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Dynamic Analysis for Enterprise Strategic Flexibility using System Engineering Methodology

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Dynamic Analysis for Enterprise Strategic Flexibility using System Engineering Methodology

by

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1	Arafa, A. and W. ElMaraghy (2011). "Manufacturing strategy and enterprise dynamic capability." CIRP Annals-Manufacturing Technology, 60, 507-510.	Published
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ABSTRACT

From a system thinking perspective, the competition / cooperation boundaries govern the evolution of a firm's adaptive strategic behaviour and drive it towards its desired objectives. Strategic flexibility is considered a sustainability advantage in today's global competitive environment. This study explores the strategic flexibility capability that fits with the market requirement and the degree of competition it faces in its market(s).

After exploring the link between the manufacturing objectives and their effect on the total industry performance in terms of profitability, product availability and capacity utilization, this study quantify the strategic effect of applying five different strategies on the enterprise strategic flexibility capability. By modeling and analyzing different scenarios using a system dynamic simulation approach and considering the market competitive dynamics, this model introduces the volume flexibility as a macro strategic measure that affects the firm's intended production capacity. The effect of enterprise volume flexibility on its market share is studied and reported.

The research explored how operations management theory on volume flexibility can be linked to the dynamic capability theory to develop new macro measures for the enterprise manufacturing strategy. Results show that matching between the firm capabilities and its external environment is a critical factor for organizational success. While the intense of competition govern the product life cycle duration and rate of change, success level is proportional to the competitor simultaneous actions and reactions and the effect differs from market to another. Results show that different product life cycle affects the industry speed and that may change the wining strategies adopted by the competing firms. As a result there are no ultimate right strategies for firms to follow. While tradeoffs between flexibility and cost are confirmed, the competitive advantage occurs when it is unique to the company and matches with the market variables for limited time. In conclusion, for industrial organization to achieve high productivity, efficiency and maximum utilization rate they need to select from a wide range of strategic capabilities rather than concentrating on a single capability or process to match the requirements of the external environment with responsive rate that matches the industry clock speed.

DEDICATION

No words or actions in this world may express my gratitude and love for my Parents.

With all their love, support, and patience, it is to them that I dedicate this thesis.

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I like to give my sincere thanks to my dissertation advisor, Prof. Waguih ElMaraghy, for his direction, assistance, encouragement, and guidance. He challenged me to this research topic. In each phase of this research, he provided invaluable support. He was always there to encourage me. Beyond his guidance on the research work, he also showed me how to conduct a research and how to be a good researcher even under very tight deadlines.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF NOMENCLATURE

A_T	Product Total Attractiveness
A_P	Attractiveness From Price
A_v	Attractiveness From Availability
S_P	Preference For Price
S_V	Preference For Availability
D_P	Delivery Performance
D_d	Delivery Delay
RD_d	Reference Delivery Delay
B	Backlog
S	Shipments
P	Price
LP	Lowest Available Price
O	Orders Received To The Firm
dO_r/dt	Total Industry Order Rate
dA/dt	Product Adoption Rate
WOM	Word Of Mouth
POP	Market Population
σ	Number Of Products Per Customer
I_B	Installed Base Of The Product
dD/dt	Discard Rate
S_A	Actual Shipment
S_d	Desired Shipment
NDD	Normal Delivery Delay
C	Production Capacity
S_o	Outsourced Shipments
O_D	Outsourcing Performance Delay
C_{AD}	Capacity Acquisition Delay
NCU	Normal Capacity Utilization
C_T	Target Capacity
MES	Minimum Efficient Scale Of Production
EID	Expected Industry Demand
NPI	New Product Introduction Rate

NPD	Time Required For The New Product Development
Fc	Fixed Cost
UFc	Unit Fixed Cost
UVc	Unit Variable Cost
a	Number Of Capacity Units Required Per Part Produced
b	Contribution Margin For The Product
LS	Learning Curve Strength
MS_T	Target Market Share

CHAPTER I

ENTERPRISE STRATEGIC FLEXIBILITY

1.1. Research Motivation

For industrial organizations to succeed and survive in volatile fast changing markets, they should build a reliable architecture that allows them to develop a sustainable competitive advantage. Building such reliable architecture automatically reduces their organizational flexibility. As a result, any current successful capability contains risk of rigidity and bureaucratic grid lock in the face of the continuous changing environment and short windows for opportunities. As a consequence, organizations are confronted with a dilemma: on the one side, they have to develop reliable patterns of selecting and linking resources in order to attain superior performance and competitive advantages and on the other side this contains considerable risk of becoming locked into exactly these "successful reliable capabilities".

Industrial researchers developed flexible manufacturing systems to respond to the request for more variety of product styles dictated due to new market challenges and uncertainties. These systems are capable of adapting to changing demand patterns which in turns gave a sort of competitive advantage and production flexibility to the organizations that implemented it. Though, bureaucratic organizations with flexible production systems will suffer both the high cost of such production systems setup and the negative consequences of being rigid in a fast changing competitive environment and may break down and exit the industry very fast. This bring to attention the importance of the capability the enterprise build over time and how dynamic it is to match with the market changing conditions. The strategic decision in this case is irreversible, vital for success and in most cases there is a trade offs in selection.

This study aims to develop a strategic frame work that helps industrial enterprises to manoeuvre with the changing external environment by expanding the concept of "Flexible Manufacturing System" from the production level to the system level to create

"Global Strategic Flexibility" for the enterprise which can be considered as a boarder view of flexibility in industrial organizations. In this stream, "Flexible" means giving a "Dynamic Capability" that allows organizations to occupy a favourable market position and to continuously create, define, discover and exploit entrepreneurial opportunities that are valuable in reference to the market benchmark at any point of time and to the process of organizational wealth creation as well.

The study takes into consideration the rigidity developed through the organizational life cycle stages, the forces generated from the industry dynamics through the interactions of firms together fighting over maximizing their market share and profitability, and finally the individual needs, preferences and capabilities as a foundation for the dynamics of the competing market landscape. All these consideration are enveloped with evolutionary mechanisms.

1.2. Research Objective

Structural and operational decisions are strategic and irreversible as they may or may not increase the manufacturing flexibility as competitive capability to the firm. The objective of this study is as follows:

- Explore the dynamics of volume flexibility and the possible avenues that may affect it.
- Evaluate the strategic benefit of gaining volume flexibility capability from direct capacity adjustment, strategic alliances, or changing the targeted market segment and considering both the expected behaviour of competition and the market dynamics.
- Develop new macro measures for organizations to evaluate and plan their strategies by quantifying the relative importance of, and gains from, their long term decisions.
- Develop a strategy simulator for industrial enterprises using system dynamics to enhance their decision making capability based on educated assumption and considering the disequilibrium market dynamics.
- Finally, to conduct a comparative analysis for decisions taken by the enterprise considering the simultaneous actions from competitors under different market scenarios.

1.3. Thesis Statement

Linking volume flexibility, founded in operations management theory, with the dynamic capability theory via system dynamics allows for rational enterprise strategic decision making capability and hence achieves organizational strategic flexibility that may outperform competition.

1.4. Thesis hypotheses

The process of creating dynamic capabilities is built by continuous integration and coordination of all organizational activities. Internal activities are represented in process planning, information process and automation capabilities. While external activities are represented in strategic alliances, virtual cooperation and supplier relation. The hypotheses of this research are as follows:

- Matching between the firm capabilities and its external environment is a critical factor for organizational success.
- Success level is relative to the competitor simultaneous actions and reactions while the effect differs from market to another according to the occurring scenarios.
- The competitive advantage occurs when it is unique to the company and matches with the market variables for limited time.
- A trade-off between flexibility and cost govern the relationship between the manufacturing priorities and controls the strategic direction of any industrial enterprise.
- Customer preferences evolve according to the intensity of the competition.
- Competition affects firms' profitability and market share.
- The relative importance of the dynamic capabilities value for organization at any point of time is proportional to the competition performance.
- This weight factor represent the relative importance of the capability value is decided based on the interaction between the organization and its rivals within their external and internal environment at any point of time.

- Any change in the environment conditions may change the weights of the activated capability and accordingly will change the organization market position and the relative importance of its developed capability.

1.5. Novelty of Research

1.5.1. Novelty of Scope and Methodology

- Developing a strategic framework that guide the enterprise strategic decision making process.
- Developing new macro measures for enterprise manufacturing strategy by integrating the traditional volume flexibility into a nonlinear dynamic model.
- Linking enterprise strategic decision making with volume flexibility into a nonlinear system dynamic model.
- Quantifying the dynamic capability of enterprise organization considering the disequilibrium market dynamics in a comparative game theoretic analysis by considering the simultaneous strategic decisions of competition.

1.5.2. Novelty of Analytical Approach

The approach is based on relating the manufacturing objectives and their effect on the total enterprise performance to profitability, product availability and capacity utilization using a system dynamic model that capture the strategic intent of the competing firms. This is an attempt to better manage the strategic decisions faced by managers in different market scenarios.

1.5.3. Novelty of Model Parameters

- Introducing a comparative reference price to the latest available price in the market to support the price competitiveness as effective parameter that changes the market dynamics and hence affect the relative importance of the firms developed capability.
- Introducing the firm's outsourcing performance through outsourcing delay in reference to the industry normal delivery delay standards and the production backlog to study the effectiveness of developing speed to market strategy.

- Coupling two product life cycles to examine research and development effect by introducing new products on firm's market share and dynamics.
- Linking the learning effect to the enterprise volume flexibility to explore the advantage gained by changing the unit variable and fixed cost of the product and hence studying the effectiveness of adopting intense labour training strategy to advance the firms market position.
- Relating the volume flexibility relationship with the enterprise market share and the firm's strategic intent to analyze the effective strategy in different market speeds.

1.6. Research Approach

Using a system dynamics methodology, the study constructs a formal model for dynamic competitive environment that test the hypothesis of the firm's dynamic capabilities derived from the developed evolutionary perspective of a complex industrial landscape. This is done in a way to verify any findings of which resources, individually or in combination, account for a firm's success and what strategies that firm can use to occupy the favourable market position relative to its competition.

1.7. Dissertation Structure

Chapter 2 first presents a critical literature review for the manufacturing strategy then for the manufacturing capability by introducing its components, relationships and internal dynamics. To explain the concepts of competitive advantage and what makes it sustainable and dynamic with the external challenging market environment; specific focus is given to the dynamic capability theory, its life cycle, added values and cost. The dilemma of organizational rigidity is tackled by linking the concepts of manufacturing trade-offs, strategic agility, organizational inertia with the degree of fit with external environment and the industry life cycle and customer preferences evolution. To represent the competitive environment, the manufacturing landscape concept is reviewed and presented.

Chapter 3 presents a new representation for a complex industrial landscape, how it is formed, how it can evolve over time and what are the factors that affect its transformation. First, a comparison between the complex view of economics and the traditional one is presented to highlight the risk and limitation of the assumptions introduced in the Neo-classical models. The factors that affect the industrial landscape such as agents, business solutions, and profitability are introduced and discussed in details to draw a rigid boundary for the theoretical representation of the proposed landscape. Finally, considering all these factors, an evolutionary mechanism for the landscape is introduced.

Chapter 4 presents the used modeling tool to explain why specifically system dynamics as a concept fits with the scope of this research. After explaining the conceptual model structure, a detailed discussion for the model variables and sub-models are introduced one by one. Starting from the product attractiveness, order demand, capacity planning and control, new product development, following to the volume flexibility sub-model, a detailed set of differential equations are presented. The base case simulation results are first presented before introducing the first case study with 3 scenarios that highlight the quantitative approach of the enterprise strategic flexibility. This allows for a comparative analysis between two competing firms to explore the effectiveness of using different set of strategies and also to evaluate the relative importance of the organization capability in facing its competition. To show the difference in strategic performance due to different market speeds and industry setup, another case study that represents a fast market is represented to examine the same set of strategies used in the first case. A conclusion from both cases is driven to prove the thesis hypothesis.

Chapter 5 focuses on validating the presented model and results. A sensitivity analysis is first conducted before introducing another two case studies. These two case studies represent the extreme case analysis to show the importance and significance of the new developed macro measure; namely volume flexibility. After each case a comparative analysis is conducted to conclude the results.

Chapter 6 presents the conclusion, the main findings and finally a recommendation for future work.

CHAPTER II

DYNAMIC COMPETITIVE CAPABILITY

2.1. Manufacturing Strategy Literature Survey

Classification of research direction on the manufacturing strategy can be classified in six different categories. Manufacturing capabilities includes literature on competitive priorities, i.e. cost, quality, delivery, flexibility, etc. Strategic choices include literature on specific structural and infrastructural criteria like human resource, technology, information technology, organization and management and environmental aspects. Best practices include literature on advanced manufacturing technologies and better management practices like JIT, TQM, OPT, etc. Trans-national comparison includes literature on cross-country wide studies comparing various nations' manufacturing strategy practices. Performance measurement includes research on performance measurement system design, development and assessment methodologies (such as survey, scale development, empirical research methods, etc.). And literature survey includes articles which reviewed the manufacturing strategy literature. A detailed analysis for literature survey done on manufacturing strategy considering all the above categories is shown in Table 1.

Table 1 Manufacturing Strategy literature Survey

Method	Best Practices	Literature Survey	Manuf. Capab.	Performance Measurement	Process	Strategic choices	Transn. Comp.	Grand Total
Conceptual			3					3
Descriptive	3		20	6	2	5		36
Empirical	4	4	10	4	5	1		28
Exploratory longitudinal				1	1	2		4
Exploratory cross-sectional	10		16	3	2	6	1	38
Grand Total	**17**	**4**	**49**	**14**	**10**	**14**	**1**	**109**

More detailed description for the direction and the contribution to research on the manufacturing strategy in both the manufacturing capability and strategic choices categories is presented in appendix D. A more comprehensive presentation can be found in (Dangayach and Deshmukh 2001).

The methodologies used in research are classified in five categories as follows:

- *Conceptual*: Used to present basic/fundamental concepts on manufacturing strategy.
- *Descriptive*: Explain manufacturing strategy content, processes or performance measurement issues.
- *Empirical*: Using data for study from existing database, review, case study, taxonomy or typology approaches.
- *Exploratory cross-sectional*: Survey where information is collected at one point in time.
- *Exploratory longitudinal*: Survey where data collection is done at two or more points over time in the same organizations.

2.2. Manufacturing Capability

Skinner introduced manufacturing strategy as to exploit certain properties of the manufacturing function to achieve competitive advantages (Skinner 1969b). Since his work, scholars contributed in defining the manufacturing strategy under the umbrella he proposed. Manufacturing strategy was described as a consistent pattern of decision making in the manufacturing function linked to the business strategy (Hayes and Wheelwright 1984a). Also it was defined as a tool for effective use of manufacturing strengths as a competitive weapon for achievement of business and corporate goals (Swamidass and Newell 1987). The more accepted one and commonly used is "a pattern of decisions, both structural and infrastructural, which determine the capability of a manufacturing system and specify how it will operate, in order to meet a set of manufacturing objectives which are consistent with the overall business objectives" (Platts *et al.* 1998).

