elements. It also illustrates the complexity of the partner selection process in Virtual Enterprises. The interrelationships among the elements of the domain may cause a new partner selection process or the disbanding of the Virtual Enterprise.

Once the elements of the Partners domain and their relationships were analyzed, it is possible to perform the mapping between the Virtual Enterprise and Partners domains. This mapping determines the elements of the matrix, [C], in Equation 5.6.

5.4.7 Mapping between the Virtual Enterprise and Partner Domains

Once more, it is important to notice that the objective of the mapping between the Virtual Enterprises and Partners domains is to answer the question of how the element of the Virtual Enterprise domains are dealt with in the Partners domain. To meet this objective, the mapping seeks to answer the following questions with respect to Virtual Enterprises:

- How to achieve opportunism?
- How to achieve excellence?
- How to use and integrate technologies from different partners?
- How to reach beyond the organization borders when needed?
- How to build and maintain trust?

As in previous mappings, the mapping presented below is only one of the possible mappings between these two domains. Other mappings could be found and they do not have to be similar to the mapping presented here.

Table 5.8 shows the mapping between the Virtual Enterprise and the Partners domains in a lower triangular matrix. In this table, the elements of the Virtual Enterprise domain were located in the rows and those of the Partners domain occupy the columns. In this mapping, opportunism is achieved by strategy in the Partners domain. As explained earlier, the strategy is in a constant process of creation, evaluation, and reassessment. This process aims at fulfilling the opportunity that created the need for the creation of the Virtual Enterprise. The strategy can vary, according to the market situation the Virtual Enterprise aims to profit. For example, one strategy can be to have a partner with exposure to a given market and then use its experience and knowledge to penetrate that market with a different solution.

Table 5.8. Reorganized Design Matrix of the Virtual Enterprise and Partners Domains at the Second Level.

Virtual Enterprise Domain	Partners Domain			
	Culture	Strategy	Processes	Knowledge
Trust	x			
Opportunism		x		
Technology IT	x		x	x
Technology Others	x		x	x
Excellence	x		x	x
No Borders			x	x

A Virtual Enterprise requires partners with a matching strategy to satisfy its strategic requirements. Matching strategies and objectives allow the creation of an organization that considers individual objective of the partners, as well as the objectives of the Virtual Enterprise as a whole. Wildeman [1998] explained that a lack of agreement in the strategy usually leads to a premature disbanding of the organization. Therefore, the objectives that originally brought partners to participate in the Virtual Enterprise are not satisfied.

To achieve 'excellence', Virtual Enterprises may use the 'micro' and 'macro' processes, the individual knowledge of the partners and the collective knowledge of the organization, as well as the culture element. 'Macro' and 'micro' processes make possible the collaboration and integration of the core capabilities of the members of the Virtual Enterprise. Collectively, a Virtual Enterprise provides comprehensive solutions to customers. These solutions would not have been possible without the joint effort and contribution of each partner. The cultural dimension plays a very important role in achieving excellence. It can be said that the organization culture is the most important means of achieving excellence. By creating, developing, and nurturing a strong organizational culture in all the functions of the organization, companies accomplish excellence. Examples of how a corporate culture contributes to achieving excellence are the creative and innovative uses of technology to achieve a customers' satisfaction.

Both types of 'technology' (Other and IT) in the Virtual Enterprise domain are mapped to 'process', 'knowledge', and 'culture' elements in the Partners domain. Virtual Enterprises use and integrate the technology of different partners by creating and implementing the appropriate macro and micro processes. Through the collaboration and integration of the core capabilities of its partners, Virtual Enterprises either find new uses of existing technologies or create new technologies.

Service-oriented organizations, on the other hand, provide new or better services through similar means. Knowledge and expertise are required to use and integrate technologies or services from different partners. Virtual Enterprises not only need knowledge of single technologies or services, but also the expertise to make these individual skills work together. This combination of knowledge allows Virtual Enterprises to overcome the limitation of single enterprises and offer solutions rather than isolated products. In addition, the integration of process and knowledge would not be possible without a supporting culture.

Complementary core capabilities make possible the division of labour in the Virtual Enterprise [Sandhoff 1999]. In the creation of core processes, each partner contributes only in its area of expertise or core capabilities. In this manner, Virtual Enterprise can react faster to the changing market conditions and bring solutions to the market earlier than its competitors and other type of organizations. As explained earlier in Chapters 2, the adjective 'complementary' is crucial. Companies are usually not interested in collaborating with other companies in their area of expertise or core competencies. This fact has been widely acknowledged in previous research [Bailey et al. 1998, Wildeman 1998]. It was also confirmed by the findings of the survey, presented in Chapter 4.

'No borders' is mapped to process and knowledge in the Partners domain. Organizations reach beyond their individual boundaries by collaborating with others. Partner companies also need to complement each other in their knowledge. Complementary knowledge and skills are crucial to the success of the Virtual Enterprise. Companies are always looking for other organizations that complement both their skills and knowledge. Complementing knowledge helps to providing better solutions to their customers. This element also contributes to the creation of new knowledge. The contribution of individual knowledge of the partners allows Virtual Enterprise to create new knowledge and achieve goals that none of the partners could achieve individually.

'Trust' in the Virtual Enterprise domain is mapped to 'culture' in the Partners domain. It was seen earlier that trust is critical to Virtual Enterprises, since it influences all other elements in the domain. An organizational culture that nurtures trust and collaboration is one of the most important partners' credentials.

A matching culture is definitely required to become a member of a Virtual Enterprise. Sieber [1998] identified some of the factors to be considered. Some of the factors to be taken into consideration are: similar rules of delegation, analogous communication behaviour, and comparable approaches to the exchange of mission-critical data and information, as well as homologous ethical standards. Disagreements in the partners' perception or understanding of these factors can damage the performance of the Virtual Enterprise and easily lead to the premature disbanding of the organization.

Table 5.14 shows the reorganization of the design matrix shown in Table 5.13. It can be seen that the design is coupled. First, the Virtual Enterprise and Partner domains have a different number of elements. Second, it is not possible to change 'no-borders' without affecting two or more elements. Therefore, the mapping does not satisfy Axiom I.

Equation 5.6 can be rewritten as Equation 5.9. In this equation, the matrix ([C]) is similar to Table 5.8.

$$\begin{Bmatrix} VE_5 \\ VE_1 \\ VE_{2\_1} \\ VE_{2\_2} \\ VE_4 \\ VE_3 \end{Bmatrix} = \begin{bmatrix} x & & & \\ & x & & \\ x & & x & x \\ x & & x & x \\ x & & x & x \\ & & x & x \end{bmatrix} \begin{Bmatrix} PA_4 \\ PA_1 \\ PA_2 \\ PA_3 \end{Bmatrix} \tag{5.9}$$

where:

VE_1: Opportunism
VE_{2_1}: Technology (IT)
VE_{2_1}: Technology (Others)
VE_3: No borders
VE_5: Excellence
VE_5: Trust

PA_1: Strategy
PA_2: Processes
PA_3: Knowledge
PA_4: Culture

Table 5.9 shows a general view of the state of the design up to this point. In as much as possible, elements that are used to map the elements on the left domain have been located at the same level in the neighbouring domain.

This table shows that ‘change’, ‘education’, and ‘partnership’ in the Agility domain do not have a corresponding element in the Virtual Enterprise domain. It can also be seen that in the Partners domain, ‘process’ is used to satisfy three elements in the Virtual Enterprise domain: ‘technology’, ‘no borders’ and ‘excellence’. Another important observation is that ‘change’ (in the Agility domain) remains explicitly unmapped in both the Virtual Enterprise and the Partners domains.

It can be concluded that the design up to the second level of the hierarchy is coupled. That means that changes in the elements of one domain affect more than one element in the neighbouring domain.

This finding illustrates the complexity of the design of Virtual Enterprises. In practical terms, this means that it is difficult for a Virtual Enterprise to deal with its own changes. It is ironic that an organization meant to be flexible and deal with changes in the market conditions and customers’ needs, seems to be unable to deal with its own changes.

Table 5.9 First and Second Levels of the Design Hierarchy.

	Domains			
	Market	Agility	Virtual Enterprises	Partners
	MA: New market conditions	FR: Agility (Flexibility)	DP: Virtual Enterprises (VE) or web of VEs	PV: Partners Companies
Business	MA1: Increased competition	FR1: Market and Competence	DP1: Opportunism	PV1: Strategy
	MA2: Uncertainty and risk	FR2: Change		
Technological	MA3: Technological Advances	FR3: Technology	DP2: Technology (IT)	PV2: Processes
	MA4: Product complexity	FR4: Integration	DP2: Technology (Others) DP4: No borders	
	MA5: Knowledge-based economy	FR5: Education		PV3: Knowledge
	MA6: Product Variety	FR6: Quality	DP5: Excellence	
		FR7: Partnership	DP6: Trust	PV4: Culture

5.4.8 Structure and Workforce

In Chapter 3 and during the introduction of the domains, it was established that the Virtual Enterprise domain was equivalent to programs and offices in organizational design. It explained that in Virtual Enterprises, the ‘programs and offices’ are scattered over the partner companies, instead of in a single organization. However, it has not been explained how these ‘programs and offices’ are arranged and managed in Virtual Enterprises, to form a viable organization.

A similar situation occurs with the Partners domain. It was shown that this domain is equivalent to the process domain and that partner companies are those that support Virtual Enterprises. Nonetheless, partners were analyzed as entities, without considering the role of their workforces. Furthermore, the analysis did not include the changes taking place in the workforce.

In organizations with a hierarchical structure, the hierarchy not only links ‘programs and offices’, but also deals with their arrangement and the management. A similar role in Virtual Enterprises is performed by the structure of the organization. This is perhaps the reason why Klüber [1998] included ‘structure’ as one of the dimensions in his analysis of virtual organizing.

Kluber [1998] also suggested optimizing the structure of a Virtual Enterprise based on both global and individual objectives. Global objectives are those of the Virtual Enterprise as a whole. Individual objectives are those specific to each partner. This approach is consistent with the analysis and understanding of Virtual Enterprises as systems. It was shown in Chapter 3 that Virtual Enterprises have emergent properties. That is, as organizations, they can achieve goals and objectives that any of the partners could attain independently.

Chapter 2 explained the limitations of hierarchical structure. It also introduced the most common structures in Virtual Enterprises: that star-like, democratic alliances, and federations. Virtual Enterprises overcomes the limitations of hierarchical structures by using flatter hierarchies. In addition, other strategies can be used. This analysis is deferred, until the analysis of the third level of the design.

According to [Campbell 1998], the internal strategy of a Virtual Enterprise determines its structure instead of the opposite. The choice of a structure depends on the interest of the organization as a whole, as well as the individual interests of the partners. For example, deciding if the structure should be 'star-like' or 'democratic alliance' depends on the relative power of the partners as well as the contribution of each partner to the solution offered by the Virtual Enterprise. In cases where a more powerful partner leads the organization, the 'star-like' structure may be recommended. Alternatively, if the majority of the members have equivalent powers, the suggested structure can be a democratic alliance.

Changes in the workforce are very important factors, since human resources are critical to the success of companies in the market. Workers are the actors of a company. As such, they are the ones that envision and implement strategies that result in companies succeeding in the market. The impact of a highly skilled workforce can be felt in every function of the company. The capabilities of highly skilled employers allow companies to develop new technologies and to grow. In addition, their knowledge and determination materialize all the goals of the company.

Changes in the workforce have been influenced by the current market conditions. Some of the factors influencing these changes are: emergence of a knowledge-based economy, globalization and deregulation of international law, and advances in technology. Traditionally, the role of the workforce has been relegated to a second-class issue, if not completely underestimated. In the past, the worth of a company was measured by the size of their facilities and workforces; the larger the company and its workforce, the more successful the company. This is, in fact, a quantitative measurement.

The emergence of a knowledge-based economy has transformed the appreciation of the workforce from a quantitative to a qualitative one. Today, not only is the number of employers that matters, but also their knowledge or quality. As highly qualified human resources keep getting scarce [Parunak 1997], this new understanding of the value of the workforce has resulted in an increasing competition for attracting and keeping highly skilled workers within the company.

Globalization and deregulation have caused displacements in the workforce. As regulations are lifted, new attracting opportunities appear for companies to transfer their operations to other locations. Pressured by customer demands for lower prices, companies are either transferring or outsourcing their operations to other regions, where labour costs are significantly lower. For example, in 2002, JDS Uniphase, once the second largest high-tech employee in the Ottawa-Carleton region, moved its headquarters and almost all its operations to China. Its office in Ottawa was reduced to a handful of staff dealing mainly with administrative functions.

The effects of globalization have also been felt in the outsourcing policies of many companies. Many companies, including giants such as Microsoft® and IBM® are regularly outsourcing, part of their product development processes, manufacturing or customer services, to other regions in the world where the cost of labour is cheaper.

Technological advances in Information and Communication technologies have made it possible to gain access to a skilled workforce regardless of its geographical location.
Once the analysis of the design at the second level is performed, a similar decomposition and analysis will be carried out for the third level. In this case, the sub-elements identified at the second level are decomposed again and their relationships are analyzed. The purpose of this analysis is the same: to identify if the design at the third level is decoupled, coupled or uncouple.

5.5 Third Level of the Design Hierarchy

The analysis of the design at the third level decomposes the elements identified at the second level of the hierarchy. The elements at the third level can be interpreted as sub-elements of those in the second level. The analysis at this level will identify the vectors and matrices in Eqs. 5.4 to 5.6.

It was shown earlier that the design at the second level was coupled and did not satisfy the Independence Axiom or Axiom I. This finding suggests that the design at this level should remain coupled. However, one of the objectives of the chapter remains to be satisfied. This objective deals with the satisfaction of the current market conditions by the selection criteria used in the partner selection process. Therefore, two important reasons can be mentioned for performing the analysis at this level: (1) to identify whether the design remains coupled or not, and (2) to evaluate the satisfaction of the current market conditions by the selection criteria.

5.5.1 Market Domain

During the analysis of the second level, it was shown that increased competition, as well as uncertainty and risk were the two factors of the business clusters in the Market domain. Increased competition has resulted in both growth and diversification of the markets where companies operate. Therefore, the sub-elements of increased competition are growth in existing markets, market diversification, and shorter products life cycles.

Market growth is achieved by introducing products faster than other companies do. Growth can also be achieved by offering better or more advanced products. It has been shown that in offer similar in quality, the determining factor is how fast the new product is made available to the market [Fine and Whitney 1996]. This is clearly illustrated by the following example. After the introduction of Windows operating system by Microsoft in the late 1980's, the introduction of IBM's OS/2 Warp® and Linux did not capture significant market shares. This happens despite of these two operating systems being technically better than Windows. Presently, Windows is used in more than 90% of the personal computers in the world.

Companies also increase market shares by moving beyond their traditional markets, and achieving market diversification. Diversification also allows companies to balance temporary surges of supply and demand [Parunak 1997].

Companies deal with uncertainty and risk by sharing resources and risks (risk spreading). These two factors are closely related. Sharing is a very effective way of risk spreading. It is not limited only to financial risk, but also extends to information, knowledge and infrastructure. Among other things, it serves as a safeguard for aggressive market strategies, technological development, and investments. Financially, companies share, for instance, research and development efforts, and infrastructure. In addition, partners exchange information about market characteristics and trends as well as technology. Hence, the uncertainty and risk element of the second level of the hierarchy is decomposed in the sharing and risk spreading at this level.

For the technological cluster, the rapid technological advances in Information and Communication Technology have made possible a faster access and distribution of information. Furthermore, they have almost eliminated time and space constraints and allowed companies and teams to work concurrently. These two sub-elements have been already explained in the analysis of the second level of the hierarchy.

The growth in the complexity of the products has led to information-rich products. Information-rich products are products that integrate knowledge from several disciplines. Increasing complexity has also caused a change in approach for designing and manufacturing of products and services. This new approach is based on the understanding of the impracticality of a full “in-house” development and the need for collaborative work. Companies are, therefore, focusing on developing their own core competencies and reaching beyond their boundaries for complementary core capabilities (collaboration).

As the competition for new customers increases, companies are being forced to increase the variety of their products and services. Individualized solutions are solutions adapted to individual customers' wishes [Chen et al. 1999]. This adaptation has shifted the role of the customer in the development of products and services. Now customers are at the center of the design and manufacturing processes and are taken into consideration from very early stages. Product variety has also forced companies to increase their first-time capabilities.

An example of individualized and comprehensive offers can be found in the computer networking industry. No so long ago, customers needing a computer network had to buy the hardware, the software for each desktop, and the networking software from different suppliers. They also had to install and maintain the software in each desktop and the server to have the network up and running. Currently, the situation has changed drastically since companies offer "network ready" solutions. Their offers satisfy the all-networking needs of customers in a single transaction. By contacting these companies, customers get the hardware, all the software (including installation) and even network administration services, if so is desired.

Leaving aside legal and anti-competitive arguments, the evolution of the Windows operating system can also be used to illustrate the migration from selling products to selling solutions (satisfaction of individual customer needs). Computer users have a well-defined set of needs. They want to use the computer for information processing, communicating, and enjoyment. Windows has migrated from a "stand-alone" operating system to "one-stop" shopping software. Initially, users were forced to acquire other software independently, to satisfy their needs. Currently, Windows meets all its customers' needs. Needs such as: word processing, multimedia (listening music, watching clips and videos), Internet use, and communication (chatting and e-mailing) are all being offered in a single product.

Table 5.10 Reorganization of the Elements of the Market Domain at the Third Level.

	Offers adapted to individual needs	Faster distribution of inf.	Elimination of time and space constraints	Collaboration	Integration of knowledge	Information rich products	Focus on core capabilities	Sharing	First time capabilities	Creation of new knowl.	Designing with the customer	Shorter Product Life Cycle	Diversification	Risk spreading	Growth in existing markets
Market diversification	x							x						x	
Sharing														x	
Designing with the customer	x	x	x												
Information rich products	x	x	x	x	x		x								
Focus on core capabilities			x	x	x	x			x						
Offers adapted to individual needs		x	x	x	x	x					x				
Elimination of time and space constraints	x	x		x	x	x	x								
Shorter products life cycles		x	x	x	x		x	x							
Collaboration	x	x	x		x	x	x		x						
Integration of diverse knowledge	x	x	x	x		x	x	x		x					
Faster distribution of information			x	x	x	x			x		x				
Growth in existing markets	x											x			
Risk spreading								x					x		
First time capabilities		x		x	x		x								
Creation of new knowledge	x	x	x	x	x	x	x	x							

The emergence of a knowledge-based economy has made possible the integration of knowledge and skills from different disciplines in products and services. This integration also facilitates the creation of new knowledge; knowledge that has found it ways into new products or services. An illustrative example of this phenomenon is the development of external devices in the Personal Computer industry. Earlier, the prevailing forms for information storage were tapes and hard drives. Currently, 'store and go' devices can store as much information as previous technologies in a fraction of the size. A similar process has taken place in the electronic industry; portable audio-devices can storage far more music than compact disk (CD) media.

Table 5.10 shows the most important relationships that can be identified based on the analysis presented at the second level of the hierarchy. It shows that it is not possible to obtain a lower triangular matrix. That means that changes in some of the elements in the domain cannot be done without affecting other elements.

These relationships are provided here without explanations. Two important reasons are responsible for this decision. First, the relationships among these elements were explained during of the supra-elements of the elements considered at the second level. Second, the number of elements in the domain has almost tripled, growing from 6 to 15. This means that, in principle 210 (15 x 14), possible relationships would have to be analyzed. This becomes impractical when it is considered that the only purpose of the analysis is to identify if the elements are related.

5.5.2 Agility Domain

During the analysis of Agility domain at the second level of the hierarchy the decisions domains of agility were introduced. The related attributes of each decision domain are used as the sub-elements in the Agility domain. These attributes are summarized in Table 5.11. In this table, the attributes used in the mapping are numbered to differentiate them from those left outside of the mapping (listed with bullets).

Once more, no explanations of the relationship among the elements in the domain are provided. The number of elements at this level for the Agility domain has increased from 7 to 19. This means that 342 (19 x 18) relationships would have to be explained, which is impractical. As in the case of the elements in the Market domain, the relationships shown in Table 5.12 can be derived from the arguments stated during the analysis of the elements of the domain at the second level.

Table 5.12 also shows that it is not possible to obtain an upper triangular matrix. This means that changes in some of the elements in the domain cannot be achieved without affecting other elements in an orderly manner.

5.5.3 Mapping between Market and Agility Domains

The reorganized mapping between the Market and the Agility domains is shown in Table 5.13. These mappings identify how the elements in the Market domain are satisfied by the elements in the Agility domain. In this table, the elements of the Market and Agility domains occupy rows and columns, respectively.

The mapping shown in Table 5.13 does not satisfy the Independent Axiom since it was not possible to obtain an upper triangular matrix. Such a matrix would indicate that elements could be changed without affecting other elements. It should also be noticed that the number of elements in each domain differs. The Market domain has 15 elements and the Agility domain has 19. Even in the case of a one-to-one mapping (1:1), this difference in the cardinality of the domains, creates a coupled design.

Table 5.11. Elements of the Agility Domain at the Third Level.

Second Level	Third Level
Market and Competence	1. New product introduction 2. Multi-venturing capabilities 3. Shorter development cycle times
Change	1. Response to changing market requirements 2. Continuous improvements 3. Culture of change
Technology	1. Information accessible to employees 2. Skill and knowledge enhancing technologies
Integration	1. Leadership in the use of the current technology 2. Develop business practices difficult to copy 3. Concurrent execution of activities 4. Enterprise integration
Quality	1. Customer-driven innovations and customer satisfaction 2. Products with substantial value-addition 3. First time right design
Education and Welfare	1. Learning organizations • Multi-skilled and flexible people • Continuous training and development • Employees' satisfaction
Team building	• Empowered individual working in teams • Cross functional teams • Teams across company borders
Partnership	1. Rapid partnership formation 2. Strategic relationship with suppliers 3. Trust-based relationships with customer and suppliers • Decentralized decision-making

Table 5.12. Reorganization of the Elements of the Agility Domain at the Third Level.

	Multi-venturing	First time right design	Continuous improvements	Culture of change	Skill and knowledge	Information accessible	Response to changing	Shorter development	Customer driven innov.	New product develop.	Dev. bus. practices dif	Substantial value-added	Rapid partnership form.	Strategic relationships	Trust-based relation.	Learning organizations.	Concurrent execution	Leadership in technol.	Enterprise integration
Concurrent execution of activities	x		x	x		x	x	x		x			x	x	x			x	x
Shorter development cycle times			x		x	x	x			x			x	x	x		x	x	x
Enterprise integration	x		x	x		x	x	x		x		x	x	x	x	x	x	x	
Multi-venturing capabilities				x			x			x		x	x	x	x				x
Learning organizations					x	x											x	x	x
New product introduction	x		x				x	x	x			x	x	x	x	x			
Continuos improvements				x			x	x	x	x	x	x			x	x			
Response to changing requirements	x			x				x	x	x	x	x	x	x		x			
Culture of change										x		x	x	x	x				
Leadership in the use of technology											x	x	x			x	x		x
Trust-based relat. with customers and sup.	x												x	x		x	x	x	x
Strategic relationships with suppliers													x		x	x	x	x	x
Products with substantial value addition			x		x		x									x		x	
Information accessible to employees					x											x			
Skills and knowledge enhancing technologies						x										x		x	
First time right design									x							x		x	
Rapid partnership formation				x			x	x									x	x	x
Dev. business practices dif. to copy		x	x																x
Customer driven innovations			x	x			x			x									

Table 5.13 Reorganized Design Matrix of the Mapping between the Market and Agility Domains at the Third Level.

Market Domain	**Agility Domain**																		
	New product introd.	Multi-venturing cap.	Shorter development cycles	Response to changing r.	Culture of change	Inf. accessible to employees.	Skills and knowledge enhancing technologies	Leadership in using tech.	Bus. practices hard to copy	Concurrent execution	Customer driven innov.	Products w/ substantial value addition	First time right design	Learning organizations	Continuous Improvements	Enterprise integration	Partnership formation	Strategic relationship.	Trusted relationships
Growth in existing markets	x		x					x			x		x		x		x		
Market diversification		x	x					x			x		x				x		
Shorter prod. life cycle			x	x						x					x	x	x	x	x
Risk spreading				x	x										x	x		x	x
Sharing										x						x		x	x
Faster dist. of information						x	x											x	
Elim. of time and space cons.										x						x		x	
Focus on core capabilities								x	x							x		x	x
Collaboration										x						x		x	x
Satisf. of ind. customer needs											x	x							
Designing with the customer				x							x				x				
First-time capabilities								x					x						
Information rich products														x		x			
Integration of diverse know.							x							x	x	x		x	x
Creating of new know.							x							x	x	x		x	x

$$
\begin{Bmatrix} MA_{11} \\ MA_{12} \\ MA_{13} \\ MA_{21} \\ MA_{22} \\ MA_{31} \\ MA_{32} \\ MA_{41} \\ MA_{42} \\ MA_{52} \\ MA_{51} \\ MA_{53} \\ MA_{43} \\ MA_{61} \\ MA_{62} \\ MA_{73} \\ MA_{74} \\ MA_{71} \\ MA_{81} \\ MA_{72} \\ MA_{82} \\ MA_{83} \end{Bmatrix} =
\begin{bmatrix}
X & & X & & & & & X & & & X & & X & & & & & X & & X & & & & & & \\
& X & X & X & & & & X & & & X & & X & & & & & & & X & & & & & & \\
& & X & X & & & & & & X & & & & & & & & X & X & X & & X & X & X & X & X \\
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& & & & & & & & & & & & & & & & & & & & X & X & & & & \\
& & & & & & & & & & & & & & & & & & & & & X & & & &
\end{bmatrix}
\begin{Bmatrix} AG_{11} \\ AG_{12} \\ AG_{13} \\ AG_{21} \\ AG_{23} \\ AG_{31} \\ AG_{32} \\ AG_{41} \\ AG_{42} \\ AG_{43} \\ AG_{51} \\ AG_{52} \\ AG_{53} \\ AG_{62} \\ AG_{61} \\ AG_{63} \\ AG_{74} \\ AG_{23} \\ AG_{44} \\ AG_{81} \\ AG_{71} \\ AG_{82} \\ AG_{83} \\ AG_{84} \\ AG_{72} \\ AG_{73} \end{Bmatrix}
\quad (7.10)
$$

where:

MA_{11}: Growth in existing markets
MA_{12}: Market Diversification
MA_{13}: Shorter products life cycle
MA_{21}: Risk spreading
MA_{22}: Sharing
MA_{31}: Faster access and distribution of information
MA_{32}: Elimination of time and space constraints
MA_{41}: Focus on core capabilities
MA_{42}: Collaboration
MA_{43}: Information rich products
MA_{51}: Designing with the customer
MA_{52}: Satisfaction of individual customer needs
MA_{53}: First time right design
MA_{61}: Integration of knowledge
MA_{62}: Creation of new knowledge

AG_{11}: New product introduction
AG_{12}: Multi-venturing capabilities
AG_{13}: Shorter development cycle times
AG_{21}: Response to changing requirements
AG_{22}: Continuous improvements
AG_{23}: Culture of change
AG_{31}: Information accessible to employees
AG_{32}: Skill and knowledge enhancing technologies
AG_{41}: Leadership in the use of current technology
AG_{42}: Develop business practice difficult to copy
AG_{43}: Concurrent execution of activities
AG_{44}: Enterprise integration
AG_{51}: Customer driven innovations
AG_{52}: Products with substantial value-addition
AG_{53}: First time right design
AG_{61}: Learning organizations
AG_{71}: Rapid partnership formation
AG_{72}: Strategic relationships with suppliers
AG_{73}: Trust-based relationships with customers and suppliers

Equation 5.4 can be rewritten as Equation 5.10. In this equation, the matrix [A] is similar to Table 5.13.

5.5.4 Virtual Enterprises Domain

The elements of the Virtual Enterprise domain at the third level of the hierarchy are obtained by combining the strategic reasons for forming Virtual Enterprises, identified by [Goldman et al. 1995]; and the most important attributes of the characteristics of Virtual Enterprises. The strategic reasons for forming Virtual Enterprises are:

1. Sharing infrastructure.
2. Sharing Research and Development.
3. Sharing risk and costs.
4. Linking complementary core competencies.
5. Reducing concept to cash time through sharing.
6. Gaining access to markets.
7. Sharing market or customer loyalty.
8. Migrating from selling products to selling solutions.
9. Increasing facilities and apparent size.

The elements derived from the characteristics of Virtual Enterprises are shown in Table 5.14. These elements are added because it became obvious that the strategic reasons do not allow the satisfaction all elements in the Agility domain.

Table 5.14 Additional Elements of the Virtual Enterprise Domain at the Third Level.

Second Level	Third Level
Opportunism	1. Identification or creation of market opportunities 2. Gaining access to new markets 3. Responsiveness
Technology	1. Sharing information and skills 2. Use of Information Technology
No borders	1. Cooperation
Excellence	1. Customer-centered and dependent on innovation 2. Excelling in core capabilities (all-star teams)
Trust	1. A culture of trust and sharing 2. Build through repetition 3. Mutual dependency 4. Trust among individual

The strategic reasons have multi-dimensional effects. In general, they allow companies to use their resources in more effective and creative ways. Indeed, these reasons are closely related to the main characteristics of Virtual Enterprises, introduced during the analysis of the second level of the design hierarchy. They can be seen as two faces of the same coin. Most of these characteristics are self-explanatory.

These strategic reasons are closely related. For example, sharing infrastructure, research and development, risk and costs, reduce concept to cash time.

Once the market opportunity is identified, companies find where the resources they need are available, and how to gain access to them. By sharing, companies link their core competencies to bring products to market faster. Products reach markets faster since companies carry out the product development process concurrently. A concurrent development allows companies to reduce the time; from the identification of the opportunity to the moment when the product is introduced in the market.

Companies join Virtual Enterprises to gain access to new markets, sharing market or customer loyalty. Companies not only need to have good products, technologies, and solutions, but also they need to able to bring them to market. Forming Virtual Enterprises to share market opportunities with others is critical for many organizations. One illustrative example is the Personal Computer industry. Formerly, personal computers were sold only with the operating system. Currently, personal computers not only come with the operating system, but also with other software such as browsers, encyclopaedias, graphic utilities, dial up connections, multimedia utilities, etc. This allows relatively small manufacturers of software to gain access to broad markets. They are using the brand names of computer manufacturer as their distribution channels. In this way, small software manufacturers have gained a relatively easy access to markets that otherwise they would have had difficulty penetrating.

This example also illustrates the high customer-oriented nature of agile organizations and Virtual Enterprises. That is a migration from selling products to selling solutions. In the early days of the Personal Computer (PC) industry, manufacturers were selling products. It was the responsibility of the customer to go and add applications to the computer. Nowadays, in contrast, Personal Computer manufacturers are selling solutions. It is not only the computer they sell; it is also a solution to the information processing and communication needs of their customers. That is the reason why computers are presently shipped with a bundle of applications.

It is interesting to notice that this solution-oriented approach has also increased the price of the PC. The price currently charged for a PC covers both cost plus extras for the value-added activities. These value-added activities are, in this case, the software applications bundled into a desktop, in addition to the operating system. This value-adding approach seems to be working since Personal Computer manufacturers that provide solutions have larger volume sales than those that let users acquire all the bundled applications by themselves.

In bringing new solutions to market, companies need to concentrate on their own core competencies and cooperate with other partners. This allows companies to shorten the product life cycle and use core capabilities of other enterprises. Shorter product life cycles are a direct consequence of companies trying to be the first in bringing products to the market. Companies try to be first, because those that arrive first can gain a significant portion of a given market [Goldman et al. 1995]. In any time-window[1] of a market opportunity, companies that bring a product in the first half of the window are usually the ones that obtain the largest profits [Fine and Whitney 1996]. The importance of being first is illustrated by the example of Windows, IBM's OS/2 Warp, and Linux operating systems explained earlier.

The additional elements summarized in Table 5.14 were explained during the analysis at second level of the hierarchy and in Chapter 2, during the study of the characteristics of Virtual Enterprises.

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[1]The time window is an industry dependent concept. In some industries and sector such as Information Technology, it can be very short (in the order of months). In other such as the aerospace industry it could be several years.

Table 5.15. Reorganization of the Elements of the Virtual Enterprise Domain at the Third Level.

	Identifying market opportunities	Gaining access to new markets	Responsiveness	Customer centered and dep. on innovate.	Sharing markets or customer loyalty	Build through repetition	Migrating from selling prod. to selling sol.	Trust among individuals	Sharing information and skills	Use of IT	Complementary core capabilities	Excelling in core capabilities	Sharing infrastructure	Cooperation	Increasing fac. and apparent size	Reducing concept to cash time	Sharing risks and costs	Sharing research and devel.	Mutual dependency	A culture of trust and sharing
Gaining access to new market	x		x		x		x													
Identifying or creating market opportunities		x	x																	
Reducing concept to cash time thr. sharing			x	x					x	x	x	x	x	x	x		x	x		x
Responsiveness				x							x	x	x	x		x	x		x	
Migrating from selling products to sell. sol.					x		x		x	x	x	x		x					x	
Mutual dependency									x		x		x				x	x		x
Sharing markets or customer loyalty							x					x			x		x			x
Sharing information and skills										x	x		x	x		x	x	x	x	
Cooperation									x	x	x	x	x			x		x		x
Sharing research and development										x	x	x	x	x	x	x	x			x
Sharing risk and costs											x		x	x	x	x		x	x	x
Complementary core capabilities										x		x	x	x		x		x	x	x
Use of Information Technology									x				x	x					x	x
Sharing infrastructure														x	x	x	x			x
A culture of trust and sharing						x		x											x	
Increasing facilities and apparent size					x								x			x	x	x		
Customer centered and dep. on innovation							x					x								
Build through repetition								x											x	x
Trust among individuals						x														x
Excelling in core capabilities																				

The relationships among the elements of the Virtual Enterprise domain at the third level are shown in Table 5.15 in an upper triangular matrix. Due to the large number of elements (20), no explanations are provided. In this case, it would have been required to account for 380 (20 x 19) possible relationships among the elements in the domain.

It can be seen in Table 5.15 that is not possible to change some of the elements, without affecting other elements in the domain. Therefore, the elements of the domain are not independent.

5.5.5 Mapping between Agility and Virtual Enterprise Domains

The reorganized mapping between the Agility and the Virtual Enterprise domain for the third level of the hierarchy is shown in Table 5.16. In this table, the elements of the Agility domain are located in the rows, and the elements of the Virtual Enterprise domain in the columns.

It was shown during the analysis of the design at the second level that the characteristics of Virtual Enterprises did not match all the requirements of agility, at least explicitly. At that point, it was not possible to identify characteristics of Virtual Enterprises to satisfy 'Education' in the Agility domain. This situation creates three possible alternatives.

The first and obvious alternative is to leave the sub-elements of 'Education' unmapped. The second alternative is to consider that Virtual Enterprises inherit some of their characteristics from agile enterprises (as explained in Appendix A). The third alternative is to map 'learning organizations' (in the Agility domain) to elements of the Virtual Enterprise domain. This last mapping is the only one shown in Table 5.16.

The mapping based on the inheritance of the characteristics of agile enterprises by Virtual Enterprises can be explained as follows. The characteristics that are transferred from agile to Virtual Enterprises are the sub-elements of 'Education'. This understanding is consistent with the analysis of Virtual Enterprises as agile organizations. This argument is further supported by the analysis presented at the beginning of this chapter. There, Virtual Enterprises were seen as one of the possible ways of achieving agility. Under these circumstances, the mapping from the Agility to Virtual Enterprise domain is obtained by sub-elements similar to those in the Agility domain. This 'inherited' mapping is, therefore, a one-to-one (1:1) mapping.

A second mapping can be obtained using the existing elements of the Virtual Enterprise domain to satisfy the elements of the Agility domain. In this second approach, the development of learning organizations is mapped to 'sharing research and development', 'sharing risks and costs', 'sharing information and skills', 'linking core capabilities', 'cooperation', 'excelling in core capabilities', 'mutual dependency', as well as 'a culture of trust and sharing'.

Table 5.16 shows that the Agility and the Virtual Enterprise domains have a different number of elements. The Agility domain has 19 elements while the Virtual Enterprise domain has 20. This difference means that even in the l case of a one-to-one (1:1) mapping, the design is coupled. This table also shows that it was not possible to reorganize the entire mapping above the main diagonal of the matrix to obtain an upper triangular matrix. That indicates, once more, that the design is coupled. Therefore, it does not satisfy the Independence Axiom (Axiom I).

Equation 5.5 can be rewritten as Equation 5.11. In this equation, the matrix [C] is similar to Table 5.16.

Table 5.16. Reorganized Design Matrix between the Agility and the Virtual Enterprise Domain at the Third Level.

Agility Domain	**Virtual Enterprise Domain**																			
	Identifying market opportunities	Gaining access to new markets	Reducing concept to cash time	Customer centered and dep. on innovate.	Responsiveness	Sharing markets or customer loyalty	Migrating from selling prod. to selling sol.	Built through repetition	Trust among individuals	Mutual dependency	Increasing fac. and apparent size	Sharing risks and costs	Sharing infrastructure	A culture of trust and sharing	Use of IT	Sharing research/develop.	Excelling in core capabilities	Complementary core capab.	Cooperation	Sharing information and skills
New product introduction	x	x		x																
Multi-venturing capabilities		x				x														
Shorter development cycle times			x								x	x	x			x	x	x	x	x
Customer driven innovations				x			x										x			
Response to changing requirements					x								x				x	x	x	x
Strategic relationships with suppliers						x						x	x			x		x	x	x
Leadership in the use of technology							x										x	x	x	
Trust-based relationships w/ supp/cust.				x				x	x					x			x			
Culture of change					x				x	x				x						
Rapid partnership formation					x					x		x	x	x		x		x	x	
Concurrent execution of activities											x		x	x	x	x		x	x	x
First time right design												x	x			x	x	x	x	x
Enterprise integration						x						x	x	x	x	x	x	x	x	x
Information accessible to employees														x	x			x	x	x
Skills and knowledge enhancing techn.															x					x
Learning organizations										x		x		x		x	x	x	x	x
Products with substantial value addition							x								x		x	x	x	x
Develop business practices hard to copy					x													x	x	
Continuos improvements													x				x	x	x	x

$$
\begin{Bmatrix} AG_{11} \\ AG_{12} \\ AG_{13} \\ AG_{51} \\ AG_{21} \\ AG_{83} \\ AG_{41} \\ AG_{82} \\ AG_{84} \\ AG_{23} \\ AG_{81} \\ AG_{31} \\ AG_{53} \\ AG_{32} \\ AG_{43} \\ AG_{44} \\ AG_{52} \\ AG_{61} \\ AG_{62} \\ AG_{73} \\ AG_{63} \\ AG_{71} \\ AG_{72} \\ AG_{74} \\ AG_{42} \\ AG_{31} \end{Bmatrix}
=
\begin{bmatrix}
X&X&&X&& &&&&& &&&&& &&&&& \\
&X&&&& X&&&&& &&&&& &&&&& \\
&&X&&& &&&&& &&X&&X& &X&X&X&X& X \\
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&&&&& &&&&& &&&&& &&&&& \\
&&&&X& &&&&& &&&&& &&&&X& X \\
&&&&& &&&&& &&&&X& &X&&X&X& X
\end{bmatrix}
\begin{Bmatrix} VE_{11} \\ VE_{12} \\ VE_{13} \\ VE_{41} \\ VE_{14} \\ VE_{17} \\ VE_{42} \\ VE_{62} \\ VE_{52} \\ VE_{53} \\ VE_{54} \\ VE_{61} \\ VE_{16} \\ VE_{22} \\ VE_{33} \\ VE_{51} \\ VE_{43} \\ VE_{15} \\ VE_{21} \\ VE_{32} \\ VE_{31} \end{Bmatrix}
\qquad (7.11)
$$

where:

AG_{11}: New product introduction
AG_{12}: Multi-venturing capabilities
AG_{13}: Shorter development cycle times
AG_{21}: Response to changing requirements
AG_{22}: Continuous improvements
AG_{23}: Culture of change
AG_{31}: Information accessible to employees
AG_{32}: Skill and knowledge enhancing technologies
AG_{41}: Leadership in the use of current technology
AG_{42}: Develop business practice difficult to copy
AG_{43}: Concurrent execution of activities
AG_{44}: Enterprise integration
AG_{51}: Customer driven innovations
AG_{52}: Products with substantial value-addition
AG_{53}: First time right design
AG_{61}: Learning organizations
AG_{81}: Rapid partnership formation
AG_{82}: Strategic relationships with suppliers
AG_{83}: Trust-based relationships with customers and suppliers

VE_{11}: Identifying and creating market opportunities
VE_{12}: Gaining access to new markets
VE_{13}: Reducing concept to cash through sharing
VE_{14}: Responsiveness
VE_{15}: Sharing research and development
VE_{16}: Sharing risks and costs
VE_{17}: Sharing markets or customer loyalty
VE_{21}: Sharing information and skills
VE_{22}: Use of IT
VE_{31}: Cooperation
VE_{32}: Linking complementary core capabilities
VE_{33}: Sharing infrastructure or increasing facilities
VE_{41}: Customer-centred and dependent on innovation
VE_{42}: Migrating from selling products to selling solutions
VE_{43}: Excelling in core capabilities
VE_{44}: Increasing facilities and apparent size
VE_{51}: A culture of trust and sharing
VE_{52}: Built through repetition
VE_{53}: Mutual dependency
VE_{54}: Trust among individuals

5.5.6 Partners Domain

The sub-elements of the Partners domain at the third level of the design hierarchy are the selection criteria introduced in Chapter 4. These criteria are shown in Table 5.17. These criteria are the attributes that partners companies need to have in order to satisfy the requirements of a Virtual Enterprise.

Table 5.17 shows that two interesting facts. First, not all the elements at the second level of the hierarchy have sub-elements at the third level. That is the case, for example, of knowledge and structure. None of the criteria used for selecting partners deal explicitly with these two elements. Second, the size and location criteria do not belong to any of the elements in the second level of the hierarchy.

Table 5.17. Elements of the Partners Domain at the Third Level of the Hierarchy.

Second Level	Third Level
Strategy	Development Speed
	Delivery Capabilities
	Business Strength
	Cost of Development
	Financial Security
	Strategic Position
Processes	Technical Capabilities
	Use of Information Technology
Culture	Cultural Compatibility
	Management Ability
	Collaborative Record
Knowledge	
	Size
	Location

The relationships among these criteria are shown in Table 5.18 in an upper triangular matrix. It can be seen that ‘development speed’ is related to ‘technical capabilities’, ‘the use of Information Technology’, ‘management ability’, and ‘size’. The time required to produce a part or component is directly related to the ability of the technical capabilities of the company. Companies with better technical capabilities or knowledge are usually capable of producing a product faster. In addition, the use of information technology may speed up the exchange of information and data as well as other operations related to the part.

Table 5.18. Reorganized Relationships among the Elements of the Partners Domain at the Third Level.

	Financial Security	Use of Information Tech.	Cultural Compatibility	Strategic Position	Management Ability	Size	Development Speed	Cost of Development	Collaborative Record	Technical Capabilities	Location	Delivery Capabilities	Business Strengths
Cost of Development	x	x			x					x			
Development Speed		x			x	x				x			
Collaborative Record			x	x	x								
Size				x*			x	x	x*	x			
Use of Information Technology						x	x	x		x	x		
Technical Capabilities							x	x					
Management Ability							x	x	x			x	
Strategic Position									x				
Cultural Compatibility									x				
Financial Security													
Delivery Capabilities											x*		
Location												x*	
Business Strengths													

x: relationship x*: conditional, rare, unlike or unusual relationship

The ability of management to plan, assign resources, execute and verify the activities is critical for meeting deadlines during the development of parts or items. The size of the company can also influence the development time. Size is seen in the context of a larger workforce and infrastructure. These two factors can significantly reduce the development time since they both make possible to perform a given amount of work in a shorter period.

‘Delivery capabilities’ is related to ‘location’. The physical location of a partner can improve delivery time. ‘Business strength’, on the other hand, is not seen as related to other elements in the domain.

‘Cost of development’ is related to ‘financial security’, ‘technical capabilities’, ‘the use of Information Technology’, and ‘management ability’. The influence of these elements on cost can be both positive and negative. On the positive side, better technical capabilities can reduce costs by performing activities faster and better. ‘Information ‘Technology’ can also be used to reduce the cost of development, since it may help to shorten development time by sharing information and data. In addition, decisions made by managers can influence the cost of the item. On the negative side, a partner with lower technical capabilities may increase the cost of the product by increasing its development time. Lower technical capabilities can also affect the quality of the manufactured part. Problems with planning, execution or verification of activities by management can also increase the cost of development.

Financial security is not seen as related with any other element in the domain.

‘Technical capabilities’ is related to ‘development speed’ and ‘cost of development’. These relationships were explained above.

The ‘use of Information Technology’ is related to ‘development speed’ and ‘cost of development’, as well as ‘technical capabilities’, ‘size’ and ‘location’. Information Technology allows companies to carry out their operations faster and more efficiently. It also makes it possible for companies to gain access to complementary technical capabilities regardless of their physical location. Information Technology also contributes to increase the apparent size of a company. In these cases, companies present themselves as a single organization when in reality they are several companies linked together.

‘Cultural compatibility’ is related to the ‘collaborative record’ of the companies. Companies with similar corporate cultures tend to collaborate more often than those that are culturally incompatible [Bronder and Pritzl, 1992]. According to Sieber [1998], cultural compatibility includes factors such as similar rules of delegation, analogous communication behaviour, and comparable approaches to the exchange of mission-critical data and information as well as homologous ethical standards.

‘Strategic position’ is related to ‘collaborative record’. The strategic position of a partner is one of the most important reasons for collaborating and forming Virtual Enterprises. The strategic position of a partner may include technical capabilities, knowledge, access to markets, etc.

‘Management ability’ is related to ‘development speed’, ‘delivery capabilities’, ‘cost of development’, and ‘collaborative record’. All these relationships, except for the one between management ability and collaborative record, have been explained earlier. Management is critical for the success of collaboration. The more capable management is in performing its functions, the more probable that companies will succeed and collaborate in the future.

‘Collaborative record’ is related to ‘cultural compatibility’, ‘strategic position’, and ‘management ability’. These relationships have been explained already.

‘Size’ is related to ‘development speed’, ‘cost of development’, ‘technical capabilities’, and ‘collaborative record’. The relationships between ‘size’ and ‘development speed’, ‘cost of development’ and ‘technical capabilities’ all have the same foundation: a larger workforce and facilities. These two factors, in principle, contribute to a reduction in developing time and by extension, the ‘cost of development’. In addition, larger companies have more human resources available to carry out tasks.

On the other hand, size can be used as an advantage for collaboration. Campbell [1998] and Goldman et al. [1995] refer to collaborative situations in which partners are brought into the relationship because of their size. In the biotechnology sector, for example, small companies are leaders in research and then collaborate with larger companies for the commercialization of their products Campbell [1998]. Goldman et al. [1995] explained how a company collaborated with IBM for manufacturing its products, because of IBM’s reputation and size.

‘Location’ may be related to ‘delivery capabilities’ since geographical proximity of a company may improve delivery capabilities.

It can be noticed in Table 5.18 that it is possible to change individually the elements in the Partners domain without affecting other elements by following the order suggested by the matrix.

5.5.7 Mapping between the Virtual Enterprises and Partners Domains

The mapping between the Virtual Enterprise and the Partner domains is shown in Table 5.19 in an upper triangular matrix. In the table, the elements of the Virtual Enterprise domain occupy the rows, and the elements of the Partners domain are placed in the columns. As in the previous mappings, this is only one of the possible ways to map the elements in both domains.

‘Identifying’ and ‘creating market opportunities’ as well as ‘gaining access to new markets’ are mapped to ‘business strength’, ‘strategic position’ and ‘management ability’. Management is instrumental in either identifying or creating market opportunities, where the core capabilities of the company can be put to use. The creation or identification of these opportunities relies on the company’s ability to do business and its strategic position. In some cases, ‘gaining access to new markets’ can be mapped to ‘location’. Wildeman [1998] indicated the use of this strategy, for example, to gain access to the Chinese market.

However, it should be noticed that ‘location’ here is understood differently. In this case, it is not the geographical proximity of the partners, but where partners conduct all or parts of their operations.

Table 5.19Reorganized Design Matrix between the Virtual Enterprise and the Partners Domains.

Virtual Enterprise Domain	Partners Domain												
	Location	Size	Development Speed	Delivery capabilities	Collaborative Record	Financial Security	Cultural Compatibility	Strategic Position	Cost of Development	Use of IT	Technical Capabilities	Business Strength	Management Ability
Gaining access to new market	x*							x				x	x
Reducing concept to cash time thr. sharing			x	x						x	x		x
Responsiveness			x	x								x	x
Migrating from selling products to sell. sol.										x*	x	x	x
Customer centered and dep. on innovation											x	x	x
Sharing risk and costs						x			x			x	x
Link. Complementary core capabilities										x	x		x
Sharing infrastructure									x	x	x		x
Increasing facilities and apparent size									x	x	x		x
Sharing research and development									x	x	x		x
Sharing information and skills										x	x		
Identifying or creating market opportunities								x				x	x
Mutual dependency												x	x
Cooperation										x	x		x
A culture of trust and sharing							x						x
Trust among individuals					x		x						
Build through repetition					x								
Excelling in core capabilities											x		
Use of IT										x			
Sharing markets or customer loyalty								x					

x: relationship x*: conditional, rare, unlike or unusual relationship

'Reducing concept to cash time through sharing' is mapped to 'development speed', 'delivery capabilities', the 'use of Information Technology', 'technical capabilities', and 'management ability'. Developing and delivering parts or items as fast as possible, can be used to reduce the product developing time process. Therefore the time required from the initial idea of a product to the moment the product is introduced in the market is also reduced. 'Technical capabilities' and the 'use of Information Technology' also contribute to a faster development process. The former avoids the duplication of efforts and taking advantage of the core capabilities of others. The latter eases the exchange of information and data among partners. 'Management ability' is also very important in reducing the product developing time. Management plans, executes, and verifies all the activities related to the development of products and it is instrumental in achieving a shorter development time.

‘Responsiveness’ is mapped to ‘development speed’, ‘delivery capability’, ‘business strength’, and ‘management ability’. A shorter product development time, and ‘delivery capabilities’ make possible for partners to react faster to changes in the market trends, by reducing the development process of a product or service. ‘Business strength’ and ‘management ability’ are used to keep market awareness by identifying and tracking market changes, threats and opportunities. These two elements may be utilized to adapt to the changes in the market and consumer trends.

‘Sharing research and development’ is mapped to ‘technical capabilities’, the ‘use of Information Technology’ and ‘management ability’. The technical capabilities, knowledge, and information that result from research and development efforts are shared with other partners. Information technology is the vehicle that speeds up the sharing process. Management is the enabler of sharing first, by understanding the need and benefits of sharing, and second, by implementing initiatives that nurture sharing and collaborative work.

‘Sharing risk and cost’ is mapped to ‘financial security’, ‘business strength’, and ‘management ability’. ‘Management ability’ and ‘business strength’ allow companies to implement risk and cost-sharing strategies. The financial security supports these strategies by investing in the company’s priorities, the development of new technology, expansions to new markets, etc.

‘Sharing markets and customer loyalty’ is mapped to ‘strategic position’. Goldman et al. [1995] pointed out that sharing markets and customers is one of the most important strategic reasons for forming Virtual Enterprises. The partners’ ability to share markets and customer loyalty can be seen as strategic, in gaining access to new markets.

‘Sharing information and skills’ is mapped to ‘technical capabilities’ and the ‘use of Information Technology’. In addition, the ‘use of Information Technology’ is mapped to the similar element in the Partners domain. These relationships have been explained already.

‘Cooperation’, ‘liking of core capabilities’ (integration), ‘sharing infrastructure’ and ‘increasing facilities’ are mapped to ‘technical capabilities’, the ‘use of Information Technology’ and ‘management ability’. These mappings are at the centre of the formation of Virtual Enterprises and the partner selection process. In these two processes, partners are selected based on their complementation of core capabilities, and their ability to integrate these core capabilities into the Virtual Enterprise. Management is critical to almost all sharing, since it plans and implements strategies as well as policies to realize the benefits of sharing.

‘Customer centered’ is mapped to ‘technical capabilities’, ‘business strength’ and ‘management ability’. ‘Technical capabilities’ allow the satisfaction of the customers’ needs, while ‘business strength’ and ‘management’ materialize a ‘customer centered’ strategy.

‘Migrating from selling products to selling solutions’ is mapped to ‘technical capabilities’, ‘business strength’ and ‘management ability’. In some cases, ‘Information Technology’ can also be used to satisfy this element. To provide customer with solutions to their problems rather than isolated products, companies need to cooperate and integrate their core capabilities with others. The challenges of cooperation and integration point out to the need of both a strong business operations and management. The use of Information Technology can enhance the scope of an offer by electronically linking core capabilities of several partners. This model is often used in the service industry.

‘Excelling in core capabilities’ is mapped to ‘technical capabilities’. ‘Excelling in core capabilities’ deals with the formation of all-star teams capable of facing different business opportunities [Goldman et al. 1995]. One of the most important attributes of these teams is the ability of their members to excel in their core capabilities.

‘A culture of trust and sharing’ is mapped to ‘cultural compatibility’ and ‘management ability’. The role of trust in Virtual Enterprises has been already analyzed. The most effective way to deal with the issues associated with trust and sharing is by having a compatible corporate culture. Once more, the critical role of management as an enabler and implementer of the trust and sharing policies needs to be taken into account.

‘Built through repetition’ is mapped to ‘collaborative record’. The most effective way to develop trust between organizations or individuals is by establishing relationships and evaluating its results over time. Trust among partners is therefore built by collaborating.

‘Mutual dependency’ is mapped to ‘business strength’ and ‘management ability’. It was explained earlier that mutual dependency is what Byrne [1993] refers to as ‘co-destiny’. The business strength of a partner and its managerial ability can be used to deal with the issues of mutually dependency and win-win relationships. In these relationships, each partner wins and it is rewarded according to its contribution to the Virtual Enterprise.

‘Trust among individuals’ is mapped to ‘cultural compatibility’ and ‘collaborative record’. These relationships were explained during the analysis of the ‘culture of trust and sharing’ element.

Two facts should be noticed about the matrix on Table 5.19 .First, the number of elements in each domain is different. The Virtual Enterprise domain has 20 elements while the Partners domain has only 13. That means that even in the case of a one to one mapping (1:1), the design is coupled. Thus, it does not satisfy Axiom I.

In addition, Table 5.19 shows that changing some elements in the Virtual Enterprise domain affects more than one element in the Partners domain.

$$
\begin{Bmatrix} VE_{12} \\ VE_{13} \\ VE_{14} \\ VE_{52} \\ VE_{53} \\ VE_{16} \\ VE_{51} \\ VE_{11} \\ VE_{33} \\ VE_{15} \\ VE_{21} \\ VE_{54} \\ VE_{31} \\ VE_{32} \\ VE_{17} \\ VE_{41} \\ VE_{42} \\ VE_{43} \\ VE_{22} \\ VE_{61} \\ VE_{62} \end{Bmatrix}
=
\begin{bmatrix}
X & & & & & & & X & & & & X & X \\
& & X & X & & & & & & & X & & X \\
& & X & X & & & & & & & & X & X \\
& & & & X & & & & & & & & \\
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\end{bmatrix}
\begin{Bmatrix} PA_{51} \\ PA_{61} \\ PA_{11} \\ PA_{12} \\ PA_{52} \\ PA_{17} \\ PA_{51} \\ PA_{16} \\ PA_{14} \\ PA_{21} \\ PA_{22} \\ PA_{13} \\ PA_{17} \end{Bmatrix}
\tag{7.12}
$$

where:

VE_{11}: Identifying and creating market opportunities
VE_{12}: Gaining access to new markets
VE_{13}: Reducing concept to cash through sharing
VE_{14}: Responsiveness
VE_{15}: Sharing research and development
VE_{16}: Sharing risks and cost
VE_{17}: Sharing markets or customer loyalty
VE_{21}: Sharing information and skills
VE_{22}: Use of IT
VE_{31}: Cooperation
VE_{32}: Linking complementary core capabilities
VE_{33}: Sharing infrastructure
VE_{44}: Increasing facilities and apparent size
VE_{41}: Customer-centred and dependent on

PA_{11}: Development speed
PA_{12}: Delivery capabilities
PA_{13}: Business strength
PA_{14}: Cost of development
PA_{15}: Financial security
PA_{16}: Strategic position
PA_{17}: Management ability
PA_{21}: Use of IT
PA_{22}: Technical capabilities
PA_{41}: Cultural compatibility
PA_{42}: Collaborative record
PA_{51}: Location
PA_{52}: Size

innovation
VE_{42}: Migrating from selling products to selling solutions
VE_{43}: Excelling in core capabilities
VE_{51}: A culture of trust and sharing
VE_{52}: Built through repetition
VE_{53}: Mutual dependency
VE_{54}: Trust among individuals

Equation 5.6 can be rewritten as Equation 5.12. In this equation, the matrix [C] is similar to Table 5.19.

5.5.8 Structure and Workforce

The limitations of hierarchies were analyzed in Chapter 2. It was shown that organizations with hierarchical structures were characterized by: (1) a high level of centralization, (2) stagnation and bureaucracy, (3) focus on functions rather than on the underlying process, and (4) the isolation of internal units. These limitations restricted companies in their capacity to cope with rapidly changing market conditions. Therefore, organizations were unable to compete in a dynamic market place, since they lack the flexibility and responsiveness needed to succeed in such environments.

Agile and Virtual Enterprises overcome the high level of centralization, by having a decentralized decision-making process, shared leadership and flat hierarchies. In Virtual Enterprises, partner companies may take different roles depending on the market opportunities. In some instances, a partner can be the leader, while in others they may take a less active role [Sieber 1998, Franke 2001]. Partner companies should be able to adapt to these diverse roles. Flat hierarchies, are effectives in collaborative forms where the point of contact is not management, but individuals or teams that have the required complementary core capabilities [Sieber 1998].

Stagnation and bureaucracy are dealt with a rapid formation of partnerships. By reacting quickly, companies take advantage of different market opportunities.

Virtual Enterprises focus on the underlying process, rather than on functions. Focusing on the process is at the core of the formation of Virtual Enterprise. Several factors illustrate this fact; the design of the organization according to the product or process being produced, use of complementary core capabilities, gaining access to the core capabilities, regardless of their geographical location, and the partner selection process. Thus, the isolation of internal units becomes almost impossible because only the needed 'units' are used in the formation of Virtual Enterprises.

The shift in the appreciation of the role of the workforce has resulted in companies focusing in the education, team building and welfare of their workforces. Yusuf et al. [1999] related education to the need for a continuous training and development, as well as for multi-skilled and flexible people. In addition, they linked team building with empowering individuals working in teams, the creation of both cross-functional and multi-enterprises teams. Welfare of the workforce takes into account the satisfaction of employees.

To be able to react quickly to changes companies need of multi-skilled and flexible people that change according to the companies' needs. A continuous training and development of the workforce, allow companies to achieve flexibility and to have a multi-skilled workforce. Beside, the advances in Information and Communication technologies have made possible to access skills and knowledge globally.

Empowered individuals and teams actively contribute to the operation of companies. They are, in addition, capable of making decisions rather than waiting for instructions from higher management levels. The empowerment of individuals and teams is consistent with the decentralized decision-making process implemented in Virtual Enterprises.

Cross-functional and multi-enterprise teams address two critical problems: (1) the scarcity of a knowledgeable workforce, and (2) the cyclical difficulties in the market [Parunak 1997]. The scarcity and dispersion of a highly skilled workforce, have pushed companies to use their expertise opportunistically, or only when they are required.

Companies understand that it is far more efficient to use external human resources for highly specific tasks, rather than keeping them permanently in staff. Besides, highly skilled workers have the opportunity to use and apply their skill in a variety of projects without belonging to any specific organization permanently.

Multi-enterprise teams make possible for companies to use their core capabilities in several value added chain. In this way, companies can better utilize their workforces. In market downturns, companies often opt for releasing part of their workforce. Releasing part of the workforce is more than a change in numbers. It also means the disappearance of part of the acquired knowledge and developed expertise, since those that once held them, are not longer present [Fine and Whitney 1996]. The formation of multi-enterprise teams helps to diminish this outflow by keeping and utilizing the workforce in other value-adding chains.

5.6 Summary of Findings

Table 5.20 and 5.21 summarize the results of the design process presented in this chapter. Table 5.20 shows the relationships among the elements of the domain, the number of elements in the domain and classification of the design or mappings for each level of the design hierarchy. The values in the ‘Mapping’ column are the mappings between two contiguous domains. Thus, the cells corresponding to the Market domain in this column have been left empty. For example, ‘coupled’ for the Agility domain at the second level of the hierarchy means that the design between the Market and Agility domain is coupled.

Table 5.20 shows two important facts. First, except for the first level of the hierarchy, the design is always coupled and does not satisfy the Independent Axiom. Second, 87% (7 out of 8) of the relationships’ matrices in the domains do not allow orderly changes in the elements. This occurs in the second and third levels of the design hierarchy.

Table 5.20. Summary of the Design.

Level of the Hierarchy	Domain	Relationships within the domain	Nb. of Elements	Mapping
First	Market	Independent	1	
	Agility	Independent	1	uncoupled
	Virtual Enterprise	Independent	1	uncoupled
	Partners	Independent	1	uncoupled
Second	Market	Dependent. Orderly changes are not possible	6	
	Agility	Dependent. Orderly changes are not possible	7	coupled
	Virtual Enterprise	Dependent. Orderly changes are not possible	6	coupled
	Partners	Dependent. Orderly changes are not possible	4	coupled
Third	Market	Dependent. Orderly changes are not possible	15	
	Agility	Dependent. Orderly changes are not possible	19	coupled
	Virtual Enterprise	Dependent. Orderly changes are not possible	20	coupled
	Partners	Dependent. Orderly changes are possible	13	coupled

According to Axiomatic Design, these matrices should have been empty matrices in which changes in one of the elements do not affect other elements in the domain. In practical terms, these fact means that the design of Virtual Enterprises, as presented in this chapter, has little or no probability of success. The coupling of the designs indicates that variations in some of the elements of the domains may cause changes to other elements. Those changes may ultimately result in the premature disbanding of a Virtual Enterprise.

Table 5.21 shows the overall design of Virtual Enterprises as analyzed above. In this table, in as much as possible, mapped elements in each domain were located at the same level. The empty spaces indicate that elements in the domain on the left remain explicitly unmapped in a given domain.

Table 5.21 clearly illustrates the problems in the design of Virtual Enterprises. The most evident fact shown in the table is the lack of mapping between some of the elements of the domain. In the second level of the hierarchy, the elements in the business cluster ('Market and Competence' as well as 'Change'), in the Agility domain, are satisfied only by 'Opportunism' in the Virtual Enterprise domain. 'Change' also remains unmapped in the Partners domain.

In the technological cluster, "Integration' is mapped to two elements in the Virtual Enterprise domain ('Technology (Others)' and 'No-border'). Furthermore, these two elements of Virtual Enterprises are mapped to a single element in the Partners domain: 'Process'. In addition, 'Education' does not have a mapping element in the Virtual Enterprise domain. One solution to this lack of mapping is to add 'Education' to the Virtual Enterprises domain. The need for such addition proves that the characteristics of Virtual Enterprises, as analyzed in Chapter 2, are incomplete.

The third level of the hierarchy shows a similar pattern of unmapped or unsatisfied requirements. In the business cluster, two elements of the Virtual Enterprise domain ('Identifying or creating market opportunities' and 'Gaining access to new markets') remain unmapped in the Partners domain.

The lack of mapping of the elements of Virtual Enterprise becomes more evident when the sub-elements of the 'Technology', 'No border', and 'Excellence' are considered. These sub-elements are satisfied by a single element in the Partners domain: 'Technical capabilities'.

Although, it was possible to map ‘Education’ to ‘Knowledge’ at the second level, the sub-elements of Education remains unmapped in the Partners domain, at the third level. Moreover, the elements of the Partners domain do not provide means of satisfying the needs of the ‘mutual dependency’ and ‘trust among individuals’, in the Virtual Enterprise domain.

This lack of mapping between the elements of the Virtual Enterprise and Partners domains, at the third level, points out to needs of the re-evaluation of the selection criteria used in the partner selection process.

At the beginning of the chapter, four objectives were stated. The first objective dealt with providing a unified and consistent view of the relationships among the current market conditions, agility, Virtual Enterprises, and the partner selection process. The design represented in Table 5.21 achieves this objective. It allows seeing the relationships among the elements of the four domains.

The second objective focused on gaining a better understanding of the reasons of disbanding in Virtual Enterprises. The analyses performed throughout the chapter indicate that premature disbanding occurs because of the highly interrelated nature of the elements in the different domains of the design. It has been shown repeatedly, that both the elements within the domains and the mappings do not allow orderly changes. This means that variations in the elements of one domain produce undesirable or uncontrollable changes, in elements of other domains. These changes can lead to the disbanding of the Virtual Enterprise.

Table 5.21 Design Hierarchy for Virtual Enterprises (1/3).

	Domains			
	Market	Agility	Virtual Enterprises	Partners
	MA: New market conditions	FR: Agility (Flexibility)	DP: Virtual Enterprises (VE) or web of VEs	PV: Partners Companies
Business	MA1: Increased competition	FR1: Market and Competence	DP1: Opportunism	PV1: Strategy
	MA11: Growth in existing markets	FR11: New product introduction	DP11: Identifying or creating market opportunities	? ?
	MA12: Market diversification	FR12: Multi-venturing capabilities	DP12: Gaining access to new markets	
	MA13: Shorter product life cycle	FR13: Shorter development cycle times	DP13: Reducing concept to cash time through sharing	PV11: Development speed PV12: Delivery capabilities
	MA2: Uncertainty and risk	FR2: Change		
	MA21: Risk spreading	FR21: Response to changing requirements	DP14: Responsiveness	PV13: Business strength
	MA22: Sharing	FR22: Continuous improvements FR23: Culture of change	DP15: Sharing Research and Development	
			DP16: Sharing risks and costs	PV14: Cost of development PV15: Financial security
			DP17: Sharing markets or customer loyalty	

Table 5.21. Design Hierarchy for Virtual Enterprises (cont 2/3).

	Market	Agility	Virtual Enterprises	Partners
Technological	MA3: Technological Advances	FR3: Technology	DP2: Technology (IT)	PV2: Processes
	MA31: Faster access and distribution of information	FR31: Information accessible to employees	DP21: Sharing information and skills	
	MA32: Elimination of time and space constraints	FR32: Skill and knowledge enhancing technologies	DP22: Use of IT	PV21: Use of IT
	MA4: Product complexity	FR4: Integration	DP3: Technology (Others) DP4: No borders	?
	MA41: Focus on core capabilities	FR41: Leadership in the use of current technology		PV22: Technical capabilities
		FR42: Develop business practices difficult to copy		
	MA42: Collaboration	FR43: Concurrent execution of activities	DP41: Cooperation	
	MA43: Information rich products	FR44: Enterprise integration	DP42: Linking complementary core capabilities	
			DP43: Sharing infrastructure	
			DP44: Increasing facilities or apparent size	
	MA5: Product Variety	FR5: Quality	DP5: Excellence	?
	MA51: Designing with the customer	FR51: Customer driven innovations	DP51: Customer-centered and dependent on innovation	
	MA52: Satisfaction of individual customers' needs	FR52: Products with substantial value- addition	DP52: Migrating from selling products to selling solutions	
	MA53: First time capabilities	FR53: First time right design	DP53: Excelling in core capabilities	

Table 5.21. Design Hierarchy for Virtual Enterprises (cont 3/3).

	Market	Agility	Virtual Enterprises	Partners
Technological	MA6: Knowledge-based economy MA61: Integration of knowledge MA62: Creating new knowledge	FR6: Education FR61: Learning organizations	[Education]↑	PV3: Knowledge
		FR7: Partnership FR71: Trust-based relationship with customers and suppliers	DP6: Trust DP61: A culture of trust and sharing	PV4: Culture PV41: Cultural compatibility
		FR72: Strategic relationships with suppliers	DP62: Mutual dependency	PV16: Strategic position
			DP63: Built through repetition	PV42: Collaborative record
			DP64: Trust among individuals	PV17: Management ability
		FR73: Decentralized decision-making FR74: Rapid partnership formation		PV51: Location PV61: Size

[ ] ↑: Elements inherited from the Agility domain

The design of a Virtual Enterprise, as analyzed in this chapter, has little or no probability of success if changes in the elements of the domain take place. However, it should be noticed that the analyses shown in this chapter considered all the elements known in each domain. It is possible that some Virtual Enterprises are formed to achieve a subset of the elements considered here. In these cases, it might be possible to achieve a design that is uncoupled. These designs might allow orderly changes without harmful side effects.

The third objective aimed at providing solutions to improve the high premature disbanding rate in Virtual Enterprises. Unfortunately, the only solution that could be drawn is avoiding changes in the membership of the Virtual Enterprise. One effective way to avoid such changes is to conduct a reliable and comprehensive partner selection process.

This conclusion contrasts with other research that suggested the formation of the web of Virtual Enterprises and the utilization of a network broker, as the most practical solutions for disbanding [Franke 2001]. Web of Virtual Enterprises and network brokers are very useful of achieving trust and dealing with integration and collaboration among the members of the web. Nonetheless, a critical question remains unanswered: What to do if a substitution of a member company is needed? It may be argued that other members of the web could be used as a substitute. Although this is a possible solution, it implicitly assumes two conditions: similarities between substituting partners and a modular design of the Virtual Enterprise.

Similar organizations capable of achieving a smooth substitution of partners are seldom found in industry. Similarity is rare because companies are constantly trying to differentiate from their competitors. Competitors often develop similar but incompatible technologies to force customer loyalty and to retain market shares. Leaving trust and human resources issues aside, substituting one partner by another may entitle a considerable amount of rework just to achieve a technological match.

The desktop and portable segments of the Computer Industry can be used as examples. The desktop market segment is highly modular and it allows ‘mixing and matching’ of the parts and subsystems, even in the case of brand-name manufactures. In contrast, the portable market segment is highly integrated. Sometimes, even power cables from two manufacturers cannot be exchanged.

The Virtual Enterprise needs to have a modular architecture since an integral architecture will increase considerably the complexity of substituting partners. A modular architecture is the only one that allows for mix and match of components. It uses a bottom-up design process based on the standardization of functions and interfaces. Functions are standardized to some extent while interfaces are standardized to an extreme degree [Fine and Whitney 1996]. This finding is consistent with Theorem 9 of the design of large systems, presented in Chapter 3.

The product or service a Virtual Enterprise aims to deliver, may interfere with the standardizations of functions and interfaces. However, even in the case of a modular architecture, the Virtual Enterprises deals with other organizations and human beings that cannot be considered as merely inanimate parts or subsystems.

The ongoing analysis together with the analysis of design of Virtual Enterprise using Axiomatic Design show, that the use of a network broker or the web of Virtual Enterprises has an important but limited application. It should be used only in cases where the architecture of the Virtual Enterprise and its products are modular.

The four and last objective aimed at evaluating the satisfaction of the needs of Virtual Enterprises, by selection criteria used in the Partner Selection process. The mapping between the Virtual Enterprise and the Partners domains, at the third level, showed that the needs of Virtual Enterprises are not satisfied by the selection criteria. In other words, the selection criteria do not evaluate partners effectively enough, to satisfy the needs a Virtual Enterprise. The mapping made it clear that selection criteria considered only a small fraction of the requirements of Virtual

Enterprises. Criteria such as costs and the use of Information Technology allow measuring specific requirements of the Virtual Enterprise concretely. Other criteria such as business strength and financial security need to be revised.

The mapping also showed that technical capabilities are used to satisfy many requirements in Virtual Enterprises. Therefore, it is critical to identify other selection criteria that can be used to meet some of the requirements assigned to technical capabilities.

In addition, the mapping shows that location and size, although important in outsourcing relationships do not play a similar role in Virtual Enterprises. This finding was made obvious by the lack of corresponding elements in the other domains of the design.

The selection criteria should be expanded to consider the issues related to the workforce. New selection criteria should evaluate partners according their aptitudes towards their workforces. These criteria must consider the education, welfare and team building of the workforce.

6 Partner Selection in Virtual Enterprises

6.1 Introduction

The formation of a Virtual Enterprise needs from the contributions of all its members or partners to succeed. As explained in Chapter 2, the collaborative work among partners, the complementation of their core competencies and their integration are three of the most important factors for the success of Virtual Enterprises. Therefore, Virtual Enterprises need to carefully select their members, since they determine the success a Virtual Enterprise.

However, those memberships are diverse in nature. Each member of a Virtual Enterprise brings to the organization not only core competencies, but also other distinctive characteristics such as: different management styles, and corporate cultures. The fundamental issue lies in the need to achieve a complete and harmonious integration, rather than the integration of only core capabilities. Thus, Virtual Enterprises can work as a team to achieve their goals. Core capabilities and skills, then, become a necessary, but not a sufficient condition to belong to a Virtual Enterprise.

The partner selection process aims to select the best possible partners to form a Virtual Enterprise. To fulfill this objective, the selection of a given partner needs to satisfy both individual interests from the members, and the objectives of a Virtual Enterprise as a whole.

The selection process requires of two important elements: (1) the selection criteria used to evaluate partners and (2) decision making methods for selecting partners, as evenly as possible. Selection criteria should provide a comprehensive and robust evaluation of the partners' credentials. They also need to take into account the requirements of the Virtual Enterprise and the market conditions in which they operate. The method should integrate these criteria, in order to select of the most appropriate partners.

This chapter presents an analysis of the partner selection problem. The analysis includes the definition of the problem, the analysis of the selection criteria and the comparison of two decision-making methods. Specifically, it compares the Analytical Hierarchy Process and the Axiom II of the Axiomatic Design Theory. In addition, a case study illustrating the use of both methods is presented.

6.1.1 The Selection of Partners

Chapter 2 analyzed the three phases in the life cycle of a Virtual Enterprise. These phases are: design, management, and disbanding. The design phase not only establishes the objective and functional requirements of the organization, but also determines the required core capabilities and selects partners. Next, the management phase focuses in achieving the objectives and the functional requirements set in the design phase through the integration of core capabilities. Once the market opportunity has passed, the Virtual Enterprise disbands.

The selection of partners takes place in the design phase. After the objectives and functional requirements are established and the required core capabilities determined, the partner companies capable to fulfill these functional requirements are selected. This process was represented in the lower section of Fig. 3.4.

However, the selection process may also occur in the management phase. This happens when a Virtual Enterprise needs to replace one or more of its members. Several reasons may create this situation. The most common arguments for leaving a Virtual Enterprise are related to a change in focus of the leaving partners and the "corporate fit" among partners [Wildeman 1998]. In other instances, the Virtual

Enterprise may need to find a new partner due to the inability of the member to collaborate with others. Additionally, some partners may prove unable to meet the functional requirements of the Virtual Enterprise.

Fine and Whitney [1996] pointed out that it is critical for companies, to understand what is required and to be able to find capable partners. According to Fig. 3.4, mapping the customers' needs to the functional domain determines the required core capabilities. Chapter 2 explained that the analysis of core capabilities identifies the activities and interfaces in the process chain. It also makes it possible to take 'make or buy' (collaborative) decisions, since gaps between interfaces are the functions partners must fulfill. This was defined by Reithofer and Naeger [1997] as the partner problem.

6.1.2 Problem Definition

The partner problem can be formulated using 'the switching principle' [Mowshowitz 1999]. Chapter 5 explained that the switching principle separates the abstract requirements of the tasks from their satisfiers. Switching is the dynamic assignment of satisfiers to the abstract requirements in such a way that the strategic goals of the Virtual Enterprise are met. The abstract requirements are the needs of the tasks and the concrete satisfiers are the resources required to meet those needs.

In the partner selection problem, the gaps identified during the analysis of core capabilities are the abstract requirements, and the partners are the concrete satisfier of those tasks. The partner process is, therefore, equivalent to switching.

In principle, the partner selection problem can be interpreted as an assignment problem and modeled using a bipartite graph, as shown in Fig. 6.1. In this figure, the activities that require collaboration are represented on the left and the partners companies on the right. Links associate activities and partners with their potential satisfiers. The assignment of tasks to satisfier needs to specify the activity and the selection criteria. Specifications establish the inputs, outputs and the requirements to perform the activity. The selection criteria evaluate the satisfaction of the requirements by the prospective partners. Based on these evaluations, the best candidates are chosen.

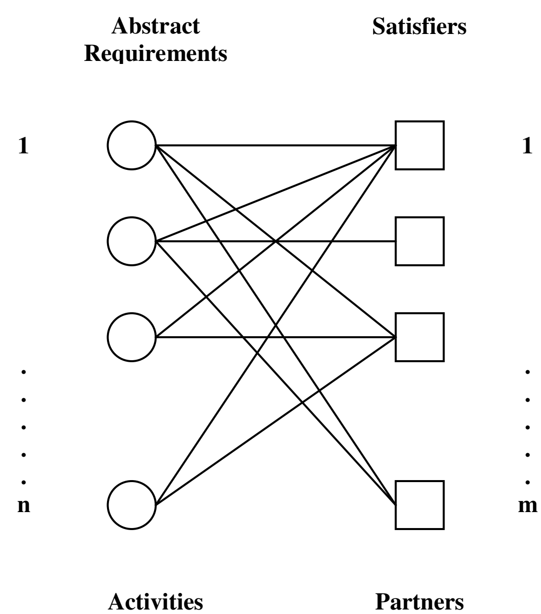


Figure 6.1. Partner Selection Problem for a given $t = t_x$.

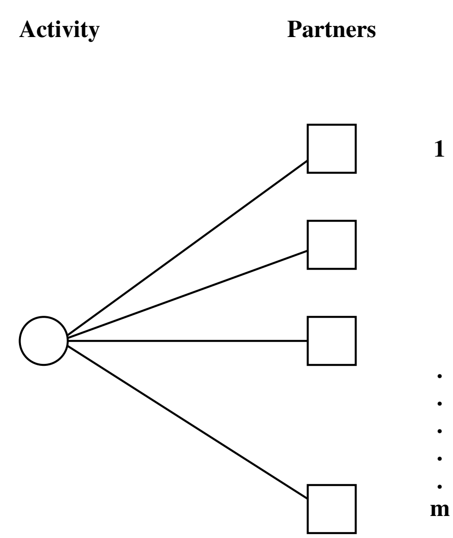


Figure 6.2. Partners Selection for an Activity.

Fig. 6.1 represents better the results of the selection process than the process itself. To analyze the selection problem, each activity has to be considered independently, as shown in Fig. 6.2.

Fig. 6.1 and 6.2 are simplified representation of the problem, since they do not consider the dynamics or time dependency of the problem. In Fig. 6.1, both abstract requirements and satisfier are represented by sets with a fixed cardinality. In reality, due to the market orientation of Virtual Enterprises, changes may occur in either abstract requirements or satisfiers, at any time. This means that both sets in the bipartite graph will have changing cardinalities. The single addition of time to the partner selection problem increases the complexity of the modeling, since most of the known algorithms for solving assignment problems do not considered sets with variable cardinality.

For a single activity, a time dependent representation of the partner selection problem, can be mathematically defined as follows:

$$\gamma(t) = f(\mathbf{P}(t), \mathbf{A}(t), \mathbf{S}(t), \mathbf{C}(t); \mathbf{t}) \qquad (6.1)$$

where:

$\gamma(t)$: partner selection problem.
$\mathbf{P}(t)$: a set of prospective partner companies, $\mathbf{P}(t) = \{p_1, p_2, \ldots p_m\}$, $m \geq 1$.
$\mathbf{A}(t)$: a set of activities of the product, $\mathbf{A}(t) = \{a_1, a_2, \ldots a_h\}$, $h \geq 1$.
$\mathbf{S}(t)$: a set of specifications for each activity, a_i.
$\mathbf{S}(t) = \{s_1, s_2, \ldots s_p\}$, $p \geq 1$.
$\mathbf{C}(t)$: a set of selection criteria for assigning activities to partner companies.
$\mathbf{C}(t) = \{c_1, c_2, \ldots c_r\}$, $r \geq 1$.
$\mathbf{t}$: time.

The partner selection problem for a single activity or module is formulated as follows:

> "Which partner company p_i is capable of performing the activity a_j according to the specifications s_k, that better satisfies the selection criteria c_l at a given time t_x?"

The term **P**(t) in Eq. 6.1 refers to a pool of partner companies that, at least, have the core capabilities needed by the Virtual Enterprise to deliver a product to the market. The activities (**A**(t)) refer to the different subsystems, technologies, or components in which the partner companies have expertise. A different set of selection criteria may be specified for each activity or subsystem. The specifications' term, **S**(t), deals with the design, manufacturing or management specifications needed to perform the activity. In addition to the technical specifications, other specifications such as cost and quality can be added. The selection criteria are the parameters used to evaluate how partner companies meet the specifications of the activities, and the requirements of the Virtual Enterprise.

Eq. 6.1 represents the situation faced by a Virtual Enterprises in the design phase. In this expression, all the variables are time dependent. This formulation of the partner selection process does not assume that partners, specifications, or the selection criteria remain constant during the Virtual Enterprise life cycle. It still applies when partners with a better economy of scale substitute other companies with better Research and Development capabilities. This change will be represented as a change in the specifications of the activities that companies are assigned. Furthermore, Eq. 6.1 can deal with a situation in which a given company does not satisfy the selection criteria (or activities' specifications) at a future time. More importantly, it allows a dynamic selection of partners, when activities, specifications, or the satisfaction of the criteria change.

In general, the partner selection is a multi-criteria and multi-objective decision making problem characterized by risk, uncertainty, and eventually subjectivity in the evaluation and selection of prospective partner. Several objectives, often contradictory, have to be considered in the partner selection process such as cost and quality.

To explain risk, uncertainty and subjectivity, the environment in which the decision making process takes place has to be considered [Changkong and Haimes 1983]. Risk in decision-making refers to the possibility of estimating the future stages of the environment, either objectively or subjectively. The estimation of the probability of risk is based on available data (objective estimation), or on the subjective judgments of the decision-maker. Decisions under uncertainty are those in which the probability of future states of the environment cannot be estimated reliably. Although, the elements of risk still remain in this kind of problem, they cannot be quantified. Subjectivity deals with the existence of information about the criteria involved in the decision-making process and its environment. Objective decisions are those based on enough and reliable information. Otherwise, the decision is subjective.

6.2 Problem Analysis

Section 6.1 introduced the partner selection problem. This section analyzes multi-objective and multi-criteria decision-making problems, from a general perspective. Using the system theory, this section examines the decision-making problems without referencing any specific decision making method. This analysis provides the foundations for comparing decision-making methods presented in Section 6.4.

Fig 6.3 shows a general representation of a multi-criteria decision-making problem. This representation considers the decision-making problems as systems [Changkong and Haimes 1983]. As explained in Chapter 3, a system is a set of parts or components that works together to achieve certain goals. A system interacts with the environment in two forms: inputs and outputs. The inputs are usually the conditions in the environment, where a system exists and the stimuli that cause a reaction from system. The outputs are consequences of the inputs being processed by the system.

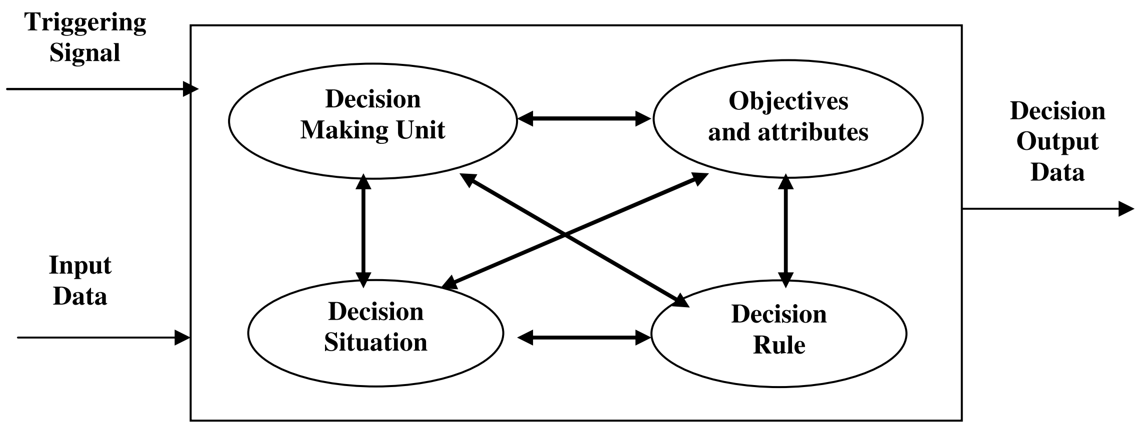


Figure 6.3. A General Representation of a Decision-Making Problem.

In the partner selection problem, the inputs are the evaluation of the partner according to the set of criteria. These criteria are established in the objectives and attributes unit of the decision-making problem. The triggering signal is either the formation of a Virtual Enterprise due to the identification of a market opportunity, or the substitution of one or more partners in an existing Virtual Enterprise. The output of the problem is the ranking of the potential partners according to their satisfaction of the selection criteria.

Multi-criteria decision-making problems have two inputs and at least one output. The inputs are decision-making situation and the data needed to make the decision. The outputs are the decisions taken due to the inputs. According to Changkong and Haimes [1983], and Yu [1985], the components or sub-systems of a decision-making problem are:

1) a decision-making unit,
2) a set of objectives and its hierarchy,
3) a set of attributes or a complete set of objective-attribute relationships,
4) the decision situation, and
5) the decision rule.

The following sections introduce these components and analyze them, in the context of Virtual Enterprises.

6.2.1 Decision-Making Unit

The Decision-Making unit processes the information from all other sub-components. This unit is required in any decision-making problem. It takes as inputs the rest components of the systems. In addition, its outputs become also the output of the decision-making problem or the system. Internally, a decision-making unit has at least one component: the decision-maker. It may include components such as calculations and graphics that help to make the decision, depending on the complexity of the problem.

6.2.2 Objectives and Attributes

The set of objectives and its hierarchy helps to formulate of the decision problem precisely. The objectives identify the desired state that the problem under study should reach. These objectives may be achievable or not, however, they provide a reference to measure or evaluate the quality of a given alternative. A hierarchy, on the other hand, is a result of a well-defined set of objectives. The hierarchy organizes the objectives from general to specifics. The highest level of the hierarchy contains the most general objectives. Although the objectives at this level can be broad and non-operational, they are the starting point of the decision-making problem. At the lowest level of the hierarchy, the objectives become more specific and narrow in scope. This transformation from broad to specific objectives is a result of dividing broad and complex objectives into simpler ones. The process stops when the objectives are simple enough to be operational. An objective becomes operational if, at least, exist one practical mean to measure or evaluate the satisfaction of the objective. In a hierarchy, the objectives at lower levels contribute to achieve the objectives of the next higher level.

Attributes are assigned to the objective located at the lowest level in the hierarchy. An attribute is a measurable quantity that reflects the level of achievement of a given objective. Attributes should be measurable and comprehensible. An attribute is measurable, if for a given alternative, it can be assigned a practical value. This value should indicate the degree of satisfaction of the objective associated with the attribute. Besides, an attribute is comprehensible, if it accurately represents the achievement of its related objective.

A set of attributes for a given decision making problem has to be complete, operational, decomposable, independent and minimal. A set of attributes is complete when it represents all the aspects related to a decision-making problem. The operability characteristic deals with the ability of the attributes to provide meaningful ways to evaluate different decisions. To manage complexity, the decision-making problem is decomposed into smaller and less complex sub-components. Therefore, as the objectives are decomposed into simpler sub-objectives, attributes should be subdivided. Each attribute should represent one and only one aspect or objective of the problem. Although achieving the total independence of attributes it is not always possible, their interactions should be minimized.

A set of attributes is minimal if a smaller set of attributes that completely represents the decision-making problem cannot be found. In principle, more that one set of attributes may be minimal since each set represents only one of the possible solutions to the problem.

The partner selection process aims to choose the best available partners to form the Virtual Enterprise. The high level objective can be divided into three sub-objectives: business, technological and management objectives. These sub-objectives in turn are divided into attributes. This hierarchical decomposition is shown in Fig. 6.3. The attributes at the lower level of the hierarchy are the selection criteria used for selecting partners. These criteria were identified in Chapter 5 and are analyzed in the Section 6.3.