Manufacturing strategic objectives were identified as *Cost*: production and distribution of products at low cost; *Quality*: manufacture with high quality or performance standards; *Delivery dependability*: meet delivery schedule; *Delivery speed*: react quickly to customer orders to deliver fast or as promised; and *Flexibility*: react to changes in product, product mix, modification to design, fluctuations in material, and changes in sequence (Wright 1984).

Based on the operation strategy models, to develop manufacturing capabilities, the manager will have decisions in two categories: structural and infrastructural. Structural decisions are concerned with the capacity, technology, facilities, and sourcing. Infrastructural decisions are concerned with the workforce, quality, production planning and organization, as shown in Figure 1.

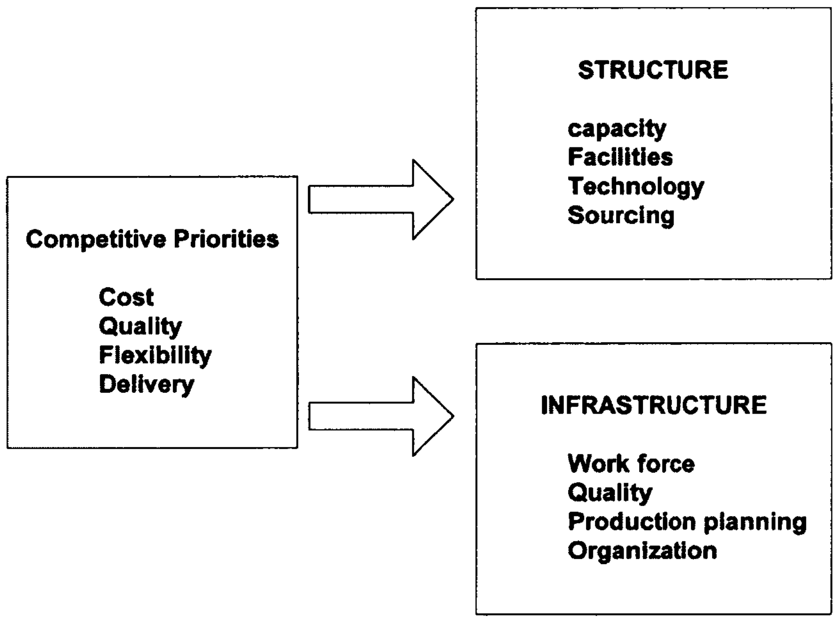


Figure 1 Operation strategy model

Selecting the firm's resources at the first place and then managing, accumulating and bundling them will develop certain capability that can be focused toward certain task(s). Managing and bundling the task specific capabilities will create functional capabilities which in turn will lead to cross functional capabilities if carefully managed. This hierarchies of capabilities was presented by (Eisenhardt and Martin 2003).

2.3. Manufacturing Capabilities Relationship and Dynamics

Scholars in the strategy field debated over the relationship between manufacturing competitive priorities. The debate involved three perspectives: the trade off, cumulative and integrative models. Some researchers called for plants to focus on a single manufacturing capability and devote their limited resources accordingly (Wright 1984), while others claim that advanced manufacturing technology enables concurrent improvements in quality, cost, flexibility, and delivery (Mapes *et al.* 1997). In spite of these two extreme perspectives, the integrative perspectives seek to settle differences between trade off and cumulative model. The "sand cone model" presented by (Ferdows and De Meyer 1990) advocating that plants should build capabilities sequentially, first seeking high quality, then dependable delivery, followed by speed and cost as show in Figure 2. Each successive capability becomes the primary focus once minimum levels of the preceding capabilities have been achieved.

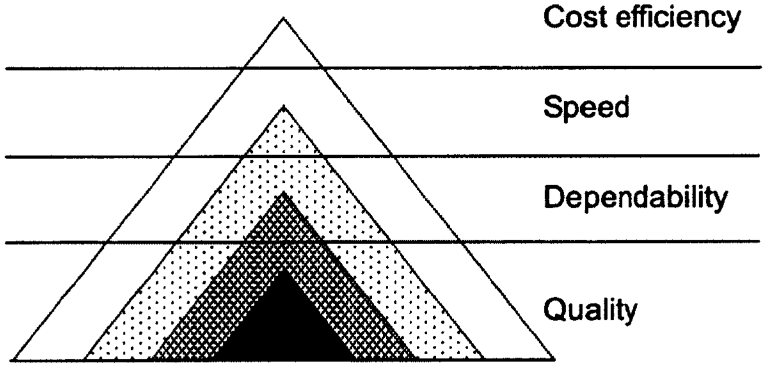


Figure 2 Sand cone model (Ferdows and De Meyer 1990)

Arguably, in their empirical study, (Boyer and Lewis 2002) addressed this debate by studying 100 plants. Their findings suggested that the trade-offs between quality, cost, flexibility, and delivery remains. As a result industrial organizations have to priorities their capabilities and select among them in a way that will lead to success. The specific attribute for success was not identified in this study.

Also cumulative manufacturing capabilities can be viewed as flow and stocks due to its natural of bath dependency and irreversibility. Assuming that there are supportive relationships and inhibiting relationships between capabilities, (Größler 2005) investigated the dynamics of accumulation processes of strategic capabilities in manufacturing, i.e. cost, quality, delivery and flexibility. The Y-form of strategic capabilities, shown in Figure 3, was derived from an empirical examination of capabilities within manufacturing plants. In that study, 465 manufacturing plants from 14 countries were investigated with the help of the IMSS questionnaire (International Manufacturing Strategy Survey). The proposed sequence of capabilities identified the lower levels 'quality' then 'delivery' as the base for an accumulation of capabilities. 'Flexibility' and 'Cost' were put on one level and it was assumed a trade-off relationship rather than a supportive relationship exists between the two.

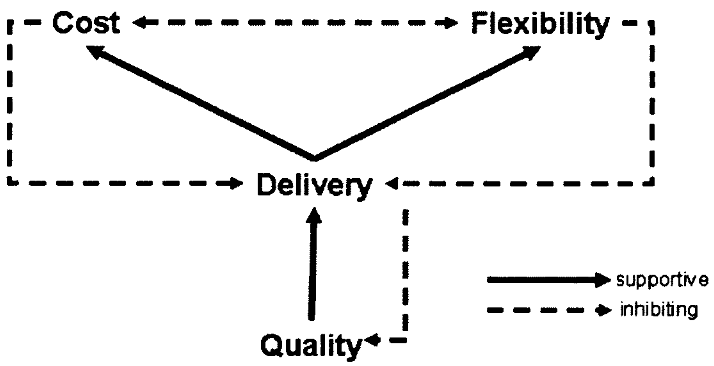


Figure 3 Conceptual model of strategic resource hierarchy (Größler 2005)

The analysis was conducted with the help of an exploratory system dynamics model, shown in Figure 4 , which represents a hierarchy of these accumulative capabilities.

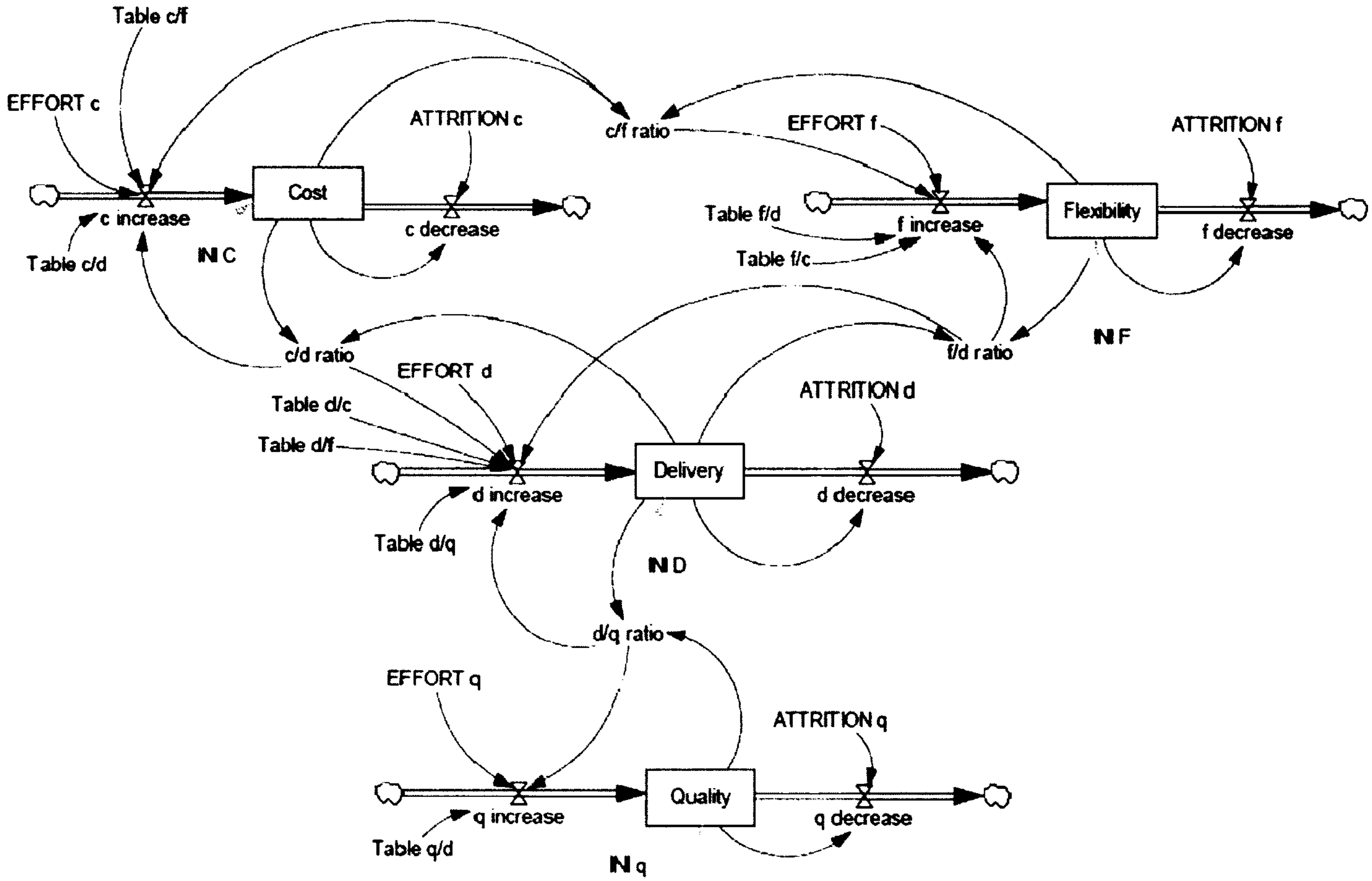


Figure 4 System dynamics model of strategic capability (Größler 2005)

The model reflected the mechanism of capability accumulation and trade-off. However, little did it add to the question of what exactly causes supportive relationships between capabilities and how they can be oppressed or linked to the enterprise external environment? Also the effect of competitor's strategies and its effect on the total industry performance and market dynamics were ignored in most of these studies.

The relationship between the choice of strategic resources that built a dynamic capability and the effect of these capabilities over the organization performance using a system dynamic perspective was the focus of many scholarly researches. (Heene and Sanchez 1997) identified that the strategic resources and capabilities of a firm build a system. The system components depend on each other and affect each other. These dependencies establish feedback loops, so that resources and capabilities influence themselves. Also the study identified that the systems of resources and capabilities are not stable over time. Capabilities develop and decay dynamically and their relationships change over time. Thus, the dynamics of each resource and each capability as well as the dynamic and complex interaction between them can be influenced and must be managed.

To include the external environment, (Größler 2007) introduced another dynamic view on strategic resources and capabilities applied to an example from the manufacturing strategy literature. The study argued that industrial company's performance is substantially determined by the strategic resources it possesses and by the capabilities that can be derived from them. The application of these internal resources and capabilities to an external context of markets and competition is a critical factor contributing to the success of a company. The illustrated approach was built based on Warren's strategy dynamics (Warren 2002) using a system dynamics methodology as shown in Figure 5. The finding concluded that the resources and capabilities can be interpreted as stocks in dynamic simulation models following ideas from system dynamics.

Selecting certain resources to develop organizational capabilities using flexible, agile, or lean production systems are just a part of the overall organizational success that will help in achieving better performance. Though, achieving better performance can be deceiving by itself because the local optima may be considered as the best individual performance in reference to certain set of targets and performance indicators but not to the whole system performance. In short the success measure is relative to the degree of fit with the external environment as will be discussed and elaborated later in more detail.

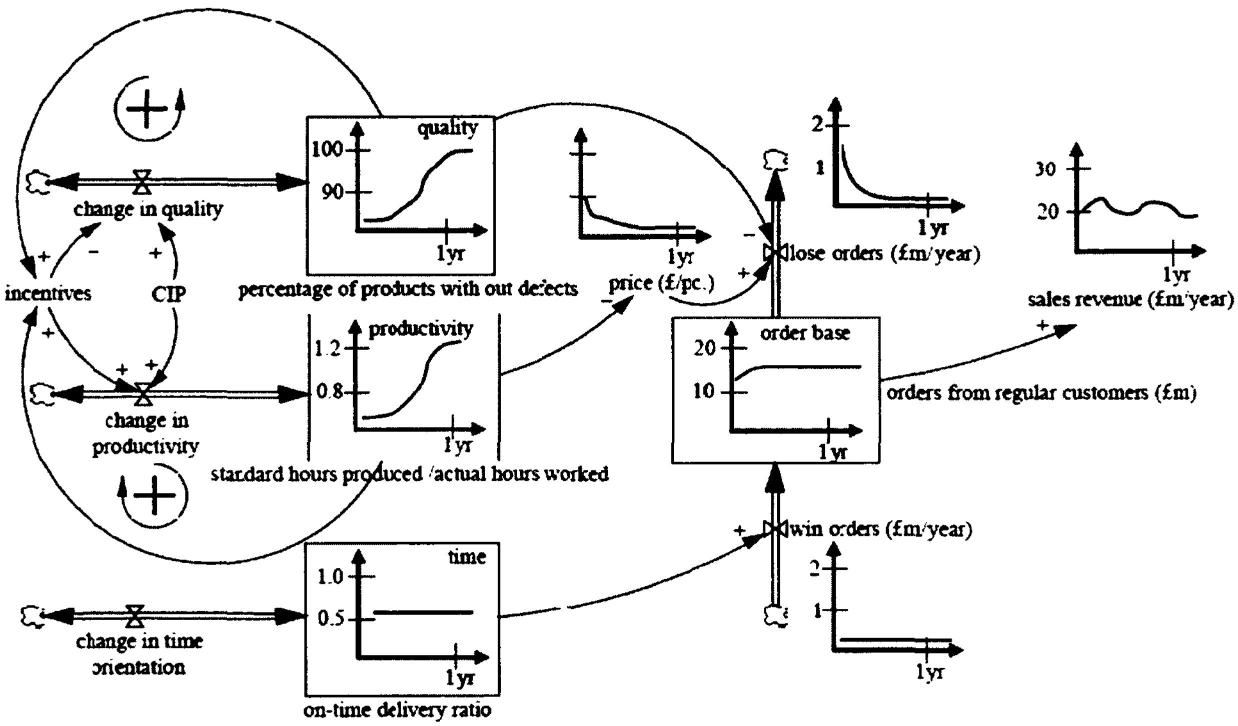


Figure 5 Dynamic resource / capability system (Größler 2007)

2.4. Sustainable Competitive Advantage

In volatile markets, it is impossible to predict which competencies or strategies will be successful and for how long. The selection process for the firm's strategies based on the evaluation of its current available resources and capabilities can be considered as reactive management, yet it can be very effective on the short term run. While deciding the strategic choices that the firm wants to have in its future choices, developing the resources and capabilities that help it to do so is proactive management. In both cases managers will have choices to make regarding the resources to acquire, capabilities to develop and strategies to select. The multi dimensional decision causes a level of complexity. Unfortunately, firms will also be limited by their available capabilities in the selection process and constrained by the fact that the relative value of capabilities and resources varies over time and cost money and effort to develop.