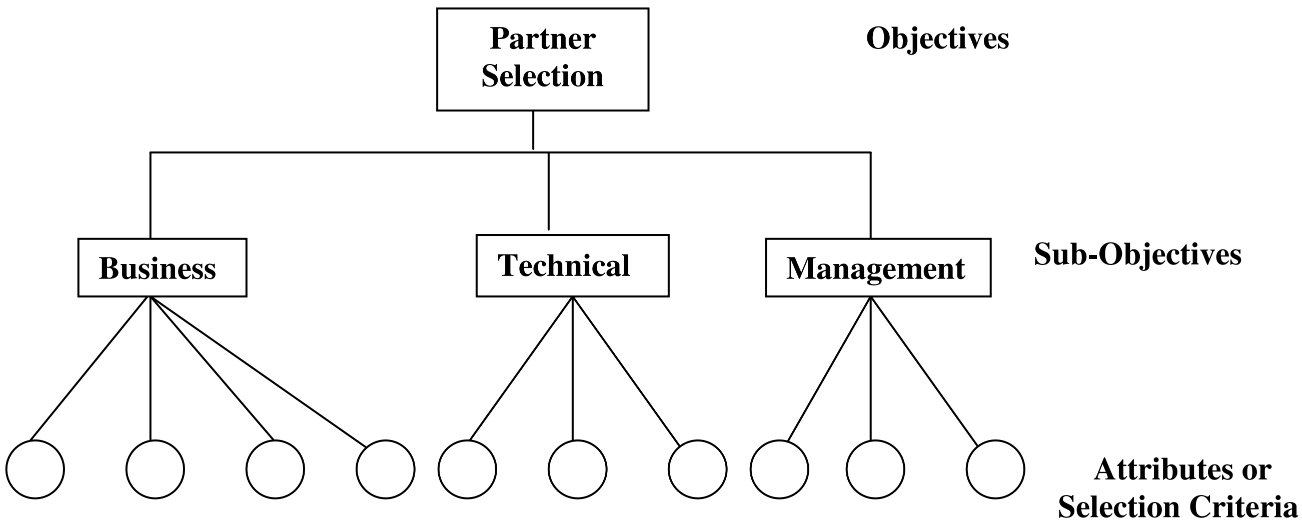


Figure 6.3. Objectives and Attributes of the Partner Selection Problem.

6.2.3 Decision Situation

The decision situation sub-component defines the structure of the problem and the decision environment in multi-criteria decision-making problems. The decision situation requires a complete characterization of the boundaries (or scope) and the basic components of the problem. An accurate description of this sub-component should take into account the following elements:

- the problem inputs and their availability.
- a set of decision variables and attributes.
- the cause-effect relationships among decision variables and their attributes.
- a set of alternatives.
- the states of the decision environment.

The decision situation sub-component produces a decision and may be other outputs. The scope and type of inputs of the decision situation vary, according to the problem under analysis. In the simplest case, the scope of a decision situation has three elements:

- a set of available alternatives,
- a set of attributes that are used as decision variables, and
- a description of the current state in the environment in which the decision is made.

The inputs, in this case, are those used to calculate the values of attributes for each alternative, at a given state in the environment. In addition, the decision-maker is the only element in the decision-making unit. Buying a house and a selection from several job offers are examples of this type of decision making problems. In these cases, both the objectives and the alternatives are clearly stated.

The most complex scenario is when the number of decision variables is large and they are highly interrelated. In this case, relationships among attributes or objectives and decision variables are complex. Furthermore, possible alternatives are expressed as cause-effect relationships because they are difficult to state explicitly. This scenario involves the decision-maker and other units of the decision-making problem that interact with the user. The design and manufacturing of large systems such as airplanes belong to this complex scenario.

Decision situation units are not unique. Each specific problem may have a different decision unit, depending on its complexity. Besides, there are not formal guidelines for choosing a decision situation unit. At the end, factors such as the nature of the problem, experience of the decision-maker, ingenuity and judgment all influence a given choice of a decision unit.

In the partner selection problem, the input to the decision unit is the set of credential of the potential partners, the attributes are the selection criteria used for selecting partners and the decision variable is to select partners according to the ranking obtained in the decision rule unit. The alternatives are the potential partners. The state of the decision environment can be either the formation of a new Virtual Enterprise or the substitution of one or more partners, during the management phase.

6.2.4 Decision Rule

The Decision Rule deals with making a selection from a set of alternatives. These alternatives are expressed explicitly or implicitly depending on the complexity of the problem. The selection of the "best" alternative implies a certain order, ranking, or preference, based on some criteria or rules. In general, these criteria evaluate performance, satisfaction of objectives or quality. The Decision Rule unit is a set of rules used to evaluate or rank a set of available alternatives, as evenly as possible. These rules are directly extracted from the statement of objectives of the problem. Alternatively, the rules are derived from the objectives and stated independently. An example of the former is the maximization of some single objective problem, such as maximize profit or minimize losses. In this case, the objective and the decision rule are similar. The latter case appears, when objectives are measured indirectly. For instance, when measuring quality, the number of defective parts in a sample size, may be used as the derived variable. In this case, the alternative that provides the smallest number of defective devices is the one that maximizes quality.

There is a close relationship between goals and decision rules. A goal is the value of a particular attribute that determines its rejection or acceptance. Attributes and goals have a bi-univocal relationship: for each goal, there is an attribute, and for each attribute, there is a goal. Goal-decision relationships evaluate alternatives through their corresponding set of attributes by dividing the set into acceptable and unacceptable subsets. Transitively, each member of a set of alternatives becomes a member of these two mutually exclusive subsets.

Decision Rule units try to either optimize or satisfy a set of alternatives. The units that optimize the alternatives rank all the available alternatives. In this case, it is always possible to choose the best available alternative using certain implicit criteria of the Decision Rule unit. On the other hand, other types of units, seek sets of alternatives that satisfy a set of rules (satisfying rules). In this situation, there is a trade-off between the optimality and the simplicity of the solutions. This type of Decision Rule unit does not carry out an extensive search for the best available alternative, saving both cost and time. Once the alternatives are separated in smaller and manageable subsets, these subsets are compared again each other and the best possible subset is chosen.

The Decision Rule unit deals with the selection of alternative. The alternatives are chosen using decision-making methods. The chapter presents two decision-making methods that can be used for selecting the partners. One of the methods, the Analytical Hierarchy Process, uses an optimizing rule for selecting alternative. The second method, Axiom II from Axiomatic Design uses a satisfying rule for choosing partners. These two methods are analyzed in Section 6.4.

6.2.5 Summary

This section has analyzed the partner selection within the framework of decision making problems. The analysis is based on considering both Virtual Enterprises and decision-making problems as systems. Table 6.1 summarizes the components of the decision making problem, in the context of the partner selection process in Virtual Enterprises.

The next two sections analyze the Decision Situation and Decision Rule units in more detail. The analysis of the Decision Situation focuses on attributes of the decision situation or selection criteria. The study of the Decision Rule presents two decision-making methods with different decision rules.

Table 6.1. Components of Decision-Making Problem in Partner Selection.

Decision Making Problem Units	**Partner Selection Problem**
Inputs	Credential of potential partners
Triggering Signal	Formation of a Virtual Enterprise or substitution of one or more partners.
Output	Ranking of partners
Objectives	Select the best possible partner
Sub-objectives	Selecting partners according to business, management and technical credentials
Attributes	Selection criteria
Decision Situation	
Problem Input	Credential of the partners
Decision variables	Choose partners according to ranking
Attributes	Selection criteria
Alternatives	Partner companies
State of the environment	Formation of a new Virtual Enterprise or substitution of one or more of the current partners.
Decision Rule	
Optimizing	The Analytical Hierarchy Process
Satisfying	Axiom II from Axiomatic Design

6.3 The Criteria for Selecting Partner Companies

The selection criteria to choose partner companies are one of the less studied topics in Virtual Enterprises. Research on Virtual Enterprises have been focused on a general view that underestimates the relevance of the selection criteria and the selection process. Most of the time, authors only emphasize the importance of the process, but provide neither a set of selection criteria nor a concrete approach to carry out the selection process.

Fortunately, the selection of partner has been studied better in outsourcing, strategic alliances and collaborative relationships. These reseach can be used to study the selection criteria in Virtual Enterprises (see Appendix A) . A comprehensive analysis of the criteria for partners' selection in Virtual Enterprises should include the analysis of the criteria used in outsourcing decision-making as well as those considered during the formation of strategic alliances. Furthermore, the analysis should consider the influences of agility and the new characteristics that distinctively identify Virtual Enterprises.

6.3.1 Selection Criteria in Outsourcing

Before analyzing the selection criteria for outsourcing decision-making, it is useful to consider the context in which these criteria are used. Outsourcing is a process that involves two major steps: the selection of subcontractors and the management of the outsourcing relationships.

Fine and Whitney [2001] proposed a partner selection process that considers the following steps.

1) Prepare precise Request For Quotations (RFQ) using customer's needs.
2) Decide who qualifies to bid.
3) Obtain bids.
4) Chose the best qualified bid .
5) Modify, negotiate or improve the bid.

These are universal steps that apply to any outsourcing situation, regardless of the item or component being outsourced.

To effectively prepare a request for quotation a company needs to decide what complementary core capabilities are needed and where in the product development process these capabilities are required. The product realization process and the product architecture can be used to decide about these two issues [Fine and Whitney 1996, Chu et al. 2000]. The product realization process and the product architecture should identify the components that are easily decomposable and have clear and well-defined interfaces. Those components are the best candidates for outsourcing. Definitely, these two issues should be addressed before attempting to select any subcontractor.

This chapter focuses on the fourth step of the partner selection process (choosing the best-qualified bid). Choosing the best-qualified bid requires both a set of selection criteria and a decision-making method for evaluating the partners. This section analyzes the criteria used for making outsourcing decision. Decision-making methods are analyzed in the next section.

Traditionally, the selection of partner companies has been based on factors such as location; cost associated with the service provided, or simply habits [Grenier and Metes 1995]. Equally important is fact that the supplier selection (evaluation) is not carried out regularly. Although these criteria still have a role to play, they are not the only focus in Virtual Enterprises.

Appendix A analyzes strategic outsourcing and identifies time, quality, and cost as the three most important criteria used in outsourcing decision making. These criteria have been used for a long time with both positive and negative results. During the mass production era, these criteria were probably all that was needed to satisfy the market demands and achieve a large economy of scale. The leadership of a company was mainly based on how fast and cost-efficiently a product could be brought to the market, with an acceptable quality. This understanding was based on two fundamental beliefs: (1) that markets were infinite and that all manufactured products could be sold if prices were low enough [Gardiner 1996] and (2) markets were considered predictable and based on transactional relationships between suppliers and customers [Hirsh, Thoben and Hoheisel 1998].

Fine and Whitney [1996] expanded this traditional view of outsourcing to consider other important factors such as core capabilities, and the dependencies created in outsourcing. They concluded that a company should avoid outsourcing functions that belong to its core capabilities. Moreover, they pointed out that functions that provide competitive knowledge, customer visibility, or market differentiation should be kept ‘in house’, even when they are non-core competencies.

6.3.2 Selection Criteria in Strategic Alliances

Brendon and Przilf [1992] proposed the selection of partners according to three general criteria: complementarity, strategic and cultural compatibility. Companies that become partners should complement each other core capabilities and expertise. This complementation should increase the value adding potential of the partners. It should also enable companies to collectively achieve goals that they could not achieve on their own. The strategic compatibility focuses on the matching of strategies between the alliance and its members. Taking part in a strategic alliance should always complement the member companies' individual strategies. This strategic compatibility is considered critical in the success of the alliance. Cultural compatibility measures the compatibility of the members' corporate culture. Failure to consider cultural issues during the selection process may result in unsuccessful alliances. The evaluation of cultural compatibility must also include factor external to the organization. Issues such as national culture and traditions need to be considered.

The factors considered for each selection criteria are summarized in Table 6.2. The cultural compatibility is evaluated by making a cultural profile of the partners. The cultural profile should evaluate the position of the company towards the issues shown in Table 6.2. The profile identifies both similarities and differences between partners. It also helps to determine possible areas of conflict that could jeopardize the success of the alliance.

It can be seen that the selection criteria used in strategic alliances is more general that the one used in outsourcing. These criteria allow a more comprehensive evaluation of the partners' credentials.

Table 6.2 Selection Criteria Used in Strategic Alliances.

Criteria	Factors
Complementarity	Complementation in core capabilities
	Common intentions
	Compatible vision
	Balanced position of power
	Mutual gains
	Risks
	Potential for increasing shareholders value
Strategic compatibility	Strategic goals considering value potential, product, markets and regions
	Configuration of the alliance
	Lifespan of the alliance
Cultural compatibility	Workforce
	Quality
	Cost
	Innovation
	Technology
	Customer orientation
	Environmental issues

6.3.3 Selection Criteria in Virtual Enterprises

Chapter 2 mentioned that only a few research have dealt with this subject. Zhang et al. [1998] studied the partner selection in Virtual Enterprises using cost, quality, capacity, and delivery delays as selection criteria. The Analytical Hierarchical Process (AHP) was used as the decision-making method for carrying out the selection. Although this work focused on Virtual Enterprises, it can be seen that the selection criteria used, take into account only the influences of outsourcing on Virtual Enterprises.

Several studies have been conducted to identify the criteria used in collaborative relationships of a varied nature. Bailey et al. [1998] studied the selection criteria in collaborative relationships. Wildeman [1998], on the other hand, identified the selection criteria used in instances of Virtual Enterprises.

Bailey et al. [1998] conducted a survey to identify the criteria used to select partners in industrial fields such as electronics, aerospace, biotechnology, as well as design and manufacturing. They identify as the most important criteria:

1) Technical capabilities,
2) Cultural compatibility,
3) Development speed (time),
4) Strategic position,
5) Management ability,
6) Security,
7) Collaborative record,
8) Business strength, and
9) Cost of the development.

These criteria were ranked according to how managers consider them during the selection process. It seems that in this case, the size of the partner company does not play a major role for the managers involved.

Wildeman [1998] also carried out a survey to identify selection criteria. This work proposed to divide the partner selection process into two phases: (1) evaluation of the partners and (2) evaluation of the partnership. This approach is based on the understanding that a successful collaborative project starts with the successful partners. In summary, this approach starts by considering the components of the system before analyzing how the components will fit and work together. The partner phase focuses on the analysis of partners as individual and autonomous units. That is if the partners are not in a solid situation on their own, it is almost impossible to succeed within the collaboration. The partnership phase analyzes the relationship among partners. It takes into account 'soft' or management related issues that are beyond the core competencies of the partners. Factors such as management style, and corporate culture should be considered during the evaluation of the partnership.

The criteria identified for the evaluation of partners are:

1) Complementary [skills] core capabilities,
2) Market position,
3) Financial position of the partner,
4) Management philosophy, and
5) Size.

Most of the criteria above are self-explanatory. The market position evaluates the possibility of gaining access to new markets through partners. The management philosophy is used to evaluate a potential fit among the partners. It takes into account issues such as management style, openness to cooperation and consistency in decision-making.

The criteria utilized for the evaluation of the partnership are:

1) Chemistry,
2) Complementarity,
3) Culture,
4) Trust,
5) Commitment,
6) Financial position of the partnership, and
7) Openness.

In contrast with the selection criteria for the partner phase, the criteria used in the partnership phase are qualitative and subjective. It can be seen that these criteria deal with 'soft' issues that are both difficult to evaluate and subjective.

As in the case of the partner phase, most of the criteria are self-explanatory. Chemistry takes into account the relationship between managers. The complementarity of core capabilities evaluated in the partner phase, it is now extended to consider management and 'soft' issues between the partners. Culture considers the corporate culture of the partners. Wildeman [1998] argued that similar cultures are not a prerequisite for a successful partnership, and that it can be even not desirable. Openness takes into consideration the management attitude towards change and new ideas as well as towards collaboration.

It should be noticed that the relative importance of both phases varies. During the preliminary evaluation of the partners, the focus is on the partners. Wildeman [1998] proposed to assign 70% of the importance to the criteria for evaluating partners . In the partnership phase, the relative importance of the criteria is shifted to give more weight to the 'soft' issues. In this phase, the criteria for evaluating the partnership receive 70% of the importance.

Table 6.3 shows a comparison of the selection criteria used for partner selection. In the table, similar criteria are located in the same row for comparison purposes. It can be seen that for the partner phase, Wildeman [1998] did not consider cost and time of development in the evaluation of partners. On the other hand, Bailey et al. [1998] did not include the size of the company in their analysis.

The comparison of the criteria of the partnership phase becomes even more complex because of the different terminology and the lack of precise definitions in the surveys. It should be noticed that collaborative record and trust are considered equivalent criteria. These two criteria are not equal; however, they are strongly related, since trust is achieved by establishing collaborative relationships. Furthermore, business strength has no equivalent in the Wildeman's [1998] set. Chemistry, complementarity, commitment and openness can be evaluated by combining several criteria.

Table 6.3. Comparison of Selection Criteria from Previous Research.

	Bailey et al. [1998]	Importance (1-9)	Wildeman [1998]	Importance (%)
Partner Phase	Technical Capability (TC)	7.9	Complementary skills	36
	Financial Security (FS)	5.0	Financial position of partner	15
	Management Ability (MB)	5.2	Management Philosophy	13
	Strategic Position (SP)	5.2	Market Position	33
	Development Speed (DS)	5.3		
	Cost of Development (CD)	3.8		
			Size	3
Partnership Phase	Cultural Compatibility (CC)	6.0	Culture	16
	Financial Security (FS)	5.0	Financial position (partnership)	15
	Collaborative Record (CR)	4.8	Trust	16
	Business Strength (BT)	4.5	Chemistry	23
			Complementarity	18
			Commitment	12
			Openness	7

To gain a more comprehensive understanding of the criteria used for partner selection, the scope of some of the selection criteria originally proposed by Bailey et al. [1998] is expanded to include the findings of Wildeman [1998]. To that extent, the financial security criterion is now considered in evaluating both the partners and the partnership in a Virtual Enterprise. The collaborative record will also take into account trust among partners. In addition, business strength will take into account the chemistry between interacting managers, how the partners complement each other goals and objectives (complementarity) and their commitment to the Virtual Enterprise. The business strength criterion is also used to evaluate the openness of partners.

It should be noticed that the size of the company and its location are not considered as selection criteria. Location is made irrelevant by the use of Information and

Communication technologies. The size of the company is not included because of three important reasons. First, Goldman et al. [1995] did not include the size in the characteristics of Virtual Enterprise because the size of the partner in itself is irrelevant to formation of Virtual Enterprise. Second, it has been found that in rapidly changing market sectors such as biotechnology and computer industry, the small companies are the leading companies in forming Virtual Enterprises [Campbell 1998]. Third, Virtual Enterprises are used by smaller companies as a mean to increase their apparent size since they can present themselves to customers as larger organizations.

Table 6.4. Selection Criteria for Partner Selection in Virtual Enterprises.

	Criterion	**Importance (1-9)**
Partner Phase	Technical Capability (TC)	8.1
	Financial Security (FS)	6.9
	Management Ability (MB)	7.4
	Strategic Position (SP)	6.3
	Development Speed (DS)	6.3
	Cost of Development (CD)	6.9
	Delivery Capabilities (DC)	8.5
	Use of Information Tech. (IT)	6.2
Partnership Phase	Cultural Compatibility (CC)	5.8
	Financial Security (FS)	6.9
	Collaborative Record (CR)	7.7
	Business Strength (BS)	6.7

In addition, a selection criterion that takes into account the use of Information Technology is added. This addition may be considered redundant by those that see the use of Information Technology as a prerequisite for forming Virtual Enterprises. Nonetheless, the final decision to whether include the use of Information Technology as a selection criterion or not should be left to the concrete instances of Virtual Enterprises.

Table 6.4 shows the final set of selection criteria and their importance. These criteria and their importance were identified by the survey presented in Chapter 4 and Appendix B.

In summary, this set of selection criteria shows that considering only cost, quality and time in the selection of partners in Virtual Enterprises is an oversimplification of the partner selection problem in Virtual Enterprises [Kluber 1998]. The set of selection criteria presented above takes into account factors related to outsourcing and factor related to the strategic and market oriented nature of Virtual Enterprises.

The next section compares two of the decision-making methods that can be used to carry out the partner selection as well as numeric examples of these methods.

6.4 Decision Making Methods

Section 6.2 explained that decision-making methods are used by the Decision Rule unit of the decision-making problem. This section presents two decision-making methods: The Analytical Hierarchy Process and Axiom II from Axiomatic Design. The main different between these two methods is how they perform the ranking of the alternatives or potential partners. The Analytical Hierarchy Process ranks the all the alternatives according to their satisfaction of the attributes (selection criteria). Axiom II, on the other hand, not only ranks the alternatives, but also considers how the alternatives match the satisfaction rules.

6.4.1 The Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) [Saaty 1980] is a methodology for modeling unstructured decision-making problems. Unstructured decision making problems are those in which there is not a clear arrangement of the components of the problems. Based on a system viewpoint, AHP simultaneously analyzes the structural and functional perspective of a decision-making problem.

The structural perspective deals with the arrangements of the system components. These arrangements or decompositions are based on a physical (or others) organizing principles and according to a certain type of flow. The flow defines the relationships and dynamics of the system structure. Different types of flows, such as the flow of materials, people or information may be used. This decomposition identifies quantitative and qualitative relations among the different aspects of the problem (dimensions).

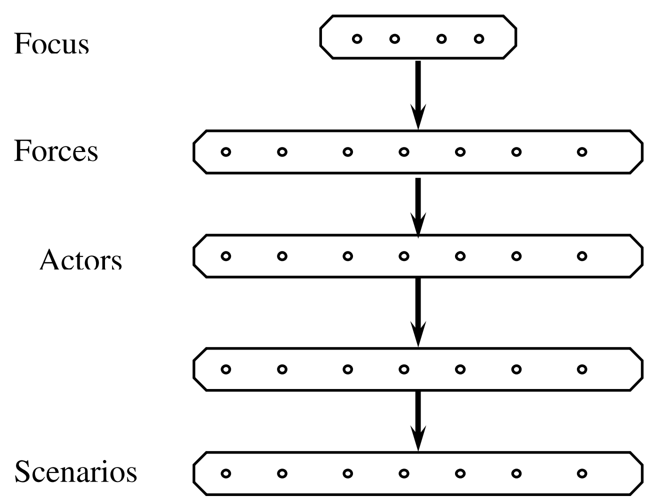


Figure 6.4. General Hierarchy of AHP.

The functional perspective addresses the functions that the system is expected to serve. It considers the objectives a system component should fulfill. In a hierarchical decomposition based on functions, components in lower levels contribute to higher levels of the hierarchy and to the overall objectives or focus of the decision-making problem. In this way, the structure becomes a vehicle for analyzing the functionality of the system. Furthermore, in the same process the function dynamically influences the structure of the system represented by the hierarchy.

Fig. 6.4 shows a general hierarchy representation of a decision-making problem according to the Analytical Hierarchy Process. The overall objectives (focus) are located at the highest level of the hierarchy. In contrast, the scenarios or alternatives occupy the lowest level. These two levels are always present in any decision problem. Between these two extremes, other levels may appear depending on the complexity of the decision-making problem. As the complexity of the decision-making problem increases, the hierarchy becomes deeper (i. e. it has more levels). Objectives are decomposed into sub-objective. Sub-objectives influence the objectives and reduce the complexity associated with measuring the objectives. The forces in a decision-making problem affect the sub-objectives. These forces, in turn, are influenced by the actors or people involved in the decision. Actors on the other hand, represent their own objectives and policies. The objectives are influences by the strategies. Finally, the scenarios or alternatives influence the strategies.

One of the properties of Analytical Hierarchy Process (AHP) is its ability to analyze the influence of lower levels on higher levels of the hierarchy. For example, it is possible to analyze the influence of the strategies on the actors or on the overall objectives of the decision-making problem. Moreover, it assumes that given a set of n activities, the decision-maker is capable of providing judgment of the relative importance of each activity against others. Judgments are quantified in such a way that their qualitative interpretations are also taken into account. Based on these assumptions, AHP provides a framework for a quantitative and qualitative use of information about the decision-making problem.

The calculation process, first, transforms the judgments of the decision-maker from qualitative to quantitative. This transformation provides a set of weights associated with individual components of the hierarchy. Second, the method determines the relative importance of each component in the hierarchy. Finally, the alternatives are ranked according to their impact on the objectives or focus of the hierarchy.

The following example illustrates the algorithm used by the Analytical Hierarchy Process to rank a given set of alternatives. The hierarchy shown in Fig. 6.5 represents a decision problem. This is a simple hierarchy composed of only three levels: objectives, criteria, and alternatives. The overall objectives of the problem, **O** = {o_1, o_2, … o_p } ∀ p ≥1, the criteria or attributes used to measure these objectives **C** = {c_1, c_2, … c_m } ∀ m ≥1, and the alternatives available, **D** = { d_1, d_2, … d_k }∀ k ≥1.

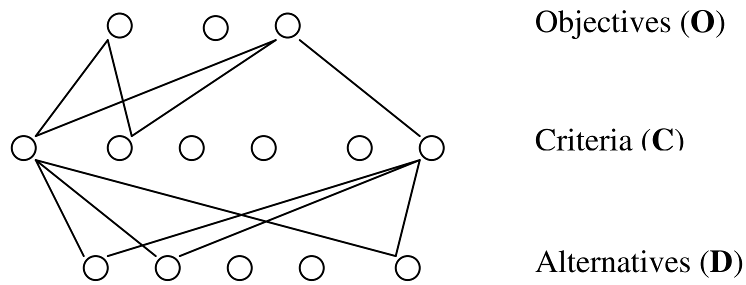


Figure 6.5. A three levels hierarchy

Starting from the lower level of the hierarchy, the algorithm compares each of the alternatives (third level of the hierarchy) with respect to each criterion (elements of the second level). Each comparison only considers two alternatives at a time. It answers the question about which of the two alternatives is most influential for a given criterion. The decision-maker uses a scale that qualitatively classifies the strength of the influences. These qualitative magnitudes are associated with numeric values and are shown in Table 6.5.

Table 6.5. AHP Primary Comparison Scale.

Result of the Comparison	Scale Value
Equally	1
Weakly	3
Strongly	5
Very strongly	7
Absolutely	9

Let us assume that the qualitative preferences for the criterion C_1 for three alternatives are as shown in Table 6.6. The content of this table reads as follows. The decision-maker indicates that alternative D_2 is absolutely more than alternative D_1. Therefore the element (D_2, D_1) is assigned a value of 9 . Alternative D_3 is weakly more important that the alternative D_1, thus element (D_3, D_1) is assigned the value 3. Alternative D_2 is strongly more important than alternative D_3 hence element (D_2, D_3) is assigned a value of 5. The rest of the elements of the matrix are obtained as reciprocals of the values of the elements already known. That means, for example, the element (D_2, D_1) = 1 / (D_1, D_2). In addition, each alternative is considered as equally important with respect to itself.

Table 6.6. Pairwise Comparison Matrix for Criterion C_1.

	D_1	D_2	D_3
D_1	1	1/9	1/3
D_2	9	1	5
D_3	3	1/5	1

Each of the comparisons performed to obtain Table 6.6 is called pairwise comparison. The matrix obtained as a result of the pairwise comparisons is called, thus pairwise comparison matrix.

Once the elements of the matrix are identified, a priority vector is calculated. This priority vector is the right eigenvector of the pairwise comparison matrix. The priority vector identifies the overall preferences of the decision-maker for the criterion C_1.

To measure the deviation from consistency the method uses the Consistency Index (CI). It is calculated as $(\lambda_{max} – n)/(n-1)$, where λ_{max} is the larger eigenvalue and n is the order of the matrix.

The Consistency Ratio (CR) is defined as the ratio between the Consistency Index (CI) and Random Index [Saaty 80]. The values for RI depend on the order, n, of the comparison matrix. It is suggested that CR should not be larger than 0.1 or 10% in order to guarantee an acceptable consistency.

Following a similar procedure, the preferences for all criteria are found. Afterwards, a matrix is formed with all the priority vectors of the criteria. In this matrix, the columns represent the criteria **C** and the rows the alternatives **D**.

Priority vectors for each objective with respect to each criterion **C** (second level of the hierarchy) are determined following a similar procedure. The final priority vector is calculated as shown in Eq.6.2.

$$P_{vo} = AC \text{ x } (CO)^T \qquad (6.2)$$

where:

P_{vo}: Priority vector of objectives,

AC: Priority vectors matrix of the alternatives-criteria, and

CO: Priority vector matrix of the criteria-objectives

for i = 2 to L, L: levels in the hierarchy

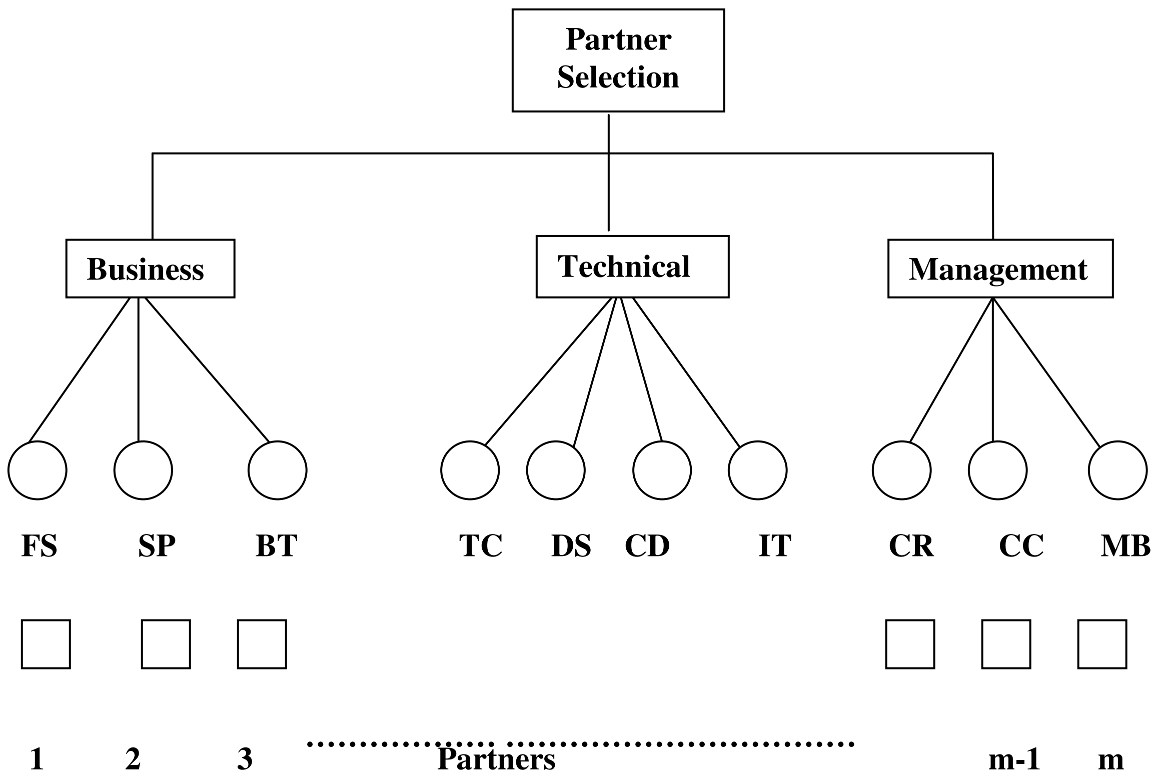
- Pairwise comparison matrix A_i
- Obtain the largest eigenvalue of A_i, λ_{max}
- Calculate eigenvector for λ_{max}
- Calculate Consistency Index (CI); CI =(λ_{max} - n) / (n-1); n: matrix order
- Calculate Consistency Ratio (CR); CR = CI/R

Obtain the final composite priority vector (PV) of influence of the problem:

$$PV = \prod_{i=L}^{1} A_i$$

Figure 6.6. Analytical Hierarchy Process Algorithm.

This priority vector ranks all the alternatives **D**, according to the preferences of the decision-maker. These preferences are obtained from the pairwise comparison matrices, like the one shown in Table 6.6. The general algorithm of the Analytical Hierarchy Process for a hierarchy of L levels is shown in Fig.6.6.



FS: Financial Security
CD: Cost of Development
CR: Collaborative Record
MB: Management Ability
SP: Strategic Position
TC: Technical Capabilities
CC: Cultural Compatibility
IT: Information Technology
BS: Business Strength
DS: Development Speed

Figure 6.7. Representation of the Partner Selection Problem using AHP.

The hierarchy used for the partner selection problem is derived from the decomposition of the objectives explained in Section 6.2. Fig. 6.7 shows the hierarchy used for selecting partners. It can be seen that the selection criteria are divided in three clusters. These clusters allow the decision maker to focus selectively on the criteria that are more important for a given situation. The method allows, for example, changing the relative important of the business cluster in relation to the management and technical cluster. The lower level of the hierarchy contains the potential partners.

6.4.2 Axiom II from Axiomatic Design

Axiomatic Design [Suh 1990] was introduced in Chapter 4 during the analysis of Virtual Enterprises as systems. Axiom II (Information Axiom) deals with the selection of the "best" design of all possible design identified by Axiom I.

Axiom II guides the decision making process for the selection of design alternatives Axiom II does not have to be applied only within the boundaries of Axiomatic Design.

Information Axiom (Axiom II) states that from all design alternatives that satisfy Axiom I, the alternative with smaller information content is the best. Associated with the Axiom II is the concept of information. Information content is the minimum amount of information required to completely describe a system, process, or activity.

Axiom II requires the decision-maker to consider each criterion from two viewpoints: individual view and system view. The individual view uses the selection criteria to independently evaluate the quality of each alternative. The evaluation is independent since alternatives are evaluated according to their own merits regardless on what the system view may require. The system view, on the other hand, establishes the desired value of each criterion without considering what the alternatives available are. The values assigned to the criteria may be ideal or not depending on the choice of the decision-maker. The decision-making is based on how each alternative satisfies the requirements of the system. The alternative with a higher level of satisfaction is the one chosen.

In a general form, the selection criteria in these two views may follow probabilistic distributions. Fig. 6.8 illustrates a possible representation of the individual and system ranges for a criterion that follows a uniform distribution. The common range is the overlapping region between the individual and system range.

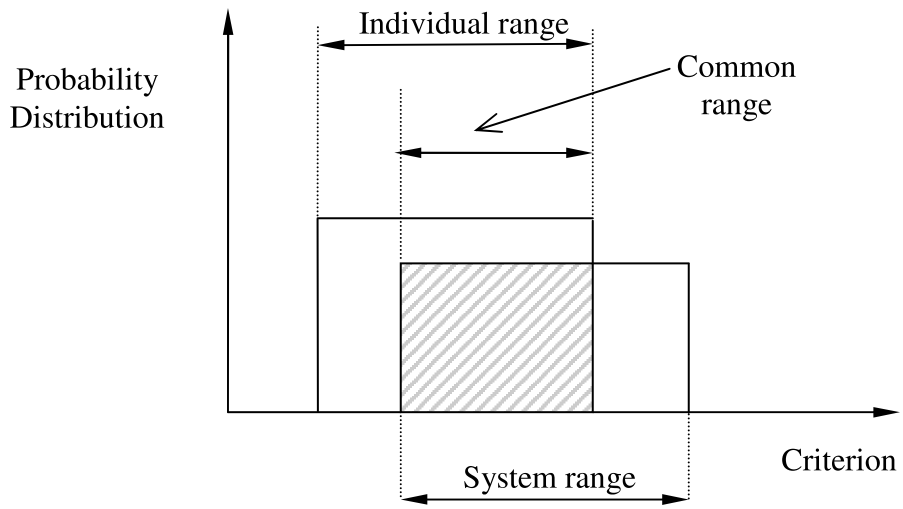


Figure 6.8. Probability Distribution of the Individual and System Ranges.

For the probability distribution in Fig. 6.8, the information content (***I***) can be defined as in Eq. 6.3 [Nakazawa and Suh 1984 and Nakazawa 1985]. ***I*** represents the probability success of the system, when a given criterion is chosen.

$$\boldsymbol{I} = \ln \text{(System range/ Common range)} \qquad (6.3)$$

If the individual range equals the system range, the information content for a criterion is zero ($\boldsymbol{I} = 0$). That is, the range (value) of a given criterion fully satisfies the requirements of the system. On the other hand, if the common range is zero, the information content becomes infinite ($\boldsymbol{I} = \infty$). That means that the system requires an infinite amount of information to use this criterion.

It should be noticed that the information content of each criterion is dimensionless. Therefore, criteria with different measuring units can be combined, since the units of the criteria cancel out, during the calculation of the information content. The total information content of a given alternative is the sum of the information content of each individual criterion. This expression holds even when the criteria are statistically dependent [Nakazawa and Suh 1984]. In the case that selection criteria are statistically dependent, the individual and system ranges are expressed in terms of conditional probability. The selection of the best alternative is based on how the alternative minimizes the information content of the he problem.

6.4.3 Comparison of Methods

The comparison of the Analytical Hierarchy Process and Axiom II from Axiomatic Design is based on the components of the decision making problems presented in Section 6.2.

The decision-making unit is similar for all the methods. It may be composed of one or more decision-makers. Each method considers objectives and attributes differently. The Analytical Hierarchy Process uses the hierarchy decomposition as an integral part of the decision-making process. The hierarchy simplifies the complexity of the decision-making by dealing with subset of the components of the decision-problem. The information derived from the hierarchy is used to analyze the influence of the lower levels on the higher levels of the hierarchy. This is a useful since it allows “what-if” analyses. These analyses explore the effects of the changes of one or more components, in the overall objectives of the system.

Axiom II uses the hierarchy to reduce complexity and improve the objectivity. Similarly to the Analytical Hierarchy Process, the objectives become more concrete in lower levels of the hierarchy,. Carrying out “what-if” analyses with Axiom II is more complex than with the Analytical Hierarchy Process, since Axiom II needs to re-evaluate the criteria for both individual partners and the Virtual Enterprise as a whole (system range).

Regarding the decision situation unit, the Analytical Hierarchy Process does not require the ideal or desired state of the system as input, like Axiom II does. Axiom II needs to know the requirements of the system to make a decision. Axiom II may use probabilistic formulations to deal with risk, uncertainty, and subjectivity. The Analytical Hierarchy Process, on the other hand, does not deal directly with these situations. AHP uses pairwise comparisons to determine the priorities of one of the elements of the hierarchy with respect to another. The result of the comparison may perfectly take into account risk, uncertainty, and subjectivity, but their consideration is not explicit to the decision-maker.

The analysis of the decision rule also shows differences between these two methods. The Analytical Hierarchy Process uses an optimizing rule. It also ranks the alternatives in the problem and choose the one that either maximizes or minimizes the decision making rule. Axiom II, in contrast, first take into account the needs of the system and then selects the alternative that minimizes the overall information content. In short, AHP uses an optimizing decision rule, while Axiom II uses a satisfying rule.

The above analysis shows that each method has both advantages and disadvantages. The decision-maker needs to select the method that better satisfies the need of the problem under study.

The disadvantage of the Analytical Hierarchy Process is the so-called rank reversal. Rank reversal refers to the case in which the final ranking of alternative is changed by the addition of slightly different new alternative. This behaviour of AHP has generated strong criticisms [French, 1988, Dyer, 1990]. Critics suggest changing the way in which AHP carries out the pairwise comparison may solve this problem. The replies from AHP creators and practitioners have been that rank reversal is an intrinsic characteristic of the method that can even be beneficial [Saaty 1990, Harker and Vargas 1990]. The rank reversal is avoided when criteria are normalized to consider their differences in measuring units [Lane and Verdine 1989, Eelko et al. 1997].

The criticism of Axiom II refers to the difficulties associated with the evaluation of the information content in some practical situations.

In this section two decision-making methods commonly used in practice have been presented. The Analytical Hierarchy Process (AHP) uses a hierarchy representation of the decision-making problem to explore the influence of lower levels of the hierarchy on higher levels. In addition, it simplifies decision-making efforts by comparing only two given components at a time, through pairwise comparisons. The method ranks the alternatives according to how they influence the objectives of the decision. Axiom II from Axiomatic Design evaluates the alternatives by considering the individual quality of the alternative and the demands from the system. The alternative with smaller information content is the best.

The main difference between both methods is the decision rule. The Analytical Hierarchy Process uses an optimizing rule, while Axiom II uses a satisfying rule.

The next section presents a case study in which these two methods are implemented and compared.

6.5 Case Study

This section compares the Analytical Hierarchy Process and Axiomatic Design using the values of the selection criteria obtained from the survey presented in Chapter 4. The objective of this section is to compare the ranking from both methods. This comparison makes it possible to draw conclusions about the advantages and disadvantages of using these methods in the partner selection process.

To facilitate the comparison of the methods, the Management, Technical and Business clusters are considered equally important in the selection process.

Table 6.7 shows the evaluation of the selection criteria for nine (9) partner companies from the respondent of the survey.

Table 6.7. Evaluation of the Selection Criteria for Partners.

	Criterion Partners	1	2	3	4	5	6	7	8	9
1	Technical Capabilities (TC)	7	8	7	7	8	8	8	9	7
2	Development Speed (DS)	7	4	7	5	8	2	7	2	7
3	Financial Security (FS)	5	8	8	8	6	7	7	9	8
4	Collaborative Record (CR)	8	6	7	6	8	8	7	9	7
5	Business Strength (BS)	7	8	7	5	6	7	5	7	7
6	Cost of Development (CD)	6	6	7	7	9	8	8	9	7
7	Cultural Compatibility (CC)	8	5	7	7	6	7	5	3	7
8	Strategic Position (SP)	7	6	6	5	5	7	7	7	6
9	Management Ability (MB)	6	6	8	7	8	7	7	7	8
10	Use of Information Technology (IT)	5	5	3	7	5	5	5	4	5

Table 6.8 shows both a global and local (cluster based) relative importance for each criterion. The global importance is the weight of the criteria as determined in Chapter 4, during the analysis of the selection criteria. The local importance, on the other hand, is the weight given to the criteria using the comparison scale of Analytical Hierarchy Process. Local weights are calculated considering only elements in the same cluster. For example, the Cultural Compatibility (CC) criterion has a global relative importance of 5.8 and a local importance of CC of three (3), since it is the least important criterion in the Management cluster.

Tables 6.9 to 6.11 show the pairwise comparison matrices and the priority vectors for the criteria in the third level of the hierarchy with respect to the clusters in the second level. In addition, they show the largest eigenvalue, Consistency Index (CI) and the Consistency Ratio (CR) of each pairwise comparison matrix. It can be seen that all the pairwise comparison matrices have a CR smaller than 0.1 and therefore are considered consistent. The priority vector for each matrix identifies the most important criterion in each cluster.

Table 6.8. Global and Local Rankings of the Selection Criteria.

Cluster	**Criterion**	**Global Importance**	**Local Importance**
Management	Cultural Compatibility (CC)	5.8	3
	Management Ability (MB)	7.4	5
	Collaborative Record (CR)	7.7	9
Technical	Technical Capability (TC)	8.1	9
	Development Speed (DS)	6.3	5
	Cost of Development (CD)	6.9	7
	Information Technology (IT)	6.2	3
Business	Strategic Position (SP)	6.3	3
	Financial Security (SE)	6.9	9
	Business Strength (BT)	6.7	5

It can be noticeed that the relative importance among criteria is maintained in the priority vectors. In the Management cluster, for example, Collaborative Record (CR) ranks first with a value of 0.49. This result is consistent with the importance assigned to this criterion earlier. Similarly, Technical Capability ranks first in the Technical cluster with a priority vector of 0.38. The priority vector for the Business cluster ranks first Financial Security, with a value of 0.53

Table 6.9. Priority Vector for Management Cluster.

	CC	CR	MB	PV
CC	1	0.6	0.33	0.1860
MB	1.7	1	0.55	0.3205
CR	3	1.2	1	0.4935

λ_{max} = 2.91, CI = 0.0450, CR = 0.0126

Table 6.10. Priority Vector for Technical Cluster.

	TC	DS	CD	IT	PV
TC	1	1.8	1.3	3	0.3792
DS	0.55	1	0.71	1.7	0.2143
CD	0.77	1.4	1	2.33	0.2857
IT	0.33	0.6	0.43	1	0.1208

λ_{max} = 3.95, CI = 0.0159, CR = 0.0176

Table 6.11. Priority Vector for Business Cluster.

	SE	SP	BS	PV
SP	1	0.33	5	0.1699
FS	3	1	1.8	0.5274
BS	1.7	0.6	1	0.3027

λ_{max} = 2.99, CI =0.001, CR = 0.0

Table 6.12 depicts the system and design ranges for the selection criteria. These ranges are chosen by the decision-maker or the Virtual Enterprise, prior to performing the selection process. For this case study, these ranges followed a uniform probability distribution.

Table 6.12. System and Design Ranges for Selection Criteria.