The typical strategic planning process for indusial enterprise starts by defining the firm's business strategy that it will possess. Firms have to generate a portfolio of capabilities that will determine the contribution of the manufacturing function to business performance. Following different market scenarios, aggressive strategy may cause unutilized capacity due to the lags in reducing capacity while conservative strategy with lags in capacity expansion and unfulfilled backlog may lose portion of the market share to its competitor allowing a chance of locking the market to their competitor's favour (Arthur 1989). But finally, industrial enterprise should seek to develop competitive advantage and mange its market position to compete in dynamic markets with respect to their competition. These increases the level of complexity mangers faces in their long term decisions.

One of the most familiar frameworks for strategic analysis is known as porter's five forces framework (Porter 1998). The five competitive forces that directly affect the organization market positions are the threat of new entrants, threat of substitute products or services, bargaining power of suppliers, bargaining power of buyers, and rivalry as shown in Figure 6. Other factors such as political, economic, social and technological affect the set of forces that shape any market structure and organization position as well. Each organization has its own capabilities, strengths and weaknesses through each stage of its life cycle.

The interaction between organizations at their different life cycle stages creates forces that affect all participants in the industry. For instance, in volatile markets, new entrants with their pioneering skills, new business models and almost only the necessary amount of investment, may treat the big existing bureaucratic successful organizations with their mass production and distribution capabilities and shake their market position just by adding a new value to the existing chain of values or by introducing new business model. By analyzing the competitive forces, Porter claimed that firms can gain a complete picture of what's influencing profitability in the industry and so spot ways to work around constraints on profitability or even reshape the forces in its favour. By understanding these forces, firm may be able to manage its market position.

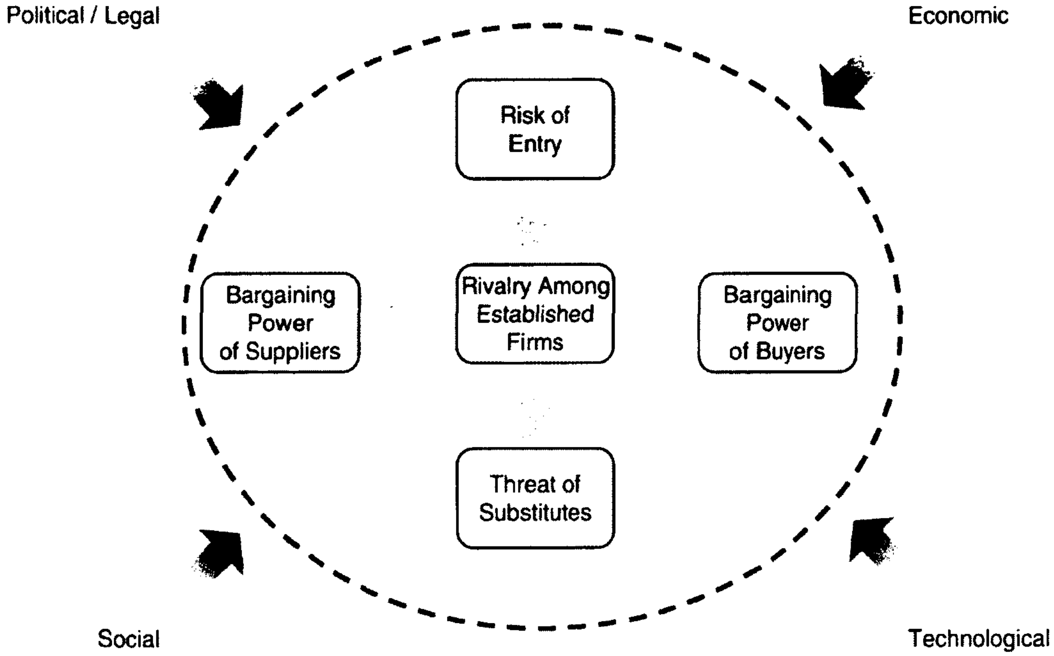


Figure 6 the five forces that shape industry competition (Porter 1998)

Due to the fact that firms don't act alone by themselves in markets, their strategic behaviour affects the final outcome. The Strategic Conflict Approach (Shapiro 1989), using tools of game theory, view the firm's competitive outcomes as a function of the effectiveness with which firms control and manage their rivals through strategic investments, pricing strategies, signalling, and control of information. This approach was criticized because it failed to capture the simultaneous choices over many variables that characterize competition in most industries as it incorporated only a small number of "fixed" variables in order to remain analytically tractable which in reality would be changing over the relevant time horizons (Gary *et al.* 2008). And finally, the rationality requirements and common knowledge assumptions imposed on the agents of the game are usually optimistic (Porter and Van der Linde 1995), which is not always the case as firms may select their strategies according to their ability of risk taking levels and the current and expected available market space. Also it is important to mention that this approach did not include the firm's internal resources and its effect on performance.

Another approach known as the Resource-Based View (RBV) argues that resources that are simultaneously valuable, rare, imperfectly imitable and imperfectly substitutable are a source of competitive advantage (Barney 1991). The underlying assumption of the RBV of the firm is that resources are heterogeneous across organizations and that this heterogeneity can sustain over time (Peteraf 1993). The RBV was considered as static approach and did not specifically address how future valuable resources could be created or how the current stock of valuable resources can be refreshed in changing environments (Barney 2001). The dynamic capability perspective proposed a solution for this static view of the RBV.

The following sections will elaborate on the source of competitive advantages by focusing on the available avenues for creating dynamic sustainable competitive advantage and highlighting the link between the competitive strategic behaviour of the firm and how it affects customer preferences and industry life cycle.

2.5. Dynamic Sustainable Capabilities

For organization to succeed and survive in a dynamic competitive landscape, they should build a reliable architecture that allows them developing sustainable competitive advantage. The original definition for the dynamic capability is 'the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments' (Teece *et al.* 1997). In return, this will help the organization to maintain their favourable position in the market landscape and allow them to evolve with the changeable environment by adapting with its conditions. And finally, the competitive advantage of firms lies with its managerial and organizational processes, shaped by its (specific) asset position, and is limited by the available paths only.

As defined by (Teece *et al.* 1997), the term 'dynamic' refers to the capacity to renew and change in the resource base so as to achieve correspondence with the changing business environment; certain innovative responses are required when time-to-market and timing are critical, the rate of technological change is rapid, and the nature of future competition and markets difficult to determine. The term 'capabilities' emphasizes the key role of strategic management in appropriately adapting, integrating, and reconfiguring internal and external organizational skills, resources, and functional competences to match the requirements of a changing environment. In conclusion, the competitive advantage of firms lies with its managerial and organizational processes, shaped by its (specific) asset position, and the paths available to it (time dependant). The factors that will help in determining a firm's distinctive competence and dynamic capabilities are organized in three categories: processes, positions, and paths. Each will be discussed as follow:

2.5.1. Paths

Paths were referred to the strategic alternatives available to the firm, and the presence or absence of increasing returns and attendant path dependencies. Where a firm can go is a function of its current position and the paths ahead. Its current position is often shaped by the path it has traveled. Thus a firm's previous investments and its 'history' constrain its future behaviour. This highlights the importance of the initial conditions for the enterprise.

2.5.2. Processes

A managerial and organizational process refers to the way things are done in the firm, or what might be referred to as its routines, or patterns of current practice and learning. Organizational processes have three roles: coordination/integration (a static concept); learning (a dynamic concept); and reconfiguration (a transformational concept). Examples of each of those roles are described in Figure 7.

2.5.3. Position

Position refers to the firm's current specific endowments of technology, intellectual property, complementary assets, customer base, and external relations with suppliers and competitors. Specific assets are the difficult-to-trade knowledge assets and assets complementary to them, as well as its reputational and relational assets. Such assets determine the firm's competitive advantage, examples shown in Figure 8.

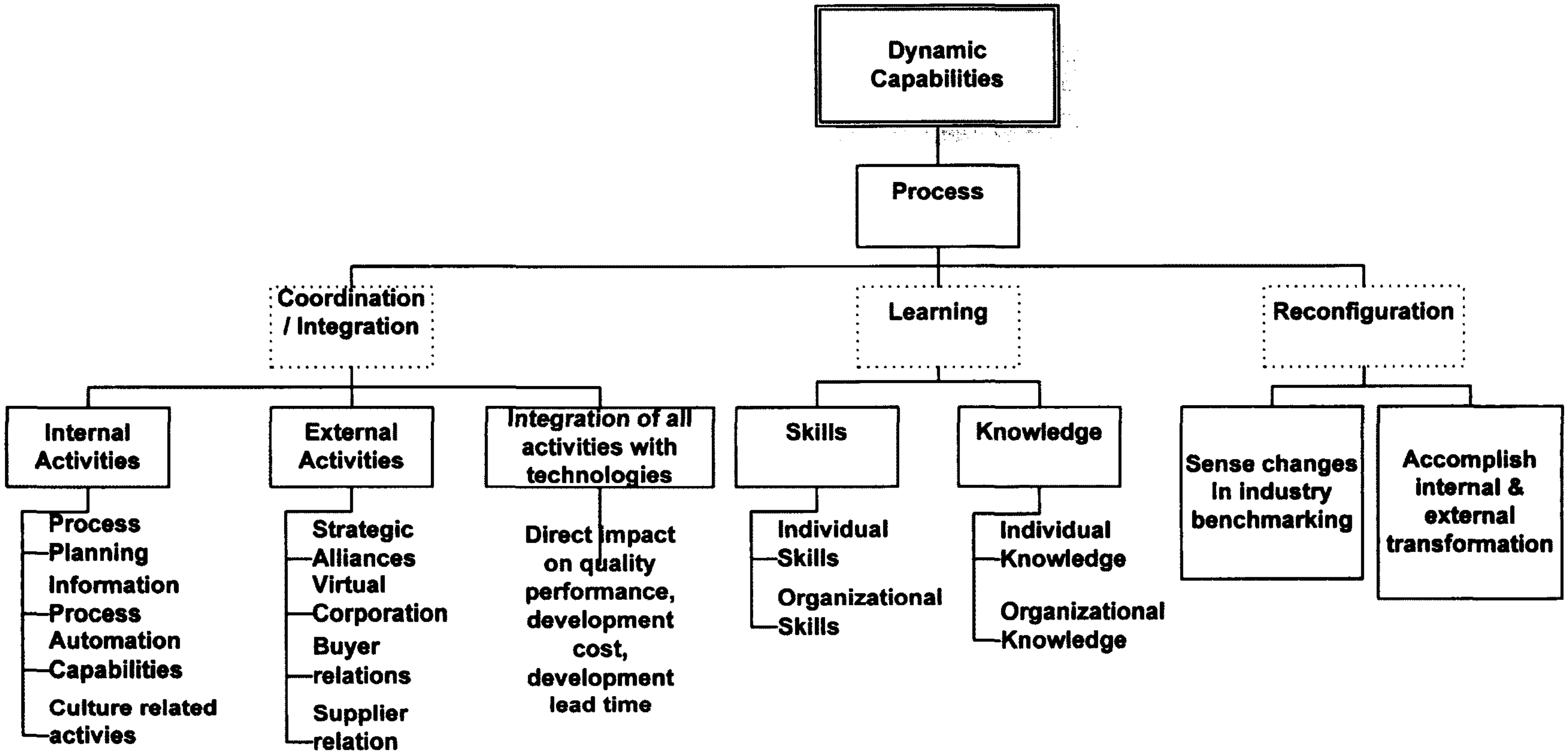


Figure 7 Examples of the roles of process in the dynamic capability

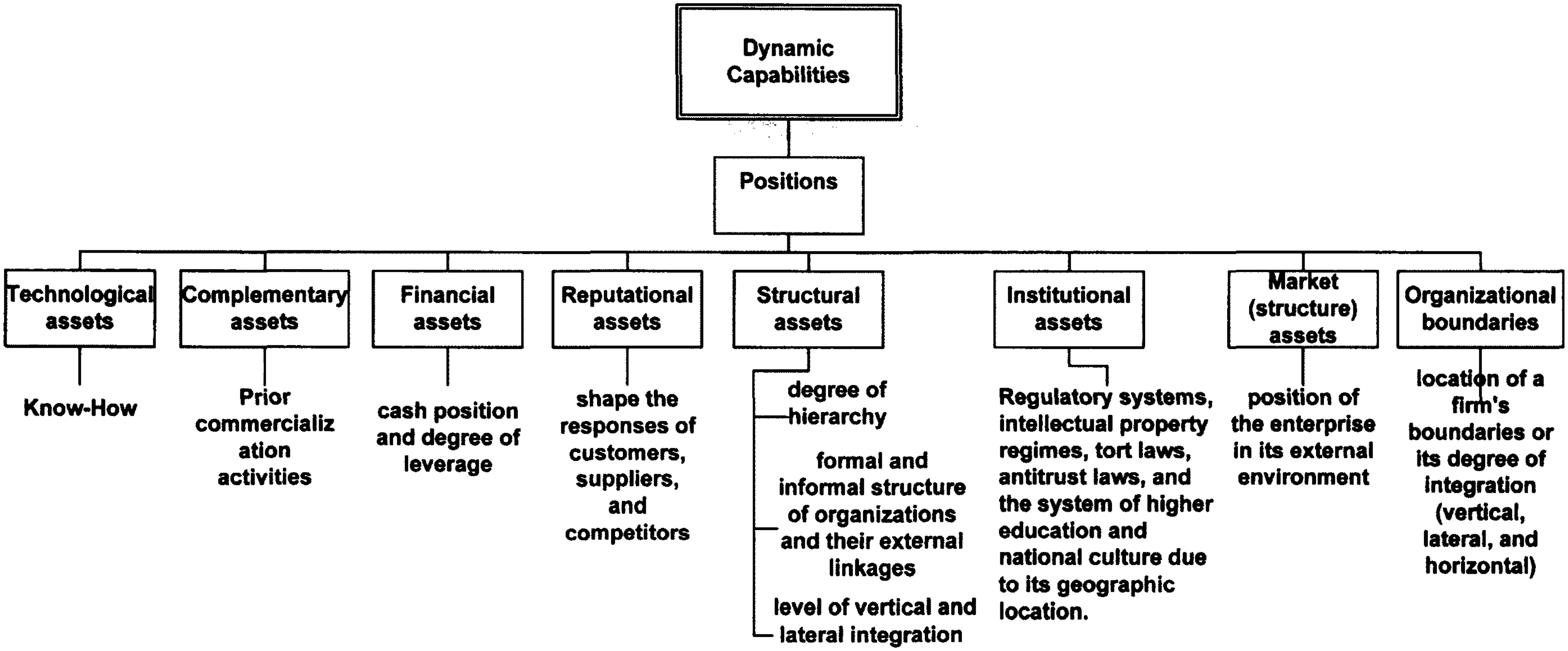


Figure 8 Examples of positions in the dynamic capability

(Bowman and Ambrosini 2003) building on (Teece *et al.* 1997) explained that dynamic capabilities comprise four main processes: reconfiguration, leveraging, learning and creative integration.