Cluster	Criterion	System Range	Design Range
Management	Cultural Compatibility (CC)	2.23	1
	Management Ability (MB)	1.24	1
	Collaborative Record (CR)	1.15	1
Technical	Technical Capability (TC)	1.01	1
	Development Speed (DS)	2.72	1
	Cost of Development (CD)	2.32	1
	Information Technology (IT)	2.14	1
Business	Strategic Position (SP)	1.82	1
	Financial Security (SE)	1.59	1
	Business Strength (BT)	1.55	1

The result of the Analytical Hierarchy Process and Axiom II are summarized in Table 6.13. It can be seen that both methods provide different rankings for the companies. AHP ranks first the 9th company, while Axiom II ranks first, the 5th company. It should also be noted that companies 5 and 9 switch ranking positions. Still more interesting is the fact that the information content for companies 6 and 8 is infinite. This fact remains unnoticed in the AHP ranking. Nonetheless, company 6 ranks last in AHP.

Table 6.13. Ranking from AHP and Axiom II.

Ranking	AHP		Axiom II	
	Partner	Priority Vector	Partner	Information Content (I)
1st	**9**	0.122	**5**	6.53
2nd	**3**	0.120	**7**	6.70
3rd	**5**	0.118	**9**	7.06
4th	**7**	0.116	**1**	8.80
5th	**4**	0.111	**2**	9.16
6th	**8**	0.107	**4**	9.43
7th	**2**	0.106	**3**	10.97
8th	**1**	0.104	**6**	∞
9th	**6**	0.096	**8**	∞

6.6 Summary

This chapter analyzed the Partner Selection Problem in Virtual Enterprise. First, it introduced a time dependent formulation of problem in Virtual Enterprises. The formulation considers the partner companies, the activities to be performed, their specifications, and the selection criteria to be used during the selection process. All these parameters are time dependent and therefore, the partner selection problem in itself becomes time dependent. The inclusion of time in dealing with the partner selection problems makes it possible to carry out the selection process at any time during the design or management phase.

The chapter also analyzed the partner selection as a multi-criteria decision making problem. It was shown, that the partner selection problem has all the units of a decision making problem. The Decision Situation and Decision Rule units were analyzed in more detail. The Decision Situation unit includes the attributes or selection criteria used in the selection process. The Decision Rule unit includes the decision making methods for ranking the alternatives.

The set of selection criteria for partner selection in Virtual Enterprises includes criteria used in outsourcing and strategic alliance decision making, as well as other criteria specific to Virtual Enterprises.

Two decision making methods were studied; the Analytical Hierarchy Process and Axiom II from Axiomatic Design. The main difference between these two methods is the rule they use to rank alternatives. The Analytical Hierarchy Process uses an optimizing rule, while Axiom II uses a satisfying rule.

The chapter concluded with a short case study evaluating the ranking obtained by these two methods. The methods provide similar, but not equal rankings.

7 Robust Management of Virtual Enterprises

7.1 Introduction

Chapter 2 analyzed the three phases of the life cycle of a Virtual Enterprise. These phases are design, management, and disbanding. In the design phase, the objectives and functional requirements of the future organization are established. In addition, the partners companies are selected. The management phase, on the other hand, deals with how to achieve of the objectives and how to satisfy the functional requirements identified in the design phase. Partners integrate their core competencies, management style, corporate culture as well as business practices to work as one monolithic organization. Finally, the disbanding phase deals with ending the relationship among partners, and eventually the evaluation of the results of the collaborative work.

However, a Virtual Enterprise faces of internal and external influences during its life. Changes in the management of the partners companies or in the market place are just two of many examples. These changes affect the satisfaction of the initial goals and objectives of the Virtual Enterprise. More importantly, they may cause the disbanding of the organization.

The objective of robust management of Virtual Enterprises is to achieve the best possible performance of the organization by considering the influence of internal and external factors. It should make possible for Virtual Enterprises to live their full life cycle and succeed even when the initial conditions in which they were formed change.

This chapter presents a methodology for the robust management of managing Virtual Enterprises. First, the most important definitions in Robust Design are introduced. Second, a management methodology for Virtual Enterprises based on robust design principles is presented. Third, numerical experiments are performed for investigate the effect of control and noise factors on the management of Virtual Enterprises.

7.2 Robust Design

Robust Design is an engineering methodology used to achieve high quality products at lowest possible cost[1] [Phdake 1989]. It is a cost-effective solution to reduce the variation in the product performance in the customer environment. By helping products perform as expected, Robust Design contributes to improve customer satisfaction.

The foundations of Robust Design are found in experimental design theory. By planning statistical experiments, Robust Design obtains dependable information about the decision-making parameters involved in the design process. However, Robust Design is more than the application of statistical experimental design principles. It uses experimental design from an engineering perspective to reduce cost, improve quality and the product development life cycle, and optimize of the performance of products

At the center of Robust Design is the concept of quality. Ideally, quality is the ability of a product to perform as expected without harmful consequences. Products should achieve their target performance under all intended operating conditions, during its complete life cycle [Phdake 1989]. Alternatively, quality can be defined as the combination performance characteristics that make a product attractive to a customer and the ability of the product to deliver the expect performance [Fowlkes and Creveling 1995]. The product should perform on target not once, but each time it is

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[1] The application of Robust Design is not restricted to products. It also may be applied to processes and services.

used during its expected life. In addition, the performance of the product should be achieved under all its operating conditions.

A lost of quality occurs when the performance of a product deviates from the target performance. Taguchi [1993] measures the loss of quality in terms of the total loss incurred by society as a whole, when products fail to perform as expected. If a product performs on target, the loss of quality is zero. As the performance of a product deviates from its target value, the loss of quality increases. The ideal quality or a zero deviation from performance may not be economically feasible. However, it still can provide guidelines about practical values for the design and manufacturing of a product.

Robust Design aims to achieve the highest possible quality of a product, by considering the causes that affect its performance. The impact of these causes of variations is minimized through a procedure called parameter design. This procedure optimizes the design of a product by identifying the sources of variations in its performance and reducing the effects of those causes. Parameter design does not attempt to eliminate the causes of variations. It is only concerned with reducing their negative effects, since many of these causes are beyond the control of the designer. For example, factors such as the conditions of the road and the weather influence the performance of an automobile. These conditions are difficult to predict accurately. Nonetheless, Robust Design tries to minimize the effect of these factors on the performance of the automobile.

The benefits of Robust Design are multidimensional. It improves product quality, performance, and engineering productivity. In addition reduces cost[2]. Product

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[2] The term cost includes both before and after sale costs. The cost before sale considers the expenses associated with all the activities related to a product from the original idea to its delivery to a customer. The after sale cost relates to the loss of quality. It includes the expenses due to the recall of the product and more importantly its impact in customer satisfaction.

quality improves, since the products are able to perform as expected during their complete life cycles without dangerous side effects. On the other hand, it increases engineering productivity, by simultaneously studying the effect of several design parameters with less experimental efforts[3]. Besides, it improves the efficiency of the decision-making process. Decision-makers can concentrate on the selection of the best combination of the design parameters rather than on performing the experiments. The best combinations of design parameters are those that minimize the variations in the performance of the product. A more efficient decision-making process means that companies can produce products faster. A faster decision-making process helps to keep development and manufacturing cost low and to achieve high quality products.

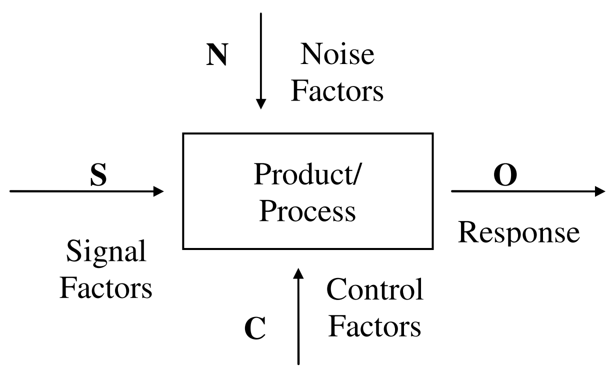


Figure 7.1. P-Diagram for the robust management of Virtual Enterprises.

Instrumental to Robust Design is the P-diagram shown in Fig. 7.1. The P diagram is a general representation of the four types of factors that appear in any product, process, or services. The diagram is composed of four components: signal factors (S), noise factors (N), control factors (C) and output or response (O) [Phdake 1989]. The signal factors are the parameters set by the user of a product or the controller of a process. A signal factor also causes a certain response in the product or process.

[3] For example, Robust Design needs nine experiments to study the effect on a product performance of four variables that take three different values. In contrast, the study of the effect of each variable independently needs 64 (4^3). This difference becomes larger as the number of variables grows.

Signal factors are chosen based on the knowledge about the process or product under study. For example, at a very simplified level, an automobile moves faster because the driver presses the gas pedal deeper. In this case, the pressure on the gas pedal is the stimulus (signal factor) that causes the car to move faster (response).

Noise factors are those parameters that are difficult to control and measure. They can also be parameters that are difficult to predict accurately. The reasons that make a factor hard to control vary widely. They can range from a prohibitively high cost to a lack of adequate way to measure a parameter effectively. Following with the example of the automobile, different road or weather conditions are example of noise factors. It is hard for a designer to predict all the different road conditions in which the car will function. They are the factors responsible for the loss of quality in a product or process.

Noise factors can take different values called levels. These levels may vary as a function of time, the environment and even different instances of the same product. For instance, the road can be asphalt, gravel or sand. The speed of the car because of a higher pressure on the gas pedal for these road types together with the weather conditions is hard to predict. Furthermore, the response of the car depends on the time the automobile has been in use and the vehicle itself. In general, it is possible to specify some of the statistical characteristics of the noise factors but not exact values.

Control factors, on the other hand, are parameters set by the designer. These parameters are set in such a way that the product performs as expected. In the example of the automobile, the output torque from the engine increases, when more pressure is applied on the gas pedal. The torque is transmitted, then, to the wheels and the car moves faster. The designer can specify the torque required to move the car at certain speed. Control factors take different values or levels, similarly to noise factor. The levels of control factor could have both positive and negative effects on other parameters related to the product or process, such as cost. Some levels may increase cost, while other can keep the cost unchanged or even decrease it.

A response is the output of the product or process. It is the reaction of the product or process to the input of signal factors. A product can have more than one response due to signal factors. This response is defined in Robust Design as quality characteristic.

The application of Robust Design requires three steps: (1) experimental planning, (2) performing the experiments, and (3) selection and verification of the optimum of control factors.

The experiments are planned using the information obtained from the P-diagram. This step, first, identifies the main functions, side effects and failure modes of the product or process. Second, the noise factors and the testing conditions for evaluating the quality loss are set. Third, the quality characteristic to be measured and its objective function are chosen. Fourth, the control factors and their levels (values) are identified. This step finishes with the selection of the experimental matrix. The matrix is chosen based on the number of control factors and it determines the number of experiments to be performed. In addition, it establishes the levels of the control factors that can be studied. Section 7.3 deals with the implementation of the planning phase for the robust management of Virtual Enterprises.

Once the experiments are performed, the analysis of results identifies the optimum levels of the control factors. It is possible, then, to predict the performance of the product or process when the optimum values of the control factors are used. Confirmation or verification experiments are performed to validate the accuracy of the optimum values of the control factors under different operating conditions. Verification experiments also identify interactions among factors. Section 7.4 covers the analysis of results and identifies the optimum levels of the control factors for the robust management of Virtual Enterprises.

7.3 Robust Management of Virtual Enterprises

The principles of Robust Design can be used to manage Virtual Enterprises and monitoring their performance. By using Robust Design principles in Virtual Enterprises, the influences of control and noise factors on the management of Virtual Enterprises can be studied. This approach allows a Virtual Enterprise to achieve the best possible performance, while satisfying the objectives of the organization.

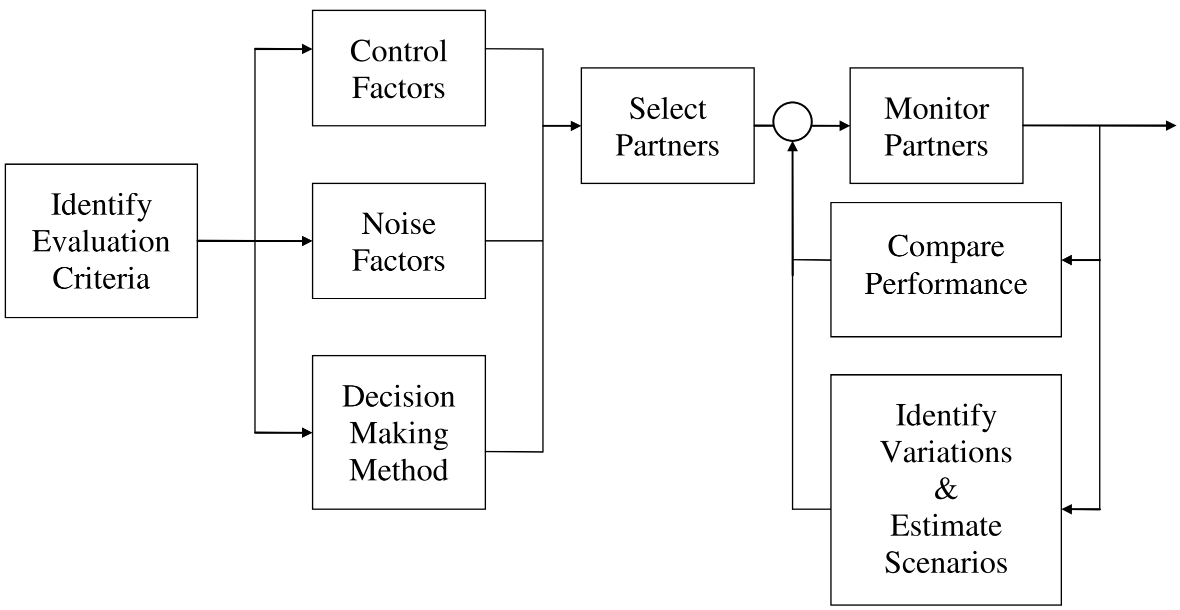


Figure 7.2. Methodology for a Robust Management of Virtual Enterprises.

A methodology for robust management of the Virtual Enterprises is shown in Fig. 7.2. It follows five steps.

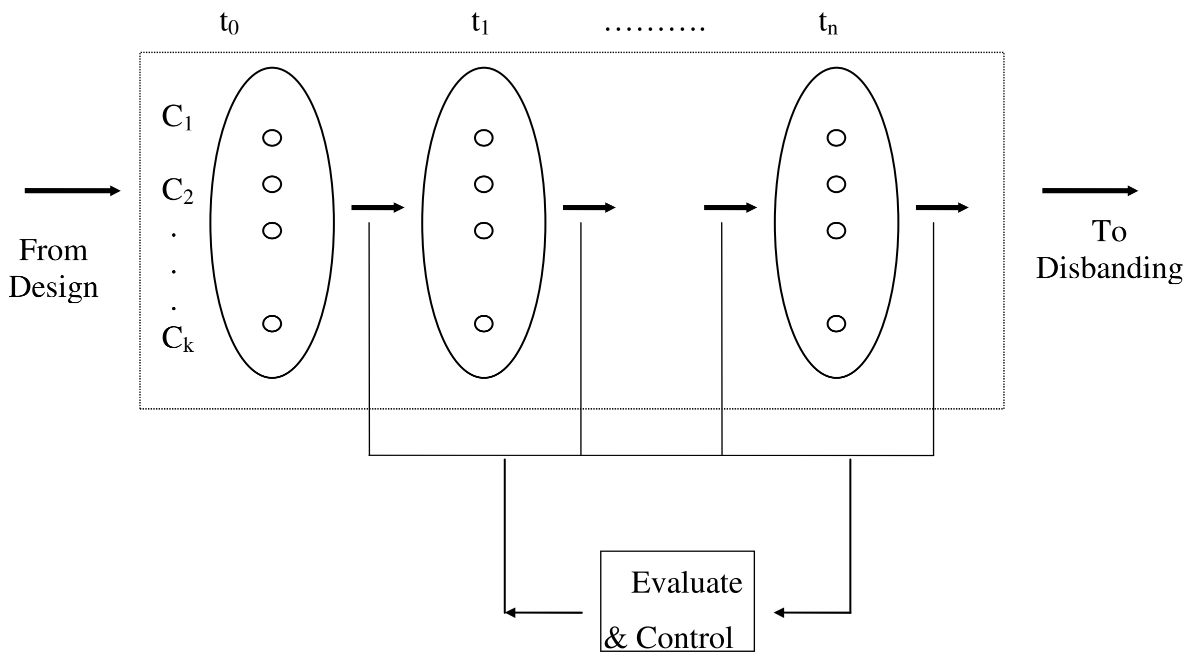
1) Identification of the evaluation criteria,
2) Identification of the components of the P-diagram,
3) Selection of the decision-making method,

4) Selection of partners companies, and
5) Monitoring.

First, the criteria for selecting and evaluating partners' performance have to be chosen. Once these criteria are known, the four components of the P-diagram can be identified. Selection criteria are divided into control and noise factors, according to the ability of measuring them accurately. The signal factor (S) is the input to the management process. It represents the desired level of performance of the Virtual Enterprise. It is worth noting that achieving the highest level of performance might not be always possible. Factors such as the unavailability of specific core competencies may require setting of a lower level of performance. Further, it is possible to conservatively estimate the success rate of a Virtual Enterprise and leave some room for errors, omissions, and inconsistencies.

The third step requires the selection of the decision-making method to be used for selecting and evaluating partner companies. After the decision making method is chosen, an initial evaluation of the performance of the process should be conducted. This evaluation is carried out with the initial values of the control and noise factors. That is, the values used for selecting partner companies as members of the Virtual Enterprise. The results of the evaluation serve as references for measuring future variations in the control and noise factors, as well as in the overall performance of the Virtual Enterprise.

Considering Virtual Enterprises as systems makes it possible to consider the individual contribution of partner companies (or subsystems) to the overall system. Each partner plays a role in the overall output of the process. Therefore, the success of the process can be evaluated by considering the performance of each member. In addition, this evaluation needs consider the overall goals of system. The fact that overall objectives of the Virtual Enterprise play a more important role than objectives of individual members is instrumental in the stability and success of the organization.



$t_0, t_1, t_2, \ldots t_n$: stages (time steps) $C_1, C_2, C_3, \ldots C_k$: evaluation criteria

Figure 7.3. Management phase as a consecutive set of time dependent stages.

Appendix B explains the need for a regular evaluation of the partners' performance in Virtual Enterprises. Evaluation should be carried out regularly to avoid variations that can lead to the disbanding of the organization. The management phase can be divided in a series of consecutive stages toward a goal, as shown in Fig. 7.3. These stages represent the variation in time of the partners' performance. Once the individual performances are known, the overall performance can be estimated by taking into account partners' contributions and the objectives of the Virtual Enterprise as a whole.

This approach makes it possible an early detection of irregularities and problems. If significant changes are detected, their effects on the overall management of the Virtual Enterprise are estimated and corrective measure can be taken. These corrective measures contribute to keep the management process under control. The feedback from the output to comparison stage helps guiding the process towards its most desirable outcome.

7.4 Case Study

The selection of the criteria or factors for measuring the performance of Virtual Enterprises is the first step in the methodology. It is also critical to its successful application. In the selection of these criteria, the following two goals were set. First, the criteria should measure as effectively as possible the performance of both partner companies and the Virtual Enterprise as a whole. In addition, the criteria should link the design, management, and disbanding phases. Chapter 2 explained that the life cycle of Virtual Enterprises is an interconnected process, where the outputs of one phase are the inputs of the next phase. Therefore, the ability of these criteria to provide such a link is important.

Robust management uses the same criteria used for selecting partners in the design phase. These criteria represent the objectives and functions that a Virtual Enterprise should fulfill. Similarly, if the Virtual Enterprise already exists, these criteria can be used to evaluate the performance of individual members, as well as of the organization. They measure the capabilities and competencies of the members of the Virtual Enterprise to work together successfully and achieve the objectives of the organization.

The criteria used for the management of Virtual Enterprises are those identified in Chapter 4. They are summarized in Table 7.1. However, each phase of the Virtual Enterprise life cycle uses them differently. The design phase considers the ideal or most desirable tendency of these criteria. For example, the technical capabilities, development speed, financial security, and business strength criteria are expected to be as high as possible. Moreover, the cost of development should be as low as possible, without sacrificing the quality of the product or service offered by the Virtual Enterprise.

On the other hand, these ideal or more desirable tendencies can encounter some difficulties in practice. The management phase considers the actual values that these criteria take for a partner at any stage of this phase. This phase measures the materialization of the ideal tendencies set in the design phase. For instance, the technical capabilities should be as high as possible; however, the evaluation of this criterion can be downgraded, if an essential team member or senior technical staff becomes suddenly unavailable for an extended period. Similar consequences may result when a manager leaves one of the member organizations. Although these examples deal with the influence of the human resources on the actual grading of the selection criteria, other causes may appear.

In the disbanding phase, the comparison among the ideal tendencies, as well as the final and initial values of the criteria can provide an estimation of the performance of a Virtual Enterprise during its life cycle. It should be noticed that the disbanding could take place at any time during the management phase, not only at the end of the relationship. The robust management methodology attempts to identify when both internal and external factors are causing the Virtual Enterprise to deviate from the desirable performance. This behaviour may cause a premature disbanding of the organization. In those cases, corrective actions should be taken.

The comparison between ideal or desirable tendencies versus real tendencies is advantageous. First, it allows for a unified approach in which ideal tendencies and their real values are used throughout the complete Virtual Enterprise life cycle. Second, it simplifies the decision-making procedures due to the underlying commonalties between the tendencies and actual values. Third, it facilitates measuring the overall performance of a Virtual Enterprise and of its individual members.

Table 7.1. Control and Noise Factor for the Robust Management of Virtual Enterprises.

Criterion	Symbol	Control Factor	Noise Factor
Technical Capabilities	TC	X	
Development Speed	DS	X	
Financial Security	FS	X	
Collaborative Record	CR	X	
Business Strength	BS	X	
Cost of Development	CD	X	
Matching Aims	MA		X
Cultural Compatibility	CC		X
Strategic Position	SP		X
Management Ability	MB		X

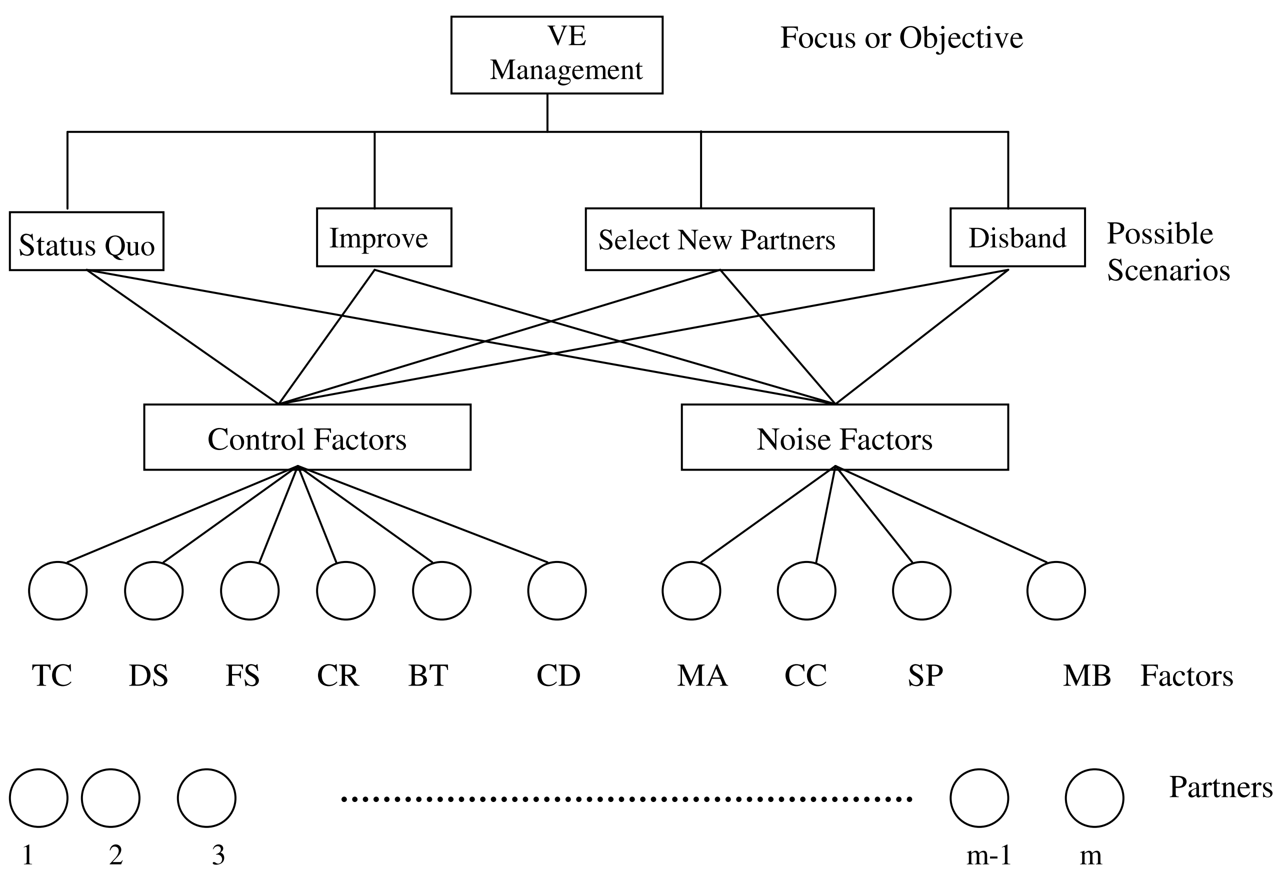


Figure 7.4. Hierarchy of the Robust Management of Virtual Enterprises.

The classification of a factor as either control or noise factor is based on the ability to measure these criteria successfully and effectively in practice. Table 7.1 shows the classification of control and noise factors. Six (6) of the criteria are selected as control factors and four (4) as noise factors. Control and noise factors are selected according to how objectively they can be measured in practice. It can be seen that mainly management and human resources related factors are classified as noise factors. These criteria are considerably more difficult to measure objectively than the ones assigned to the control factor set.

The Analytical Hierarchy Process (AHP) is the decision-making method used in this case. It was introduced in Chapter 6. AHP is used because it allows analyzing the influence of lower levels on the upper levels of the hierarchy. Fig. 7.4 shows the hierarchy used in this study. The focus is the management of the system and its success rate. Four possible scenarios can take place in a Virtual Enterprise and influence the focus. They scenarios are: status quo (SQ) or continuing with the current management strategy, improve the strategy (IP), select new partners (NP) or disband (DB). The next lower level of the hierarchy contains the control and noise factors clusters. This division allows for the isolation of the influences of each cluster in the overall objective of the system. On the next level, the control and noise factors are located. The actors (partner companies) that make a Virtual Enterprise works influence these factors.

This hierarchical representation allows studying the influence of lower levels of the hierarchy on the next upper level. For example, the influence of the partners or member of the Virtual Enterprise on the control and noise factors and their influence on any of the four scenarios can be analyzed.

7.4.1 Experimental Planning

The influences of both control and noise factors on the management of Virtual Enterprises are studied through simulations. These simulations allow identifying the relationships between lower levels of the hierarchy and the focus. Three relationships are of a particular interest:

1) The relationships between the individual control and noise factors (fourth level) and control and noise factor clusters (third level).
2) The relationships between the control and noise factor clusters (third level) and the possible management scenarios (second level).
3) The relationships between the scenarios (second level) and the focus of the hierarchy.

To carry out the simulations the objective functions, the boundaries of the experimental region and the number of experiments to conduct have to be established. The next two sections deals with the selection of the objective functions and the definition of the boundaries of the experimental region.

7.4.2 Identification of Objective Functions

The quality characteristics are the expected responses from the product or process under study. Taguchi [1993] suggests measuring the loss of quality with a quadratic function ($y = x^2$). This choice acknowledges the intuitive understanding of what should be a quality loss function. Taking as a reference the target performance of a product, the quality loss should be small if the response has a small deviation from its target value. As the deviation from the target grows, the loss of quality should also increase.

An objective function optimizes the quality loss function. By optimizing the quality loss function, the quality characteristic is also optimized, since the quality loss function measures the deviation from the target of quality characteristic. Robust Design focuses on the minimizing the deviation from the target rather than in achieving a target value. Those target values are set based on engineering and design considerations. Furthermore, Robust Design minimizes the influences of the noise factors on the problem under consideration. This is the reason why the objective functions are also known as signal-to-noise (S/N) ratio. In general, the S/N ratio is the ratio of the desired response upon the influence of noise factor. They are mathematically expressed taking into consideration the quadratic quality loss function as:

$$S/N = \mu^2/\sigma^2 \tag{7.1}$$

where:

μ: mean (the desired part of the response or signal), and

σ: standard deviation (influence of the noise factors).

To improve the additivity of the effects of the control factors, a logarithmic transformation is applied to Eq. 7.1.

$$\eta = 10 \log_{10} (\mu^2/\sigma^2) \tag{7.2}$$

where:

η: signal to noise ratio (S/N) or objective function

Equations 7.1 and 7.2 are both referred as signal to noise ratios. However, their domains are different. In Eq. 7.1 the domain is $(0, \infty)$, while Eq. 7.2 the domain is $(-\infty,\infty)$. In the latter case, there is a better additivity of the effects of two or more control factors.

The specific form of the S/N depends on the type of responses of product or process. In general, there are two types of problems: static and dynamic [Phdake, 1989]. In static problems, the S/N can be of different types such as: smaller-the-better; nominal-the-best, larger-the-better and signed-target. For example, in smaller-the-better type of problems, the smaller the value of S/N the better the optimization and the solution. This is the case, for instance, of decreasing the losses due to friction in mechanical devices. In dynamic problems, the S/N ratios can be continuos-continuos, continuos-digital, and digital-continuos. For instance, a continuos-

continuos kind of problems has a continuous signal and a continuos response or output. That is the case, for example, of a servomotor.

The type of the objective functions (S/N ratio (η)) used for the elements of first, second and third levels of the hierarchy are shown in Table 7.2. Each objective function was chosen depending on how the element affects the focus or top level of the hierarchy.

Table 7.2. Problem Type and S/N Ratio for the Components of the Hierarchy.

Parameter	Problem Type	Objective Function (η)
Final Rankings	larger-the-better	$-10\ Log_{10}\ (r_1^2)$
Status Quo (SQ)	larger-the-better	$-10\ Log_{10}(r_2^2)$
Improve (IP)	larger-the-better	$-10\ Log_{10}\ (r_3^{\ 2})$
New Partners (NP)	smaller-the-better	$-10\ Log_{\ 10}(1/r_4^2)$
Disbanding (DB)	smaller-the-better	$-10\ Log_{10}\ (1/r_5^2)$
Control Factors (CF) cluster	larger-the-better	$-10\ Log_{10}\ (r_6^{\ 2})$
Noise Factors (NF) cluster	smaller-the-better	$-10\ Log_{10}\ (1/r_7^2)$

r_1: vector of the VE management
r_2: vector of the SQ cluster
r_3: vector of the IP cluster
r_4: vector of the NP cluster
r_5: vector of the DB cluster
r_6: vector of the CF cluster
r_7: vector of the NF cluster

The overall ranking from Analytical Hierarchy Process is analyzed as the-larger-the-better problem type. This means that the larger the ranking a company gets, the larger its contribution to the satisfaction of the management objectives. For the Status Quo, Improve, New Partner selection and Disbanding clusters problem types were set as follows. The Status Quo (SQ) and Improve (IP) scenarios are considered as the larger-the-better type of problem. These two scenarios should be maximized since they contribute to an efficient management. On the other hand, the New Partner selection (NP) and disbanding (DB) scenarios are considered the smaller-the-better type. These two components are considered as having disturbing influences to the management of a Virtual Enterprise. Thus, the sensitivity of the management of the Virtual Enterprise to these two scenarios should be minimized. The case of the Control (CF) and Noise (NF) factor clusters is more evident. The influence of the control factors, as a whole, on the management of the Virtual

Enterprise should be maximized, while the influence of noise factors on management should be minimized.

7.4.3 Design of Experiments

The matrix of experiments in Robust Design is a mean to study the effects of the changes of control and noise factors on the performance of a given product or process. It establishes the experimental region. The region depends on the levels (or values) assigned to each factor to study their effect on the product performance. A matrix of experiments is formed using orthogonal arrays [Taguchi 1993]. An orthogonal array is a type of matrix in which all its columns are mutually orthogonal. That is, each pair of columns has all the combinations of the levels for each factor. Furthermore, each combination appears the same number of times.

An example of an orthogonal array is shown in Table 7.3. This is an L_4 array. It studies up to three factors (the number of columns), each one with two levels or possible values. Taking for example, the first and third column from the array, the following four combinations are obtained: (1, 1), (1, 2), (2, 2) and (2, 1). It should be noted that all the possible combinations of the two factors appear. Indeed, the two factors have the same level once ((1,1) and (2, 2) and different levels twice ((1,2) and (2,1)).

Table 7.3. Example of an Orthogonal Array (L_4).

	Columns		
No.	1	2	3
1	1	1	1
2	1	2	2
3	2	1	2
4	2	2	1

Orthogonal arrays estimate the effects of the parameters more reliably and with fewer experiments. Traditional statistical methods study the effect of the changes of one variable at the time. In contrast, orthogonal arrays produce similar results with fewer experiments [Phdake 1989]. Fewer experiments mean that the effects of a larger number of factors can be studied. This results in products that have better quality and cost less to develop. In addition, it is possible to study the combined effects of individual factors more economically. Therefore, a better understanding of the effects of the factors on the product or process can be obtained.

The choice of a specific orthogonal array depends on three parameters:

1) Number of factors under study (n_F),
2) Number of levels (values of the factors), (n_L), and
3) Number of specific interaction between two factors to be analyzed (n_I)

These three quantities determine the orthogonal array to be used and the minimum number of experiments to be performed. Associated with each factor is a degree of freedom. That is, the number of changes allowed in the levels of the factor. For example, a factor with three values (levels) within the experimental region has two degrees of freedom. Taking the first level of the factor as a reference, one degree comes from changing the factor to the second level. The second degree of freedom results from switching to the third level. In this way, the effects of the changes from the first to the second and third levels are studied. The degree of freedom of the interactions between two factors is calculated as the product of the degree of freedom of each factor [Fowlkes and Creveling 1995].

The total degree of freedom of the experiment is the sum of the degrees of freedom of each factor, the degrees of freedom of the interactions to be studied, and the degree of freedom of the overall mean of the experiment. The degree of freedom of the overall mean is always one (1), regardless of how many control factors are analyzed.

The control factors are studied with an L_{18} experimental design, shown in Table 7.4. In this case we have six control factors ($n_F = 6$), and each factor is studied at three levels $n_L = 3$. In addition, no interactions between factors are considered. Therefore, the total degree of freedom for studying the control factors is 13 (6 x 2 + 1). The smallest orthogonal array for this case is an L_{18}. An L_{18} may study of up to eight (8) factors (columns of the matrix). However, the current experiment has only six (6) control factors; therefore, the first and last columns are left blank. The three levels assigned to each control factor are 1, 5, and 9, respectively. These levels are shown between parentheses in Table 7.4.

Table 7.4. Orthogonal Array L_{18} for Control Factors.

	Factor Levels							
No.	1	2	3	4	5	6	7	8
1		1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	
2		1(1)	2(5)	2(5)	2(5)	2(5)	1(1)	
3		1(1)	3(9)	3(9)	3(9)	3(9)	3(9)	
4		2(5)	1(1)	1(1)	2(5)	2(5)	3(9)	
5		2(5)	2(5)	2(5)	3(9)	3(9)	1(1)	
6		2(5)	3(9)	3(9)	1(1)	1(1)	2(5)	
7		3(9)	1(1)	2(5)	1(1)	3(9)	2(5)	
8		3(9)	2(5)	3(9)	2(5)	1(1)	3(9)	
9		3(9)	3(9)	1(1)	3(9)	2(5)	1(1)	
10		1(1)	1(1)	3(9)	3(9)	2(5)	2(5)	
11		1(1)	2(5)	1(1)	1(1)	3(9)	3(9)	
12		1(1)	3(9)	2(5)	2(5)	1(1)	1(1)	
13		2(5)	2(5)	3(9)	1(1)	2(5)	1(1)	
14		2(5)	2(5)	3(9)	1(1)	2(5)	1(1)	
15		2(5)	3(9)	1(1)	2(5)	3(9)	2(5)	
16		3(9)	1(1)	3(9)	2(5)	3(9)	1(1)	
17		3(9)	2(5)	1(1)	3(9)	1(1)	2(5)	
18		3(9)	3(9)	2(5)	1(1)	2(5)	3(9)	

The selection of these levels satisfies two goals: (1) studying the variation of the factors in the widest possible region [Phadke 1989] and (2) satisfying the Analytical Hierarchy Process (AHP) comparison scale. It should be noticed that the experimental region was set to cover this comparison scale completely. This decision is aimed to identify general trends within the boundaries of the experimental region.

On the other hand, the effects of noise factors are studied with the L_9 orthogonal array shown in Table 7.5. Four (4) noise factors ($n_F = 4$ are studied at three levels $n_L = 3$. In addition, no interactions between factors are considered. Hence, the total degree of freedom for the experiments of the noise factors is 9 (4 x 2 + 1). The smallest orthogonal array for this case is an L_9. The levels of the noise factors are similar to the one used for the control factors.

Table 7.5. Orthogonal Array L_9 for Noise Factors.

	Factor Levels			
No.	1	2	3	4
1	1(1)	1(1)	1(1)	1(1)
2	1(1)	2(5)	2(5)	2(5)
3	1(1)	3(9)	3(9)	3(9)
4	2(5)	1(1)	1(1)	2(5)
5	2(5)	2(5)	2(5)	3(9)
6	2(5)	3(9)	3(9)	1(1)
7	3(9)	1(1)	2(5)	1(1)
8	3(9)	2(5)	3(9)	2(5)
9	3(9)	3(9)	1(1)	3(9)

7.5 Analysis of Results

The analysis of results identifies the main effects of the control factors and their interactions. It has two major steps: (1) the estimation of effects of control factors, and (2) verification of the results. The estimation of the effects of the control factors starts by obtaining a summary of the statistics for all experiments. It includes the following steps:

1) Obtain a summary of the statistics for all experiments,
2) Calculate the means of the signal to noise ratio (S/N) for each experiment,
3) Determine the overall mean of the matrix of experiment,
4) Perform the Analysis of Means (ANOM) and the Analysis of Variance (ANOVA), and
5) Conduct verification experiments.

The Analysis of Means evaluates the deviation from the overall mean of each of the levels the control factors. The Analysis of Variance, in contrast, identifies the relative importance of the effects of the control factors. These two analyses determine the optimum or "best" levels of the control factors. These optimum levels are the ones that maximize the signal to noise ratio (S/N) within the experimental region, represented by the matrix of experiments. After the optimum levels are identified, the verification experiments are conducted. These experiments validate whether or not the optimum values of the control factors improve the process or product.

Verification experiments are also used to confirm the assumption about the additive model. The additive model holds, if the signal-to-noise ratios (S/N) of the verification experiments and the matrix of experiments match. Otherwise, the underlying assumption about the additive model does not hold. It should be noticed that Robust Design does not try to prove the validity of the additive model beforehand [Phadke 1989]. Instead, it initially assumes that the additive model holds, and later verifies whether this assumption is satisfied. When the additive model does not hold, experiments do not provide a valid conclusion about the effects of control factors.

The additive model is the foundation for the Analysis of Means and the use of orthogonal arrays in Robust Design. It assumes that each factor has independent effects on the objective function. This means that the overall effect of the factors can be expressed as the sum of the effects of individual factors. The effect of individual factors can be of any order (linear, quadratic, or higher), but the model does not consider the interaction among two or more factor effects. The additive model is also known as superposition or variable separable model in the engineering literature.

For example, the additive model in Eq. 7.3 represents an experimental matrix involving three factors that are study at three levels. The error term (e) in Eq. 7.3 considers the error of the additive approximation, and the error of repeatability of measuring η for a given experiment. This term is an approximation, since these errors are not random independent variables with zero mean. However, this approximation is sufficient for the analysis of results because Robust Design uses the error variance for qualitative purposes only [Phdake 1989].

$$\eta(C_f) = m + a_i + b_j + c_l + d_k + e \qquad (7.3)$$

where:

$\eta(C_f)$: signal to noise ratio (S/N) of the effects of the control factors at a given level.

C_f: control factors vector $C_f = \{A_i, B_j, C_l, D_k\}$.

m: overall mean of the experimental region.

a_i, b_j, c_l, d_k: deviation of the factors from the overall mean when set to the i, j, l, and k-th levels.

e: error.

Assuming that the additive model holds, the Analysis of Means (ANOM) uses the matrix of experiments to calculate the deviation from the overall mean as shown in Eq. 7.4.

$$E(i, j) = m - \sum_{j=1}^{n_f} \eta_j \qquad (7.4)$$

where:

E(*i, j*): effect of setting the factor *i* at a level *j*,

m: overall mean of the experimental region,

η_j: signal to noise ratio (S/N) for the *j*-th experiment, and

n_f: number of experiments where the factor *i* is at its *j*-th level.

For example, for the L_4 array shown in Table 7.2, the effect (E (1, 2)) of setting the first factor (column 1, i = 1) to its second level (j = 2) is calculated as the overall mean minus the signal to noise ratios (S/N) of the experiments 3 and 4 (lines of the

Table 7.2)[4]. Similarly, the effects of setting the third factor to level 1, E(3, 1), to its third level is the overall mean minus the signal to noise ratios (S/N) of the experiments 1 and 4, where the third factor is set to level 1.

The Analysis of Variance (ANOVA) calculates the relative importance of each of the control factors. Furthermore, it estimates the variance in the errors for the factor effects and the variance of the prediction error. Instrumental to ANOVA is the variance ratio (F). The variance ratio is calculated as the ratio of the mean square due to the factor and the error mean square. The value of the variance ratio (F) characterizes the relationship between the effect of a factor with respect to the error variance. The larger the value of the variance ratio, the larger the effect of the factor on the signal to noise ratio (S/N) of the product or process. It should be noted that Robust Design uses variance ratio to measure the factor importance qualitatively. In contrast with statistical experimental design, it does not try to infer any statistical significance or the degree of confidence of the effect of a given factor based on the variance ratio.

The simulations were performed using an algorithm adapted from a computer aided robust design algorithm proposed by Phadke [1989]. They study the influences of noise factors on the focus of the AHP (Analytical Hierarchy Process Hierarchy) hierarchy. First, an experiment, (C_i), from the control factors (Table 7.4) was chosen. Then, for each experiment, (C_i), the nine noise factor experiments ($N_1 \dots N_n$, n = 9) were performed. This procedure was executed for five (5) data sets. The data sets represent values of the 10 control and noise factors for 25 companies. Data were randomly generated to fit a standard distribution. Eight hundred and ten numerical experiments were carried out.

Table 7.6 shows the Priority Vectors (PVs), Consistency Ratios (CRs) and Consistency Indexes (CIs) of all the experiments of the control factors. Similar

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[4] The signal to noise ratio are the averages over the number of experiments performed in the experimental region.

values for noise factors are shown in Table 7.7. These values are obtained by using Analytical Hierarchy Process (AHP) pairwise comparisons.

Table 7.6. Priority Vectors, CIs and CRs for the Experiments of Control Factors.[5]

No.	Priority Vectors (PVs)						CI	CR
	TC	DS	FS	CR	BS	CD		
1	0.1667	0.1667	0.1667	0.1667	0.1667	0.1667	0.0000	0.0000
2	0.0385	0.1923	0.1923	0.1923	0.1923	0.1923	0.0000	0.0000
3	0.0216	0.1957	0.1957	0.1957	0.1957	0.1957	0.0017	0.0013
4	0.1924	0.0384	0.0384	0.1924	0.1924	0.3459	0.0001	0.0001
5	0.1473	0.1473	0.1473	0.2644	0.2644	0.0293	0.0000	0.0000
6	0.1670	0.2998	0.2998	0.0332	0.0332	0.1670	0.0003	0.0002
7	0.2998	0.0332	0.1670	0.0332	0.2998	0.1670	0.0003	0.0002
8	0.2366	0.1320	0.2366	0.1320	0.0262	0.2366	0.0006	0.0005
9	0.2646	0.2646	0.0293	0.2646	0.1476	0.0293	0.0012	0.0001
10	0.0332	0.0332	0.2998	0.2998	0.1670	0.1670	0.0003	0.0002
11	0.0383	0.1928	0.0383	0.0383	0.3461	0.3461	0.0015	0.0012
12	0.0454	0.4089	0.2275	0.2275	0.0454	0.0454	0.0005	0.0004
13	0.1670	0.0332	0.1670	0.2998	0.0332	0.2998	0.0003	0.0002
14	0.1924	0.1924	0.3459	0.0384	0.1924	0.0384	0.0001	0.0001
15	0.1473	0.2644	0.0293	0.1473	0.2644	0.1473	0.0009	0.0007
16	0.2646	0.0293	0.2646	0.1476	0.2646	0.0293	0.0012	0.0009
17	0.2998	0.1670	0.0332	0.2998	0.0332	0.1670	0.0003	0.0002
18	0.2366	0.2366	0.1320	0.0262	0.1320	0.2366	0.0006	0.0005

The pairwise comparisons were introduced in Chapter 6, during the analysis of AHP. For example, for the 8th experiment of the control factors, the levels are: 3, 2, 3, 2, 1 and 3. These levels are represented by the values of 9, 5, 9, 5, 1, and 9 (Table 7.4, row 8). The pairwise comparison matrix for the experiment No. 8 is shown in Table 7.8.