- *Reconfiguration* refers to the transformation and recombination of assets and resources.
- *Leveraging* involves replicating a process or system that is operating in one business unit into another, or extending a resource by deploying it into a new domain, for instance by applying an existing brand to a new set of products.
- *Learning* allows tasks to be performed more effectively and efficiently as an outcome of experimentation, reflecting on failure and success.
- Finally, *creative integration* relates to the ability of the firm to integrate its assets and resources, resulting in a new resource configuration.

2.6. Dynamic Capability Life Cycle (CLC)

(Helfat *et al.* 2007) introduced the concept of the organization capability lifecycle (CLC), which articulates general patterns and paths in the evolution of organizational capabilities over time. The capability lifecycle identifies three initial stages of a capability lifecycle: founding, development, and maturity. These 3 stages followed by possible branching into six additional stages: retirement (death), retrenchment, renewal, replication, redeployment, and recombination because there is no guarantee for future returns. These six stages may follow one another in a variety of possible patterns over time. Some of these branching stages also may take place simultaneously. In each branch of the capability lifecycle, historical background in the form of capability evolution prior to branching influences the succeeding evolution of the capability. The study concluded that these branches, the six Rs of capability transformation, reflect the reality that the lifecycles of capabilities may extend beyond that of the firms and industries in which they originated, and beyond the products to which they originally applied. As a result, the capability life cycle provides an explanation for the emergence and sustained heterogeneity of capabilities, but at what cost?

2.7. Dynamic Capabilities Value and Cost

(Lavie 2006) and (Pablo *et al.* 2007) studied the cost of dynamic capabilities. They concluded that dynamic capabilities involve substantial cognitive, managerial and operational costs and that deploying dynamic capabilities requires high levels of time and energy from committed managers. As a result, the implementation of certain capability that will help the organization to achieve the favourable market position is costly and organizations can't implement all the capabilities together because of the cost factor and also because some of these capabilities may contradict with each other as well. So the selection of which capability to be implemented is a very important decision. If managers misperceive the situation of the firm, they may trigger inappropriate dynamic capabilities relative to the external environment that do not enhance or maintain performance. As a result the firm will then experience both the costs of the dynamic capabilities as well as the negative consequences of their deployment (Zahra *et al.* 2006).

It can be concluded at this point that this view can be linked with the "trade off" concept introduced by strategy scholars (Porter 1998). At certain point, firms will have to irreversibly trade off some of their available options and choose between them. The end results will not be known until selection is done and processed in the market. Although the information technology revolution decreased the time delays and provided more information and in return enhanced the decision making process (Sterman 2000) and firms become capable of making educated assumption yet the time delay between choices and results constrains manager's learning ability to select effectively among different available options.

2.8. Manufacturing Strategy Trade-off

Supporting the trade-off view, (González-Benito and Suárez-González 2009) studied the role played by manufacturing strategic objectives and capabilities and its relation with business performance in empirical analysis for 148 Spanish manufacturer. The analyses indicated that cost leadership must be associated with manufacturing strategy and capabilities focused on cost reduction to be effective. In contrast, manufacturing strategy and capabilities focused on flexibility are necessary for an effective business strategy based on differentiation as show in Figure 9 .

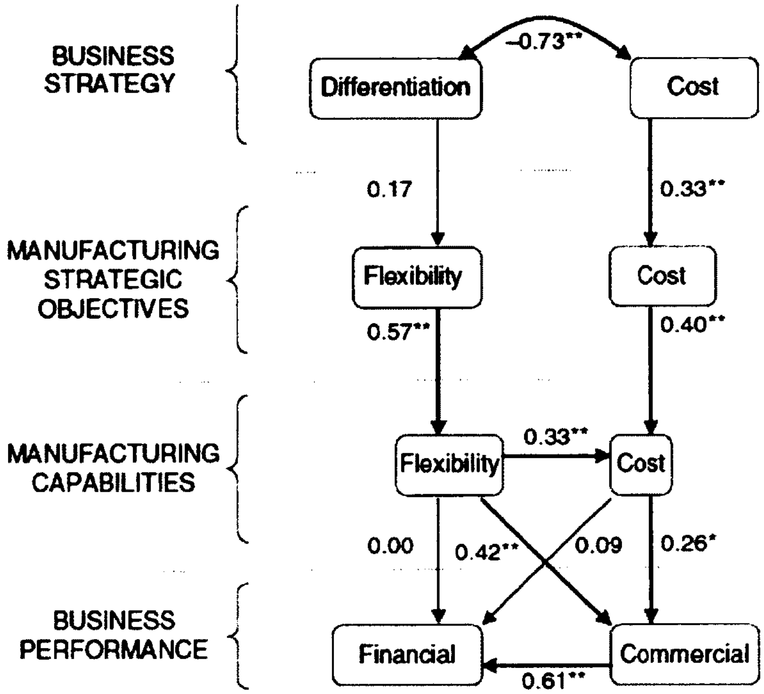


Figure 9 Alignment between manufacturing function and business strategy (González-Benito and Suárez-González 2009)

Following the trade-off concept, (Hallgren and Olhager 2009) investigated the internal and external factors that drive the choice of lean and agile operations capabilities and their impact on operational performance. The major differences in performance outcomes was related also to cost and flexibility, such that lean manufacturing has a significant impact on cost performance, and that agile manufacturing has a stronger relationship with volume as well as product mix flexibility. Both studies confirm that the firm still have to select certain capabilities and focus on it to achieve either cost or flexibility leadership as show in Figure 10.

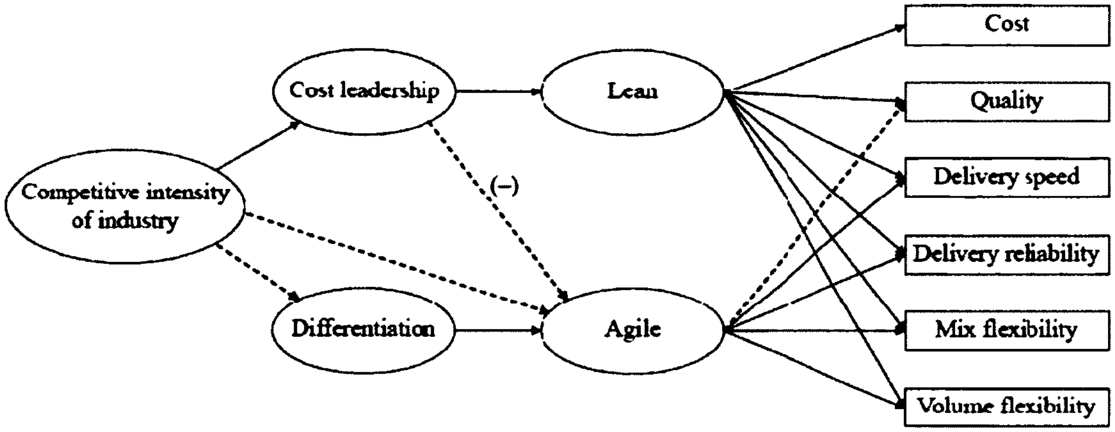


Figure 10 Lean or Agile as strategic choices (Hallgren and Olhager 2009)

2.9. Dynamic Capabilities as a source for Strategic Agility

The trade off in selection in the structural and infrastructural decisions starts from the beginning of the business cycle and evolve to expand as much as possible according to the available market space missed by competition. As the competition advances in the market, the technological complexity increases as well due to the flow of forced investments that seeks competitive advantage. So, the industry strategic portfolio, which represents the competition interaction between firms, will affect the overall market growth dynamics. And the capability of instantaneous capacity adjustment and perfect forecasting for future demands and industry capacity become the major performance variables that affect the market winner (Porter 1985). In short, it can be said that successful dynamic capabilities are those who lead to organization strategic agility.

(Roth 1993) defined strategic agility as "the ability to turn on a dime, providing the right product at the right price anywhere by leveraging value-chain-wide resources to generate economies of knowledge". (Ojha 2008) used the theoretical perspectives of dynamic capability, strength of weak ties and knowledge-based view of competitive advantage to explicate how a firm can set up strategies to build the required competencies to gain 'strategic agility capability' and its impact on the operational and financial performance under various levels of environmental turbulence.

The logic of the 'strategic agility capability' framework is that operations strategy which is a combination of structural (development of weak ties) and infra-structural (identifying new opportunities and, organizing effectively and efficiently) choices a firm makes to establish co-alignment with the market requirements results in the development of competencies that are combined to create capabilities desired by the customer. These strategies lead to the development of competencies, which in turn create the strategic agility capability. The findings can be summed in three main points:

- *First*, the ability for organizations to sense changes in the market place is a critical determinant of strategic agility.
- *Second*, strategic agility does not have any direct impact on financial performance except the fact that the strategically agile organizations have the capability to initiate changes to their manufacturing activities earlier than those who do not, and, thus gain first mover advantages. One can argue with this finding as the first mover advantage has a direct impact on the organization market share, market position and as a result can affect the enterprise financial performance.
- *Finally*, strategic agility is useful in moderate levels of environmental turbulence but not when turbulence is low or extremely high.

As stated in the study: "on the one hand when turbulence is low, changes are minimal and thus investments in achieving strategic agility do not pay off and cause financial loss. On the other hand, when change is rapid, investments made in advance modifying operations competitive capabilities may not have the necessary time to payoff and break even thus creating financial losses". This highlights the importance of the external environment.

2.10. The Degree of Fit with External Environment

A dynamic capability that does not result in the creation of resources that allow the firm to maintain or enhance its sustainable competitive advantage would not be valuable. (Helfat *et al.* 2007) argued that 'dynamic capabilities do not necessarily lead to competitive advantage'. The study explained that, while the dynamic capabilities may change the resource base, this renewal may not be necessarily valuable i.e. the new set may either only give competitive advantage or it may be irrelevant to the market at certain time. Thus the effect of dynamic capabilities on advantage and performance may be negative. This in turns gives four different outcomes that may result from the deployment of dynamic capabilities discussed as follows:

- *First*, organizational capability may lead to sustainable competitive advantage if the resulting resource base is not imitated for a long time.
- *Second*, they may lead to temporary advantage. (Rindova and Kotha 2001) argued that in 'hypercompetitive environments, competitive advantage is transient rather than sustainable'; competitive advantage can only be enjoyed for a short period of time.
- *Third*, they may only give competitive parity if their effect on the resource base simply allows the firm to operate in the industry rather than to outperform rival firms, i.e. catching up with the benchmark.
- *OR Finally*, the deployment of dynamic capabilities may lead to failure if the resulting resource stock is irrelevant to the market.

Therefore, indusial enterprises will have to adapt their manufacturing capabilities to outperform the evolving industry benchmark to keep their sustainable competitive position within the current market standards. Before explaining how competition affects the product life cycle and hence the industry life cycle and therefore the customer performances, the next section will zoom on the negative side of the dynamic capability change which is known as organizational inertia.

2.11. Organization Inertia

(Kauffman 1993) studied the complexity catastrophe as he called it. In his study, one of the biggest problems for big organizations, in their success stage, with their well established communication channels between departments, partners and alliances is the slow response to any external or internal changes. This phenomenon occurs because as the network grows, and the number of interdependencies grows, the probability that a positive change in one part of the network will lead to cascade resulting in a negative change somewhere else grows exponentially with the number of nods. This in turns means that densely connected networks become less adaptable as they grow.

In short, "Network growth creates interdependences, interdependencies create conflicting constraints, and conflicting constraints creates slow decision making and ultimately, bureaucratic grid lock" (Beinhocker 2006). The two opposing forces at work in organizations: the informational economy of scale from node growth, and the diseconomies of scale from build-up of conflicting constraints, may explain why big is both beautiful and bad. As organization grows, their degrees of possibility increase exponentially while its degrees of freedom collapse exponentially.

The theoretical and practical importance of developing and applying dynamic capabilities to sustain a firm's competitive advantage in complex and volatile external environments has catapulted the forefront of the research agendas of many scholars (Zahra *et al.* 2006). So, the dynamic capability approach focuses on the firm's ability to renew its resources in line with changes in its environment. The turbulent and changing nature of the environment suggests that resources cannot remain static and still be valuable. They must be continually evolving and developing, otherwise firms may only be able to be competitive in the short term. To have a persistent competitive advantage, firms must continue to invest in and upgrade their resources to create new strategic growth alternatives that match with the market demand, customer evolved preferences and exceed their industry benchmark. They must possess some dynamic capabilities. These capabilities are organizational processes that alter the resource stock by creating, integrating, recombining and releasing resources (Teece *et al.* 1997, Eisenhardt and Martin 2003). (Larsen and Lomi 2002) studied the effect of organization inertia during the period of capabilities adjustment and its effect on performance when change attempts are required. Using a system dynamic modeling techniques, the study represented the relationship between organizational capabilities, inertia, performance and change attempts as shown in Figure 11.

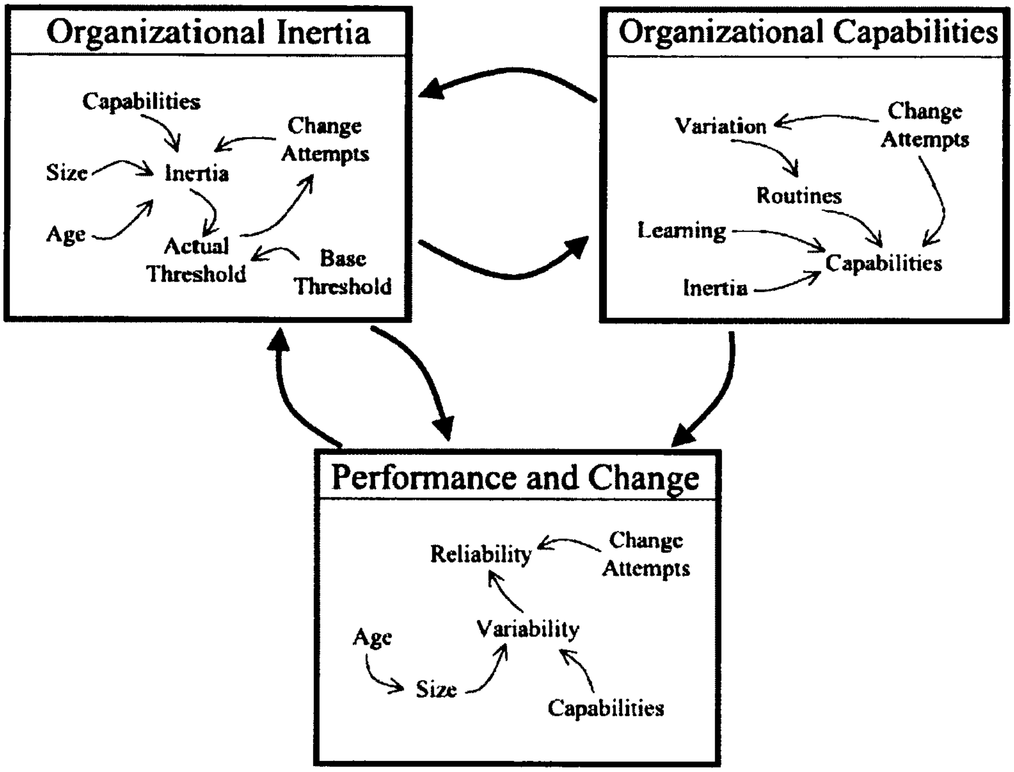


Figure 11 Organizational inertia and performance (Larsen and Lomi 2002)

The study concluded that on the one hand, as organizations grow old and large, they accumulate competencies, resources and knowledge that can be deployed to sustain and improve their competitive advantage. On the other hand, as organizations grow old and large, they become progressively more vulnerable to processes of self-reproduction that dissipate resources and decrease their ability to respond sufficiently to the challenges of innovation and change introduced by new rivals.

2.12. Industry Life Cycle and Customer Preferences Rate of Change

One of the major forces that cause organizational change is the industry life cycle. The product life cycle view (Klepper and Simons 1997) represented the industry evolution in cycles. Within each cycle there are stages where firms enter by product, business model or technology innovation to help in constructing the "emerging stage". This stage is characterized by low market volume, high uncertainty, primitive product design, and unspecialized machinery to manufacture the product. Following this stage, firms compete by different means over market share and profitability to explore the market potential and setup the industry benchmarking in the "growth stage". This stage is characterized by high growth, stable product design, and production process becomes more advanced as specialized machinery substitute labours seeking higher productivity standards. In the "mature stage" entry slows and industry shakeout occurs causing all non-successful, non-efficient firms to exit. As market growth slowdown, entry declines further due to higher barriers, market shares stabilize, innovations become less significant, and management, marketing, and manufacturing techniques become more developed. And finally during the last stage, firms exit if they didn't adapt with the next cycle of innovation derived by customer preferences needs that evolved to higher levels during this cycle.

Product strategies become driven by forecasting changes in technologies and market preferences to start new industry life cycle. The product creation processes became driven by marketing researchers who control the customer preferences for new products and educate them to realize its value. The economic power has been handed over by the producer to the consumer, hence enjoying 'more quality, more for the money, more choice, more service' (Hammer and Champy 1993) and becoming more powerful and have the final decision on deciding their right "market priorities" whether it is cost, flexibility, delivery or quality. As a result, on the one hand, the market development speed become directly related to the individual firm's expected return on investment, the realized strategies it achieves in product development and the risk level it takes. All of these factors suggest the need for competitive market to generate the dynamic of growth or in other words the "continuous improvement". While on the other hand, the consumer's preferences shape the final setup for the landscape. The more hyper-competitive interaction between firms, the shorter and faster industry life cycles are.

With this evolving preferences and competition, manufacturing systems were evolving as well to fit with these circumstances. (ElMaraghy 2009) identified four stages for manufacturing systems evolution from mass production, lean manufacturing, flexible manufacturing, all the way to reconfigurable and changeable manufacturing systems to cope with these fast evolving industry cycles. Each one of them will fit with certain industry evolution speed. As manufacturing systems evolved through different paradigms from dedicated manufacturing all the way to changeable manufacturing, so did the capacity planning challenge in these systems. Examples of that evolution include not only considering the economy of scale but also the economy of scope in the capacity expansion/reduction decisions and reducing the reaction time to scale the capacity from years and months to weeks and even days (Deif and ElMaraghy 2009). Also the design of manufacturing systems based on competitive priorities by linking it decisions to business performance in terms of cost, quality, delivery and flexibility has been presented by (Miltenburg 2009). This evolutionary perspective explains the pressure of market competition on the technology development norms. The more competition and the more technology advancement are required.

After explaining the relationship between manufacturing capabilities and organizational performance, the following section will present the performance perspective for industrial enterprise from the landscape theory lens to explain the relative success measures between competing firms to achieve the highest peaks in global industrial landscape as a metaphor for the external environment representation.

2.13. Manufacturing Fitness and Landscape theory

The origin of the fitness landscape theory is attributed to (Wright 1932). The study proposed a metaphor in which a population of organisms would evolve by moving towards a higher fitness peak as a sign for their evolution and continuity "survival for the fittest". The fitness landscape contains ranges of mountains, local peaks and valleys. A fitness landscape with many local peaks surrounded by deep valleys is called rugged landscape as shown in Figure 12. Apart from the field of evolutionary biology, the concept of a fitness landscape was used in evolutionary optimization methods such as genetic algorithms or evolutionary strategies.

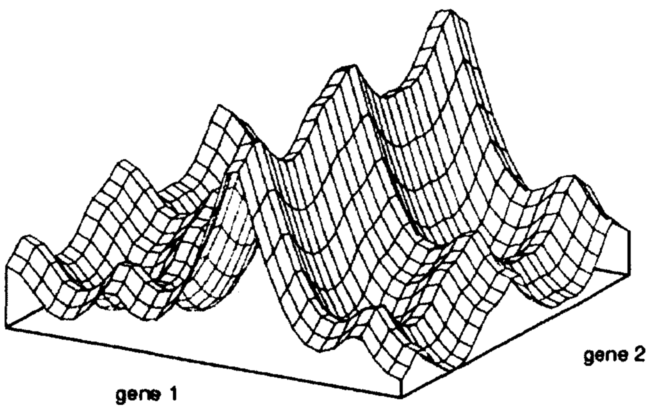


Figure 12 Rugged landscape (Wright 1932)

From a strategy context, many scholars proposed that the ultimate solution for any organization to be successful is by finding the global peak in the business landscape. As recommended and proposed from this stream of research, organizations should adapt their strategies and resources with the external environment (i.e. Landscape) and search (i.e. take adaptive walk) for the global peak of the landscape to achieve success (i.e. payoff).

From a manufacturing strategy context, (McCarthy 2004) used the fitness landscape theory as an approach to visually map the strategic options a manufacturing firm could pursue. The study examined how this theory relates to manufacturing competitiveness and strategy by proposing a definition and model of manufacturing fitness. In accordance with fitness landscape theory, a complex systems perspective was adopted to the manufacturing firms. It was argued that manufacturing firms are a complex adaptive system and that by developing and applying fitness landscape theory it is possible to create models to better understand and visualize how to search and select various combinations of capabilities that will help organizations to reach global optima.

As shown in Figure 13, each strategy has a fitness value assigned "randomly". The strategic change the firm may have is assumed to be a process of moving from one strategy to another in search of an improved fitness (i.e. taking adaptive walk) to reach the highest manufacturing fitness value. Manufacturing strategy was analyzed and coded as a string of elements (N) where each element is a capability. For any element i, there exist a number of possible states which can be coded using integers 0, 1, 2, 3, etc.

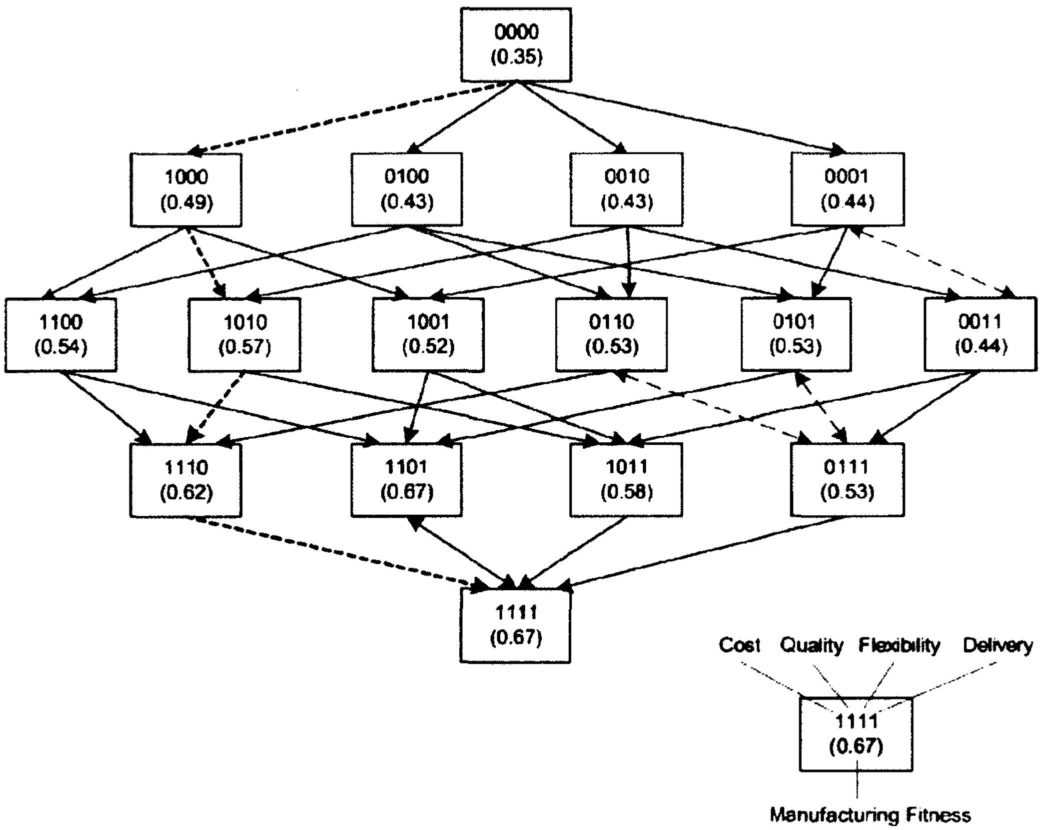


Figure 13 Manufacturing capabilities hypercube (McCarthy 2004)

The total number of states for a capability is described as A_i. Each system (strategy) S is described by the chosen states $S_1 S_2 \ldots.. S_n$ And is part of an N-dimensional landscape or design space (S). The K parameter in the NK model indicates the degree of connectivity between the system elements (capabilities). It suggests that the presence of one capability may have an influence on one or more of the other capabilities in a firms' manufacturing strategy. Similar to Kauffman's model, the fitness function $f\ (x)$, is the average of the fitness contributions, $f_i\ (x)$ from each element i, and is written as:

$$f(x) = \frac{1}{N} \sum_{i=1}^{N} f_i(x) \qquad (2.1)$$

(McCarthy 2004) concluded that by understanding the topology of a fitness landscape the manufacturing firms will know its current position on the landscape (Strategic analysis), decide where it should be (Strategic choice) and how they will get there (Implementation). Also it was claimed that the organization will take adaptive walk to move from strategy (A) to strategy (B) as shown in Figure 14. The route from (A) to (B) may be accompanied by a reduction in firm performance. The bad performance was related to the learning curve challenge and organizational disruption that normally associated with any change. This view aligned with porter's five competitive forces model (Porter 1985).

(McKelvey 1999) discussed some of the weaknesses of the NK model, particularly that the "fitness" of the system is defined as the average of the fitness of the components of the system; the assumption in Kauffman's model that every node within the network has the same number of inputs was also criticized. One can argue that taking adaptive walks in a static landscape depends on the industry type. To combine dynamic element (strategy change from A to B) on static background (the firm environment) will fit with industries that is described with little change over time. The static view may not be valid with high velocity environments (McCarthy *et al.* 2010). Strategy scholars refused the static view and are seeking to understand the dynamic processes that lead to performance differences (Porter and Van der Linde 1995, Ghemawat 2007). The idea of representing the competition on a landscape formed by local and global optima is very helpful to illustrate firm's performance difference among all players. The difference in the capabilities that the firm achieves through resource accumulation causes performance difference among rivals if it matched the market variables at any point of time.

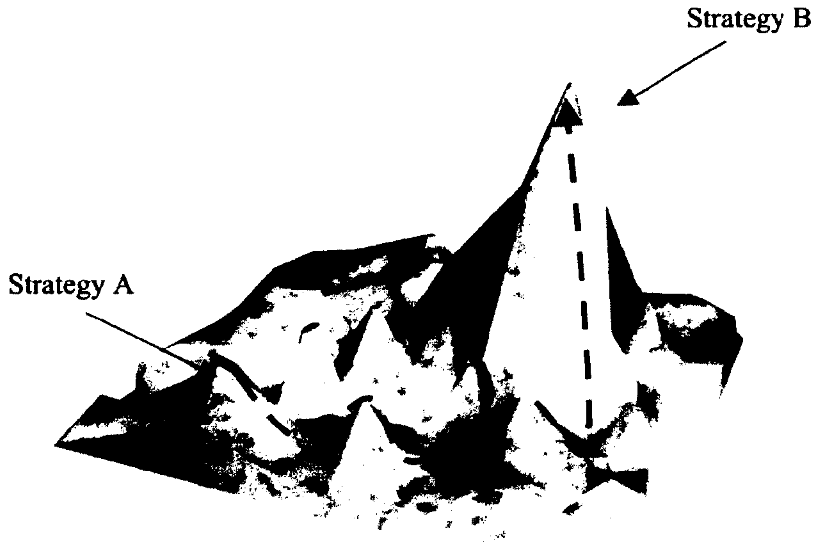


Figure 14 A route or adaptive walk from point A to B (McCarthy 2004)

So it can be said that, in the continuous competition for wealth creation and market share (objective functions for the organizational system, subsystems and driver for the firm's strategic behaviour), all firms will compete to develop sustainable competitive advantages to occupy the favourable market positions (Porter 1985) by creating valuable, rare, imperfectly imitable, and non substitutable resources idiosyncratic to the firm (Barney 1991) that cope with the external environment at any point of time (Teece *et al.* 1997) and create value with reference to competitors performance. This conclusion draws the theoretical foundation for this research.