[5] AHP represents the values of the Priority Vector, Consistency Indexes and Consistency Ratios with fourth decimal places. This representation does not imply any level of accuracy in the calculation of these values.

Table 7.7. Priority Vector, CI, and CR for Noise Factor Experiments.

	Priority Vector (PV)					
No.	MA	CC	SP	MB	CI	CR
1	0.2500	0.2500	0.2500	0.2500	0.0000	0.0000
2	0.0625	0.3125	0.3125	0.3125	0.0000	0.0000
3	0.0331	0.3223	0.3223	0.3223	0.0255	0.0283
4	0.2503	0.0498	0.2503	0.4496	0.0005	0.0006
5	0.2503	0.2503	0.4496	0.0498	0.0005	0.0006
6	0.2503	0.4496	0.0498	0.2503	0.0005	0.0006
7	0.3748	0.0414	0.3748	0.2090	0.0003	0.0004
8	0.3748	0.2090	0.0414	0.3748	0.0003	0.0004
9	0.3748	0.3748	0.2090	0.0414	0.0003	0.0004

Table 7.8. Pairwise Comparisons Matrix of Control Factors for the 8th Experiment.

	TC	DS	FS	CR	BT	CD	PV
TC	1	9/5	1	9/5	9	1	0.2366
DS	5/9	1	5/9	1	5	5/9	0.1320
FS	1	9/5	1	9/5	9	1	0.2366
CR	5/9	1	5/9	1	5	9/5	0.1320
BT	1/9	1/5	1/9	1/5	1	1/9	0.0262
CD	1	5/9	1	9/5	9	1	0.2366

λ_{max}= 6.2, CI = 0.0, CR = 0.0

The priority vector (PV) is obtained by normalizing the principal eigenvector of the matrix[6]. As explained in Chapter 6, the Consistency Index (CI) is the ratio between the maximum eigenvalue of the matrix (λ_{max}) and (n-1) (n is the order of the matrix). The Consistency Ratio (CR) measures the consistency of the comparisons. Saaty [1980] recommends that CR should not be more than 0.1 or 10. It should be noticed that the priority vectors keep the original relative importance of the criteria. For instance, technical capabilities (TC), financial security (FS), and cost of development (CD) are considered 'absolutely more important' than other factors; therefore, they get the largest values in the priority vector (PV). Indeed, the Collaborative Record (CR) factor is considered 'strongly important' with respect to other factors and its priority value ranks second. The Business Strength (BT) factor

[6] The principal eigenvector of a matrix is the eigenvector for the largest eigenvalue of that matrix.

is considered ‘as important as’ other factors and its value is the smallest in the priority vector.

The results of the pairwise comparison matrices for the second level of the hierarchy are summarized in Table 7.9. Matrices are formed based on the relative importance of the control and noise factors on the scenarios. For the Status Quo (SQ) scenarios, both control and noise factors were considered ‘equally important’. The Improve (IP) scenario considers a ‘weakly dominance’ of the noise factors over the control factors. The Select New Partners (NP) and Disbanding (DB) scenarios take into account a ‘strong’ and ‘absolute’ prevalence of noise factors over the control factors, respectively. It should be noted that priority vectors match the relative importance assigned to the scenarios in the pairwise comparison matrix. These comparison matrices are kept constant during all experiments. All pairwise comparison matrices used during the experiments are consistent, since CI is less than 10% suggested by Analytical Hierarchy Process.

Table 7.9. Priority Vectors, CIs and CRs of the Second Level of the Hierarchy.

	Priority Vectors (PV)			
	CF	NF	CI	CR
SQ	0.50	0.50	0.0	0.0
IP	0.17	0.83	0.0	0.0
NP	0.12	0.88	0.0	0.0
DB	0.10	0.90	0.0	0.0

Table 7.10 shows the mean of the ranking and the signal to noise ratio (S/N) for the company that ranks first in 18 experiments of control factors. These values are obtained using Eq. 7.4. These results show that to maximize the ranking of the company the technical capabilities criterion (TC) should be set at level 9 (when TC is considered as ‘absolutely more important’ in relation to other factors). Similarly, setting the speed of development (DS), Collaborative Record (CR) and Cost of Development (CD) to a level 9, maximize η. Financial Security (FS) and Business Strength (BT) maximize η when they are considered ‘equally important’ to other factors (level 1).

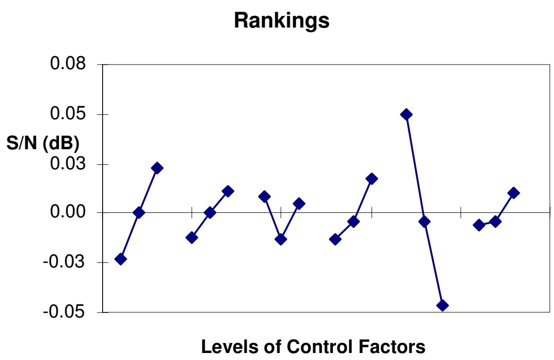
These results are shown in Fig. 7.4. In this figure, each factor is represented as a 3-tuple on the horizontal axis. For example, the first three values represent the three levels assigned to the Technical Capabilities (TC) factor. In the same way, the second set of three represents the levels of the Development Speed (DS) factor and so on for the other factors. It can be seen that the factor with the largest influence on η, is Business Strength (BT). The other factors play a significant, but less relevant role.

Table 7.10. S/N Ratio and QC for Rankings.

No.	Mean of Rankings	QC	η (dB)
1	0.268	28.609	14.565
2	0.266	28.281	14.515
3	0.268	28.543	14.555
4	0.269	28.754	14.587
5	0.267	28.327	14.522
6	0.270	28.980	14.621
7	0.265	28.510	14.550
8	0.266	29.370	14.679
9	0.268	29.161	14.648
10	0.266	28.847	14.601
11	0.265	28.582	14.561
12	0.268	29.228	14.658
13	0.268	29.309	14.670
14	0.267	28.953	14.617
15	0.266	28.708	14.580
16	0.265	28.510	14.550
15	0.269	29.526	14.702
18	0.266	28.847	14.601

QC: Quality Characteristic

In simple terms, these results show that to maximize the robustness of management, Technical Capabilities, Development Speed, Collaborative Record and Cost of Development factors have to be assigned a major influence in the selection process. These results are consistent with what is done in industry.



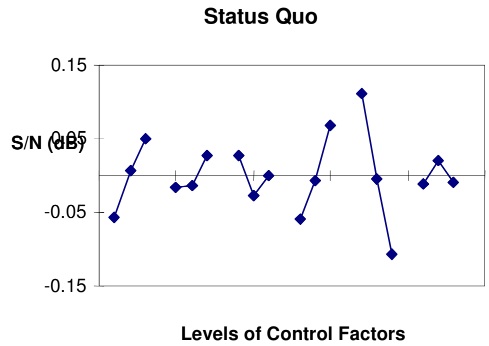
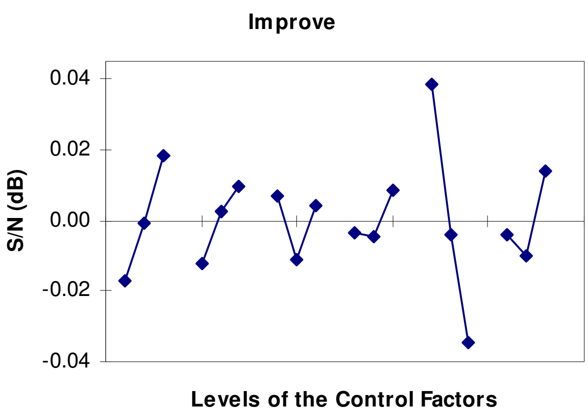


Figure 7.5. Effects of Control Factor on Rankings

Figure 7.6. Control Factor Effects for SQ.



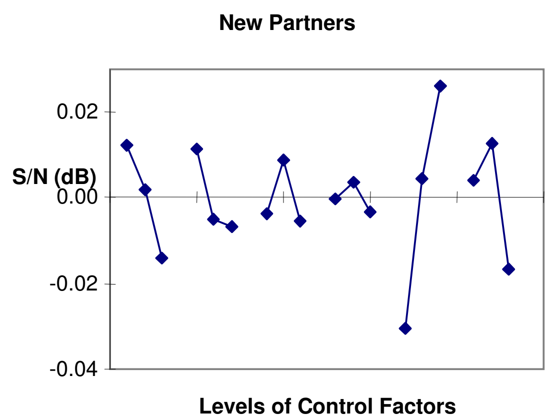


Figure 7.7. Effects of Control Factor for IP.

Figure 7.8 \Effects of Control Factor for NP.

Following a similar procedure, the levels of control factors that maximize η for the four scenarios and the control and noise factor clusters can be identified. These results are shown in Figs 7.6 to 7.9. It can be seen that the levels that maximize η vary for the different scenarios.

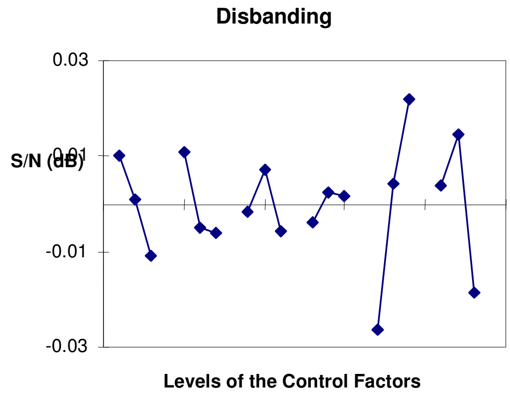


Figure 7.9 Effects Control factor for DB.

Table 7.11 shows the effects of Status Quo (SQ), Improve (IP), New Partner Selection (NP), Disbanding (DB), Control Factors cluster (CF), and Noise Factors cluster (NF) on the focus of the hierarchy, for the first ranked company. This table provides, indeed, a very interesting outcome. It can be seen that the Technical Capabilities (TC) factor maximizes η, when it is set at level 3 (9) for Status Quo (SQ) and Improve (IP) scenarios. However, setting this factor to level 1, maximizes the New Partner Selection (NP) and disbanding (DB) scenarios. That means that considering technical capabilities as important as others factors, maximize the chances of performing a new partner selection process or the disbanding of the Virtual Enterprise.

Table 7.11. Maximizing Levels of η for the First Ranked Company.

Factor	Rankings	SQ	IP	NP	DB	CF	NF
TC	3 (9)	3 (9)	3 (9)	1(1)	1(1)	3 (9)	2 (5)
DS	3 (9)	3 (9)	3 (9)	1(1)	1(1)	3 (9)	1 (1)
FS	1 (1)	3 (9)	2 (5)	2 (5)	2 (5)	1(1)	1 (1)
CR	3 (9)	3 (9)	3 (9)	2(5)	2 (5)	3 (9)	3 (9)
BS	1(1)	1(1)	1(1)	3 (9)	3 (9)	1(1)	3 (9)
CD	3 (9)	2 (5)	3 (9)	2 (5)	2 (5)	2 (5)	2 (5)

Other information can be extracted from these results. For instance, the need for improving management can come from a variation member companies' financial security or cost of development (see FS and CD rows). The level at which Financial

Security (FS) maximizes η, changes in the Status Quo and Improve scenarios. This change indicates the need for, at least, a revision of performance. The level of the CD (cost of development) factor that maximizes the management of a Virtual Enterprise varies from the second to the third level.

The analysis presented above identifies the changes in the control factors during a Virtual Enterprise life cycle. Once these changes are identified, it is possible to estimate the most predictable effects of these changes on the management of the organization. Moreover, corrective action may be taken to avoid the selection of new partners or the disbanding of the Virtual Enterprise. However, it is important to realize that both the changes in levels and the magnitude of the changes have to be taken into consideration.

These results show that the levels that maximize the robustness of the management of a Virtual Enterprise depend on how companies rank. In other words, the levels of the control factors that maximize the management of the Virtual Enterprise vary as a function of the ranking achieved by the companies. The Analytical Hierarchy Process (AHP) seems to classify the companies in three major groups: the best, the average and the worse ranked companies.

However, the effects of the controls factors for the average group are completely random. Table 7.12 shows the distribution of the levels that maximizes η, along the rankings for each factor. It can be noticed that the recommended levels of control factors for the first ranked company still play an important role in the rankings, but they vary considerably. Technical Capabilities (TC) is the most stable factor keeping its initial level 80% of the time. The initial levels of Business Strength (BT) and Cost of Development (CD) are similar to the ones identified for the first ranked company in more than 50% of the cases. Development Speed (DS) and Financial Security (FS) are the ones with the lowest repetition of the initial levels along the rankings, with more than 40% each. These results may be used to corroborate the findings of Wildeman [1998], who suggested that a previous collaborative record (CR) might have a negative effect on the management of a Virtual Enterprise.

Table 7.12 Distribution of Levels Maximizing η Along the Rankings.

	Levels		
Factor	1	5	9
Technical Capabilities (TC)	4	1	20
Development Speed (DS)	9	6	10
Financial Security (FS)	12	6	7
Collaborative Record (CR)	7	8	10
Business Strength (BT)	14	5	6
Cost of Development (CD)	9	3	13

Fig. 7.10 shows the relationships between the Control Factors cluster (CF) and the scenarios (CF vs. SQ and IP). It can be seen that the influence of the control factors cluster (CF) grows with Status Quo (SQ) and Improve (IP) scenarios. Initially, the IP plays a more relevant role, but as CF increases, its role decreases. These tendencies can explain the initial stages of the management in a Virtual Enterprise. At the beginning, there is more need for improvement, since partners have just started to work together and need to match their working styles. As the relationship progresses, there is less need for improvement and the status quo (SQ) scenario gains relevance. These two tendencies are expected to meet at one point beyond which SQ becomes more relevant than IP.

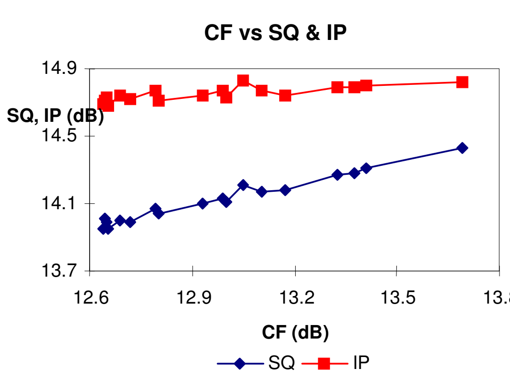


Figure 7.10. CF vs. SQ and IP

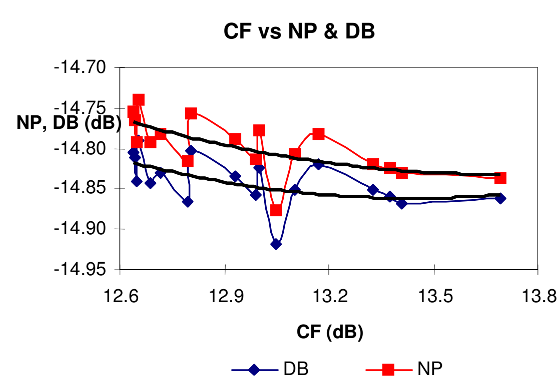


Figure 7.11. CF vs. NP and DB.

Fig. 7.11 illustrates that as the influence of control factor cluster grows, the New Partner selection (NP) and Disbanding (DB) scenarios become less probable. Indeed, the disbanding (DB) is less probable as scenarios than selecting new partners (NP). However, as the influence of the control factor cluster (CF) grows, the DB and NP tendencies get closer. Then, the DB scenario plays a more influential role than NP. This relationship between control factors, NP and DB seems to suggest that control factors play a relevant role in reducing the risk of a new partner selection process or the disbanding of a Virtual Enterprise. Once the influences of control factors has absolutely minimized the effects of NP and DB scenarios, further changes will not improve the management of a Virtual Enterprise and the organization might disband. It can be seen in Fig. 7.11 that beyond the minimum, the tendencies of DB and NP grow gradually with respect to CF.

The relationships of the noise factor cluster (NF) vs. SQ and IP are shown in Fig. 7.12. It can be noted that as the influence of noise factors grow, the Status Quo (SQ) and Improving (IP) scenarios become less probable. This relationship illustrates the negative effect of the noise factors in keeping the status quo or improving the management of a Virtual Enterprise. The tendencies of NF vs SQ and NF vs IP also reach minimum values. These values represent the point at which NF has the most negative effect on SQ and IP. However, this figure shows that the effect of noise factors can also be helpful in keeping the SQ or IP scenario. The issue, then, becomes to determine the region where the overall impact of noise factors contributes to the robustness management of a Virtual Enterprise.

The effects of the noise factor cluster on NP and DB are shown in Fig. 7.13. The NP and DB scenarios become more probable as the influences of the noise factors cluster grows. These seem to be the trends until NP and DB reach their maximum values. Beyond this point, the influence of noise factors on the NP and DB scenarios consistently decreases. Such behaviour demonstrates the contradictory effect of the noise factors in the overall management of a Virtual Enterprise. Noise factors may affect the management of a Virtual Enterprise, both positively and negatively. However, the issue here is how to benefit from the effects of the noise factors.

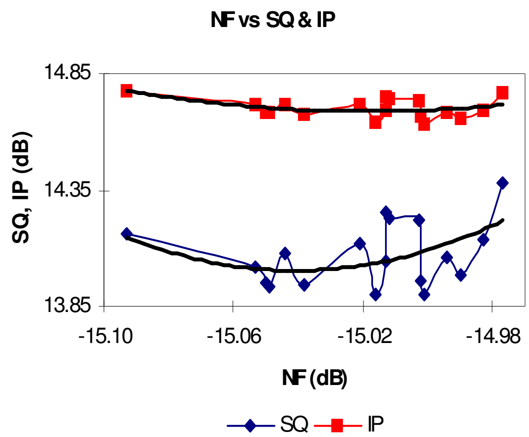


Figure 7.12. NF vs. SQ and IP.

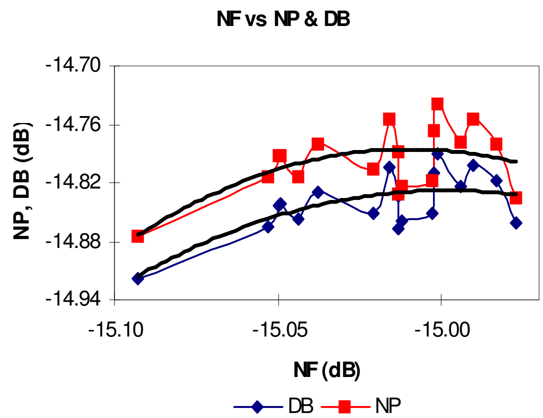
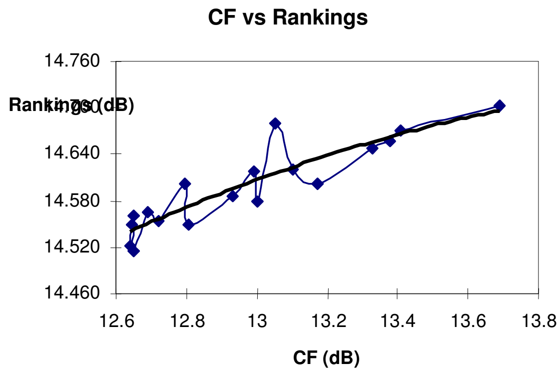


Figure 7.13. NF vs. NP and DB.

Fig. 7.14 depicts the relationship between the control factor (CF) cluster and the rankings. It shows that a growth in the effects of control factors benefits the management of a Virtual Enterprise. Fig. 7.16, on the other hand, shows the relationship between the noise factors (NF) cluster and the rankings. This relationship is less straightforward. Initially, noise factors have a negative impact on the rankings. Later, after the minimum of the tendency is reached, NF contributes to the rankings and therefore to the management of the organization. This tendency indicates that the effect of noise factors may positively contribute to the success of a Virtual Enterprise.

The remaining dependencies follow simple relationships with the rankings. The SQ and IP scenarios seem to have a direct dependency with the rankings (Figs. 7.16 and 7.17). This means that rankings seem to favour companies that contribute to either the status quo or improving scenarios. Figs. 7.18 and 7.19 illustrate the dependency of the rankings with respect to the new partner and disbanding scenarios. It can be noticed that companies are ranked in a descending order according to their possibilities favour a new partner selection process or the disbanding of the enterprise.



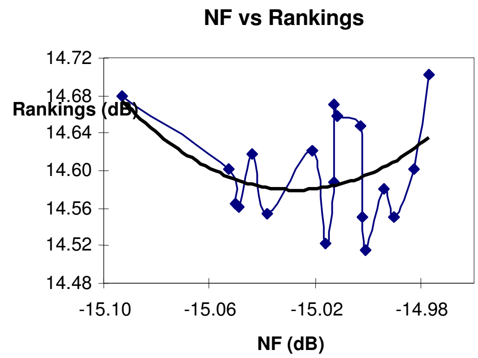
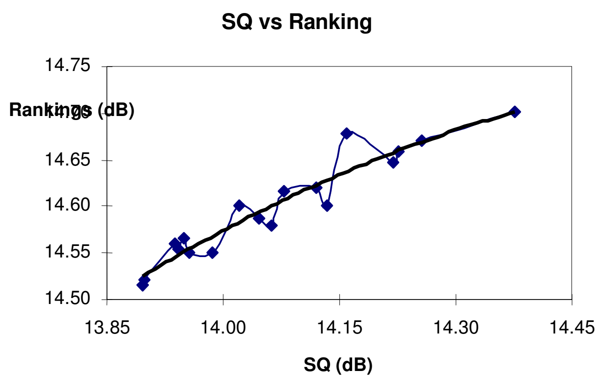


Figure 7.14. CF vs. Rankings

Figure 7.15. NF vs. Rankings.



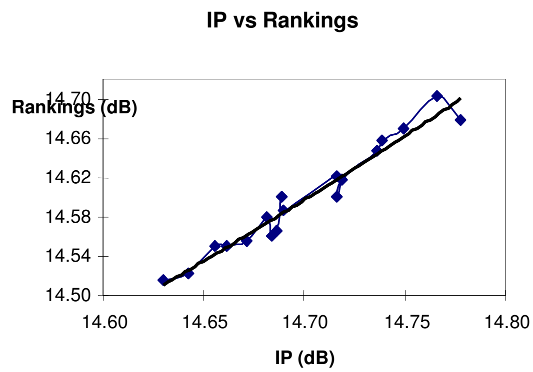
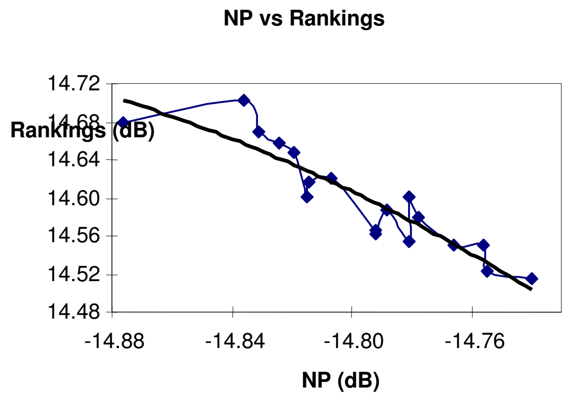


Figure 7.16. SQ vs. Rankings.

Figure 7.17. IP vs. Rankings.

7.6 Summary

This chapter introduced a methodology for the robust management of Virtual Enterprises. The methodology is based on the application of Robust Design. It aims at keeping the management of the Virtual Enterprise under control by evaluating regularly the effects of control and noise factors. The methodology includes four steps: (1) identification of the evaluation criteria, (2) identification of control and noise factors as well as the input and responses of the process, (3) the selection of the partner companies, (4) the monitoring of the partners performance.



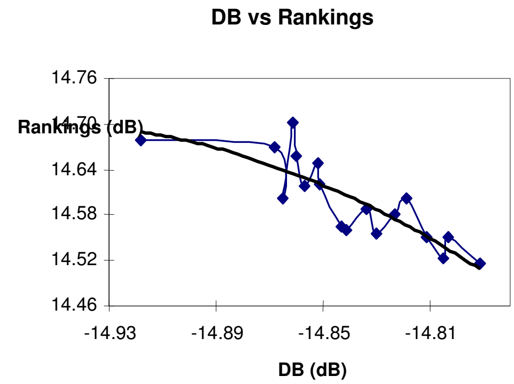


Figure 7.18. NP vs. Rankings.

Figure 7.19. DB vs. Rankings.

The chapter also investigated the effects of control and noise factors on the management of Virtual Enterprises through numerical experiments. It was found that control factors have positive effects on the Status Quo and Improving scenarios. These factors also reduce the possibilities of the New Partner selection and Disbanding scenarios. However, once the minimums in these tendencies are reached, the effects of control factors change.

Noise factors can have both positive and negative effects on the four scenarios. The factors tend to favour the New Partner and Disbanding scenarios as their influence grows. On the other hand, they can increase and decrease the possibilities of the Status Quo and Improving scenarios.

The relationship between the control factors cluster and the management of the Virtual Enterprise was found to be directly proportional. That is, a growth in the effects of the control factors benefits the management of the Virtual Enterprise. Noise factors, in contrast, can both benefits and damage the management of the Virtual Enterprise. It was also found that the Status Quo and Improve scenarios improve the management of Virtual Enterprises. The other two scenarios, New Partner selection and Disbanding seem to have a negative effect on management.

8 Conclusions and Future Work

As was discussed in Chapter 1, the objectives of the thesis were:

1) Establish the foundation for a systematic and consistent design process.
2) Provide a unified framework for the design of Virtual Enterprises.
3) Include time as a variable in the design of Virtual Enterprises.
4) Formulate a time dependent partner selection problem for improving the success rate and avoid premature disbanding.
5) Identify the reasons for failure in collaborative relationships and outsourcing,
6) Identify the importance assigned to the selection criteria in the Partner Selection Process.
7) Develop a methodology for the robust management of Virtual Enterprises.
8) Investigate the effects of selection criteria in the management of Virtual Enterprises.

These issues were analyzed in the subsequent chapters. In this chapter, the final conclusions and contributions of this thesis as well as recommendations for future work are presented.

8.1 Summary

A review of the pertinent literature was presented in Chapter 2. As the literature on the analysis and design of Virtual Enterprises revealed, the design of Virtual Enterprises has been an ad-hoc process that did not include time as a variable. The current situation in the design of Virtual Enterprises showed a high disbanding rate and failure to meet the objective the originally brought the partners together.

Current design practices failed to evaluate the satisfaction of customers' needs, functional requirements, design parameters and process variables and ignored their relationships. In addition, these practices did not take into account top-down and a bottom-up process taking place during the design of Virtual Enterprises.

The analysis of Virtual Enterprises as systems was presented in Chapter 3. Considering Virtual Enterprises as systems allowed developing a conceptual and control model for the organization. Virtual Enterprises were also analyzed as large systems, using Axiomatic Design. , This analysis considered that the elements of the design domains vary with time. The chapter proposed a model for the design of Virtual Enterprises that take into account the two designs that concurrently take place in Virtual Enterprises: the design of the organization and the product or service it delivers. This was achieved by approaching the design of Virtual Enterprises as the design of products.

Chapter 4 focuses on the identification of the reasons for failure in outsourcing and collaborative relationships. Technical and delivery capabilities as well as collaborative record, financial security and location were identified as the most important factors in the success or failure of outsourcing relationships.

Chapter 5 analyzed the design of Virtual Enterprises as organizations. It demonstrated that the switching principle of Virtual Enterprise is a subset of Axiomatic Design. The switching principle considers only the relationship between the functional and physical domains. Based on Axiomatic Design, the chapter identified the design domains and established the relationships between them. The design hierarchy was expanded into three levels. The chapter concluded that, in general, the design of Virtual Enterprise is coupled and does not have a high probability of success. This finding contributes to the understanding of the reasons for disbanding in Virtual Enterprises.

Chapter 6 developed a time dependent formulation of the partner selection problem. Once more the switching principle of Virtual Enterprises was used as a foundation. This chapter also analyzed the partner selection problem as a multi-criteria decision-making problem. Through the analysis of the selection criteria used in outsourcing and strategic alliances and incorporating the findings of Chapter 4 and Appendix B, the chapter identified a new set of selection criteria to be used in the partner selection process. The performance of the Analytical Hierarchy Process and Axiom II from Axiomatic Design were compared in a case study. These two methods seem to provide similar rankings of partners, despite of using different decision rules.

Chapter 7 proposed a robust design methodology for the management of Virtual Enterprises. The methodology is based on the regular evaluation of the partners' performance. Evaluating the partners' performance regularly identifies small variations that can, over time, cause the disbanding of the Virtual Enterprise. The chapter also investigated the relationship between the management of Virtual Enterprise and control and noise factors. . It was found that, in general, control factors favour the management of Virtual Enterprises. Noise factors, in contrast, may positive and negative effects on management.

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8.2 Conclusions

It is concluded from this research that:

1) The design of Virtual Enterprises needs to consider that two design process take place concurrently; one follows a top-down approach, while the other follows a bottom-up approach.
2) Virtual Enterprises can be analyzed as large systems, in which only a subset of the customers' needs is known, before starting the design. These needs change over time and should trigger a new design process.
3) The most important criteria influencing the general outsourcing policies are: technical and delivery capabilities. Criteria such as collaborative

record, business, cost of development and management ability are also important.

4) The design of Virtual Enterprises is coupled and it has a low probability of success. Therefore high premature disbanding rates are understandable.
5) Including time in the formulation of the partner selection problem and a robust management of Virtual Enterprises decreases the possibilities of a premature disbanding of the organization.

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8.3 Contributions of the Thesis

1) The development of a conceptual and control model for Virtual Enterprises. These two models considered Virtual Enterprises as systems and took into account the life cycle of the organization.
2) Modelling of Virtual Enterprises as two design process taking place concurrently. The partner selection process follows a top-down approach and the formation of the Virtual Enterprise follows a bottom-up approach. Both approaches are based on the application of system engineering principles and the design of products.
3) The inclusion of time as a variable in the design of Virtual Enterprises as organizations and as systems. Considering time as a variable explained the evolution of Virtual Enterprises as an organizational form, and the formulation of the partner selection as a dynamic problem.
4) The identification of the causes of failure in outsourcing and collaborative relationships as well as some of the causes of disbanding in Virtual Enterprises. The causes of failure were identified by the survey on Canadian outsourcing practices. The reasons for disbanding in Virtual Enterprises were studied through the analysis of Virtual Enterprises as a design problem.

5) The identification of the role of the selection criteria in the partner selection process in outsourcing and collaborative relationships.
6) The identification of the current outsourcing trends in Canadian design and manufacturing enterprises.
7) The robust methodology for the management of Virtual Enterprises. The methodology applies robust design principles to the management of Virtual Enterprises.
8) The investigation of the relationships between the management of Virtual Enterprises and control and noise factors used for evaluating partner's performance.

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8.4 Future Work

The thesis focuses on the analysis and design of Virtual Enterprises using system engineering as a foundation and Axiomatic Design as a design methodology. However, Axiomatic Design is only one of the many existing design methodologies. Other design methodologies such as the House of Quality and Quality Function Deployment can be used to verify or refute the findings of this research. The interaction matrices obtained by the Quality Function Deployment can be used to develop first and second order models for the analysis of Virtual Enterprises.

It is also recommended the follow up of this research with the analysis of specific instances of Virtual Enterprises. The follow up should identify whether the design of specific Virtual Enterprises remains coupled, when only a subset of the market conditions need to be satisfied .

The Integrated Definition Methodology (IDEF) can be used for the analysis of the Partner Selection problem. IDEF3 is used for the description of process flow. Using the basic modelling block of IDEF, all the activities of a Virtual Enterprise can be represented. This representation of the Partner Selection process can be transformed into a process graph [Kuziak 1999]. This transformation allows the use of Graph Theory algorithms for the analysis of Partner Selection problem.

Chapter 4 and Appendix B identified qualitative relationships among the selection criteria used in the Partner Selection problem. The analysis revealed that the selection criteria are interdependent and conflicting. Therefore, it would be beneficial to develop a fuzzy theory approach for handling these selection criteria. The approach should take into account that some of the selection criteria are imprecise. Yen and Tiao [1997] proposed a systematic approach to deal with this kind of situations.

Chapter 6 formulated the partner selection problem as the assignment problem in bipartite graphs, following the application of the 'switching principle'. No algorithm was found for handling an assignment problem using multiple criteria. It would be interesting to develop such an algorithm for assigning tasks to partners in Virtual Enterprises.

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Appendix A

A Evolution of Virtual Enterprises

A.1 Introduction

It was explained in Chapter 2 that the development of Virtual Enterprises has been an evolutionary process influenced by outsourcing, network organizations and agility. This appendix analyzes the effects of these three influences on Virtual Enterprises.

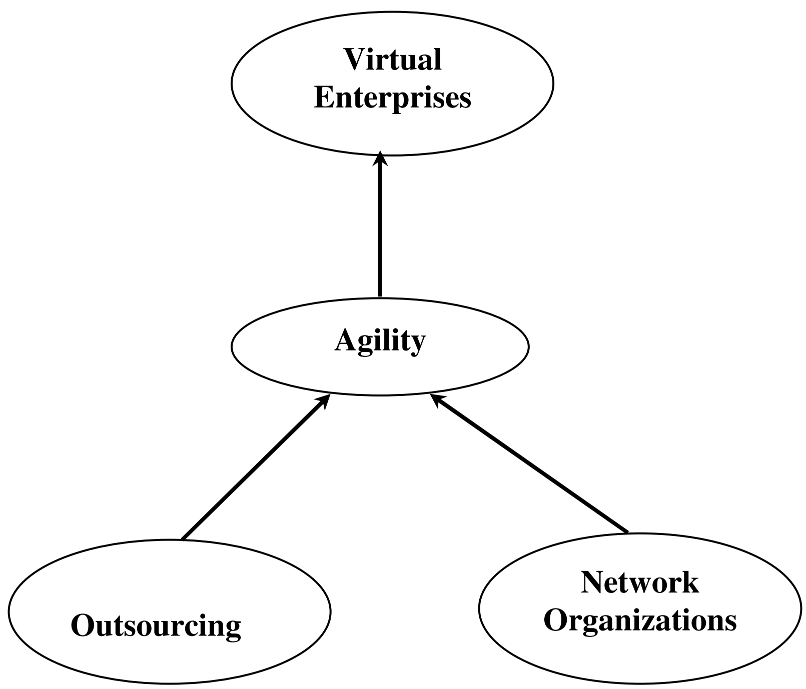

Figure A.1. Evolution of Virtual Enterprises.

Fig. A.1 summarizes the organization of the analysis. Using 5W1H methodology, this appendix analyzes outsourcing and network organizations. In the 5W1H methodology, the five 'Ws' are: what, who, why, when and where, and the 'H' is how. Next, it is shown how the current market conditions have forced companies to become agile enterprises. This appendix finishes with the analysis of Virtual

Enterprises. It will be shown that several important elements in Virtual Enterprises come from one of these three sources.

Considering Virtual Enterprises as an evolution from other organizational forms establishes the foundations for analyzing some of challenges they face. Issues such as their poor success rate, their partner selection and design process as well as their management are better understood if both advantages and disadvantages of previous organizational forms are taken into account.

A.2 Outsourcing

Outsourcing is hardly a new idea since companies have used it for sometime. Phelps and Fleischer [2002] provide an in-depth review of the work done on outsourcing all over the world. The purpose of the following analysis is not to provide an extensive study of outsourcing. The analysis that follows focuses mainly on identifying the characteristics of outsourcing that have found their way into the characteristics of Virtual Enterprises.

According to Greaver II [1999], outsourcing is the "act of transferring some of the company's recurring internal activities and decision rights to outside providers, as set forth in a contract". On the other hand, Taylor [1999] defines outsourcing as "the process of subcontracting out to outside experts the responsibilities for operating a function not related to an organization core business". Martin [1992] [cited in Halley 2000] considers outsourcing as an organizational mode in which an organization gives to another company the responsibilities of completing a task according to specific instructions. Although these definitions are brief, two important elements can be noted in relation to outsourcing: (1) outsourcing requires third parties outside the company and (2) the rationality for making outsourcing decisions is the organization core capabilities. It is commonly acknowledged that the majority, if not all, of the activities that are beyond the company core capabilities, should be outsourced. Taking these two elements into consideration, it can be concluded that outsourcing deals with the division of labour at a larger scale [Sandhoff 1999].

The focus on core capabilities has changed the companies' perspectives. Nowadays, companies consider themselves as part of globally linked supply chains [Preiss 1997]. In addition, companies have migrated from generalist to specialist. Generalist companies carry out almost all the activities by themselves with no significant contribution from outsiders. Specialist companies, in contrast, focus on their core competencies and seek outside help, in areas beyond their core competencies. This shift in perspective has many reasons. These reasons are shown later during the 5WH1analysis.

Martin [1992] classifies outsourcing in specialty, economic and capacity outsourcing. Specialty outsourcing is used in situations where the outsourcer is unable to accomplish the task by itself. These situations commonly appear in cases where the outsourcer lacks technical expertise or it is not cost-effective to perform the tasks "in-house". The outsourcing of Information Technology functions is an example of specialty outsourcing. These functions are subcontracted because companies either cannot find or do not want to have human resources "in house". For example, the shortage of Information Technology specialists in the market may not allow the company to attract and keep the needed human resources. On the other hand, the decision of subcontracting Information Technology functions may be based on financial grounds. Buying the hardware and software to run a computer network may cost the company $5,000 or $6,000. However, the specialist that runs and maintains the network may cost $35,000 or $40, 000 per year. This figure includes the salary of the specialist and other employee related expenses. If the company is capable of obtaining a similar kind of services for a fraction of cost of having an "in-house" specialist, it is possible that the function will be outsourced. Definitely, the financial considerations are only one of the criteria to consider. The company has to consider issues such as the dependency of the company on the reliability and up time of the network for performing mission critical activities. In addition, the strategic impact of the Information Technology functions on the core capabilities of the company may influence the decision of whether to outsource or have an “in-house” specialist.

Economic outsourcing considers the case in which the subcontractor has a better economy of scale than the outsourcer does. The subcontractor usually specializes in specific components or services that the outsourcer needs. Beside, the subcontractor is capable of manufacturing the component or providing the service at a lower price than the outsourcer does. Commodities such as screws in manufacturing fit this profile. Subcontractors have developed over the years the expertise and manufacturing facilities that enable them to produce the components cost efficiently and in large volumes.

Capacity outsourcing is used when the company does not have enough infrastructures to meet the demands for their product. In this case, they outsource, usually the manufacturing of product or some of the components with the objective of achieving a larger production volume. Leaving the strategic issues aside, the decision of IBM to clone its Personal Computer architecture was a capacity outsourcing. IBM knew from the analysis of the market trends that 80% or more computer applications in the 90s will be desktop based. IBM also realized that to take advantage of such market potential it could not do everything by itself. Doing all by itself would have required investing heavily in manufacturing infrastructure. To satisfy the forecasted demand, IBM decided to outsource and to allow the cloning of its computer architecture. The outsourcing of design and manufacturing of critical components, such the CPU and the operating system, followed the outsourcing of manufacturing. The benefits of this approach can be readily seen today. More than 90% of the computers used today are IBM compatible. This figure can be compared to the market share gained by its then closest competitors, Apple Computers. Although Apple Computers are better products than IBM-compatible computers, they did not achieve a large market penetration. This sharp contrast is in part due to Apple’s decision to carry out the manufacturing of its products “in-house”.

From the strategic point of view, two types of outsourcing decision processes can be identified: strategic and tactical outsourcing [Taylor 1999, Phelps and Fleischer 2002]. Tactical outsourcing is a result-driven approach focusing on deciding whether to make or buy a part, assembly, or service to meet short-term goals. It is often used, for instance, to satisfy unexpected surge in demands, or temporary unavailability of infrastructure or human resources.

Strategic outsourcing on the other hand is a process-oriented approach centered at deciding where to make or buy a part based on long-term goals [Taylor 1999, Phelps and Fleischer 2002]. If the decision is to buy, most probably, the majority of the activities and functions related to the part, will be discontinued from the company. In addition to reducing operating cost and freeing financial resources, strategic outsourcing also contributes to the company competitive advantage.

Tactical and strategic outsourcings have both advantages and disadvantages. Tactical outsourcing can be used to reduce operating cost, freeing financial resources [Taylor 1999]. It also enables to gain access to expertise and resources that are not available internally. Outsourcing is also used to deal with functions and activities that are either difficult to manage, out of control or just too expensive to maintain internally. Tactical outsourcing has also disadvantages. Companies may get too focus on the financial analysis of direct cost, overhead, working capital, as well as profits and jeopardize their competitive advantage. Companies may endanger their competitive advantage by outsourcing activities that either belong to their core competencies, or have a significant impact in their differentiation from competitors [Fine and Whitney 1996]. In addition, companies loose control over the part or component while outsourcing.

Strategic outsourcing benefits companies by improving their competitive advantage. It helps companies to focus on their core capabilities, by transferring to others a portion of their product development process. Financial and human resources freed by outsourcing can be utilized in other more critical functions of the company. Strategic outsourcing also enables companies to gain access to world-class capabilities, share risks, as well as improve, or reengineer their core business processes.

The major disadvantage of this type of outsourcing is the lack of control and the dependency created by the decision to buy. The outsourcing of non-core capabilities means loosing control over the development process of products or services. Transferring control over certain functions to other companies can have a devastating effect on the product. Issues such as quality, reliability just to mention a few, may be greatly affected by the wrong outsourcing decision. Companies also become dependent on the performance of others. They become dependent on the performance of other organization on which they might have a little or no control.

Phelps and Fleischer [2002] suggest that tactical outsourcing can and should be used before taking strategic outsourcing decisions. Tactical outsourcing can be used to determining part or components that are good candidates for strategic outsourcing. Companies can use tactical outsourcing to benchmark their expertise according to other companies in the market. Using tactical outsourcing first enables to evaluate and building trust on the candidates for establishing long-term and mutually dependent relationships.

Because strategic outsourcing focuses on the long-term goals of the company, the following analysis of the functional requirements of outsourcing addresses only strategic outsourcing.

The 5WH1 analysis Prasad [1996] is used to identify the functional requirements of strategic outsourcing. This analysis has been used successfully in Concurrent Engineering for many years. In the 5W1H analysis the five 'Ws' are: what, who, why, when and where and the 'H' is how. More specifically, the following questions need to be answered.

1) What to outsource?
2) Who should perform the outsourced tasks?
3) Why to outsource?
4) When to outsource?
5) Where to outsource?
6) How to outsource?

A.2.1 What to outsource?

To answer this question, companies need to carry out a detailed analysis to identify what are their core capabilities or competencies. Core competencies are the combination of skills and knowledge in areas in which the company has gained a competitive advantage [Coyne et al. 1997]. Core competencies are multidimensional. They include core products, core processes, and core technologies [Eversheim et al. 1999]. The three most important attributes of a given core competency are market potential, value adding, and reproducibility [Prahalad and Hamel 1990]. A core competency should enable a company to operate in a variety of market sectors. It should have a significantly value adding impact on the products or processes offered to customers. More importantly, a core competency should be hard to repeat or imitate by other companies or competitors. It must be interpreted as the distinctive signature that enables customer to associate the product only with the company and no one else.

Let us take as example the automobile industry. For years, different manufacturers have associated their vehicles with distinguishing characteristics. For instance, Japanese automakers such as Honda and Toyota have built their reputation based on quality, reliability, the above average fuel economy, and relatively affordable pricing of their vehicles. Volvo on the other hand, has created a unique image based on the safety of its vehicles. GM and Ford exploit the strengths of their vehicles and their capabilities to perform a variety of tasks. Definitely, it is well known that Japanese automobiles are small, American automobiles are not very efficient in fuel consumption and that Volvo is an expensive vehicle.

The identification of core competencies consists in a detailed investigation of the current or ‘as is’ situation of the company [Reithofer and Naeger 1997]. Afterwards, the business process is reengineered in such a way that no value adding and wasteful activities are removed. The reengineering of a business process results in the creation of a new or optimized process chain in the company.

Once the analysis of core capabilities is performed, any task, function, or activity that is not directly related to the core capabilities becomes a candidate for outsourcing. The activity removed should not influence significantly the long-term competitive advantage of the company. However, as Venkatesan [1998] pointed out, for strategic reasons, some of non-core competencies may still be performed in-house. Competitive knowledge, customer visibility, or market-differentiation are the some of the reasons for keeping non-core competencies “in house”. Items, parts, or services critical to product or process performance should not be outsourced. Furthermore, companies should keep in house the components that differentiate their products in the market.

A.2.2 Who performs the outsourced tasks?

The answer to this question lies in the partner selection process. The selection of the company to perform the outsourced tasks is the main objective of the partner selection process. A detailed analysis of the partner selection process is presented in Chapter 7. Nonetheless, the basic principles of this process are presented below.

The process chain identified during the analysis of core competencies can be used to determine the required skills, and therefore, the subcontractors [Reithofer and Naeger 1997].

The following steps for the partner selection process apply regardless of the item or component being outsourced [Fine and Whitney 1996]. Companies should be able to:

1) Write precise request for quotations (RFQ) using customer's needs,
2) Decide who qualifies to bid,
3) Obtain bids,
4) Chose the best qualified bid and,
5) Modify, negotiate, or improve the bid.

Based on the observation of leading manufacturing companies around the world, Fine and Whitney [1996] proposed this as a cyclical process where the capabilities of the suppliers are improved, if they do not meet the qualifications.

A.2.3 Why to outsource?

The answer to this question lies in the benefits that strategic outsourcing provides to companies. These benefits were analyzed earlier. Strategic outsourcing improves the company competitive advantage. It enables companies to focus on what they do best or core capabilities. By eliminating non-value adding activities, companies can achieve a better use of their human and financial resources. These resources can then be directed to functions that are more critical. In addition, outsourcing enables companies to become more flexible and gain access to knowledge. Companies can use outsourcing for sharing risk and financial investments.

A.2.4 When to outsource?

Outsourcing should be chosen when it is more effective buying than making components "in-house". It should not affect the company's competitive advantage.

A.2.5 Where to outsource?

This question can have both a general and a specific interpretation. In a general sense, it refers to the geographical location of the subcontractor. The selection of the outsourcing location is influenced by factors such as availability and technical level of the human resources, as well as the production costs, profit margins and economical incentives. This is an economical analysis and it is beyond the scope of the thesis.

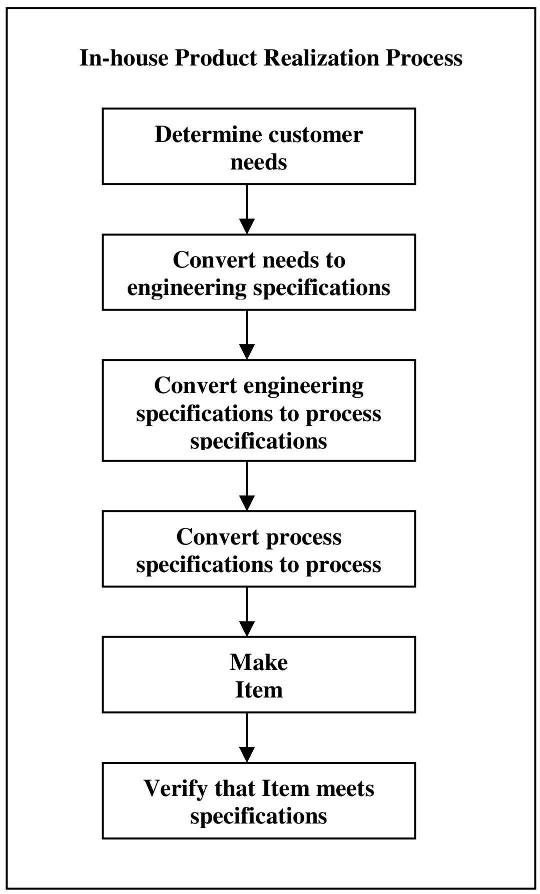

Figure A.2. Product Realization Process [after Fine and Whitney 1996]

The specific interpretation of the question deals with where in the realization process of the product or service the outsourcing decision of functions or activities should be made. The analysis focuses on the Product Realization Process since the thesis deals with Virtual Enterprises in design and manufacturing. Nonetheless, the following analysis applies almost completely to service oriented outsourcing as well.

Fine and Whitney [1996] stated that outsourcing decisions start with a robust Product Development Process. They studied design and manufacturing operations of companies in United States, Japan, and Europe and concluded that outsourcing follows a similar pattern in successful companies and that same principles apply for design of products or processes.

A simplified representation of Product Realization Process is shown in Fig. A.2. The process starts with the identification of the customers' needs. These needs are converted into engineering specification and subsequently into process specifications. Once the process specifications are identified, they are converted into the process variables used to manufacturer an item. The process finishes with the verification of the specifications.

The architecture of the product must also be taken into account during the outsourcing decision-making process. There are two well-defined types of product architecture: integral and modular. Modular architectures enable mix and match of components and subsystems due to standardization of functions and interfaces. Interfaces are far more standardized than the functions. In this case, the design of a product follows a bottom up approach. In products with an integral architecture, on the other hand, components and subsystems are designed to fit together with each other. Functions are shared by more than one module and components have multiple functions. The development of products with integral architecture usually follows a top-down approach.

A Personal Computer is an example of a product with a modular architecture. It is possible to have a motherboard from one manufacture, a hard drive from another and microprocessor from a third one. This combination from different manufacturers usually results into what Fine and Whitney [1996] call 'a viable product'. However, the same cannot be said about an airplane. It is almost impossible to mix and match components and subsystems from different manufacturers and obtain a flyable airplane.

Identifying where to outsource requires the integration of the Product Realization, Product Development Processes, the architecture of the product and competitive advantage issues. According to Fine and Whitney [1996], the best candidates for outsourcing are the components that are easily decomposable and have clear and well-defined interfaces. Outsourcing less decomposable components increases the complexity of the outsourcing. It could create problems since subcontractors cannot be given precise specifications about what they should deliver. Subcontractor will need more information since the element related to other elements. In addition, it might not allow subcontractors to further decompose their element or take [internal] decisions about the item assigned to them.

A.2.6 How to outsource?

How to outsource seeks to answer the question about how much information should be given to subcontractors. Companies need to pay a careful attention to this issue since information and knowledge are expensive to obtain and develop [Campbell 1998]. Issues related to the company competitive advantage and the type of dependency an outsourcer gets into should be considered.

Regarding the information given to the subcontractors, outsourcing can be divided into two well-defined types: black box and white-box outsourcing [Fine and Whitney 1996]. Black box outsourcing is often used with proven partners or subcontractors. In this case, design ranges and goals instead of specific details are given to subcontractor. It is called black box outsourcing, because the outsourcer is not particularly interested in how the subcontractor achieves the design goals. Respecting that the interfaces and design ranges of the parameters of the component is critical to black box outsourcing. On the other hand, in white box outsourcing detailed specifications are provided. In many cases, the specifications include blueprints of the elements. The subcontractor must precisely meet those specifications. This approach is often used with less proven or new subcontractors. Gray box outsourcing is an intermediate point between black and white box outsourcings. It includes features of both main types of outsourcing. Regardless of the type of outsourcing chosen, the steps for selecting the subcontractor should be followed.

In establishing outsourcing relationships, a company may become dependent by capacity or dependent by knowledge [Fine and Whitney 1996]. A company becomes dependent by capacity when it is capable of making a component, but it chooses to buy it instead. Time, financial resources, manufacturing infrastructure or management focus are some the reason that may influence the decision to buy. This is similar to the capacity outsourcing explained at the beginning of this section. On the other hand, a company becomes dependent by knowledge when it needs a components but it does not have the skills to make it. In this case, the company seeks a supplier with the expertise in producing the component. This dependency by knowledge is similar to specialty outsourcing.

A.3 Evolution from Network Organizations

A network organization is the combination of value adding chains of two or more companies with the purpose of satisfying mutually convenient objectives. Lipnack and Stamps [1997] identified network organizations as the organization type of the future. Network organizations bring together the contribution from different partners. They are oriented to reducing time to market, reducing cost, and increasing the flexibility [Campbell 1998, Wildeman 1998].

Five organizational principles characterized network organization [Lipnack and Stamps 1997]:

1) unifying purpose.
2) independent membership.
3) volunteerism.
4) shared leadership.
5) integration.

Networks are formed because of the common values, goals, and strategies shared by their members. Member companies are economically and legally independent entities that, in addition of taking part in the network, maintain an individual presence in the market. Members voluntarily join the network because together they can realize goals and strategies that they cannot achieve individually. Technological development, economic savings, strategic advances are few of the benefits derived from taking part in networks [Franke 2001].

Each member contributes to the network in its area of specialization or core capabilities. Interactions among member of the network take place at different level depending on the objectives and scope of the partnership. Sometimes it is appropriate to interact at company levels, while in other it may be beneficial to do so at department or individual level.

According to Snow et al. [1992] network organizations can be classified according to their structure in intra and inter organizational networks. Both internal and external networks have the same primary objective: achieving flexibility by being able to adapt to changing market conditions. Intra-organizational networks are formed within the organizations. They do not include the participation of third parties. Internally, business units or the departments of a company operate independently of the parent organization.

An example of this kind of networks is the project-based enterprise [Hammer and Stanton 1999]. In a process-oriented enterprise, financial resources are assigned according to projects, neither departments nor functional units. The process owners are the ones that are responsible for the design, control, and to provide the resources to the activities. This change orients management to the underlying process or product instead of fulfilling the demands of the hierarchy.

Hammer and Stanton [1999] describe the transformation of the Calculators Unit of Texas Instruments. The company reduced its time to market in half. The company was also able to recuperate the return of the investment in the product development process 80% faster. More importantly, Texas Instruments became a market leader in an area where it had been relegated. They achieved this success by reengineering the unit according to a process. The budget was assigned to the process, and the process owner and the team were responsible for the whole process from conception to marketing. Even, the team members were relocated to be able to work cohesively to avoid delays and bottlenecks.

Inter-organizational networks appear when companies, instead of reorganizing internally, outsource non-core competencies to others. By transferring non-core capabilities, outsourcing companies can concentrate on their own core competencies. In addition, companies free financial resources that can be used for other purposes. Inter-organizational networks can be stable or dynamic. In stable networks, members establish long-term relationships that expand for several years. Members organize usually around a large company and act as either subcontractors or suppliers. This type of arrangements is commonly used in implementing outsourcing decisions. Stable networks are typically implemented in market sectors where the demands do not change frequently.

Dynamic networks, on the other hand, are implemented in rapidly changing or discontinuous markets. They are focused on taking advantage of specific market opportunities instead of establishing long-term relationships. Opportunistic relationships are based more on the satisfaction of mutually convenient objectives than on building trust among the members of the network. By assembling core capabilities from different sources, dynamic networks achieve both flexibility and specialization. They are flexible because the can use the core capabilities of their members to provide different offers without having to carry out a full "in house" development. Specialization comes from the assembling of core capabilities.

Table A.1 summarizes the differences between stable and dynamic networks according to the nature of the relationship established, uncertainty, risk, control, target market, dependency and trust.

Table A.1. Comparison between Stable and Dynamic Network Organizations.

Characteristic	**Stable Networks**	**Dynamic Networks**
Relationships	long-term	opportunistic (short-term)
Uncertainty	low	high
Risk	low	high
Control	high	low
Markets	stable	rapidly changing or discontinuous
Dependency	low	high
Trust	high	low

During years, different types of inter-organizational networks have been used in industry. Wildeman [1998] classifies inter-organizational networks considering the lifetime of the alliance as the independent variable and control, dependency, risk and investment level as dependent variables. This classification is shown in Fig. A.3

Jägers, et al. [1998] also classified inter-organizational network structures. However, they use uncertainty as an independent variable and control is used as dependent variable. This classification is shown in Fig. A.4.

It can be seen that a common pattern emerges regardless of the independent variable used in the classification. Virtual Enterprises or as Wildeman [1998] puts it "Virtual Teams" are inter-organizational network structures with a low level of control, a short lifespan and a high uncertainty.

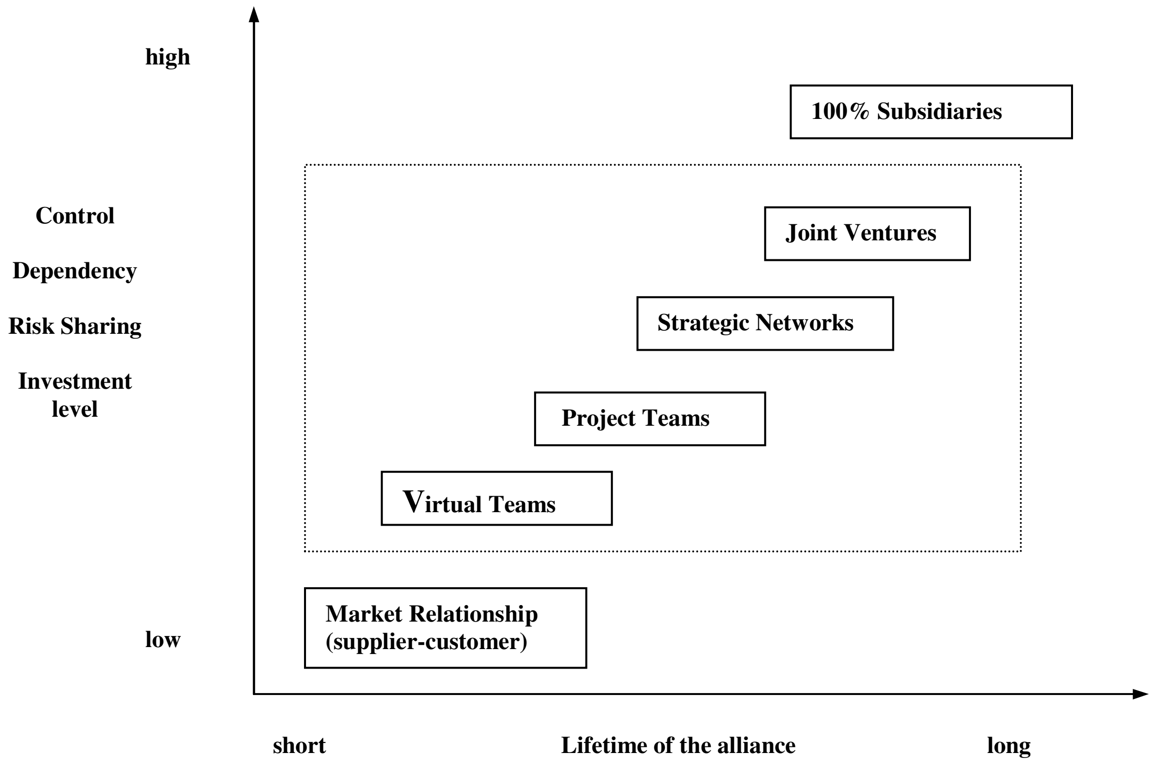

Figure A.3 Structure of Alliances [after Wildeman 1998]

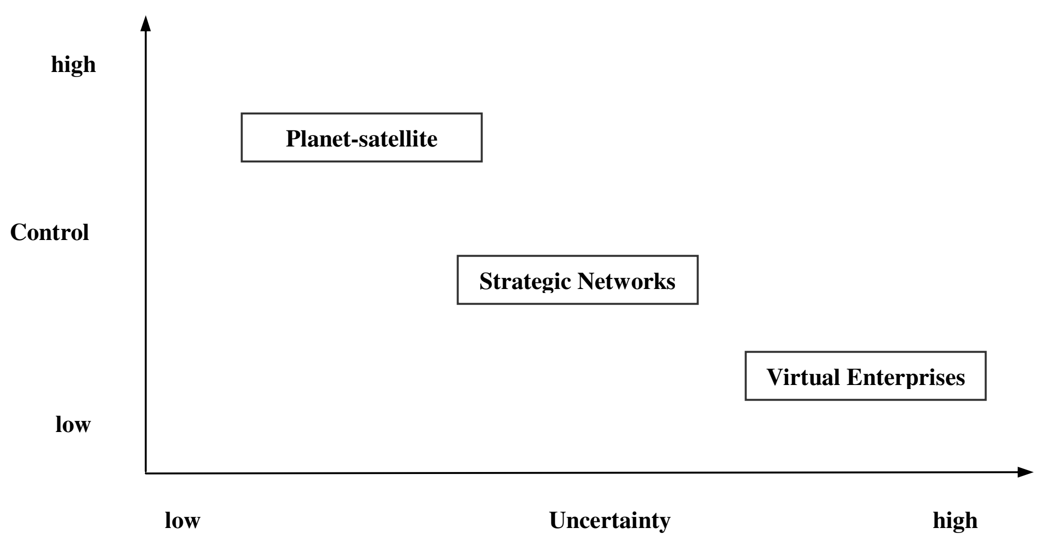

Figure A.4. Spectrum of Network Organizations [after Jägers et al. 1998]

It is important to notice that strategic alliances are the most developed structure before the emergency of Virtual Enterprises. Therefore, the following analysis focuses on identifying the most important characteristics of strategic alliances. The 5W1H analysis is also used to study strategic alliances.

A strategic alliance is the combination of value-adding chains of two or more companies with the objective of achieving or sustaining their competitive advantage [Bronder and Pritzl 1992].

The 5W1H analysis of strategic alliances seeks to answer the following questions:

1) What to contribute to a strategic alliance?
2) Who to form a strategic alliance with?
3) Why to form a strategic alliance?
4) When to form a strategic alliance?
5) Where to form a strategic alliance? and
6) How to form a strategic alliance?

A.3.1 What to contribute to the alliance?

To determine what to contribute to a strategic alliances companies should start by conducting an analysis of their current or "as is" situation [Bronder and Pritzl 1992]. The analysis of the current situation should take into account the company's mission, its value potential, strategic position, and its core capabilities. The mission of the company describes the field of activity of the company and it states the future direction in the development of the company.

Companies should also identify their value potentials. Bronder and Pritzl [1992] suggested that companies should focus on their corporate, market, financial, human and cooperation potentials. The market potential considers the markets where the company chooses to operate. It also should consider the range of products or services offered. Market potential is the most commonly exploited potential of the companies. However, significant advantages can be derived from the other potentials.

Financial potential takes into account the possibilities of using the company's financial resources to leverage its competitive advantage. Strategies such as sharing research and development projects or sharing of facilities and financial investments often results in a competitive advantage for the company.

The analysis of the human potential should explore new ways of attracting and keeping qualified human resources within the company. It should also include creative management strategies that empower the workforce. Cooperation potential deals with how companies can achieve and sustain their competitive advantage by cooperating with other companies.

Companies should assess their core capabilities. Core capabilities should enable the company to achieve the strategy or long-term goals as well as the objectives stated in its corporate mission.

A.3.2 Who to form a strategic alliance with?

Strategic alliances need to conduct a partner selection process, as in the case of outsourcing. Brendon and Przilf [1992] stated that this process is critical to the success of the alliance. They proposed to evaluate of partners according to complementarity, strategic and cultural compatibility. For companies to become partners they should complement each other core capabilities and expertise. This complementation should increase the value adding potential of the partners. It should also enable companies to collectively achieve goals that they could not achieve on their own.

The strategic compatibility focuses on the similarities of strategies of the alliance and its members. Taking part in a strategic alliance should always complement the member companies' individual strategies. This strategic compatibility is considered a critical factor in the success of the alliance. Cultural compatibility measures the compatibility of the members' corporate culture. Failure to consider cultural issues during the selection process may result in unsuccessful alliances. The evaluation of cultural compatibility must include factor external to the organization. Issues such as national culture and traditions should be considered.

A.3.3 Why to form a strategic alliance?

The answer to this question lies in the benefits that companies obtain by forming strategic alliances. Strategic alliances allow companies to save time and financial resources. It also makes it possible to gain access to knowledge and new markets [Bronder and Pritzl 1992]. By joining strategic alliances companies save both time and financial resources. Alliances enable companies to react faster to market changes and demands. Among others, time-savings can be realized in the development process of products or services, concept to cash time and market penetration. For example, cooperative Research and Development projects can substantially reduce the time required to develop specific technologies. Companies realize cost savings by sharing infrastructure and investments. Moreover, companies gain access to expertise and knowledge by collaborating with other. Rapid technological advances and shorter product life cycles challenge the ability of a company to develop products individually. Under these circumstances, companies usually opt for establishing strategic alliances. Companies also routinely use strategic alliances to gain access to new markets. It is common for companies to seek access to new markets by working with companies that already have a presence in those markets. In this way, they ease the expensive and time-consuming process of market expansion.

A.3.4 When to form a strategic alliance?

Strategic alliances should be chosen when executing projects in an alliance is more profitable than doing so individually [Bronder and Pritzl 1992]. Wildeman [1998] pointed out that this approach of doing things together is based on the understanding that the resources and core capabilities of the company are limited. To ensure a maximum profitability companies need to focus on leveraging their core competencies. Core competencies should be used in as many supply chain as it is practically possible.

A.3.5 Where to form a strategic alliance?

Strategic alliances can be implemented in any activity or function in the value adding chain where the company has expertise. Companies can form strategic alliances in areas such as Research and Development, marketing and sales. In production, logistics and the design and manufacturing of specific items, parts, components, and subsystems strategic alliances can also be formed [Bronder and Pritzl 1992].

A company may decide to play the role of an integrator. In this case, companies act as an umbrella organization and offer customers a single point of access to various services. This approach is also used in market segments that offer system-deals or solutions instead of specific products. System-deals is a term used to characterize offering in which two or more products or services are integrated in order to enhance the scope of the offerings.

Strategic alliances can be horizontal, vertical, or diagonal according to the market where member companies operate [Bronder and Pritzl 1992]. Companies operating in the same market segments form horizontal alliances. Often these companies are competitors that decide to carry out Research and Development projects together. This type of alliance is also used to protect markets from competition. The division of markets in telephone industry in Canada illustrates this situation. Bell Canada operates in Ontario and Québec, while other companies operate in Manitoba, Saskatchewan, Alberta, British Columbia, and the Maritime Provinces.

Interacting with customer or suppliers in the several value adding chains creates vertical alliances. Vertical alliances including suppliers are often used by large manufactures to assure control over critical components or subsystems. Car manufacturer in both Japan and North America have consistently used this strategy for years [Schlie and Goldhar 1989, Fine and Whitney 1996]

Diagonal alliances involve the collaboration of companies operating in different markets or industrial sectors. They are often used in the electronic and computer industry. This type of alliance is very effective in market focuses on providing systems-deals to customers.

A.3.6 How to form a strategic alliance?

To form strategic alliances companies need to decide on the period and scope of the collaboration [Bronder and Pritzl 1992]. Companies also need to determine the allocation of resources and the degree of formalization of their relationships. Companies must decide earlier in the formation stage of the alliances whether the collaboration will be short or long term. Short-term collaborations are established for meeting specific objectives and are usually tactical in nature. Examples of this type of collaboration are conducting limited Research and Development projects or sharing production facilities to manage seasonal or unexpected urges in demands. Long-term collaborations are used for meeting strategic objectives. Companies use long-term strategic alliances in joint production and manufacturing initiatives as well as marketing and sales partnerships. Managerial, financial and production resources should be allocated to the alliance. Alliances may choose to have partners contribute to the pool of resources or performing the activities using their individual resources. The formalization of the alliance is achieved by establishing legal contract, mutual control as well as setting communication and process rules among members of the alliance.

A.3.7 Phases of Strategic Alliances

Bronder and Pritzl [1992] identify analysis, configuration, partner selection, and management as the four phases of strategic alliances. During the analysis phase, the company should perform the analysis of its current situation. A company should only take part in a strategic alliance if it benefits the company competitive advantage. The analysis phase also identifies and evaluates the strategic and value-adding potentials of the cooperation.

The configuration phase establishes the field and the intensity of the cooperation. This phase includes the decision for forming a horizontal, vertical, or diagonal alliance, according to the strategic objective of the companies. Other factors such the duration of the alliance, the allocation of resources and the degree of formalization of the relationship should also be taken into consideration.

The partner selection phase deals with strategic and cultural fits as well as the complementation of the core capabilities of the partners. In the management phase the alliances is directed to the satisfaction of its strategic objectives and the objectives of the partners. During this phase, partners learn about each other and how to work together.

A.3.8 The Agile Enterprise

In response to market conditions and the needs for achieving agility companies are shifting from a sequential and functional to a concurrent and team-based product development processes [Hirsh et al. 1998]. Agile organizations need to be flexible, distributed, and have flattened managerial structures or hierarchy in which the decision making-process is delegated and distributed. More importantly, they need to focus on customizing products to individual preferences and becoming customer-centered organizations. This type of organizations also shifts the focus the organizations from providing product to providing solutions to customer needs and problems in a dynamic environment [Goldman et al. 1995, Campbell 1998].

The success of an agile strategy comes from the processes and structures that facilitate speed, adaptation, and robustness. They form a coordinated system capable of achieving competitive performance in a highly dynamic and unpredictable manufacturing environment.

It is interesting to notice that agility is a continuous and never ending process in which companies shape their operations according to the market needs [Goldman et al. 1995, Campbell 1998]. There is not a short path to achieve agility. Companies need to methodically transform themselves into an agile enterprise. This is illustrated by the fact that this transformation expands for several years. Industry leaders such as IBM and Nortel Networks have primarily focused on transforming some of its division. IBM for instance is transforming its Global Operations and E-Business divisions. Nortel Networks on the other hand, has focused on its Career Data Networks (CDN) research and development unit. These companies are using the lesson learnt to propel changes in other areas of their organizations and achieve an incremental and secure transformation into agile enterprises.

Campbell [1998] pointed out that it is very important for companies to achieve the right level of agility. She draws an analogy between agility and the insurance policies. Having extra insurance policies for very unlikely events is not a cost-effective solution. Similarly, preparing the company to react to very rare market conditions can erase the benefits associated with agility and waste the company's resources.

Grenier and Metes [1995] pointed out that despite the apparent similarities; alliances in agile organizations represent a new approach to address business needs. Goldman et al. [1995] indicated that despite the use of a similar terminology, radical changes in responsibilities and goals are taking place. The type of relationships established in agile enterprises goes beyond the traditional buyer-supplier relationships. Those companies that integrate their core capabilities and complement other companies' core competencies are partners and not suppliers. As partners, those companies share the responsibilities and benefits for the complete product development process. In contrast, a buyer-supplier relationship finishes once the components are delivered within the specifications. Suppliers do not share other responsibilities associated with bringing a product or solution to market such as marketing and customer service.

A.4 Virtual Enterprises

Chapter 2 introduced the most important characteristics of Virtual Enterprises. The analysis presented below focuses on combining the characteristics "inherited" from outsourcing, network organizations, and agility.

The 5W1H analysis of the functional requirements of Virtual Enterprises seeks the answers the following questions:

1) What to contribute to the Virtual Enterprise?
2) Who to form a Virtual Enterprise with?
3) Why to form a Virtual Enterprise?
4) When to form a Virtual Enterprise?
5) Where to form a Virtual Enterprise?
6) How to form a Virtual Enterprise?

A.4.1 What to contribute to a Virtual Enterprise?

Partners should contribute to Virtual Enterprises with their core capabilities. The answers to this question in both outsourcing and strategic network suggest a company should start by analyzing its current situation. Combining these two analyses, it can be concluded that in addition to core competencies, companies should take into account their mission, value potential and strategic position.

A.4.2 Who to form a Virtual Enterprise with?

Both outsourcing and strategic networks recommend carrying out a partner selection process. The criteria considered in outsourcing are time, cost, and quality. Strategic networks take into account the complementation of core capabilities, as well as the strategic and cultural compatibility.

A.4.3 Why to form a Virtual Enterprise?

The combined benefits of outsourcing and strategic alliances answer this question. Outsourcing and strategic alliances allow companies to focus on their core competencies and reduce cost, as well as developing time. In addition, they both can be used for sharing risk and financial investments. Moreover, they contribute to the companies' competitive advantage by increasing the flexibility of their processes, providing access to external knowledge and expertise as well as new markets.

A.4.4 When to form a Virtual Enterprise?

Forming a Virtual Enterprise should be chosen when it is more effective to buy than to make "in-house". The decision should take into account both financial and strategic factors. It should be more beneficial for the company to participate in a Virtual Enterprise than conducting business alone. This approach is often used because of the constant change in the market conditions and customers' trends.

A.4.5 Where to form a Virtual Enterprise?

A Virtual Enterprise should use the Product (or service) Realization Process to decide where partners can contribute to the Virtual Enterprise. This decision should take into account the architecture of product as well as competitive advantage issues. As much as possible, partners should contribute with modules or components that are easily decomposable and that have well-defined interfaces. This approach simplifies the specifications given to the partners and allows them to further decompose their modules if required.

A.4.6 How to form a Virtual Enterprise?

Depending on the reliability, capabilities, and the amount of information given to partners, two outsourcing extremes were identified: black box and white box outsourcings. Gray box outsourcing is an intermediate state with characteristic from both extreme situations.

Strategic networks, on the other hand, consider other factors such as the time and scope of the collaboration, the allocation of resources, and the degree of formalization of the relationship among partners.

In principle, a Virtual Enterprise should only use black box outsourcing since each partner is expected to excel in its core capabilities. In practice, different levels of gray box outsourcing are often used depending on the trustworthiness of the partners. In its purest and most elaborated form Virtual Enterprises should use black box outsourcing. The relationships among partners are temporary or based on the satisfaction of the market need. Those relationships rely on trust more than on formal contracts.

A.5 Summary

This appendix has analyzed the evolution of Virtual Enterprises. It was shown that Virtual Enterprises are derived from both outsourcing and network organizations. Several of the most important elements in Virtual Enterprises come from one of these two sources. For example, a process similar to the one used in 'make or buy' decision, can be used for identifying the core capabilities required in the Virtual Enterprises. Furthermore, many of the criteria used in the partner selection processes of outsourcing and network organizations can also be used in the partner selection process in Virtual Enterprises. The appendix also showed that Virtual Enterprises are agile enterprises oriented to satisfy the current market conditions.

Appendix B

B Survey on Outsourcing Practices in Canada

B.1 Introduction

The study presented in this appendix, was designed to gain a better understanding about how outsourcing is being used in the Canadian industrial practice nowadays. Hence the general objectives of this survey are:

1) To identify some of the risks associated with outsourcing and outsourcing decision-making,
2) To determine the use of the Product Architecture and Product Development Process in outsourcing decision-making,
3) To identify the criteria used in partner selection in outsourcing, and
4) To identify the reasons for success and failure in outsourcing relationships.

The results presented in this appendix are based on the following methodology. First, the objectives of the survey were set and the research questions of interest were identified. Second, a theoretical framework for the study was developed. This step included the development of the propositions and hypothesis of the research. Third, the design and distribution of questionnaires were carried out. Fourth, the data was collected and analyzed to draw the conclusions of the research.

B.2 Research Framework

This research seeks to answer three general questions. The first questions deals with the identification of the 'as is' situation in the outsourcing decision making in Canada. The second question aims to identify the most important reasons for success and failure in outsourcing relationships. The third question seeks to evaluate the preparedness of Canadian design and manufacturing companies to form Virtual Enterprises.

The analysis of the situation 'as is' uses a framework that links outsourcing decision making to the Product Development Process, the Product Architecture, risks, and the partner selection process.

The identification of the determinants of success and failure in the outsourcing relationship is carried out by analyzing the role of the selection criteria in determining the outcome of the relationship. The research is directed towards outsourcing relationships that took place in the last three (3) to five (5) years.

The preparedness of the companies to form Virtual Enterprises is evaluated by comparing the findings of the 'as is' situation to the characteristics of Virtual Enterprises explained in Chapter 2.

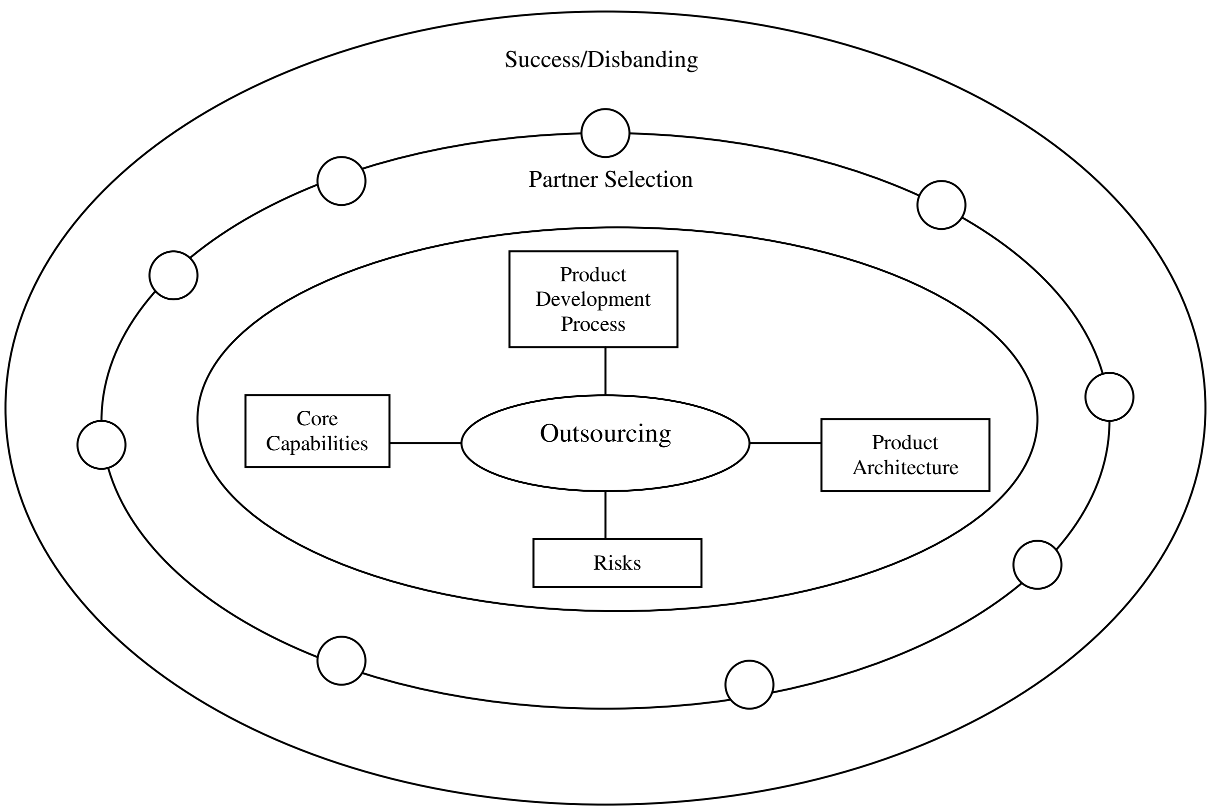

Figure B.1. Research Framework.

The research framework adopted for the survey is shown in Fig. B.1. This framework is based on the work of Fine and Whitney [1996]. Outsourcing is a broad and process-oriented strategy in which other factors beyond cost savings are taken into account. Based on the observation of successful companies around the world, they proposed a framework that considers core competencies, the Product Development Process, the product architecture and the management of the supply chain.

The framework presented below expands the understanding of the research of Fine and Whitney [1996] to include the selection criteria used during the partner selection process and the evaluation of the success or failure based on those criteria.

The framework is centred in outsourcing and its decision making process. Outsourcing decision-making is based on the analysis of the core competencies or capabilities of the outsourcing company. As explained in Chapter 2, the focus on core capabilities allows companies to identify the tasks that are good candidate for outsourcing. The framework considers system-engineering skills as one of the company's core capabilities.

These skills are used during the Product Development Process and the development of the Product Architecture. The effects of this addition on the outsourcing decision-making process are explained later in this section. Risk is also considered as an important factor in the framework. Companies need to take into consideration the risks associated with outsourcing and the dependencies created because of these decisions. By considering risks rather than ignoring them, companies can develop strategies and procedures for dealing accordingly with those risks.

At the second level, the framework considers the partner selection process. The partner selection process is both an internal and external process. Internally, a company needs to prepare itself for outsourcing by using the Product Development Process and the Product Architecture. This strategy must also take into consideration the risks associated with outsourcing. Externally, the outsourcing company should focus on finding the subcontractors that satisfy the internal requirements of outsourcing, as identified during the internal preparation. The requirements identified in the internal preparation for outsourcing are expressed through the selection criteria used for selecting partners. The criteria are represented in Fig. B.1 as the circles around the Partner Selection level. The partner selection process allows a company to select subcontractors. These subcontractors together with the outsourcing company are the ones that determine the success and failure of the outsourcing relationships.

This framework differs from the current understanding of core capabilities in which any activity that is beyond the area of expertise of a company is a good candidate for outsourcing. The understanding of outsourcing as a cost saving strategy is expanded to consider other factors such as risk and the type of dependency created by outsourcing decisions. The inclusion of the Product Development Process and the Product Architecture into the decision making process, instead of only cost, provides a general foundations on which the outsourcing decision-making can be based. Regardless of its complexity, any product or process can always be analyzed in terms of its architecture and development process. The use of the Product Development Process and the Product Architecture makes it possible to achieve a more rational and comprehensive view of the implications of outsourcing.

The following sections explain the components of the framework, in more detail.

B.2.1 Product Architecture and Product Development Process in Outsourcing Decision Making

Based on the observation of successful companies, Fine and Whitney [1996] linked outsourcing decision-making, the Product Architecture, and the Product Development Process. System engineering was identified as the linking element. The application of system engineering principles allows companies to hierarchically decompose the architecture of the product into simpler subcomponents or subsystems until the commodity level is reached. The process focuses on the satisfaction of the customer needs identified at the highest level of the hierarchy. At each level of the hierarchy, the relationships between the level and the previous and next level have to be carefully observed.

One of the conclusions of this study was that outsourcing is directly related to the development of a modular architecture of a product. That is, tasks related to the development of product with modular architecture can be outsourced easier. The study refers to situations in which the modules' boundaries are artificially redefined with the sole purpose of keeping complex interaction internal to subsystems. This approach helps both the outsourcing company and the supplier. The supplier can better understand its responsibilities and therefore meet the specifications. The outsourcing company benefits since it can state clearly the responsibilities for each supplier and can provide only a minimal set of details. Suppliers can then make further decisions and carry out decomposition, if needed, with minimum information about their items or subsystems.

B.2.2 Outsourcing, Risks and Market Differentiation

Commodities are the most decomposable items in the product architecture. They are located at the lowest level of the Product Architecture. Outsourcing beyond the commodity level has sometimes been seen in design and manufacturing as a threat. Companies have been usually concerned with the long-term effects of outsourcing policies for their survival in the market. Although risk is a multilateral, this work focuses on the analysis of risk and outsourcing regarding the Product Development Process, development of new products or specific technologies, intellectual property, and management of the supply chain and dependency.

It has been widely recognized that outsourcing creates dependency. By transferring part of their product development process to others, companies lose control over the process. Therefore, they feel more vulnerable about the consequences of such decisions on their operations. Depending on the stage of the development process, companies incur different risks. Risks associated with outsourcing the design of a product are different from the ones associated with the outsourcing of subsystems or components in the same product. Risk can also increase or decrease according to the availability of subcontractors to perform a given task. The higher the capability of the outsourcing company of finding a subcontractor for a given task, the lower the perceived risk associated with the outsourcing of the task.

Risk can also be associated with the maturity of the product whose tasks are being outsourced. Subcontracting tasks related to the development of new products are riskier to the company than outsourcing similar tasks in mature products. A similar understanding applies to the outsourcing of specific technologies. Companies are more willing to outsource specific technologies in mature products than in new products.

According to Fine and Whitney [1996], two broad kinds of dependencies may appear when outsourcing: dependency by capacity and dependency by knowledge. Dependency by capacity appears when companies are capable of making the item, but for managerial or strategic reasons they decided not to do so. The most common reasons for capacity outsourcing are management focus, time, money, and infrastructure. In dependency by knowledge on the other hand, the company needs the item but does not have the technical expertise to make it "in-house". Therefore, it subcontracts the item to another company. Dependency by knowledge is divided into dependency by component knowledge and system knowledge. In the former, the company may not know how to make the item but it knows how to use the item in the product in a way it generates a competitive advantage. The system knowledge dependency is the riskier of these two dependencies. In this case, the company not only does not know how to make the item, but also does not understand what it is buying or how to integrate the item to their process.

The observation of the industrial practice has shown that, in general, both capacity and knowledge dependency can be used towards reinforcing the company's competitive advantage in the marketplace [Fine and Whitney 1996]. The major dangers of the dependency are related to knowledge and preparedness. Companies often do not know about the kind of dependency they get into because of their subcontracting policies and therefore fail to be prepared to deal with the consequences of that dependency.

The type of dependency created by the outsourcing decision influences the way the supply chain is managed. The decision of white or black box outsourcing may be based on avoiding the company to get into a dependency by knowledge. It also influences the relationship with subcontractors. In some cases, it may be beneficial for the outsourcing company to deal with all the subcontractors involved rather than with the first level of the supply.

B.2.3 Partners Selection in Outsourcing

Partners' selection in outsourcing has been based on factors such as location, cost associated with the service provided, delivery time, or simply habits [Grenier and Metes 1995, Zhang et al. 1996]. However, as explained in Chapter 2, the demands for agility, and the development and extensive use of Information Technology in design and manufacturing, have changed the relative importance of these criteria in outsourcing decision-making. Location, for example, once considered a critical factor, has become a less important factor due to the use of electronic communication and exchange of information. Cost has also changed its relative importance. The increasing focus on satisfying customer needs and providing them with solutions has made it possible to increase the price of the product or service offered. Clearly, customers are willing to pay more for those product or services. However, customers need to see an increase of value in the product or solution offered. Delivery time is perhaps the only factor that has become more important. Chapter 2 explained that companies are consistently trying to be first in the market as a way to increase their competitive advantage.

It was mentioned during the introduction of the framework that the partner selection processes should take place both: internally and externally. The internal component relates to the preparation of the company before making the outsourcing decision [Fine and Whitney 1996]. It includes the capability of identifying qualified bidders, writing precise and competent specifications, and evaluating the bids and the verification of the items delivered. The capability of the company in performing these steps is seen as directly related with the type of dependency created during outsourcing. The more precisely the company can perform these steps the lower its dependency by knowledge.

The external component is related to the selection of partners. Several studies have been conducted to identify the criteria used in partners' selection in outsourcing, collaborative relationships, and strategic alliances. The American Society of Mechanical Engineers (ASME) [ASME 1997] and Accenture [Accenture 2001] conducted surveys to identify the selection criteria used in outsourcing. Bailey et al. [1998] studied the selection criteria in collaborative relationships while Brendon and Przilf [1992] as well as Wildeman [1998] identified the selection criteria used in strategic alliances.

The ASME survey found commitment to quality and reputation as the two most important criteria used in the partner selection process. The factor considered least important was the matching of corporate cultures. Other factors considered in between these two extremes are a previous collaborative record, the resources of the subcontracting company, price, confidentiality, as well as general and value-adding capabilities.

Accenture [2001] on the other hand, identified technical capabilities and the ability to work as a team, as the two most important attributes sought in partners. Other factors considered important were the understanding of business objectives, previous outsourcing experience, flexibility, and knowledge transfer.

Bailey et al. [1998] conducted a survey to identify the criteria used to select partners in industries such as electronics, aerospace, biotechnology, as well as design and manufacturing in the United Kingdom. This study found technical capabilities as the most important criteria for partner selection. The least important criterion for selecting partners was the cost of development.

Wildeman [1998] conducted a survey to identify the selection criteria used in forming strategic alliances by multinational companies. This work divides the partner selection process into two phases: (1) evaluation of the partners and (2) evaluation of the partnership. This approach is based on the understanding that a successful collaborative project starts with a careful selection of partners. The partner phase focuses on the analysis of partners as individual and autonomous units. That is, if partners are not in a solid situation on their own, it is almost impossible to succeed within the collaboration. The partnership phase analyzes the relationship among partners. It takes into account 'soft' or management related issues that are beyond the core competencies of the partners. Factors such as management style, and corporate culture should be considered during the evaluation of the partnership.

Wildeman [1998] identified complementary skills and the market position of the partner, as the most important criteria in the partner selection phase. Size was found to be the least important criterion. Regarding the partnership, the survey identified chemistry, complementation of core capabilities, corporate culture, and trust as the most important criteria, while the financial position of the partnership and openness ranked last. Brendon and Przilf [1992] proposed to evaluate partners according to the criteria: complementarity, strategic and cultural compatibility. However, they did not study the use of these criteria in real situations.

None of these surveys addressed the frequency of evaluation of neither the partners nor the partnership. It seems that companies are concerned with the selection of partners as a stand-alone process. The evaluation of partners is performed at the beginning, as part of the bidding process and hopefully once the relationship ends. This approach does not allow companies to identify small variations in the partners' satisfaction of the selection criteria. The cumulative effect of such variations over time could result in the failure of the relationship.