CHAPTER III

COMPLEX DYNAMIC INDUSTRIAL LANDSCAPE

3.1. Complex Adaptive Economics

Complexity economics rejects many aspects of traditional economic theory. It claimed that rational expectation theory and the general equilibrium theory are mathematically elegant but they lack empirical validity. Traditional economics assumed that people are similar in their thinking process and that they make choices as if they were solving complicated deductive equations that enable them to make the best possible decisions. The new model of economic decision making suggests replacing the perfect rationality with more realistic assumptions of inductive decision making and bounded rationality for individuals, where individuals might not conclude the same output even if they have the same inputs (Lee *et al.* 1997a).

The complexity economics concept considered the economic systems as evolutionary systems, which tend to develop, toward levels of higher internal self organization. (Lee *et al.* 1997a, Arthur 2006) proposed major 9 concepts that distinguish complexity economics from traditional economics as shown in Table 2.

Table 2 Complexity and traditional economics view comparison

	Complexity Economics	**Traditional Economics**
Dynamic	Open, dynamic, non-linear systems, far from equilibrium	Closed, static, linear systems in equilibrium
Agents	Modeled individually; use inductive rules of thumb to make decisions; have incomplete information; are subject to errors and biases; learn to adapt over time; heterogeneous agents	Modeled collectively; use complex deductive calculations to make decisions; have complete information; make no errors and have no biases; have no need for learning or adaptation (are already perfect), mostly homogeneous agents

	Complexity Economics	Traditional Economics
Networks	Explicitly model bi-lateral interactions between individual agents; networks of relationships change over time	Assume agents only interact indirectly through market mechanisms (e.g. auctions)
Emergence	No distinction between micro/macro economics; macro patterns are emergent result of micro level behaviours and interactions.	Micro-and macroeconomics remain separate disciplines
Evolution	The evolutionary process of differentiation, selection and amplification provides the system with novelty and is responsible for its growth in order and complexity	No mechanism for endogenously creating novelty, or growth in order and complexity
Technology	Technology fluid, endogenous to the system	Technology as given or selected on economic basis
Preferences	Formulation of preferences becomes central; individuals not necessarily selfish	Preferences given; Individuals selfish
Origins	Based on Biology (structure, pattern, self-organized, life cycle)	Based on 19th-century physics (equilibrium, stability, deterministic dynamics)
Elements	Patterns and Possibilities	Price and Quantity

According to the Complexity Economics, the economy is an open, dynamic, nonlinear system, far from equilibrium. Nonlinear dynamic systems are sensitive to the initial conditions. Small differences in initial conditions will be magnified over time, and thus unless the beginning state of the system are well known, the end state is unpredictable (Beinhocker 2006). Also these systems are path dependant as well, i.e. history matters (Gould 1986). The sensitivity to the initial conditions and the path dependant makes both the starting point for any organization and its adaptability to the external environment critically important to the survival and to the wealth creation process in uncertain economic environment.

The complex systems view also considers some systems to have elements (i.e. people) with a decision-making capability. As a result, the dynamics of the real economy is not centralized and can be considered as the outcome of the nonlinear interaction of billions of people. (Stalk *et al.* 1992) argued that the capability is strategic only when it starts and ends with the customer. The total sum is economy that changes over time, prices jump up and down, individual earning's change, and firms enter and exit the market.

3.2. The Risk and limitation of Neo-classical Models

Research in strategy and economics has long identified increasing returns, or positive feedback effects, as a potential source of competitive advantage. For instance, scale economies, network effects, early Information, accumulation of complementary assets, learning effects or learning via research and development. It is likely for firms that accommodate aggressive strategy that they grow faster than their rivals. Such aggressive strategies are superior because they increase both industry demand and the aggressive firm's share of that demand, boosting cumulative volume, reducing future costs, and building the firm's positional advantage until it dominates the market.

To test these assumptions, assuming perfect forecasting for future demands and industry capacity adjustments are problematic, using system dynamics, (Sterman *et al.* 2007) modelled the dynamic behaviour of two competing firms over market share to study the conventional neoclassical models. The model tests the assumptions of perfect foresight and instantaneous capacity adjustment against the bounded rational models that assume some limitation in the forecasting abilities and the capacity adjustment capabilities of the firm. The risk of ignoring the role of disequilibrium dynamics proved a contradictory finding with the neo-classical assumption in their results. A detailed presentation for this model is shown in appendix A.

3.3. Dynamic Industrial Landscape

Understanding certain behaviour of phenomena or event needs a clear definition for the system components, its inter-related behaviour and dynamicity. Searching for the best possible performance is a very hard task in that the "best performance" has to be defined first; whether it is financial returns, efficiency, saving natural resources or individual happiness might not be achieved unless there is a clear understanding and visualization for complete big picture that guide all system components in a unidirectional way. Looking for the absolute performance of part of the system or the overall optimal system performance also might be misleading question that will lead to everlasting philosophical debate. To solve this debate, the system boundaries have to be defined first. In systems where agents interact together in an open dynamic complex web relationship, all events inside the defined boundaries could be the result of other interactive variables rooted outside the system boundaries as suggested by the system thinking perspective.

From the system point of view, it can be seen that the economic structure is interrelated and linked together in a complex way providing the continuous non-ending inertia to keep moving but never reaching the equilibrium state. The oscillation within the system is a phenomenon of such interaction. And since the oscillations are a common feature in complex adaptive systems, the ups and downs emerge from the structure of the system itself rather than from any outside source. For instance, the famous beer distribution game (Sterman 1995) for the supply chain management system demonstrated that the combination of human behaviour and dynamic structure can interact to produce oscillation in a simple economic system (Sterman 2000).

Since the landscape of any market is shaped by the interaction of all agents in that market, whether they are sellers or buyers, it can be argued that searching for a global peak by taking "adaptive walks" will only lead to mapping the landscape itself at any point of time (static view) and not shaping it. In a competitive dynamic landscape, during the moving time from point to another, peaks may change to valleys. Unless the firm has the adaptability capability with responsiveness synchronized with the industrial landscape clock speed to match its frequency, it may be trapped in one of those peaks that turned to be valley in reference to other peaks (i.e. local optima). In some cases, the only way to reach global peak is by shaping it. The factors that may lead the capability to success lies beyond the boundaries of the landscape, while the results itself, whether forming a local optima or global one, will be dependent on the landscape overall conditions and all agent's actions involved inside the defined system boundaries (i.e. customer preferences, competition intensity and value realization).

From a manufacturing perspective, a definition for the coordinates representing the boundaries of the landscape will be proposed as a starting point for understating the rooted reasons for shaping global peaks in such competitive business dynamic environments. It can be said that the landscape for a certain market at certain time is formed by people's evolved preferences in satisfying their evolved needs according to their changeable capabilities and the available products or services (i.e. Business Solutions) that helps them to do so at any point of time.

As shown in Figure 15, the coordinates for the landscape are *Agents*: indicates buyer's preferences and capabilities (i.e. market segments), *Business Solution*: indicates the available product or service and finally the *Payoff*: indicates Profitability. Each will be discussed separately.

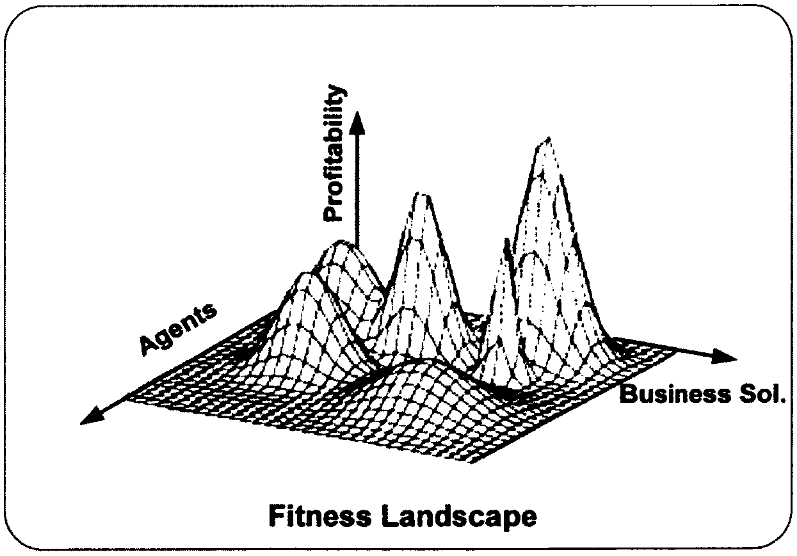


Figure 15 roughly correlated fitness landscape for market (n) at Time (t)

3.3.1. Individuals as Agents in Complex Adaptive System

In complex adaptive systems, understanding the micro-level behaviour of individual is essential to understanding the global system behaviour i.e. to understand the economy on the macro-level, it is essential to understand the micro-level behaviour of people. Economies are made of people who have their own regulations with pre-defined preferences based on their experience, knowledge and wisdom. With these defined preferences, agents categorize and compare everything according to their "ruler needs". Ruler needs is the measure of how much they need the product utility at any point of time. A person's needs change by time as they marry, give birth, age or die (demographic market changes). The roots of agent's decisions for selecting product or service that will satisfy their needs in optimal way - calculated individually – is based on the need itself and on the defined personal preferences. This in turns will determine the success or failure for any firm; the more they satisfy customers, the more payoffs they get. Whatever the priority of need is, it can be said that all people almost have the same needs that they try to satisfy according to their changeable capabilities. Also, the preferences in satisfying any need change from person to another and evolve from stage to another by time too.

The utility theory concern was focused towards the individual preferences. In economics, utility is a measure of the relative satisfaction from, or desirability of, consumption of various goods and services. The theory can shed some light towards explaining the shift of the firm's focus from products and services towards the customer. (Dupuy 1999) argued that fundamentally the most immediate consequence of globalization is the customer's victory and that the economic power has been handed over by the producer to the consumer, hence enjoying 'more quality, more for the money, more choice, more service'. As a result individuals become more powerful and have the final decision on deciding their right priorities whether it is cost, delivery or quality. Also, based on the changeable capabilities (i.e. individual financial performance), agents (buyers) will select the product or service that will satisfy their needs. For instance, during bad economic performance time, agents will focus on spending less money on essential products only. This will lead to more success for industrial enterprise that had a cost leadership strategy over their rivals even with less quality. In conclusion, individuals will assign weights that will prioritize the market variables (i.e. quality, cost, delivery and flexibility) according to the current situation (time is very important constraint). The firm that match the market priorities for a certain segment in the market will win. Although markets may have an infinite number of combinations for the manufacturing priority variables (i.e. quality, cost, delivery, flexibility), yet each market may be limited to set of segments bounded by the available products or services. Provided that all products have standard accepted quality and the customers free to select whatever matches with their needs, the market segmentation may be classified based on cost and availability as shown in Figure 16.

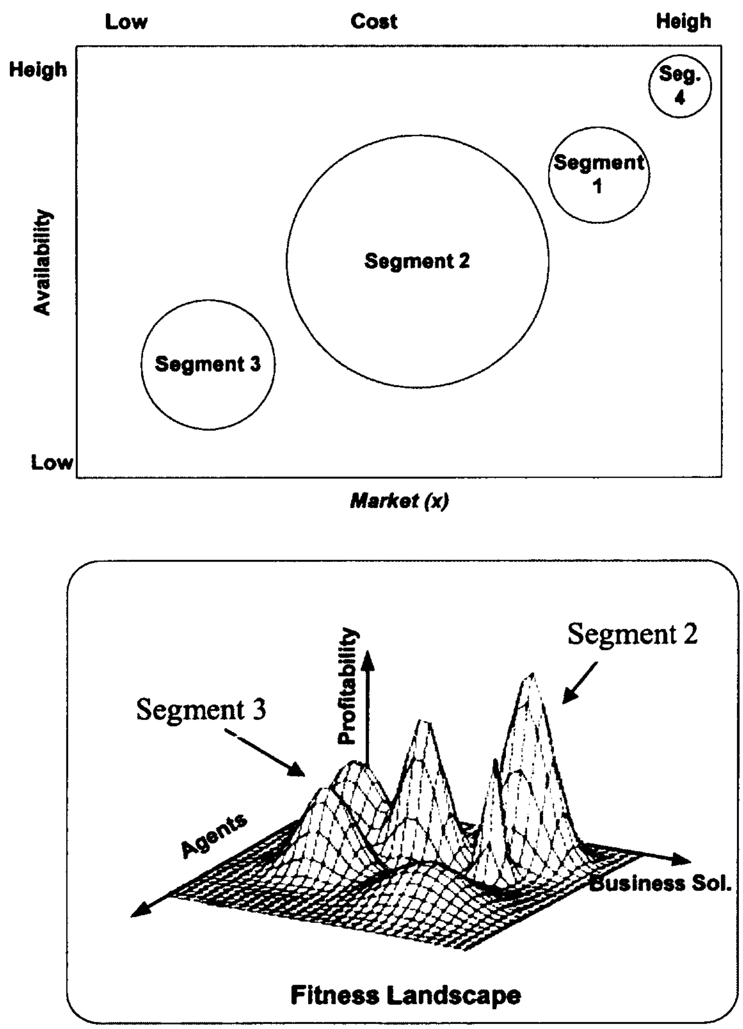


Figure 16 Market segments as manufacturing priority (Cost & Availability)

(Hallgren and Olhager 2006) proposed a framework and methodology for quantitative modeling for manufacturing strategy, based on market requirements and manufacturing capabilities as shown in Figure 17.