B.2.4 Determinants of Success and Failure in Outsourcing

Unfortunately, the determinants for success have received more attention that those for failure. This extensive focus on success might be associated with the unwillingness of companies when referring to failures. Determinants for success can always be used to infer conclusions about failure in the relationships. However, it is far more beneficial to study failure in itself and identify its reasons.

Bailey et al. [1998] found that technical capabilities, financial security, business strengths, development speed and matching aims were positively correlated with success in collaborative relationship. In addition, this study identified a negative correlation between success and cost as well as success and collaborative record. Companies that chose partners according to cost and collaborative were less successful.

Still another interesting result of this study was the accuracy in the evaluation of the selection criteria. Management ability was the criterion evaluated less accurately. This was followed by technical capabilities and development speed. Cultural compatibility and collaborative record, on the other hand, were found the most overestimated criteria. These findings point out to the areas where problems and therefore failure in the relationships are more likely to happen.

Wildeman [1998] identified the most important criteria for the start-up and management of strategic alliances. Management philosophy, complementary skills, and the size of the partners were found as the most important criteria in the partner selection phase. In addition, the chemistry between partners (and managers), the financial position of the partnership and openness were identified as the most important criteria in the partnership phase. This study also suggests that the cultural compatibility between companies can negatively affect the success of the relationship.

Regarding the disbanding of the alliance, this study identified lack of commitment as the most important reason for disbanding. Complementation of core capabilities and cultural compatibility rank second, while trust and chemistry between managers were found as the least important factors. The study also identified lack of attention to relational aspect of the relationship, lack of communication and changing circumstances as issues that need careful consideration.

B.2.5 Preparedness for Forming Virtual Enterprises

Although, the preparedness for forming Virtual Enterprises is not part of the framework, it can be evaluated by using the components of the framework. To achieve this objective, the responses of the survey will be compared to the characteristics of Virtual Enterprises introduced in Chapter 2. This comparison allows estimating the future capabilities of design and manufacturing companies to form Virtual Enterprises.

B.3 Research Methodology

A three-step research methodology was followed. The first step includes a literature review and the development of the research framework. The second step, conducted case studies in local design and manufacturing companies. These case studies focused on identifying the relevance of the issues covered in the research framework. It allowed confirming the importance of the issues covered by the research as well as the relevance of the selection criteria on the evaluation of the outsourcing relationship. The feedback received from the case study made it possible to adapt the terminology used in the survey. The third step of the methodology was the development and distribution of the questionnaires. The design of the questionnaire was based on the "Total Design Method" proposed by [Dillman 1978].

The following two sections present the steps followed to develop the questionnaire. Once the research questions were established and the research framework developed, the propositions and hypothesis of the research were identified. Research variables were then identified for evaluating the proposition and hypothesis. Finally, the questionnaire was designed to measure the variables of interest.

B.3.1 Survey Propositions and Hypothesis

For each of the objectives mentioned in Section 5.1 a set of propositions or hypothesis was developed. These propositions and hypotheses were used to first to identify the variables to be measured and then to develop the questions for measuring them.

Risk is considered the dependent variable, which is influenced by several factors. The following propositions were established for analyzing the relationship between outsourcing and risks.

1) The risk associated with outsourcing depends on the maturity of the product or technology. That is, companies are more concerned with outsourcing tasks associated with new developments than tasks related of already existing products.
2) The more decomposable the subcontracted item, the less concerned companies are about being surpassed by competitors. That is, companies are more concerned when subcontracting the design of products or subsystem than subcontracting the design of parts or components.
3) The perceived risk associated with outsourcing is directly related to the availability of subcontractors that can perform the task. The larger the number of subcontractors capable of performing the tasks, the lower the perceived risks.

For the study of the relationship between the Product Development and outsourcing, the following propositions were established.

1) The frequency with which companies use the Product Development Process indicates the importance given to this process in outsourcing decision-making. If the Product Development Process guides outsourcing decision-making, it should be used often.
2) White-box outsourcing is better, but may jeopardize the company competitive advantage and intellectual property. Black outsourcing, on the other hand, is a safer outsourcing strategy but requires more work from the subcontracting companies.

3) The more precise the specifications the company provides to subcontractors, the lower its dependency by knowledge.
4) The overall satisfaction with the results of subcontracting depends on the stage of the Product Development Process subcontracted.
5) Companies are concerned with local change made by subcontractors that may affect the Product Development Process.
6) The supply chain is informed of local changes in the Product Development Process through a communication mechanism for sharing and distributing information about the changes.

The relationship between Product Architecture and outsourcing was analyzed by considering the use of modularization and integration in outsourcing decision-making. The following propositions were established.

1) Modularization plays an important role in outsourcing decision-making. The more modular the architecture of the product, the easier the outsourcing decision making process about the subcontracting tasks.
2) The more integral the architecture of the products, the lower the risks associated with the competitive advantage in subcontracting of the tasks.

For the analysis of subcontractor selection and evaluation process, the following propositions were established.

1) Companies favour a bidding process that focuses on previous relationships.
2) The more frequently the evaluation of subcontractors, the greater the possibilities to identify small changes in performance and correct them before they become serious enough to jeopardize the success of the relationship.
3) The relative importance given to criteria depends on how easy they can be estimated or measured.
4) Some selection criteria are more important than others in determining the success or failure of the outsourcing relationship.

The following hypothesis was also established.

1) The failure in the outsourcing relationship is due to the decrease in the satisfaction of some of the selection criteria; from the time the subcontractors were chosen to the time the relationship fails.

In this case, either success or failure was considered the dependent variables. The independent variables were the selection criteria that measured the performance of the subcontractor during the relationship.

The following propositions were established to measure the preparedness of design and manufacturing companies to form Virtual Enterprises.

1) Companies are better prepared for forming Virtual Enterprises if they are specialists (focus on core capabilities) rather than generalists.
2) Companies are better prepared for forming Virtual Enterprises if they trust more their subcontractors. Trust was measured through the amount of information given to subcontractors, the communication mechanism in the supply chain, and position of the company towards the subcontractor's lack of capabilities.
3) The bidding process is open to all capable partners.
4) Companies that use Information Technology more often are better prepared for forming Virtual Enterprises.
5) Companies that focus on quality and delivery capabilities are better prepared for forming Virtual Enterprises.

The variables measured by the survey were divided in five groups. Those groups are: risk and market differentiation, product development process and product architecture, dependency, partner selection process, successful and unsuccessful relationships and the use of Information Technology. Table B.1. summarizes the variables belonging to each group.

Table B.1. Variables Measured in the Survey.

	Variables
Risks and market differentiation	• Availability of subcontractors • Decomposability of the outsourced item • Intellectual Property • Focus on core capabilities • Importance of the tasks assigned to subcontractors • Differentiation from competitors
Product Development Process and Product Architecture	• Use of PDP in outsourcing decision-making • Use of Product Architecture (Modularization and Integration) • Stages of the process where subcontracting takes place more often (design, manufacturing, assembling, customer services) • Specification of requirements • Importance of the subcontracted tasks • Local changes of the process and its implications • Communication mechanisms in the supply chain
Dependency	• Quality and quantity of the information provided to subcontractors • Checking of deliveries • Black box and white box outsourcing
Partner Selection	• Bidding process • Frequency of performance evaluation • General policies towards subcontracting • Easiness of the evaluation or estimation of the criteria
Successful Outsourcing	• Relative importance of the selection criteria • Stage of the PDP outsourced • Importance of the tasks outsourced • Satisfaction of the subcontract's objectives
Unsuccessful Outsourcing	• Relative importance of the selection criteria • Stage of the PDP outsourced • Importance of the task • Satisfaction of the subcontract's objectives
Use of Information Technology	• Integration of IT with the Product Development Process • Electronic exchange of information

B.3.2 Questionnaire Design and Distribution

The questionnaire had six sections. Section 1 dealt with the company general policies toward subcontracting. Section 2 inquired about the use of the Product Development Process and Product Architecture in outsourcing decision-making. Section 3 addressed the partner selection process and the evaluation of the subcontractor performance.

Section 4 asked about successful and unsuccessful outsourcing relationships that took place during the last three (3) to five (5) years. Section 5 was targeted to the identification of the features for a Computer Aided Outsourcing (CAO) software. The last section requested information about the respondent and his or her organization. The questionnaire is shown in Appendix C.

B.4 Questionnaire Results

The analysis of results was divided in seven sections. The first section summarizes the nature of the companies that answered the survey. The second section analyzes the relationships between outsourcing and risks and market differentiation. The third section presents the findings related to the use of the Product Development Process and the product architecture in outsourcing decision making. The fourth section deals with the partner selection process while the fifth studies the determinants of success and failure. The sixth section summarizes the finding on the use of Information Technology and the last section evaluates the preparedness of the respondents to form Virtual Enterprises

To facilitate the understanding of the results, zeros have been omitted in all the tables presented during the analysis of results. Their places are left blank.

B.4.1 Nature of the Organization

The nature of the responding organizations was identified by classifying the responses according to three criteria: size, revenue, International Standard Organization's (ISO) certification, and the company's position in the supply chain.

According to their number of employees or size, organizations were divided into three groups: small, medium, and large. This classification scheme is based on the one used by Statistics Canada to classify businesses [Statistics Canada]. The membership in these groups was identified as follows:

- Small – companies with less than 100 employees and annual revenues between $30, 000 and than $5 million.
- Medium – companies with 100 to 500 employees and annual revenues between $5 and $50 million.
- Large – companies with more than 500 employees and annual revenues greater than $50 million.

According to this classification, 32% of the respondents were small companies, 53.6% were medium sized companies, and 14.3% were large companies. Regarding annual revenue, 28.6% of the respondents have annual revenue of less than $10 million, while 35.7% have revenues between $10 and $50 million and 32.2% have revenue of more than $50 million.

Sixty-eight percent of the respondents are fully ISO certified. The remainder of the respondents are at different stages of the certification with 21.5% being ISO compliant in more than 50%.

In relation to the position in the supply chain, 7.1% of the respondents consider themselves integrators, 35.7% provide outsourcing services to other companies, while 17.8% are members of a subcontracting network. In addition, thirty-nine per cent of the respondents subcontracted some of the tasks related to their Product Development Process.

B.4.2 Outsourcing, Risk and Market Differentiation

The respondents were asked to indicate their concerns about the impact of subcontracting in the company's intellectual property. Table B.2 summarizes these findings. Companies are more concerned with subcontracting tasks related with the development of new products than they are about subcontracting specific technologies or software. The understanding of the risk associated with outsourcing decision-making is shown by the large number of companies (71%) that considered that outsourcing might affect the control over their intellectual property and know-how.

Table B.3 summarizes the responses regarding the possibility of being matched or surpassed by competitors because of the outsourcing policies with respect to parts, subsystems, and overall product design. This table suggests that the more complex the task subcontracted, the higher the concern about being surpassed by the competition.

Table B.2. Impact of Outsourcing on Intellectual Property.

	Total
New product development	71.4
Specific Technologies	57.1
Software	46.4

Companies do not feel threatened by outsourcing parts, components, or even subsystems. However, they seem to be more concerned with outsourcing of the overall product or process design.

Table B.3. Possibility of Being Surpassed by Competitors due to Different Levels of Outsourcing.

	Total
Parts or components	25.0
Subsystems	21.4
Overall product or process design	42.9

Table B.4 summarizes the importance and the frequency on which tasks are subcontracted. For the purpose of the survey, the importance of tasks was defined according to their importance in the product development process. Low-importance tasks were those for which companies can easily find a replacement. Medium-importance tasks were considered the tasks that can take some time to find a replacing company. High-importance and critical tasks were defined as those that can delay and stop the Product Development Process, respectively.

Table B.4. Importance of the Tasks Subcontracted.

Importance	Frequency	Total
Low	Rarely	12.5
	Sometimes	33.3
	Often	54.2
Medium	Rarely	4.0
	Sometimes	72.0
	Often	24.0
High	Rarely	50.0
	Sometimes	50.0
	Often	
Critical	Rarely	89.5
	Sometimes	10.5
	Often	

In general, it can be noticed that as the importance of the tasks increases, the frequency on which the tasks is subcontracted decreases. For example, respondents outsource low and medium importance tasks often, and sometimes in 88% and 94% of the cases. However, this pattern changes as the importance of the task increases. High importance and critical tasks are never outsourced often. The fact that critical tasks are outsourced sometimes in 10% of the cases might indicate that companies are forced to outsource those tasks because of the lack of internal expertise and therefore create a dependency by knowledge with the subcontractors.

Table B.5 summarizes the factors that differentiate companies from their competitors. It is argued that companies seek in subcontractors the same kind of skills they have. Therefore, the identification of these factors can provide some guidelines about the attributes searched for in successful outsourcing.

Factors such as quality, customer services, delivery capabilities and a knowledgeable and skilled workforce were found highly important. Quality was considered important by 96% of the respondents, while a knowledgeable workforce, customer services, and delivery capabilities ranked close to 92, 90, and 86 per cent respectively. Cost was also identified as an important factor by 79% of the respondents.

The respondents were divided in the importance of having a significant portion of the market and the location of the company. The perceived importance of these two factors was distributed between the medium and the high importance range. Fifty per cent of respondents found a significant portion of the market as a medium importance factor, while forty per cent indicated that location was a factor of medium importance.

Table B.5. Factors Differentiating Companies from Their Competitors.

		Quality	**Customer Services**	**Delivery Capabilities**	**Knowledgeable Workforce**	**Market Share**	**Cost**	**Location**
Low	1	3.6	3.6	3.6				7.4
	2							7.4
	3					3.6		11.1
Med	4						3.6	7.4
	5					28.6	3.6	**18.5**
	6		7.1	10.7	7.4	**28.6**	14.3	14.8
High	7	7.1	3.6	10.7	18.5	3.6	21.4	**18.5**
	8	17.9	25.0	14.3	25.9	14.3	21.4	7.4
	9	**71.4**	**60.7**	**60.7**	**48.1**	21.4	**35.7**	7.4

Regarding the competition in the market place, more than 71% of the respondents identify themselves as organizations with hard to reproduce products and strong competitors. More than 14% indicated that they produce easily reproducible products and have strong competitors, while the rest of the respondents were equally divided between easy and hard to reproduce products with no competitors.

B.4.3 Outsourcing, the Product Development Process and the Product Architecture

Table B.6 shows that the Product Development Process is not used very often during the outsourcing decision-making, since close to 60% of the respondents used it less than 25% of the time. However, almost one quarter of the respondents consider this as an important guiding tool and use it 75% of time or more. The table also indicates that product-oriented companies used the Product Development Process more than the solution-oriented companies.

Table B.6. Consideration of the Product Development Process in Outsourcing Decision-Making.

Percentage	Total
< 25	60.7
25-50	3.6
50-75	7.1
> 75	21.4
Does not apply	7.2

Table B.7 summarizes the importance of modularization and integration in outsourcing decision-making. In general, it seems that modularization does not play an important role in outsourcing decision-making. It can be seen that low and medium-importance account for 75% of the responses, with low-importance ranking first. Product oriented companies seem to consider modularization more often than solution-oriented companies.

The second halve of the table depicts the importance of integration to outsourcing decision-making. Companies consider that integration plays a medium to high importance role in outsourcing decision-making in 67% of the cases. In this case, solution-oriented companies seem to put more emphasis on integration while taking outsourcing decisions than product-oriented companies.

Table B.7. Importance of Modularization and Integration in Outsourcing Decision-Making.

	Importance	Total
Modularization	Low	39.3
	Medium	35.7
	High	10.7
	No importance	10.7
Integration	Low	18.5
	Medium	18.5
	High	48.1
	No importance	14.8

Table B.8 shows the percentage of the respondents that outsource at different stages of the Product Development Process. Respondents outsource more design and manufacturing than they do assembling and customer services. Thirty-three percent of the respondents outsource design and 82.1% outsource manufacturing while only 21.4% outsourced assembling. Customer services is the least outsourced task with only 18% of the companies outsourcing this activity.

The comparison between product and solution-oriented companies shows that product-oriented companies outsource more at the design stage than solution-oriented companies. In contrast, solution-oriented companies outsource more manufacturing than product-oriented companies. It should also be noticed that solution-oriented companies outsource more customer services than product oriented companies.

Table B.8. Stages of the Product Development Process Outsourced.

PDP Stage	Totals
Design	33.3
Manufacturing	82.1
Assembling	21.4
Customer Services	17.9

Table B.9 depicts the distribution of the design, manufacturing, assembling and customer services stages of the Product Development Process. In general, it can be seen that although companies do subcontract, only a small fraction of the Product Development Process is subcontracted. This observation applies to all the stages. The respondents outsource close to 30% of the design stage, 46% of the manufacturing stage, 40% of the assembling, and 47% of the customer services.

Table B.9. Distribution of Outsourcing for the Stages of the Product Development Process.

% of Tasks	Design	Manufacturing	Assembling	Customer Services
<10	44.4	21.7	50.0	60.0
10-20	11.1	17.4	16.7	
20-30	11.1	13.0		
30-40				
40-50	22.2	13.0		
50-60				
60-70		4.3		20.0
70-80		8.7		20.0
80-90	11.1	8.7		
> 90		13.0	33.3	
Average	28.6	45.6	39.2	47.0

The largest portion of the subcontracting of design occurs in the 10% range. Sixty-six per cent of the subcontracting takes place below the 30%. The outsourcing of the manufacturing and assembling stage shows the same pattern. More than half of respondents outsource manufacturing at less than 30% and close to 67% percent of the respondents, outsource less than 30% of assembling. Regarding customer services, the table shows that the majority of the respondents outsource less than 10% of this stage.

Based on this the table, it can be concluded that most of the outsourcing taking place is:

1) white-box or transparent outsourcing, and
2) tactical rather than strategic.

White-box outsourcing takes place at the latest stages of the Product Development Process. The fact that design is the least outsourced of the stages supports this finding. It seems that subcontractors are not involved earlier in the development of the product or process. The evidence about tactical outsourcing comes from the small portion of the stages of the Product Development Process that are outsourced. The role of partners or suppliers seems to be reduced to a small part of the product development process.

Several questions in the survey addressed the type of dependency created because of the outsourcing decision. The type of dependency was measured through actions taken by the company when no suitable subcontractor is found, the quality and quantify of the information provided to the subcontractors, and the management of the supply chain.

The results in Table B.10 show that the Product Development Process is never stopped if no subcontractor is found. The lack of a subcontractor rarely delays the product-development process. The choice taken most often is to carry out the development of the product internally or “in-house”. These findings indicate a dependency by capacity rather than by knowledge of the subcontracting companies. Only a small fraction of the respondents are willing to train the subcontractor in obtaining the skills required for the tasks. This is perhaps because of the time it could take to train the subcontractors. Fine and Whitney [1996] reported that Toyota, for example, has spent close to 20 years training subcontractors, to transform them from white to black outsourcing.

Respondents deal with the possible lack of subcontractors’ expertise with other alternatives. The most common solution suggested was the revision of the original design.

Table B.10. Choices when no Suitable Subcontractor is Found.

Choices	**Total**
Stop	
Delay PDP	3.7
Internal Develop	59.3
Train subcontractors	14.8
Others	22.0

Table B.11 shows that most often companies deal only the subcontractor responsible with the deliverable rather than with the whole supply chain.

Table B.11. Outsourcing Approach to the Supply Chain.

	Total
Subcontractor directly responsible	66.7
All the supply chain	33.3

Tables B.12 and B.13 summarize the level of detail and precision in the information given to subcontractors. It can be seen that in principle subcontractors are given only a minimal amount of information required to carry out their tasks. A small percentage of the companies (11%) combine the Product Development Process and the outsourced task in the information given to subcontractors.

The large majority of the companies provide subcontractors with precise specifications about the subcontracted task rather than leaving the subcontractor set the specifications for themselves.

Table B.12. Information Given to Subcontractors.

	Total
Detailed Information	3.6
Combination of PDP and subcontract	10.7
Minimum Information	71.4
Other	14.3

Table B.13. Precision on the Specifications Given to Subcontractors.

Requirements Specification	Design	Manufacturing	Assembling
Precisely	83.3	95.5	90.9
General	8.3	4.5	9.1
Specified by Subcontractors			
Other	8.3		

The fact that some of the respondents provided general specifications to subcontractors can be interpreted as a dependency by knowledge. Providing general specifications could mean that the subcontracting company is unable to precisely specify the required specifications. The disagreement in the numbers shown in this table comes from the companies that although included in the totals, did not identify themselves as either product or solution-oriented organizations.

Table B.14. Checking of Deliverables.

	Total
Check deliverables	88.5
Believe and trust subcontractors	7.7
Others	3.8

The large majority of the companies check the deliveries rather than accepting what the subcontractor provides (Table B.14). It can also be seen that a small percentage of the companies does not check what is delivered or ‘believe’ their subcontractors. This finding, once more evidences a dependency by knowledge in the task subcontracted. Letting the subcontractor set the specifications can be interpreted as a lack of expertise in the task subcontracted and therefore the inability to check if the delivery met the specifications. The comparison between product and solution-oriented companies indicates that product-oriented companies check deliverables more often and that solution-oriented companies used varied alternatives to check the deliveries. The most common alternatives mentioned were quality inspection and ISO certification.

The lack of an effective communication mechanism was identified in the past as one of the problems related to first-time capabilities [Fine and Whitney 1996]. The respondents were asked to state whether they were concerned or not with changes made by subcontractors. These changes may significantly affect the Product Development Process.

Overall, the respondents were concerned with changes that can affect the Product Development Process. Seventy-two percent of the respondents stated being concerned with changes done by subcontractors. In the case of Product oriented companies 80% of the respondents were concerned with the changes while solution oriented companies 73% of the respondents were also concerned.

In addition, the questionnaire inquired about how the supply chain is informed about the changes taking place. Table B.15 shows that 79% of the respondents have a good communication mechanism in place. Definitely, every company wants to have control over the changes made by subcontractors, therefore it is not surprising that no respondents acknowledged having no control over the changes made.

Overall, Tables B.10 to B.15 seem to indicate that most of the companies are dependent by capacity rather than knowledge. This conclusion is supported by the findings that most of the companies are capable of carrying out the subcontracted tasks internally, provide detailed information about the tasks subcontracted and check the deliverables.

Table B.15. Control over Changes Made by Subcontractors.

	Total
Good Communication Mechanism	79.0
No control of changes made	
Others	21.0
Changes must be approved	10.5
No changes allowed	10.5

Based on the amount of information given to subcontractors, it can be said that most of the outsourcing taking place is tactical. Certainly, providing minimal information to subcontractors helps with their management. However, this finding can also be interpreted as outsourcing companies missing the opportunity of engaging subcontractors in their strategies.

Respondents were also asked to indicate in a scale of '1' to '9' their overall satisfaction with outsourcing at different stages of the Product Development Process. '1' indicated a highly unsatisfactory and '9' highly satisfactory. The results of these rankings are shown in Table B.16.

Table B.16. Overall Satisfaction with Outsourcing.

Satisfaction	Range	Design	Manufacturing	Assembling
Low	≤ 3	18.8	4.8	31.3
	4 - 6	31.3	9.6	25.0
High	≥ 7	50.0	85.6	43.8
Average		5.6	7.5	5.7
Median		5.0	8.0	5.0

It can be seen that, in general, the overall level of satisfaction is neither low nor high but acceptable. Respondents are more satisfied with outsourcing at the manufacturing stage (86%) than in the design or assembling stages. The outsourcing of assembling seems to be less satisfactory, with only 44% of satisfaction in the highly satisfactory range. However, the table also shows that there is considerable degree of dissatisfaction in the outsourcing of design and assembling stages. As well, assembling seems to be the stage with the larger level of unsatisfactory experiences with 31% of the respondent being closer to the highly unsatisfactory boundary.

Table B.17. Summary of Percent of PDP Outsourced and Overall Satisfaction with Outsourcing.

PDP Stage	Respondents (%)	PDP (%)	Satisfaction (%)
Design	33.3	28.6	50.0
Manufacturing	82.1	45.6	85.6
Assembling	21.4	39.2	43.8

Table B.17 summarizes the data from Table B.8, B.9 and B.15. It can be seen that manufacturing is the stage that is subcontracted more often in both the fraction of the respondents and the Product Development Process. This is also the stage in which outsourcing is more successful. This finding shows that companies are better at outsourcing manufacturing than at any other stage of the Product Development Process. Therefore, they tend to outsource more at this stage. Design, on the other hand, is the second more outsourced stage, according to the number of responses, but ranks third according to the amount of tasks outsourced. However, outsourcing design seems to be more satisfactory than outsourcing assembling. This fact becomes more visible if the high and middle levels of satisfaction of design and assembling outsourcing are combined.

The design stage achieves more than 81% of the overall satisfaction while assembling gets around 68%.

B.4.4 Partner Selection in Outsourcing

This section summarizes the findings of the survey with respect to the bidding process, the general outsourcing policies and the frequency of evaluation of the subcontractors.

Regarding the bidding process, Table B.18 shows that subcontracting to companies with whom previous collaborative relationships have been established is the most common form of outsourcing. The values shown between parentheses under 'Others' are the percentages calculated with respect to all the respondents.

Table B.18. Bidding Process.

	Total
All capable companies	32.6
Trustworthy partners	18.8
Previous relationships	34.4
Others	12.5
Corporate Approved	50.0 (6.5)
Quality Survey	25.0 (3.2)

However, it should be noticed that also the bid is often open to all capable companies. Corporate approved partners and the selection of partners according to quality surveys can be considered as a form of an open (to all capable companies) bidding process. It is understood that these forms of selecting partners, include an evaluation process that is open to all companies that meet the subcontracting requirements. The addition of these two variations makes 'all capable companies' the most common form of awarding subcontracts, with 42.3% of the answers.

The hypothesis on the effect of small cumulative changes on the performance of the subcontractors was previously explained. These changes were seen as one of the main causes of unsuccessful relationships. The respondents were asked to state how often the subcontractors' performance was evaluated. These results are summarized in Table B.19.

The table shows that performance is most commonly evaluated at the beginning and end of the relationship (42%). Periodical evaluation takes place only in 30% of the cases while continuous evaluation ranks even lower at 12.1%. Those respondents that evaluate subcontractors periodically tend to do it more often either on monthly or annual bases with 44% and 33%, respectively. Close to 15% of the respondents use ISO certification and inspections or cost and delivery time to evaluate subcontractors. No conclusions could be drawn about how frequently these two evaluation procedures were used.

The rankings of the frequencies vary little between product and solution-oriented companies. However, product-oriented companies evaluate subcontractors on semi-annual and annual bases. Annual evaluations seem to be commonly used (75%). Solution- oriented companies, in contrast, tend to evaluate subcontractor more often since 64% of the respondents stated they conduct monthly evaluations.

Table B.19. Frequency of the Evaluation of Subcontractors Performance.

	Total	
Beginning	3.0	
Beginning and end	42.4	
Continuously	12.1	
Periodically	30.3	
1 month		44.4
3 months		11.1
6 months		11.1
12 months		33.3
Other	15.2	
ISO and Inspections		60.0 (9.1)
Cost and delivery time		40.0 (6.1)

These findings indicate that large variations in the subcontractor performance can take place, without being detected because of the periodicity of the evaluation. Less than 30% of the respondents, all of them solution-oriented companies, evaluate subcontractors often enough to detect small changes in performance. This value was obtained by adding the respondents that evaluate subcontractors continuously to those that evaluate subcontractor on monthly or trimestral bases.

The roles that the criteria play in the general outsourcing policies were identified by asking the respondents to evaluate the criteria in the scale of '1' to '9'. '1' indicated a not important at all and '9' extremely important.

Table B.20. Importance and Easiness of Estimation of the Selection Criteria.

	Range						
Criterion	**≤ 3**	**4 – 6**	**≥ 7**	**Average**	**Median**	**St. Dev.**	**Estimation (%)**
Technical Capabilities		3.8	**96.2**	8.1	8	1	80.8
Development Speed	20.8	19.4	**59.7**	6.3	7	2.7	50.0
Financial Security	2.6	39.7	**57.7**	6.9	7	1.6	80.8
Collaborative Record		19.2	**80.8**	7.7	7	1.2	82.1
Business Strength	3.8	28.2	**67.9**	6.7	7	1.5	71.8
Cost of Development	9.1	22.7	**68.2**	6.9	7	2.3	72.7
Cultural Compatibility	17.4	**43.5**	39.1	5.8	6	2.2	60.9
Strategic Position	4.5	**50**	45.5	6.3	6	1.8	72.7
Management Ability		23.1	**76.9**	7.4	7	1.2	61.5
Delivery Capabilities		3.8	**96.2**	8.5	9	0.8	88.5
Location	19.2	29.5	**51.3**	6.2	7	2.3	100.0
Size	23.1	**53.8**	23.1	5.3	5	1.8	100.0
Information Technology	9.1	40.9	**50**	6.1	6	2.1	86.4

Table B.20 shows the role of the criteria in establishing the general outsourcing policies of the companies. Empty cells mean that the value was zero (0) or that no value exists for the row and column intersecting at the cell. In addition, the table depicts the average, the median, and the standard deviation for each criterion. The last row of the table contains easiness of estimation for the criteria. The value of the easiness of the estimation is shown in percentages. They represent the percentage of the respondents that considered the criteria easy to estimate.

In the table, the values are grouped in three ranges. Each of these groups contains the percentage of the respondents that considered a given criterion in that range. The first range, ≤ 3, means that the criterion was considered to have an importance between one and three, or a low importance. The second range between four and six means that the criterion is considered to have a medium importance, while the last range, ≥ 7 (≥ 7 and ≤ 9), means that the criterion was seen as very important. This approach is similar to the one used by [ASME 1997] to classify the importance of the criteria.

For example, row of the development speed criterion shows a value of 20.8. This value means that 20.8% of the respondents ranked this criterion as low importance for the selection of partners. The value in the next row, 19.4, means that 19.4% of the respondents considered this criterion as of medium importance in the selection of subcontractors. The row '≥ 7', on the other hand, means that 59.7% of the answers considered development speed in the very important range (≥ 7 and ≤ 9) for the selection of subcontractors. The largest value for each criterion is highlighted in the table.

The following analysis focuses on identifying the relative importance of the criteria in the general outsourcing policies of the companies. The analysis is only based on frequency with which the respondents considered the criteria as important. It implies that the frequency on which criteria belong to the 'very important' (≥ 7) range determines their importance, in the general outsourcing policies. A more detailed analysis will be presented in the following sections.

The criteria were divided in three groups according to how often they were ranked in the 'very important' range. The two most important selection criteria were found to be technical capabilities and delivery capabilities. More than ninety-six of the respondents identified the importance of these criteria in the ≥ 7 range. Collaborative record, Business strengths, cost of development, and management ability form a second group. In this case, the importance of the criteria ranges from 80 to 68%. The third group was composed of development speed, financial security, location, strategic position), the use of Information Technology, cultural compatibility, and size (SI). The frequency these criteria were considered important ranges from close to 60% to 23.1%.

For the analysis the easiness of evaluation, three groups were also identified. The ranges set were at more than 80%, between 80 and 70% and less than 70% respectively. Two criteria were known beforehand to be the easiest to estimate: location and the size of a partner. The table also shows that development speed was identified as the hardest criteria to evaluate. Delivery capabilities, the use of Information Technology, collaborative record, financial security as well as technical capabilities belong to the first group and therefore are considered the easiest to estimate. Cost of development, strategic position and Business strength belong to the second group. The third group is composed of management ability, cultural compatibility, and development speed. The criteria in the third group were considered the most difficult to estimate.

The following pattern was identified by combining the results from the previous two analyses. Technical and delivery capabilities are both considered very important and relatively easy to estimate. Business strength, and cost of development belong to the second group in both importance and easiness of estimation and cultural compatibility and development speed were considered less important and harder to estimate. These similarities are arguably related. That is, the relative importance assigned to a criterion may be related to how easy is its estimation. If a criterion is easy to estimate, it will be used often and assigned a higher relative importance. On the other hand, a criterion that is difficult to estimate, will probably be used less frequently and given less relative importance.

Regarding the easiness of estimation of the criteria, the respondents seem to agree on criteria such as delivery capabilities, use of information technology and cultural compatibility. The larger differences are found in the estimation of development speed, strategic position, and management ability.

B.5 Determinants of Success and Failure in Outsourcing

Determinants of success and failure in outsourcing relationships were identified by asking the respondents about both successful and unsuccessful relationships that took place during the last three to five years. Successful relationships were defined as those in which 50% or more of the objectives set before starting the relationships were met. Unsuccessful relationships were considered those where less than 50% of the initial objectives were met. All the successful relationships referenced by the respondents met their objectives in more than 75%. The distribution of the unsuccessful relationships is shown in Table B.21.

Table B.21 Satisfaction of the Initial Objectives in Unsuccessful Outsourcing.

Satisfaction of the Initial Objective	**Total**
< 25	21.4
25 - 50	78.6

The evaluation of success and failure in the relationship was conducted taking into account the importance of the subcontracted tasks as well as the stage of the development process that the task belonged. Tables B.22 to B.24 summarize this information.

It can be seen in Table B.23 that the manufacturing stage was the most subcontracted stage in both successful and unsuccessful relationship with close to 45 and 54%, respectively. In addition, design ranks second in both types of relationships.

Tables B.23 and B.24 show how much of the Product Development Process stages were subcontracted in both successful and unsuccessful relationships. The comparison of these tables shows that the design stage was subcontracted at close to 80% in successful relationships and at 65% in unsuccessful ones. Manufacturing was subcontracted at close to 50% and 43% in successful relationships and unsuccessful relationships respectively. Assembling, on the other hand, was subcontracted at 72 and 73% for both types of relationships.

Table B.22 Stages of the Product Development Process Outsourced in Successful and Unsuccessful Relationships.

	Stage of PDP	Total
Successful	Design	32.1
	Manufacturing	45.3
	Assembling	19.8
	Customer Services	2.8
Unsuccessful	Design	22.7
	Manufacturing	54.5
	Assembling	22.7
	Customer Services	

Table B.23. Percentage of the Tasks Outsourced for Successful Relationships.

% of Tasks	Design	Manufacturing	Assembling	Customer Services
<10	11.1	27.1	14.3	
10-20		22.9		
20-30				
30-40		6.3		
40-50	11.1		14.3	
50-60		6.3	14.3	
60-70				
70-80	22.2			
80-90		12.5	14.3	
>90	55.6	25.0	42.9	100.0
Average	79.4	49.1	71.6	100.0

The comparison of the average values in these tables to the values shown in Table B.9 shows some large differences in the subcontracting of the design and assembling stages. The values for manufacturing in successful and unsuccessful relationships are similar to the ones identified in the general outsourcing policies. The distribution of the outsourcing tasks for the design and assembling stages are also shifted. Table B.9 depicted that the majority of the companies outsourced around 30% of the design stage, while Table B.24 shows that close to 78% of the respondents outsourced more than 70% of this stage. Table B.24 shows similar values; in this case, 60% of the respondents acknowledged outsourcing at least 80% of the design stage.

The comparison of the values for the assembling stage shows that for the general outsourcing policies, this stage was largely subcontracted at less than 20%. The values in Tables B.23 and B.24 show a shift toward subcontracting at a larger percentage (57.2%).

Table B.24. Percentage of the Tasks Outsourced for Unsuccessful Relationships.

% of Tasks	Design	Manufacturing	Assembling	Customer Services
<10	20.0	41.7		
10-20		8.3		
20-30	20.0	16.7	20.0	
30-40			20.0	
40-50				
50-60				
60-70				
70-80				
80-90	20.0			
>90	40.0	33.3	60.0	
Average	65.0	42.6	73.0	

The large differences between the quantity of work subcontracted at the design and assembling stages of the Product Development Process might indicate a bias of the respondents toward either successful or unsuccessful relationships. The fact that the quantity of the work outsourced remains relatively constant for the manufacturing stage reinforces once more that companies are better at outsourcing this stage than any other stage of the Product Development Process.

Table B.25 shows the importance of the tasks subcontracted for both success and unsuccessful relationships. In successful relationships, low importance tasks seem to be subcontracted more often than other tasks. Unsuccessful relationships seem to be happening more often in medium importance tasks.

Although these differences are not large, they may also indicate some bias from the respondents. Certainly, there is a relationship between the importance of the tasks and the level of success. The lower the importance of the tasks, the higher the chances that the tasks will not be openly considered unsuccessful. This is because replacing subcontractors can be easily found.

Table B.25. Importance of the Tasks Outsourced in Successful and Unsuccessful Relationships.

	Task's Importance	Total
Successful	Low	37.1
	Medium	28.6
	High	21.4
	Critical	12.9
Unsuccessful	Low	28.6
	Medium	42.9
	High	14.3
	Critical	14.3

B.5.1 Evaluation of the Selection Criteria

Table B.26 shows the distribution of the importance of the criteria for the general evaluation (column T) as well as for successful (column S) and unsuccessful (column U) relationships. Empty cells mean that the value was zero (0) or that no value exists for the row and column intersecting at the cell. In addition, the table depicts the average, the median, and the standard deviation for each criterion.

In the table, the values are arranged in three groups. Each of these groups contains the percentage of the respondents that considered a given criterion in that range. The first range, ≤ 3, means that the criterion was considered to have a lower importance (an importance between one and three).

Table B.26. Importance of the Selection Criteria in General Policies, Successful, and Unsuccessful Relationships.

	TC			DS			FS			CR			BT			CD			CC		
Range	G	S	U	G	S	U	GT	S	U	G	S	U	G	S	U	G	S	U	T	S	U
≤ 3			7.1	20.8	16.7	7.7	2.6	8.0	28.6		4.0	14.3	3.8		23.1	9.1	14.3	8.3	17.4	21.7	**38.5**
4 - 6	3.8	8.0	21.4	19.4	8.3	15.4	39.7	29.3	14.3	19.2	20.0	21.4	28.2	37.3	23.1	22.7	9.5	16.7	**43.5**	34.8	30.8
≥ 7	**96.2**	**92.0**	**71.4**	**59.7**	**75.0**	**76.9**	**57.7**	**62.7**	**57.1**	**80.8**	**76.0**	**64.3**	**67.9**	**62.7**	**53.8**	**68.2**	**76.2**	**75.0**	39.1	**43.5**	30.8
Average	8.1	8.3	7.2	6.3	6.8	7.4	6.9	6.7	5.9	7.7	7.2	6.5	6.7	6.9	6.2	6.9	7.0	7.1	5.8	5.6	4.8
Median	8	8	8	7	8	8	7	7	7	7	8	7	7	7	7	7	8	7	6	6	5
St. Dev.	1.0	0.9	2.2	2.7	2.8	2.0	1.6	2.0	2.6	1.2	1.8	2.4	1.5	1.4	2.3	2.3	2.3	2.4	2.2	2.4	2.5

	SP			MA			DC			LO			SI			IT		
Range	G	S	U	G	S	U	G	S	U	G	S	U	G	S	U	G	S	U
≤ 3	4.5	14.3	8.3		8.0	14.3			7.1	19.2	12.0	21.4	23.1	26.4	30.8	9.1	13.6	23.1
4 - 6	**50.0**	31.7	**50.0**	23.1	20.0	7.1	3.8	8.0	14.3	29.5	17.3	35.7	**53.8**	**56.9**	**38.5**	40.9	31.8	15.4
≥ 7	45.5	**54.0**	41.7	**76.9**	**72.0**	**78.6**	**96.2**	**92.0**	**78.6**	**51.3**	**70.7**	**42.9**	23.1	16.7	30.8	**50.0**	**54.5**	**61.5**
Average	6.3	6.4	6.0	7.4	7.0	7.2	8.5	8.4	7.6	6.2	7.1	5.7	5.3	4.7	4.7	6.1	6.1	6.5
Median	6	7	5	7	8	8	9	9	8	7	8	5	5	5	4	6	7	8
St. Dev.	1.8	2.4	2.0	1.2	2.3	2.2	0.8	1.0	1.8	2.3	2.2	2.4	1.8	2.2	2.2	2.1	2.4	2.6

G: General Outsourcing Policies S: Successful U: Unsuccessful

The second range means that the criterion is considered to have a medium importance (with values between four and six), while the last range, ≥ 7 or ≥ 7 and ≤ 9, means that the criterion was seen as very important. This approach is similar to the one used by [ASME 1997] to classify the importance of the criteria.

For example, for the development speed criterion (DS), in the intersection of the range ≤ 3 and column (T) shows a value of 20.8. This value means that 20.8 % of the respondents ranked this criterion as low importance for the selection of partners. The value in the next row, 19.4, means that 19.4 % of the respondents considered this criterion as of medium importance in the selection of subcontractors.

The row '≥ 7', on the other hand, means that 59.7% of the answers considered development speed in the ≥ 7 and ≤ 9 range or very important for the selection of subcontractors.

The largest values for each situation are highlighted in the table. It can be seen that except for the collaborative record (CC), strategic position (SP) and the size (SI) of the subcontractor criteria, in general, all other criteria were considered as very important in the selection of partners as well as in the success and failure of outsourcing. This pattern reinforces the understanding of these criteria as relevant for the partner selection and the evaluation of outsourcing relationships

The degree to which these criteria were considered important can be used to obtain a first estimate on the agreement of the importance of the criteria. It can be seen that for example, technical capabilities (TC) is considered as very important for the selection of partners and in successful outsourcing by a large number of respondents with 96.2% and 92% respectively. The consideration of the role of development speed (DS), in contrast, is divided. In this case, close to 60% of the respondents considered the criterion as very important while close to 20% considered the criteria as of a medium importance and another 20% considered the criteria with little importance in selecting partners.

However, the role of this criterion in successful and unsuccessful outsourcing is found more important with 75% and 77% respectively.

To identify the roles of the criteria in the three situations under study, the averages of the rankings were rounded and ranked from the most to the least important. The results are shown in Table B.27. It can be noted that for the selection of subcontractors, 54% of the criteria rank as very important and 46% rank as of a medium importance. For successful outsourcing, the distribution changes to 70% and 30% for the very important and medium importance criteria, respectively. In unsuccessful relationships, 46% of the criteria play a very important role, while 54% of the criteria have a medium importance.

Table B.27. Distribution of the Importance of the Criteria for All Companies.

	Range	General	Successful	Unsuccessful
Very Important	≥ 7	53.8	69.2	46.2
Medium Importance	4 - 6	46.2	30.8	53.8

The first pattern to be noticed is a variation on the number of criteria that are considered very important from general to unsuccessful outsourcing. It can be seen that the number of criteria considered very important increases from general to successful outsourcing.

This growth can be interpreted as either an overestimation or underestimation of the role of the criteria in general outsourcing. That means that some of the criteria that are considered very important to the success of the relationship are not considered properly during the selection of subcontractors. The comparison between the general and unsuccessful outsourcing shows that the distribution of the importance of the criteria is inverted. Again, it seems that in this case, the roles of the criteria are not considered accurately.

According to their importance, the criteria were divided into four groups. The first group includes the criteria with importance greater than 60% while the second group contains the criteria whose importance ranges between 40% and 60%. The last two groups are composed of those criteria with a variation between 40 and 20% and those with importance smaller than 20%.

It can be seen that for general outsourcing, no criterion belongs to the first group. Delivery capabilities (DC), technical capabilities (TC), and collaborative record (CR) belong to the second group, with delivery capabilities being the most important criteria. The third group is composed of the Management ability (MA), financial security (FS), cost of development (CD, and business strength (BT). In this group, the most important criterion was management ability, while cost of development (CD) and financial security (FS) were tied at the second level of importance in the group. The least important criteria were development speed (DS), strategic position (SP), location (LO), use of Information Technology (IT), cultural compatibility (CC), and the size of the subcontractor (SI). Development speed and strategic position ranked as the most important criteria in this last group.

In successful outsourcing, it can be seen that delivery capabilities and technical capabilities belong to the first group with the former being the most important criteria. Collaborative record, location, management ability, financial security, cost of development, business strength and development speed are the criteria located in the second group. The most important criterion in this group is collaborative record. The third group is composed of strategic position, use of Information Technology, cultural compatibility, and size with strategic position ranking first in importance.

For unsuccessful outsourcing, only delivery capabilities (DC) belongs to the first group. The second group is composed of development speed, technical capabilities, management ability, and cost of development. In this group, development speed ranks as the most important criteria. Collaborative record (CR), use of Information

Technology (IT), business strength (BT), strategic position (SP), financial security (FS), location (LO), cultural compatibility (CC) and size (SI) form the last group. Collaborative record is the most important criterion in this last group.