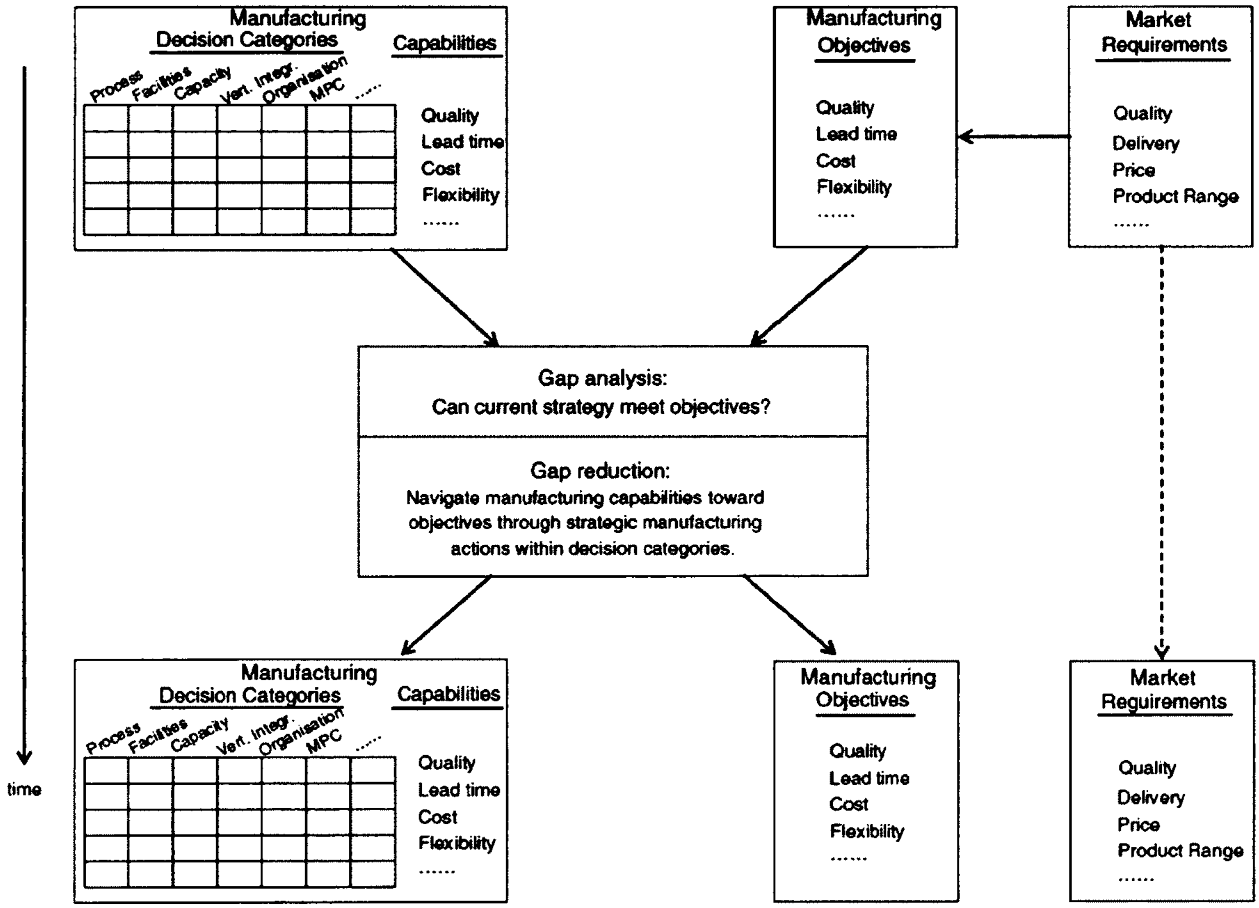


Figure 17 Measuring manufacturing objective (Hallgren and Olhager 2006)

The seven stages for quantification can be summarized as (1) measuring market requirements, (2) measuring manufacturing objectives and capabilities for the firm, (3) linking market requirements and manufacturing objectives, (4) measuring decision categories, (5) linking decision categories to manufacturing capabilities, (6) comparing manufacturing capabilities with objectives, and finally (7) modeling the strategic manufacturing actions. In conclusion, the study suggested that the quantitative model for manufacturing strategy should include three dimensions: market requirements as reference to the manufacturing capabilities, decision categories (or policy areas within decision categories), and a modeling approach.

3.3.2. Design Space for Business Solutions

After explaining the landscape segmentation and the mechanism that shape it from the customer prospective, this section will explore the source of all business solutions that satisfy these segments.

Economies rely on the existence of three factors (Beinhocker 2006): Physical Technology to enable people to create products and services that are worth trading and Social Technology that smooth the way for cooperation in creating and trading those products and services among nonrelatives. The Physical Technology (P.T.) is defined as the designs and processes for transforming matter, energy, and information in ways that are useful for human purpose, while the Social Technology (S.T.) is defined as the designs, processes and rules that organize the production force. And finally, Business plans meld P.T. and S.T. together under a strategy.

In the Physical Technology space, new inventions create both the possibility of and the need for more inventions. Each invention opens new niches for future inventions. Some inventions set off major changes and others set only small ones. Nevertheless, all inventions have ripple effect, no matter how small (Kauffman 1993). The various combinations of components and architecture define the number of possible variations of the design. These combinations cause the physical technology space of solution to unfold exponential. Architecture invention can also lead to new inventions in the components itself. For instance, in manufacturing systems, the invention of changeable factory triggers the need for new features in almost all the building modules of the factory components which in turns, when and if achieved, will be considered as a disruptive innovation for the current industry structure leading to new 'S curve' in the manufacturing industry. In detailed study of the semiconductor industry, architectural innovations tend to be more disruptive of industry structure than innovations in individual components (Adner 2002). (Christensen *et al.* 2003) found that what appear to be small changes in technology can be highly disruptive.

Just like the Physical Technology, the Social Technology design space is self feeding and exponentially unfolding and it also has modular building block (Beinhocker 2006). Even the invention in the S.T. can be considered as disruptive technology as P.T. For instance, Henry Ford 1914 development of radical new way of organizing manufacturing – the production line – was a highly disruptive S.T. that changed the structure of the automotive industry, as well as many other industries (Freeman and Soete 1997).

There are tight linkage between physical technology and social technology. As humans moves and innovate in the P.T. they cause changes in the S.T. and vice versa. Today, the management innovations depend on advances in computing and communication technology. In fact, the agricultural, industrial, and information revolutions can each be viewed as co evolutionary merry-go-rounds of advances in P.T. leading to new forms of S.T., which in turn were crucial for further advances in P.T. and so on. This means that the drivers for all innovations in the P.T. and S.T. spaces are interrelated and evolve together.

In conclusion, each individual (Agent) optimize the different needs based on the available personal capabilities to reach a satisfactory level of quality of life. This process is translated to be the criteria in the product or service selection. Some may have criteria that assign more weights to quality and durability more than to cost. Others may assign the maximum weights to the cost and everything else doesn't matter "as long as it works now" and though markets are formed into classified segments.

During any changes in the market fitness function, firms with high responsiveness and flexible dynamic capabilities may be able to provide its business solution to the market faster than its rivals and capture all the benefits of the first mover. As a result, other firm's may try to defend their current market share and react, if they were able to react at the first place! Searching the design space for all possible solutions in the Physical Technology, and Social Technology and melding them in a Business Plan creates new solutions. These solutions are selected according to their compatibility with the fitness function as shown in Figure 18.

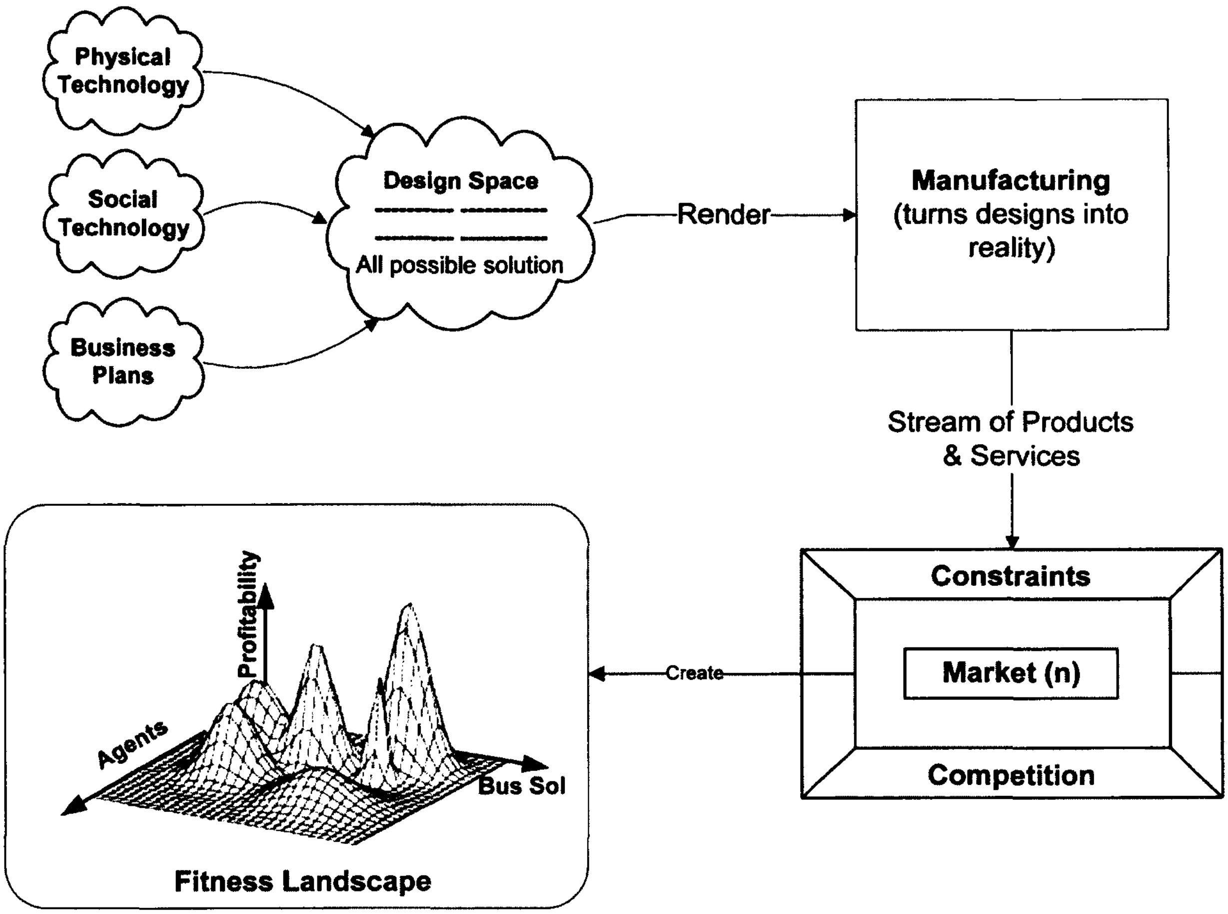


Figure 18 Design spaces and market landscape

3.3.3. Landscape Payoff: Performance or Profitability

(Stearns 1977) identified that most authors assume there is a universally understood meaning of the term fitness and that it has not been defined precisely, but that everyone seems to understand it. (McCarthy 2004) proposed definition and model of the manufacturing fitness that manufacturing fitness is the capability to survive by demonstrating adaptability and durability to the changing environment. The definition has the growth factor which is important to organizational sustainability.

Although cost, quality, delivery, and flexibility are extremely important factors in shaping the manufacturing strategy for industrial organization to compete successfully, they do not guarantee success. For example a firm with low cost product strategy will not necessarily be successful. One of its competitors can achieve better results by introducing more promotions, building different distribution channels, focusing on better quality advertising, etc. This in returns will affect both firms' market position. Thus, there is a bi-directional relationship between manufacturing's strategic capabilities, which are internally focused, and the marketing strategy of a company, which has an external perspective. From this view, manufacturing strategy acts as a dependent function of marketing strategy. Recently, manufacturing strategy became a competitive force that not only supports a given marketing strategy, but also re-designs it by offering innovative strategic chances (Größler *et al.* 2006). So the set of strategic actions adopted by the firm change the weights of the developed capabilities.

The ultimate target for profit organizations is to profit, however the absolute performance of the cost, quality, delivery, or flexibility - although they contribute to profitability process - do not guarantee it. Hence firms with great performance on these four capabilities still may get out of business under certain market circumstances. The performance measure may be derived from the simple profit equation and it will be selected as the payoff for the proposed competitive landscape. *Profit = Price – Cost.*

Firms search their design space to maximize their profits and secure their market share using different strategies. Strategies vary from specialization with a high class market segment that pays more in return to "high values products". Others may focus on wider category that focuses on prices as basic factor in their selection process by taking advantage of economies of scale. And others may target both segment by providing product portfolio (economies of scope). Targeting the largest segment by cost leadership strategy or the finest segment by high value products strategy does not imply or guarantee better return on investments (ROI) if compared to each other (i.e. achieving global peak in the landscape). (Porter 1981) explained why it is important to decide which landscape that can fit with the firm's capability to generate the highest returns among its available choices taking into consideration the competition intensity. Firms that may not fit with the current market fitness function may still have a chance to adapt and survive as long as its profitability and financial backup can cover its running expenses during the recovering and transformation period, if it was capable of doing so.

So far, the landscape boundaries are explained. The next section will integrate the proposed landscape view with evolution mechanism to explain how the industrial landscape evolve and develop over time.

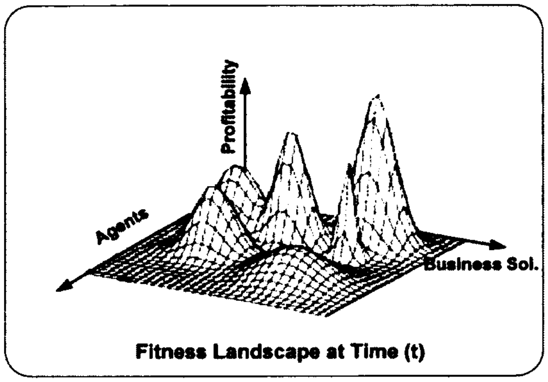
3.4. Industrial Landscape Evolution

Dawkins's famous selfish-gene theory (Dawkins 2006) stated that good replicators get replicated. The genes that are good at supporting their own replication will be replicated was the logic of replication and any other strategy will not survive in a world of competition (Dawkins 2006). Complexity economics claimed that organizations, markets, and economics are evolutionary systems. Evolution is a gradual process in which something changes into a different and usually more complex or better form. Evolution is a process of checking from an enormous space of possibilities (i.e. design spaces). It tries a bunch of designs, see what works, and does more of it and less of what didn't work (Beinhocker 2006).

As shown in Figure 20, searching, mixing and matching of all the modules and sub modules in the Physical Technology, Social Technology and Business Plans design spaces may create solutions that fit to people's needs, capabilities and preferences. These solutions may shape the market landscape if they succeed to fit with their fitness function. Successful solutions are those who will be selected by customers and generate profits and possibility for the organization to continue to the next evolved stage of its organizational life cycle. This highlights the importance of innovations and product development. All other solutions that didn't fit with the customer needs will return to its design space.

To include the simultaneous competitor's strategic behaviour the firm's Individual capabilities are a function of the industry performance that they work at. Provided that the market performance is high, this will affect the individual capabilities positively, giving them a chance to upgrade their preferences in satisfying their needs and vice versa. Changes in individual preferences and/or capabilities may generate new market segments and reshape the landscape. With small modifications either in functionality or performance in terms of time or economy for the selected solutions, repeating what is working and coping from each other, trends are created. Trends creates potential for the next level of customer preferences and expectations. The saturation of the need creates another need for variation which can be considered as opportunity for new solutions to appear. Flexible firms that will provide different solutions, or in another words will satisfy the need of variation, may be selected and passes to the next evolved cycle. In some cases, the variation in the solution is totally in the other opposite direction from the former one. For instance, by looking at the customer service section, customers are often repelled by electronic telephone answering with long menu of touchtone steps before locating someone with whom to do business. This created a potential for differentiation for other companies with customer-friendly telephone policies. These opposing directions may create swings in the trends that occurs but with continuous improvement and innovations. This can be considered as a problem for organizations that already structured their systems and resources and committed to certain irreversible strategies in a way that satisfy the old trend. Also, it is common between organizations in their success stage that mangers tend to slim any slacks in the organization seeking higher performance and more profitability under the pressure of the quarterly financial reports and share holders satisfaction. This in returns decrease the dynamic capability of the organization to manoeuvre with new trends and affect its innovation capability.