From the analysis above, it can be noticed that delivery capabilities (DC) consistently ranks first regardless of the outsourcing situation, although its importance seems to be more critical for success than for failure. However, it still seems to be the most important factor in causing the failure of outsourcing relationships. Technical capabilities (TC) ranks second in general and successful outsourcing situations. This position is exceeded only in unsuccessful outsourcing by development speed (DS). On the other hand, the size of the subcontractor ranks consistently as the least important criteria for all outsourcing situation. These rankings highlight the challenges faced in the selection of subcontractors since two of the highest ranked criteria play a very important role in both success and failure of subcontracting relationships.

In between these two extremes, other criteria gain or lose importance depending on the outsourcing situation. The financial security (FS) of the subcontractor, for instance, seems to be favoured in successful outsourcing, while it plays a less important role in general and unsuccessful outsourcing. Collaborative record (CR) appears to play a more important role for general and successful outsourcing than in unsuccessful relationships.

In summary, it can be concluded that technical capabilities (TC), financial security (FS), collaborative record (CR), business strengths (BT), cultural compatibility (CC), strategic position (SP), delivery capabilities (DC), and location (LO) are the most important criteria in successful outsourcing. On the other hand, development speed (DS), cost of development (CD), management ability (MA), and the use of Information Technology (IT) appear to be the criteria with the most important role in unsuccessful relationship.

Table B.28. Analysis of Variance.

Criterion		df	Sum of Squares	Mean Squares	F
Technical Capabilities	Treatment	2	33.35	16.68	**9.42**
	Error	194	343.64	1.77	
	Total	196	376.99		
Development Speed	Treatment	2	28.06	14.03	2.07
	Error	182	1234.73	6.78	
	Total	184	1262.79		
Financial Security	Treatment	2	27.97	13.99	**3.54**
	Error	194	765.44	3.95	
	Total	196	793.42		
Collaborative Record	Treatment	2	38.87	19.43	**6.42**
	Error	194	586.80	3.02	
	Total	196	625.66		
Business Strength	Treatment	2	11.39	5.69	2.02
	Error	191	537.86	2.82	
	Total	193	549.25		
Cost of Development	Treatment	2	0.74	0.37	0.07
	Error	164	862.20	5.26	
	Total	166	862.95		
Cultural Compatibility	Treatment	2	25.32	12.66	2.26
	Error	176	986.69	5.61	
	Total	178	1012.01		
Strategic Position	Treatment	2	3.33	1.67	0.38
	Error	164	717.48	4.37	
	Total	166	720.81		
Management Ability	Treatment	2	4.54	2.27	0.62
	Error	194	706.41	3.64	
	Total	196	710.95		
Delivery Capabilities	Treatment	2	26.78	13.39	**9.61**
	Error	194	270.27	1.39	
	Total	196	297.05		
Location	Treatment	2	56.25	28.12	**5.30**
	Error	194	1029.94	5.31	
	Total	196	1086.18		
Size	Treatment	2	20.61	10.30	2.46
	Error	188	785.96	4.18	
	Total	190	806.57		
Information Technology	Treatment	2	4.14	2.07	0.37
	Error	170	952.60	5.60	
	Total	172	956.74		

It is interesting to notice that except for the collaborative record (CR) and subcontractor size (SI) criteria the roles assigned to the criteria in general outsourcing are never the largest value in the triad.

It was not clear whether the data followed a normal distribution or not. Therefore, the parametric and non-parametric tests of the selection criteria for the outsourcing situations were conducted. The parametric test conducted was the Analysis of Variance (ANOVA) and the nonparametric test was the Friedman-R test.

Follow-up tests to identify the differing means were also carried out. The follow up test for the Analysis of Variance was the Bonferroni comparisons, while the Wilcoxon signed rank test was used after Friedman-R tests.

Table B.27 summarizes the Analysis of Variance. This analysis compares the means of the importance of the selection criteria in the three outsourcing situations: general, success, and unsuccessful. It can be seen that the means differ for the technical capabilities, financial security, collaborative record, delivery capabilities, and location criteria.

The Bonferroni comparisons for these criteria at 1% significance are shown in Table B.29. These comparisons identify the means causing the differences in the analysis of variance. Three comparisons were made (c = 3) at 1% significance.

The t-value used for these comparisons is $t_{0.01,\infty} = 2.326$. The intervals between two means in the Bonferroni comparisons are formed around zero. If zero is in the interval, the means do not differ significantly.

In general, this table shows that there are not significant differences in the means of the general and successful outsourcing (column A). The differences in the means always appear in the comparisons between the general and unsuccessful outsourcing (column B) and successful and unsuccessful outsourcing (column C). For the technical capabilities criterion the means differ in the comparison of general vs. unsuccessful outsourcing and successful and unsuccessful outsourcing.

In the case of the financial security and collaborative record criteria, the means differ only in the comparison between the general and successful outsourcing. The means of the delivery capability criterion differ in both general vs. unsuccessful and successful vs. unsuccessful outsourcing. The means of the location, on the other hand, differ only in the comparison between the successful and unsuccessful outsourcing.

The analysis of variances, therefore, indicates that the most important criteria are delivery and technical capabilities, collaborative record, location and financial security, in this order. The comparison of these findings with other research shows both similarities and differences. The technical capabilities and financial security criteria have always been identified as an important criterion in outsourcing, strategic alliances, and collaborative relationships [Wildeman 1998, Bailey et al. 1998].

Table B.29. Bonferroni Comparisons for All Companies.

Criterion	A General vs. Successful	B General vs. Unsuccessful	C Successful vs. Unsuccessful
Technical Capabilities	(-0.64, 0.36)	(**0.33, 1.52**)	(**0.47, 1.66**)
Development Speed	(-1.43, 0.59)	(-2.26, 0.15)	(-1.84, 0.57)
Financial Security	(-0.54, 0.95)	(**0.11, 1.88**)	(-0.10, 1.68)
Collaborative Record	(-0.20, 1.11)	(**0.42, 1.97**)	(-0.04, 1.52)
Business Strength	(-0.81, 0.46)	(-0.28, 1.25)	(-0.11, 1.43)
Cost of Development	(-1.03, 0.85)	(-1.28, 0.93)	(-1.20, 1.03)
Cultural Compatibility	(-0.75, 1.13)	(-0.12, 2.09)	(-0.31, 1.90)
Strategic Position	(-0.98, 0.73)	(-0.75, 1.27)	(-0.64, 1.40)
Management Ability	(-0.37, 1.06)	(-0.68, 1.02)	(-1.03, 0.68)
Delivery Capabilities	(-0.38, 0.50)	(**0.40, 1.45**)	(**0.34, 1.40**)
Location	(-1.72, 0.02)	(-0.51, 1.54)	(**0.33, 2.40**)
Size	(-0.10, 1.46)	(-0.28, 1.59)	(-0.97, 0.92)
Use of Information Technology	(-0.68, 0.68)	(-1.16, 0.42)	(-1.16, 0.42)

The findings related to the delivery capabilities, location and collaborative record are different. Delivery capabilities and location were not considered as selection criteria in other research. Collaborative record is perhaps the most controversial of these findings. Previous surveys have identified a negative role of this criterion in either collaborative relationships or strategic alliances.

One possible explanation for this difference is the characteristics of sample used. This survey focused on design and manufacturing companies involved in outsourcing relationships while the other survey targeted collaborative relationship or strategic alliances.

The Friedman-R test for the means of the three outsourcing situations shows that the probability distribution among these means differ at $\chi^2 = 0.05$. The Wilcoxon signed rank tests show that the general and unsuccessful outsourcing means differ at the 0.025 significance level ($\alpha = 0.025$) while the means of successful and unsuccessful outsourcing are different at the 0.01 significance level. ($\alpha = 0.01$).

Table B.30. Relationship between Weighting of the Criteria and Success.

Criterion	r
Delivery Capabilities	0.66
Technical Capabilities	0.59
Development Speed	0.53
Financial Security	0.53
Location	0.53
Collaborative Record	0.53
Management Ability	0.53
Business Strength	0.52
Cost of Development	0.52
Size	0.51
Cultural Compatibility	0.51
Strategic Position	0.51
Information Technology	0.51

To determine the importance of the selection criteria in the success or failure of the outsourcing relationships, the weightings given to each criterion were correlated with the level of success of the relationship. Tables B.29 and B.30 show the Spearman's rank correlation coefficient (r) for each criterion.

The results in Table B.29 show that all the criteria are positive rank correlated with the success of the relation. These values should be interpreted with caution. All the respondents identified a level of success of 75% or more. This in fact may have affected these results. Still, it can be seen from the table that the same criteria identified by the analysis of variance as significant have a larger rank correlation.

Table B.30 shows the Spearman rank correlation coefficients in unsuccessful relationships. The values in the table seem to indicate that management ability, development speed, financial security, business strength and the use of information technology are positively rank correlated with failure than the other selection criteria.

It should be noticed that the 'traditional' selection criteria: cost, location and delivery capabilities do not appear to have a positive rank correlation with failure. Still another interesting result to notice is that collaborative record ranks last.

Table B.31. Relationship between Weighting of the Criteria and Failure.

Criterion	r
Management Ability	0.66*
Development Speed	0.66*
Financial Security	0.63*
Business Strength	0.54*
Information Technology	0.47*
Size	0.41
Cost of Development	0.32
Strategic Position	0.29
Location	0.28
Delivery Capabilities	0.24
Cultural Compatibility	0.16
Technical Capabilities	0.12
Collaborative Record	0.03

(*) indicates statistical significant at 5%

This result can be interpreted as collaborative record having almost no effect in the failure of the outsourcing relationships.

The results of the second column, the rank correlation between general and unsuccessful outsourcing, suggest that collaborative record, development speed, cost of development, delivery and technical capabilities are positively rank correlated in these two outsourcing situations. This result means that those companies that considered the previous criteria important for the general outsourcing policies, also considered them important in the failure of the relationship.

The last column in Table B.31 shows that technical and delivery capabilities, collaborative record, strategic position cost of development, management ability, business strength, and development speed seem to be positively rank correlated in successful and unsuccessful outsourcing relationships.

Table B.32. Correlation between the Frequencies of the Weightings in Different Outsourcing Situations.

	A	B	C
Criterion	General vs. Successful	General vs. Unsuccessful	Successful vs. Unsuccessful
Technical Capabilities	0.78*	0.62*	0.90*
Development Speed	0.67*	0.90*	0.64*
Financial Security	0.54	0.52	0.57
Collaborative Record	0.84*	0.92*	0.81*
Business Strength	0.76*	0.55	0.65*
Cost of Development	0.88*	0.82*	0.74*
Cultural Compatibility	0.73*	0.44	0.21
Strategic Position	0.50	0.38	0.77*
Management Ability	0.61*	0.56	0.72*
Delivery Capabilities	0.91*	0.81*	0.83*
Location	0.70*	0.22	0.25
Size	0.36	0.10	0.17
Information Technology	0.75*	0.55	0.25

(*) indicates statistical significant at 5%

It can be noticed that some criteria are positively rank correlated in all the comparisons, while others are only in either one or two comparisons. The criteria that are positively correlated in all comparisons are: technical capabilities, development speed, collaborative record, cost of development and delivery capabilities. These criteria seem to be considered as the most important criteria in all outsourcing situations. Business strength and management ability, in contrast, are positively rank correlated only in the comparisons between general vs. successful and successful vs. unsuccessful. This suggests that these criteria may play an important role in the failure of the relationship.

Location and the use of information technology are only positively rank correlated in general vs. successful comparison. This result can be interpreted as the respondents having a bias toward the importance of these two criteria. However, these criteria do not seem to be important in either the failure or success of the relationship.

Table B.33. Differences in the Evaluation of the Criteria in Failure and Success.

Criterion	Difference
Development Speed	-0.6
Information Technology	-0.4
Management Ability	-0.2
Cost of Development	-0.1
Size	0.0
Strategic Position	0.4
Business Strength	0.7
Collaborative Record	0.7
Financial Security	0.8
Cultural Compatibility	0.8
Delivery Capabilities	0.9
Technical Capabilities	1.1
Location	1.4

Table B.32 was obtained by subtracting the averages of the importance of the criteria in unsuccessful relationships from those in the successful relationships. These differences indicate the accuracy in the evaluation of the criteria.

The criteria that were evaluated less accurately were development speed, the use of information technology, and management ability. In contrast, respondents seem to be over evaluating the importance of the location, technical and delivery capabilities. It is argued that the larger the difference, the more likely the appearance of problems in the evaluation.

B.5.2 Overall Evaluation

This section attempts to provide a unified view about the findings of the survey, regarding the determinants of success and failure. Obtaining universal conclusions is difficult because of the diversity of the data collected. The analysis of the results presented above highlighted many of the differences in the data. For example, the importance of the tasks outsourced in both successful and unsuccessful relationship was not very similar. The percentage of the Product Development Process also differed considerably. Other factors such as the product and market-orientation of the organizations and the subjective issues related to the evaluation of the relationships also increase the complexity of the analysis. Nonetheless and despite of all of these limitations, we think that general patterns can be found by analyzing the data from the survey.

In Table B.34 the results of the entire statistic presented above are summarized. The first column shows the frequency that respondents considered the criteria important. The second column depicts the results of the Analysis of Variance and the third row shows the results from the Spearman rank correlation.

The ranking scheme used in the frequency column has two components: the range and the relative position in the range. For example, the ranking of the financial security criterion is H-7, for the general outsourcing policies. That means that the criterion was ranked in the 'high important' range and relatively to all the criteria in that range; it was located at the 7th place. The rankings were obtained using the largest values of the criteria.

Table B.34. Overall Evaluation of the Selection Criteria.

Criterion	Frequency	ANOVA	Spearman Success	Spearman Failure
Technical Capabilities	**H-1**	**2**	**2**	
Development Speed	**H-6**		**3**	**1**
Financial Security	**H-7**	**5**	**3**	**2**
Collaborative Record	**H-2**	**3**	**3**	
Business Strength	**H-5**		**4**	**3**
Cost of Development	H-4		4	
Cultural Compatibility	M-2		5	
Strategic Position	**M-2**		**5**	
Management Ability	**H-3**		**3**	**1**
Delivery Capabilities	**H-1**	**1**	**1**	
Location	**H-8**	**4**	**3**	
Size	M-1		5	
Use of Information Technology	**H-9**		**5**	**4**

The table shows that some criteria are consistently identified as important, regardless of which method is used to evaluate their importance. In order of importance, the criteria that belong to this group are: technical capabilities, delivery capability, collaborative record, location, and financial security.

Other criteria are identified as important by either some evaluation methods or types of companies. According to the method of evaluation, business strength and the use of information technology rank relative high in importance in the analysis of its frequency and they were found significant by Spearman rank correlation in both success and failure of outsourcing relationships. However, the analysis of variance did not identify these criteria as important.

Management ability ranks relatively high in the analysis of the frequency but it was only identified as an important criterion in the Analysis of Variance for solution-oriented companies. Nevertheless, it is positively rank correlated with both successful relationships and unsuccessful relationships. Strategic position, in contrast, was found mainly of a medium importance in the analysis of frequencies and significant in the Analysis of Variance for solution-oriented companies.

Notably in this analysis is the fact that cost of development, size, and cultural compatibility were identified as important, only once. Despite that cost of development ranks relatively high in the analysis of frequencies, it was identified important in neither the Analysis of Variance nor Spearman rank correlation (with the exception of success in which it ranks the second last). Size and cultural compatibility were found important only by the Spearman correlation with success.

The cost of development was found by Bailey et al. [1998] as the least important criteria and negatively rank correlated with success. In that research, the author argued that it was possible that the respondents may have been unwilling to acknowledge the importance of cost in their decision-making process. The finding of the survey with respect to cost of development may be used to reinforce this understanding. However, the opposite approach may be also valid. The similarity of the findings might suggest that in fact a shift in the importance of cost is taking place. It was explained in Chapter 2, companies are able to charge more, if they are able to show customer that a significant value is added to their product or service.

Table B.35 shows the rankings of the frequency of the criteria for general outsourcing policies, successful and unsuccessful relationships. Although a few patterns can be noticed (and have been highlighted) in the table, most of the criteria follow their own variation pattern. The analysis of each individual variation may prove to be both impractical and of little use. Instead, this table can be used to track the variation on the importance of the criteria for different outsourcing situations and the different types of companies. For example, the comparison between rankings in the three outsourcing situations can be used to identify inaccuracies between the perceived and real role of the criteria. For example, development speed is considered in general outsourcing a criterion with relative low importance in the 'high importance' range. However, its importance increases considerably for both successful and unsuccessful relationships. Therefore, it can be suggested to change the role of the criterion, accordingly, when establishing the general outsourcing policies.

Table B.35. Rankings of Criteria for General Outsourcing, Successful, and Unsuccessful Relationships.

Criterion	G	S	U
Technical Capabilities	**H-1**	**H-1**	**H-3**
Development Speed	H-6	H-3	H-2
Financial Security	H-7	H-6	H-6
Collaborative Record	**H-2**	**H-2**	**H-4**
Business Strength	H-5	H-6	H-7
Cost of Development	H-4	H-2	H-3
Cultural Compatibility	M-2	H-8	L-1
Strategic Position	M-2	H-7	M-1
Management Ability	H-3	H-4	H-1
Delivery Capabilities	**H-1**	**H-1**	**H-1**
Location	H-8	H-5	H-8
Size	M-1	M-1	M-2
Use of Information Technology	H-9	H-7	H-5

G: General Outsourcing Policies S: Successful U: Unsuccessful

B.5.3 Use of Information Technology

This section presents the findings of the survey about the use of Information Technology. Two questions were dedicated to inquiring about this criterion. The first question asked about the use and integration of Information Technology. The second question tried to identify the most important features of a Computer Aided Outsourcing software.

The question related to the use of information technology did not ask about the use of computers. It is clear that computers are extensively used in many tasks. The question focused on the use of Computer Aided Design and Manufacturing (CAD/CAM) software and its integration. Forty-three percent of the respondents use these software without integrating them. For those that do integrate the software to their Product Development Process, the level of integration varies considerably. Close to 55% of the respondents have 50% or more of their CAD/CAM tools integrated to their Product Development Process. Close to half of the respondents in this group report to have achieved integration beyond 75%. In addition, close to 22% of the respondents acknowledge a level of integration below 25%.

The survey also inquired about the most important features that a Computer Aided Outsourcing software should have. Table B.36 depicts the percentage of responses. It can be seen that subcontractor selection and evaluation are the most wanted features. Risk evaluation ranks second and workflow analysis ranks last. Respondents also indicated the need for integration. In that regard, they indicated that the software should be able to integrate with other software already in use and it should allow the handling of suppliers.

Table B.36. Features of a Computer Aided Outsourcing Software.

Features	**Responses (%)**
Work Flow Analysis	50
Subcontractor Selection	61
Subcontractor Evaluation	61
Risk Evaluation	57

B.5.4 Preparedness for Forming Virtual Enterprises

Chapter 2 introduced the six most important characteristics of Virtual Enterprises. It was shown there that these characteristics are: opportunism, excellence, technology, no borders, trust, and one identity.

The analysis of the preparedness of the respondents to form Virtual Enterprises takes in reference these characteristics and tries to evaluate them according to the findings of the survey. Out of the six characteristics mentioned above, opportunism and one identity could not be evaluated because they were not measured by the survey. The other four characteristics are evaluated either directly or indirectly using the findings of the survey. However, this evaluation is not meant to provide a conclusive and in-depth study transition to forming Virtual Enterprises. It objectives are more modest and directed towards the identification of a possible 'as is' situation in this migration process.

Excellence was evidenced by the focus on core capabilities and the factors differentiating the companies in the market place. It is clear from the survey the respondents' focus on core capabilities. This understanding was obtained by both direct and indirect measures.

The first strong evidence is that no respondent was willing to subcontract in its area of expertise. The second of important indication is the ranking of technical capabilities. Regardless of the orientation of companies, the outsourcing situation, or the outcome of the technical capabilities was found a very important criterion. It was also found that quality, customer services as well as the recognition of the importance of a knowledgeable and skilled work force are three of the most important differentiating companies from their competitors. Although, other factors such as mass customization and a customer centred approach could not be measured, it is possible to conclude that companies seem to satisfy the requirements of this characteristic.

The satisfaction of the technology characteristic was measured by the communication with subcontractors and the use of information technology, mainly the use of software and their integration to the Product Development Process. The survey did not enquire about innovation and therefore it will not be considered here. The findings of the survey with respect to the use of software show that although software is used extensively, it is not well integrated with the Product Development Process. Close to 50% of the respondents use either Computer Aided Design (CAD) or Computer Aided Manufacturing (CAM) but have not integrated them. In addition, integration seems to be a slow process with only less than 20% of the respondents achieving integration of the software and the Product Development Process beyond

75%. On the other hand, the results of the survey suggest that companies have a good communication mechanism in place to inform subcontractors about changes. The survey did not ask whether the communication was carried out electronically or not. In general, it can be concluded that the companies do not seem to be using information technology at the level required to form Virtual Enterprises. The major challenges seem to be in integrating of different types of software (CAD, CAM, for the management of the supply chain) and the integration of the software with the Product Development Process.

The no borders characteristic is difficult to evaluate. On the one hand, outsourcing is taking place and that implies the use of multidisciplinary and external expertise in the product or services development process. On the other hand, the survey shows that the kind of outsourcing that is taking place is not the one required in Virtual Enterprises.

One of the main objectives of Virtual Enterprises is to take advantage of market opportunities by bring products to market as quickly as possible. Companies try to meet this objective by sharing the Product Development Process with others. Ideally, the most advantageous form of sharing the Product Development Process is black-box outsourcing. In black-box outsourcing, partners take a portion of the development process at the design stage and continue to collaborate in all the other stages. Black-box outsourcing also implies the recognition of dependency by knowledge where each partner contributes to the product in its specific areas of expertise. Moreover, in black-box outsourcing, partners are given more information regarding the development process of the product or service.

The findings of the survey show, however, show differently. Most of the outsourcing taking place is not black-box outsourcing and it is concentrated in the manufacturing stage (82%). This trend may affect the formation of Virtual Enterprises, since companies are not outsourcing enough at the design stage (33%) and therefore they might be losing valuable time in bringing the products to market. The survey also found that most of the companies are using tactical outsourcing and becoming dependent by capacity since they mainly assign to subcontractors low and medium-importance tasks. All these findings seem to indicate that the needs of the no borders characteristics are not met by the current outsourcing practices.

Several findings indicate the lack of trust on subcontractors. Companies provide only minimum information to subcontractors and are rarely willing to train them. Mainly, subcontractors are assigned low and medium-importance tasks and companies show a high level of concern in the subcontracting of tasks related to the development of new products or specific technologies. These findings lead to the understanding that companies do not trust subcontractors as required in Virtual Enterprises.

The partner selection process shows that companies are starting to have a bidding process opened to all qualified bidders. This approach coincides with the focus of Virtual Enterprises on gaining access to the skills and knowledge they required, regardless of their geographical location. The relative importance assigned to the selection criteria seems contradictory. On one hand, companies value criteria such as technical and delivery capabilities that are very important for forming Virtual Enterprises. On the other hand, they also value criteria that are considered less relevant for the formation of Virtual Enterprises, such as collaborative record and location. The focus on collaborative record, in design and manufacturing companies is justified, since it has a more comprehensive meaning than ‘having worked before’. Collaborative record means that subcontractors are familiar with the designs and equipments; they have already succeeded in the steep learning curve of working with the outsourcing company and they understand how the outsourced products are used and applied [ASME 1997].

It is interesting to note that the use of Information Technology was not found to be important for neither the type of company nor the different outsourcing situations.

B.6 Summary of Findings

In summary, the findings of the survey show that:

1. Companies still see outsourcing as a threat to their market survival. They seem to be concerned with outsourcing beyond the commodity level.
2. Quality, having a knowledgeable and skilled workforce, customer services, and delivery capabilities are the most important differentiating factors in the market.
3. Cost is still seen as a very important market-differentiating factor, although it ranks lower than the factors mentioned earlier. Location is the least important differentiating factor.
4. Overall, less than 30% of the Product Development Process is outsourced. The majority of the tasks outsourced are of low or medium importance.
5. Most of the outsourcing taking place is white-box outsourcing.
6. The most common dependency created by outsourcing decisions is dependency by capacity.
7. Most of the outsourcing seems to be tactical rather than strategic.
8. The most outsourced stage of the Product Development Process is manufacturing.
9. There is a lack of trust on subcontractors. They are considered suppliers rather than partners. Therefore, they received minimal information about the tasks they perform and outsourcing companies do not share information about the Product Development Process with subcontractors.
10. The bidding process is still based in previous collaborations. However, companies are starting to use an open bidding process in which all the qualified partners can bid.
11. Subcontractors are evaluated more often at the beginning and end of the relationships. Continuous or periodical evaluations are also used. Monthly evaluations are the most used form of periodical evaluation.

12. The most important criteria influencing the general outsourcing policies are: technical and delivery capabilities. Criteria such as collaborative record, business, cost of development and management ability are also important.
13. In general, technical and delivery capabilities as well as collaborative record, financial security and location were to be found the most important factors in the success or failure of outsourcing relationships.
14. To form Virtual Enterprises, companies will have to ease their concerns about outsourcing, increase their black-box outsourcing, increase their trust on subcontractors, and improve in the integration of CAD/CAM tools and their Product Development Process.

Appendix C

SUBCONTRACTING POLICIES IN CANADIAN DESIGN AND MANUFACTURING FIRMS

DIRECTIONS

Please choose as many answers as apply per question. Indicate your choice with a check mark (√) in the box provided. Write in the space provided if that is your choice.

Fill free to write comments beside your answer if you feel that appropriate.

If any question does not apply to your company, please indicate so with **N/A** beside the question number and leave the answer blank.

DEFINITIONS

For the purpose of this survey the following definitions are used:

- **Subcontracting:** The establishment of a business relationship between your organization and another external organization (partner, supplier or vendor) that operates under a different management. Other terms commonly used to define subcontracting are: outsourcing and contracting out
- **Network:** A temporary or permanent organizational structure that allows companies to share both responsibilities and profits in a larger contract or project
- **Product Development Process (PDP):** The process that includes all the tasks associated with creation of a given product, from the initial identification of the customer needs to manufacturing and delivery of the product to customers

If the return envelope provided is misplaced, please return the survey form to the following address:

Dr. Chris Zhang / Marco Pego
Advanced Engineering Research Laboratory
Department of Mechanical Engineering
57 Campus Drive
Saskatoon, Saskatchewan, S7N 5A9

SECTION A-COMPANY GENERAL POLICIES TOWARDS SUBCONTRACTING

1.	Identify which one of the following that best describes your company. ☐ We **subcontrac**t all or the majority of the tasks to other companies. ☐ We provide services on **subcontracting** basis to other companies. ☐ We are a member of a network where we **subcontract** and provide services on a **subcontracting** basis, depending on the project. ☐ Other (Please specify) ____		
2.	Please, indicate whether or not your company is concerned about the impact of **subcontracting** on the company's intellectual property in the following situations?		
	New product development	☐ YES	☐ NO
	Specific technologies	☐ YES	☐ NO
	Software	☐ YES	☐ NO
	Other (Please specify.)	☐ YES	☐ NO
		☐ YES	☐ NO
3.	Is your company concerned with the possibility of your competitors matching or surpassing your products due to your **subcontracting** policies in the following situations?		
	Subcontracting of part(s) or component(s)	☐ YES	☐ NO
	Subcontracting of sub-system(s)	☐ YES	☐ NO
	Overall product or process design	☐ YES	☐ NO
	Other (Please specify.)	☐ YES	☐ NO
		☐ YES	☐ NO

4.	How important are the tasks assigned to **subcontractors** in your company? (To answer, for the level of **Importance** choose the most appropriate answer(s) from the other columns.)			
	Importance	**Few**	**Average**	**Most**
	LOW (My company can easily find a replacement company if needed.)	☐	☐	☐

	MEDIUM (It can take some time to find a replacement company in the market.)	☐	☐	☐
	HIGH (It can delay the development of the product.)	☐	☐	☐
	CRITICAL (The development of the product will stop.)	☐	☐	☐
5.	Identify which one of the following that best describes your company's approach when dealing with **subcontractors**. ☐ My company deals only with **subcontractors** that are directly responsible for the deliverables. ☐ My company deals with all the **subcontractors** involved, regardless whether or not they are directly responsible for the deliverables. ☐ Other (Please specify.) ____			
6.	A **module** is a clearly identifiable component in a product that allows for standardization and interchangeability. According to this definition what is the role of **modularization** in your **subcontracting** decisions? ☐ LOW (We rarely **subcontract** the production of **modules**.) ☐ MEDIUM (We occasionally **subcontract** the production of **modules**.) ☐ HIGH (We usually only **subcontract** production of **modules**.) ☐ NO ROLE (**Modularization** is not the guiding criterion.) Please specify. ____________________			
7.	**Integration** is considered the capability of successfully making the components of a product work together to provide a given function, or service. Considering this definition, what is the role of the **integration** in your **subcontracting** decisions? ☐ LOW (The components of the product(s) are highly interchangeable.) ☐ MEDIUM (There is a balance between interchangeable and specific components.) ☐ HIGH (The components of the product(s) are mainly specific to the product) ☐ NO ROLE (**Integration** is not the guiding criterion.) Please specify. __________________________			
8.	Please identify all of the following tasks that your company either perform **in-house** or are **subcontracted** and about what percentage. To answer, check the box in either the **In-house** or **Subcontracted** columns, and estimate the percentage in the last column.			

	Task	In-house	Subcontracted	Percentage (%)
	DESIGN	☐	☐	
	MANUFACTURING	☐	☐	
	ASSEMBLING	☐	☐	
	CUSTOMER SERVICES	☐	☐	
	OTHER (Please specify.) 1.	☐	☐	
	2.	☐	☐	
	3.	☐	☐	
9.	Overall, how do you characterize the dependency of your company on **subcontractors**? ☐ LOW (**Subcontractors** are only assigned low importance tasks.) ☐ MEDIUM (**Subcontractors** are assigned important but not critical tasks.) ☐ HIGH (**Subcontractors** are assigned critical tasks) ☐ DOES NOT APPLY (My company does not depend on **subcontractors** at all) ☐ Other (Please specify.) ________________________			

10. Please indicate how strongly you agree or disagree with the following statements. Use the scale of “9 to 1” with 9 being “**Agree Strongly**” and 1 being “**Disagree Strongly**”. Choose the number which best indicates your choice.

Criterion	Agree Strongly ←								Disagree Strongly →
My company **subcontracts components** related to the development of new products.	9	8	7	6	5	4	3	2	1
My company **subcontracts** 50 % or more of the tasks related to the development of new products.	9	8	7	6	5	4	3	2	1
My company **subcontracts** tasks related to products developed at a reasonable (medium) scale, but not mass production.	9	8	7	6	5	4	3	2	1
My company **subcontracts** tasks related to massively produced products.	9	8	7	6	5	4	3	2	1

SECTION B-PRODUCT DEVELOPMENT PROCESS AND SUBCONTRACTING

1. When taking **subcontracting** decisions, how often does your company consider the **Product Development Process**?

☐ less than 25% of the cases.
☐ 25 - 50% of the cases.
☐ 50 - 75% of the cases
☐ 75 - 100% of the cases.

2. In the development of a new product or process, if **<u>no suitable subcontractor</u>** is found your company will:

☐ Stop or abandon the development.
☐ Delay the development until a suitable **subcontractor** is found.
☐ Develop the product or process internally.
☐ Train the most suitable **subcontractor** to obtain the required skills.
☐ Other. (Please specify.)

____

3. Identify the scope of the information provided to subcontractors.

☐ Detailed information about the overall **Product Development Process**.
☐ A combination of general information about the **Product Development Process** and specific
information about the **subcontract**.
☐ Only the minimum information that allows **subcontractors** to carry out their tasks.
☐ Other. (Please specify.)

____

4. In providing your company's **subcontractors** with design specifications does your company:

☐ Precisely specify the requirements.
☐ Provide general requirements and let the **subcontractors** develop their own specifications.
☐ Use the specifications that the **subcontractors** develop on their own.
☐ Does not apply.
☐ Other. (Please specify.)

____

5. In providing your company's **subcontractors** with manufacturing specifications does your company:

☐ Precisely specify the requirements.
☐ Provide general requirements and let the **subcontractors** develop their own specifications.
☐ Use the specifications that the **subcontractors** develop on their own.
☐ Does not apply.
☐ Other. (Please specify.)

____

6. In providing your company's **subcontractors** with assembling does your company:

☐ Precisely specify the requirements.
☐ Provide general requirements and let the **subcontractors** develop their own specifications.
☐ Use the specifications that the **subcontractors** develop on their own.
☐ Does not apply.
☐ Other. (Please specify.)

____

5. How does your company ensure that what is delivered by the **subcontractors** meets the original specifications?

☐ We check the deliverables and try to help our **subcontractors** to meet the specifications.
☐ We believe and trust our **subcontractors.**
☐ We do not check what the **subcontractors** deliver.
☐ Other. (Please specify.)

____

6. Based on previous experiences, please specify your overall satisfaction with the results of **subcontracting** the stages of the **Product Development Process (PDP)**. Use the scale of "9 to 1", with 9 being "**Highly Satisfactory**" and 1 being "**Highly Unsatisfactory**". Choose the number which best indicates your choice.

PDP Stage	**Highly Satisfactory** ←								**Highly Unsatisfactory** →
Design	9	8	7	6	5	4	3	2	1
Manufacturing	9	8	7	6	5	4	3	2	1

Assembling	9	8	7	6	5	4	3	2	1
Other (Please specify.) 1.	9	8	7	6	5	4	3	2	1
2.	9	8	7	6	5	4	3	2	1
☐ This question does not apply to my company.									

7. Is your company concerned about changes made by **subcontractors** on their own that affect the **Product Development Process**?

☐ YES, WE ARE ☐ NO, WE ARE NOT

8. How do you inform the whole supply chain about changes in specifications made by **subcontractors** on their own?

☐ We have a good communication mechanism in place.
☐ We do not control the changes in specifications that our subcontractors make.
☐ Other. (Please specify.) ____

SECTION C-SUBCONTRACTORS SELECTION AND EVALUATION PROCESS

1. The bidding process for tasks to be subcontracted is open to:

☐ All capable or available companies.
☐ Trustworthy partners only.
☐ Companies with whom previous relationships have been established.
☐ Other. (Please specify.) ____

2. Please identify when does your company evaluate the performance of the **subcontractors**.

☐ Only at the beginning of the **subcontract**. That is when the **subcontract** is awarded
☐ At the beginning and at the end of the **subcontract**.
☐ Periodically. Every ______ month(s).
☐ Other. (Please specify.) ____

3. Indicate how important each of the following criterion is when your company is selecting **subcontractors**. Use the scale of "9 to 1", with 9 being "**Extremely Important**" and 1 being "**Not at all Important**". Choose the number that best indicates your choice. For each criterion please also indicate how easy it can be evaluated or

estimated.										
Criterion	Is this criterion easy to estimate?	**Extremely Important** ←								**Not at all Important** →
Technical Capabilities	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1
Development Speed	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1
Financial Security	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1
Collaborative Record	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1
Business Strength	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1
Cost of Development	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1
Corporate Cultural Compatibility	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1
Strategic Position	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1
Management Ability	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1
Delivery Capabilities	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1
Location (Geographical proximity)		9	8	7	6	5	4	3	2	1
Subcontractor Size		9	8	7	6	5	4	3	2	1
Use of Information Technology	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1
Other (Please specify.) 1.	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1
2.	☐ YES ☐ NO	9	8	7	6	5	4	3	2	1

SECTION D-SUBCONTRACTING INSTANCES

SUBSECTION D.1

In order to answer the following questions it is needed that you focus on **one (1)** specific subcontracted task that took place during the last **three (3)** years and **<u>50% or more</u>** of the initial objectives of the subcontract were met.

1. Estimate how the original, or initial objectives, of the subcontract were met.

☐ 50 to 75 % ☐ 75 % or more

2. Indicate the role of each of the following criterion that was used in achieving the results specified in the previous question. Use the scale of "9 to 1", with 9 being "**Extremely Important**" and 1 being "**Not at all Important**". Choose the number that best indicates your choice.

Criterion		**Extremely Important** ←								**Not at all Important** →
Technical Capabilities		9	8	7	6	5	4	3	2	1
Development Speed		9	8	7	6	5	4	3	2	1
Financial Security		9	8	7	6	5	4	3	2	1
Collaborative Record		9	8	7	6	5	4	3	2	1
Business Strength		9	8	7	6	5	4	3	2	1
Cost of Development		9	8	7	6	5	4	3	2	1
Corporate Cultural Compatibility		9	8	7	6	5	4	3	2	1
Strategic Position		9	8	7	6	5	4	3	2	1
Management Ability		9	8	7	6	5	4	3	2	1
Delivery Capabilities		9	8	7	6	5	4	3	2	1
Location		9	8	7	6	5	4	3	2	1
Subcontractor Size		9	8	7	6	5	4	3	2	1
Use of Information Technology		9	8	7	6	5	4	3	2	1
Other (Please specify.) 1.		9	8	7	6	5	4	3	2	1
2.		9	8	7	6	5	4	3	2	1

3. Which of the following stages of the **Product Development Process (PDP)** were **subcontracted**, and about what percentage of the total PDP? If the stage was **Subcontracted** check the second column and estimate the percentage in the third column. Otherwise, leave the columns blank.

PDP Stage	Subcontracted	Percentage of Total PDP (%)
Design	☐	
Manufacturing	☐	
Assembling	☐	
Customer Services	☐	
Other (Please specify.) 1.	☐	
2.	☐	

4. How important were the **Product Development Process** the tasks assigned to **subcontractors**?

☐ LOW (My company easily found a replacement company.)
☐ MEDIUM (Finding a replacement company took some time.)
☐ HIGH (It delayed the development of the product.)
☐ CRITICAL (The development of the product came to stop.)

SUBSECTION D.2

In order to answer the following questions it is needed that you focus on **one (1)** specific subcontracted task that took place during the last **three (3)** years and **<u>50% or less</u>** of the initial objectives of the subcontract were met.

1. Estimate how the original, or initial objectives, of the subcontract were met.

☐ less than 25 % ☐ 25 to 50 %

2. Indicate the role of each of the following criterion that was used in achieving the results specified in the previous question. Use the scale of "9 to 1", with 9 being "**Extremely Important**" and 1 being "**Not at all Important**". Choose the number that best indicates your choice.

Criterion		Extremely Important ←								Not at all Important →
Technical Capabilities		9	8	7	6	5	4	3	2	1
Development Speed		9	8	7	6	5	4	3	2	1
Financial Security		9	8	7	6	5	4	3	2	1
Collaborative Record		9	8	7	6	5	4	3	2	1
Business Strength		9	8	7	6	5	4	3	2	1
Cost of Development		9	8	7	6	5	4	3	2	1

Corporate Cultural Compatibility		9	8	7	6	5	4	3	2	1
Strategic Position		9	8	7	6	5	4	3	2	1
Management Ability		9	8	7	6	5	4	3	2	1
Delivery Capabilities		9	8	7	6	5	4	3	2	1
Location		9	8	7	6	5	4	3	2	1
Subcontractor Size		9	8	7	6	5	4	3	2	1
Use of Information Technology		9	8	7	6	5	4	3	2	1
Other (Please specify.) 1.		9	8	7	6	5	4	3	2	1
2.		9	8	7	6	5	4	3	2	1

3. Which of the following stages of the **Product Development Process (PDP)** were **subcontracted**, and about what percentage? If the stage was **Subcontracted** check the second column and estimate the percentage in the third column. Otherwise, leave the second and third columns blank.

PDP Stage	Subcontracted	Percentage (%)
Design	☐	
Manufacturing	☐	
Assembling	☐	
Customer Services	☐	
Other (Please specify.) 1.	☐	
2.	☐	

4. How important were the **Product Development Process** the tasks assigned to **subcontractors**?

☐ LOW (My company easily found a replacement company.)
☐ MEDIUM (Finding a replacement company took some time.)
☐ HIGH (It delayed the development of the product.)
☐ CRITICAL (The development of the product came to stop.)

SECTION E-SOFTWARE FEATURES

The findings of this survey shall be incorporated into a software tool. This tool aims to easy the management of subcontractor relationships. It will be made freely available to all the participants in this survey. Please identify which of the following features would you like to see included in the software. You can suggest other features at the end of the survey.

☐ Workflow Analysis. This section allows to define the Product Development Process of the components of the product to be design and manufactured. Moreover, it helps to analyze if subcontracting a specific tasks is a viable alternative.

☐ Subcontractor Selection. This section allows to define the criteria to be used in the partner selection and to choose the relative importance of these criteria. Furthermore, it links to the Workflow Analysis. In this way, the selection of each partner and subcontractor is related to the specific items of the Product Development Process.

☐ Subcontractor Evaluation. This section allows to periodically evaluate the subcontractors performance. It also will help to identify irregularities in the subcontractors performance faster. This section will include Quality Control and lead time tracking too.

☐ Risk Evaluation. This section allows to evaluate the risks the company can get into due to the subcontracting decision.

☐ Please specify other features you would like to be included in the software

____

____

____

SECTION F-YOU AND YOUR ORGANIZATION

In order to successfully identify the main issues addressed in this survey we need to collect some information about you and your organization.

1. We define a **product** as a device that provide any kind of specified services or capabilities, but does not add value to the device. On the other hand, the term **solution**, is used to identify the cases where there is a tangible value addition to the product that provides financial, time, or other savings to the customer. According to these definitions, what is the market focus of your company?

☐ PRODUCT ORIENTED ☐ SOLUTION ORIENTED

2. Is your company ISO 9000 certified or equivalent?

☐ 25% or less .
☐ 25 to 50 %.
☐ 50 to 75 %.
☐ 75 to 99 %.
☐ Fully.

3. Which of the following best describes your company in the market place?

☐ We have products that are easy to reproduce, but no or almost no competitors.
☐ We have products that are easy to reproduce and strong competitors.
☐ We have products that are hard to reproduce, but no or almost no competitors.
☐ We have products that are hard to reproduce and strong competitors.
☐ Other. (Please specify.) ____

4. How do you classify the use of Information Technology in your company within design, manufacturing, and assembling related tasks?

☐ We use CAD and/or CAM software, but we have not the integration of tools for the **Product Development Process**.

We have CAD and CAM tools integrated to our **Product Development Process**.

☐ 25% or less .
☐ 25 to 50 %.
☐ 50 to 75 %.
☐ 75 to 100 %.

☐ Other. (Please specify.) ____

5. How important are the following factors in differentiating your company from its competitors? Use the scale of "9 to 1", with 9 being "**Extremely Important**" and 1 being "**Not at all Important**". Choose the number that indicates your choice.

Factor	**Extremely Important ←**								**Not at all Important →**
Quality	9	8	7	6	5	4	3	2	1
Customer Care	9	8	7	6	5	4	3	2	1

Delivery Capabilities	9	8	7	6	5	4	3	2	1
Knowledge and skilled worker	9	8	7	6	5	4	3	2	1
A significant portion of the market	9	8	7	6	5	4	3	2	1
Cost/Price	9	8	7	6	5	4	3	2	1
Location (Geographical Proximity)	9	8	7	6	5	4	3	2	1
Other. (Please specify.) 1.	9	8	7	6	5	4	3	2	1
2.	9	8	7	6	5	4	3	2	1

6. Does your company electronically exchange product and/or process information with your **subcontractors**?

☐ YES, WE DO ☐ NO, WE DO NOT

7. How does your company position itself?

☐ We are experts in one or two specific areas.
☐ We generally work in broad areas, but with little specialization.
☐ Other. (Please specify.) ______________________________

8. Is your company willing to subcontract in their area of specialization?

☐ YES, WE DO ☐ NO, WE DO NOT

9. What is your position or title?

☐ Executive/Director ☐ Vice President/Senior Manager
☐ Research ☐ Manager
☐ Other (Please specify.) ________________

10. What are your company's total revenues per year?

☐ under 25 000 ☐ 25 000 - 1 million
☐ 1 million to 10 millions ☐ 10 millions - 50 millions
☐ 50 millions - 250 millions ☐ 250 millions - 1 billion
☐ 1 billion or more

11. How many employees are in your company?

☐ 0 - 10	☐ 11 - 20
☐ 21 - 50	☐ 51 - 100
☐ 101 - 200	☐ 200 - 500
☐ 501 - 1 000	☐ 1 001 - 5 000
☐ 5001 - 10 000	☐ 10 001 or more

ADDITIONAL COMMENTS

If you wish to suggest or comment on any section of the survey, please do that below.

THANK YOU VERY MUCH FOR YOUR ASSISTANCE

You have made a major contribution to the success of this project. Please place the questionnaire in the enveloped provided and mail it to us. We will send you a final report of our findings as soon as it is available. The software will be available from download over internet.