Any changes in the parameters that govern the landscape will reshape it. As the environment changes, the fitness function changes, and therefore what is high fitness peak today might not be a high peak tomorrow (Beinhocker 2006)(Beinhocker 2006). Changing demographics, social changes, energy availability, row material availability, new technologies, emergence of new market segment, changes in individual spending behaviour due to bad economic performance, competitors exist, enter or merge, or changes in the governmental rules and so forth, will create different opportunities that will be captured by firms who has flexible management systems that allows them to take advantage of these changes and fill the gap. And thus, this will shape the new landscape for that market as shown in Figure 19. This continuous process of changes makes the landscape dynamic and never settles down. The dynamic characteristic of the landscape drives all organizations to try to form the highest peak at any given time rather than searching for a global optimum at the current market which can be considered as short term success.



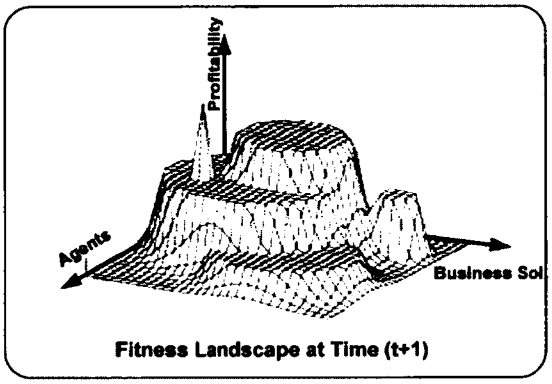


Figure 19 Fitness Landscape for market (n) at Time (t) and (t+1)

Strategy researchers concluded that the last long successful companies are those who had sustainable competitive advantage over their competition through differentiation for long periods in terms of cost, variety, more functionality or environmentally friendly products. (Kumar *et al.* 2000) defined these successful companies as the "Market Driving Companies"; those who lead the development of the next stage through differentiations instead of competing with the "Market Driven Ones". A wide research stream studied this issue to discover mechanisms for creating market space through innovation and development.

From the above discussion, it can be concluded that the industry structure and its dynamics at the end favour the evolution process of individual's preferences and markets toward the "better solution". And because evolution is recursive: its output from one cycle is the input of the next round. The stage of evolution repeats itself through the continuous innovation process in one of the three design spaces: Physical Technology, Social Technology or Business Plans. And because the time between each stage in the evolution process varies from one industry to another (Gort and Klepper 1982), some may be seen stable while others are extremely volatile. Figure 20 shows the proposed evolution mechanism.

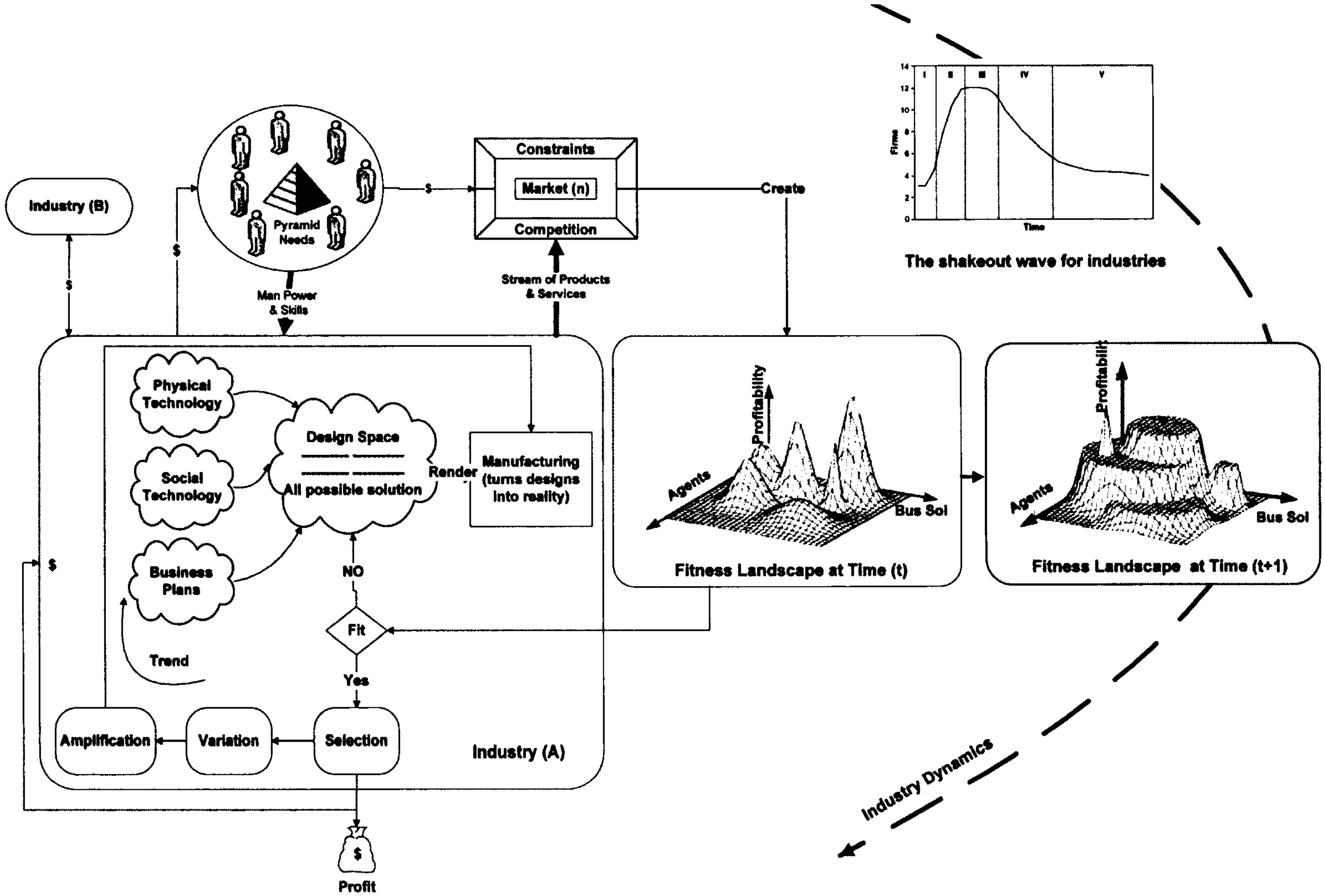


Figure 20 Market evolution mechanism

Industries evolve in cycles. Within each cycle there is stages where companies enter by innovation to help in constructing the emerging stage, compete by different means over market share to explore the market potential and setup benchmarking in the intermediate stage, stabilize in the mature stage causing all other non-successful companies to exit, and finally exit if didn't adapt with the next cycle of innovation. The flow of companies entering and existing form the market is one of the main characteristics of the economic structure, otherwise will harm the evolution process. In other words, the evolution process would have stopped if we were successful to keep all the current companies, and achieve stable predictable market behaviour with no entry or exit. (Hannan *et al.* 1995) in their studies of the organizational populations of international markets found that while there is tremendous amount of innovation and change in the economy at the level of markets, there is much change at the level of individual companies. The study concluded that the change in the economy is driven more by the entry and exit of firms than the adaptation of individual companies.

This view suggests the following for model representation:

a) Customers should be segmented according to manufacturing objectives with different attractiveness weights as a foundation for the market dynamics.
b) Attractiveness weights change from market to another and evolve over time.
c) The system is complex, nonlinear and adaptive.
d) Capacity adjustment cannot be instantaneous and perfect foresight for the future is impracticable for studying the dynamic behaviour of competing firms.
e) Simultaneous strategic behaviour for competition should be considered.
f) Firm's success level and customer preferences are function of the market benchmark and rivals performance.
g) The macro industry behaviour constraint the possible strategic moves for firms.
h) The possible strategic moves are time and path dependant and therefore any representation for such activities should be represented in a continuous time frame.

CHAPTER IV

STRATEGIC FLEXIBILITY FORMULATION AND RESULTS

4.1. Modelling Tool

System dynamics was developed in 1950 by Jay W. Forrester in Massachusetts Institute of Technology (MIT). System dynamics simulation is performed to learn about the dynamics of the system behaviour that may impact the planning solution by using close loop feedback and to design policies to improve system performance. It treats the interactions among the flows of information, money, orders, materials, personnel, and capital equipment in a company, an industry, or national. The main characteristics of this method are the existence of complex system, the change of system behaviour, and the existence of the closed loop feedback.

System dynamics can represent not only a powerful approach for modeling highly interrelated systems but also transfers these models to mathematical descriptions that allows a comprehensive analysis of system behaviour. Whereas the basic modeling permits users to obtain a general system understanding, analyses require detailed functional information about implied elements and relations (Lindemann *et al.* 2009). System dynamics (SD) research has made numerous contribution to a range of management subfields, including operations, organization behaviour, marketing, behavioural decision making, and strategy.

Using system dynamics helps in understanding the behaviour and evolution of complex systems over time where the state of the system at the current moment is a function of the state of the system at the previous moment, and some changes between the two moments. It deals with internal feedback loops (either positive or negative) and time delays that affect the behaviour of the entire system. The positive feedback occurs when the connections between the system elements are reinforcing while negative feedback occurs when there is a damping cycle. The time delay is the time between the action and reaction to respond either positively or negatively. In his study, (Sterman 2000) concluded that the dynamic behaviour in complex systems is a result of the structure of the system itself. His models and experiments showed that no matter what is done, the only way to change the system reaction is to change the structure of the system itself. New technology, different customer requirement, new governmental rules, raw material availability, or even new businesses model are examples of the components that cause structural changes in the economic performance. Also, the information technology revolution decreased the time delays of the economic system. It provided more information for individual who in return enhanced their decision making process (Lindemann *et al.* 2009) and become capable of making educated assumption and decisions.

It is important to understand the fundamental concepts to help us to construct, analyze, and test the model. Some fundamental concepts that play an important role in model development are depicted below:

Level: A level represents something that may accumulate, like a tank with water. Any flow directed to the level increases the level, and the flow going out of the level decreases the level. Practically, a level can represent the amount of capital in the company, the amount of working force, the number of members in a population etc.

Rate: Rates are the physical or conceptual entities in systems that move over time. Examples of rates include people, material, or subjective concepts such as satisfaction.

Auxiliaries: auxiliary variables are "intermediate concepts added to the model to aid clarity".

Bounded Rationality: The need for alignment among strategic objectives and operating performance measures has been framed in terms of bounded rationality (Morecroft 1985, Sterman 2000, Sterman *et al.* 2007). The models that recognize that decision makers rely on simple mental models which have serious limitations become increasingly deficient as problems grow more complex and as the external environment changes become more rapidly and the uncertainty increases. Mainly the concept states that human mind cannot solve dynamically complex problems. People "misperceive feedback" because "the mental models people use to guide their decisions are dynamically deficient". System dynamics is a tool to overcome the normal responses to bounded rationality, such as habits or rules of thumb (Sterman 2000).

Delay: this function is required to postpone effects such as situations when it takes time for decision making process or gathering information from the market.

Detail Complexity: systems or decision-making situations characterized by many components or alternatives from which to choose have detail complexity due to the large numbers of combinations they present.

Dynamic Complexity: Dynamic complexity occurs in systems characterized by large numbers of interactions over time where feedback and delays make it impossible to intuitively determine the behaviour of even simply structured systems (Sterman, 2000).

Endogenous variables: Model variables that lie within the boundary of a model where the structure and policies within the modeled system influence the variables' behaviour.

Exogenous variables: Variables outside the model boundary that have no causal connection from the endogenous variables within the model boundary but have causal connections to the endogenous variables in the model. Ideally, exogenous variables remain constant throughout the time horizon of the model.

Feedback: Feedback occurs in a system when its own past activity influences its future. Negative feedback in a system causes the system to seek a goal such as when a thermostat starts and stops heating and cooling systems. In system dynamics models, negative feedback loops are called balancing loops. Positive feedback generates continuous growth or decay, such as when a bank account accrues compound interest. In system dynamics models, positive feedback loops are called reinforcing loops.

Graphical system Behaviour: Graphs of the behaviour of key variables in a system are an important product of system dynamics models. Typical patterns on system dynamics graphs show growth, decay, goal setting, and oscillation.

The system dynamics approach involves:

- Defining problems dynamically, in terms of graphs over time.

- Determine for an endogenous, behavioural view of the significant dynamics of a system, a focus inward on the characteristics of a system that themselves generate or intensify the supposed problem.
- Thinking of all concepts in the real system as continuous quantities interconnected in loops of information feedback and circular causality.
- Identifying independent stocks or accumulations (levels) in the system and their inflows and outflows (rates).
- Formulating a behavioural model capable of reproducing the dynamic problem under study. The model is usually a computer simulation model expressed in nonlinear equations.
- Deriving understandings and applicable policy insights from the resulting model.
- Implementing changes resulting from model-based understandings and insights.

Mathematically, the basic structure of a formal system dynamics computer simulation model is a system of coupled, nonlinear, first-order differential (or integral) equations. Simulation of such systems is easily accomplished by partitioning simulated time into discrete intervals of length (dt) and stepping the system through time one (dt) at a time. Each state variable is computed from its previous value and its net rate of change.

As explained earlier, behaviour is a consequence of system structure. The importance of levels and rates appears most clearly when one takes a continuous view of structure and dynamics. Although a discrete view, focusing on separate events and decisions, is entirely compatible with an endogenous feedback perspective, the system dynamics approach emphasizes a continuous view. The continuous view strives to look beyond events to see the dynamic patterns underlying them. Moreover, the continuous view focuses not on discrete decisions but on the policy structure underlying decisions. Events and decisions are seen as surface phenomena that ride on an underlying tide of system structure and behaviour. It is that underlying tide of policy structure and continuous behaviour that is the system dynamicity's focus and that is why this tool was selected.

4.2. Model Structure

The model boundary is at the industry level including the dynamic environment in which the firm operates. Instead of focusing at the firm-level, factors within an industry are taken into account when crafting strategy, including intra-firm organizational factors, inter-firm competition and cooperation, and firm-to-industry interactions. The model captures the organizational interlink through various feedback loops. The broad boundary presented with exogenous variables is set to capture a wide range of feedback effects managers often fail to consider during their decision making process. The strength and weights of variables depends on the particular industry and differs from one to another.

The model can be configured to represent an arbitrary number of firms and though the simultaneous interaction is considered and calculated. This includes the strategic intent towards capacity adjustment decisions, advertising spending, pricing strategies, volume flexibility and other factors. On the supply side, each firm receives orders from customers, then manufactures and ships the products, and this adds to the installed base in the market. On the demand side, customers are segmented into two major segments based on attractiveness to product availability or product prices. The model also explore the link between the manufacturing objectives and their effect on the total industry performance in terms of profitability, product availability and capacity utilization in an attempt to better manage the strategic decisions managers face in different market scenarios.

In a zero sum market competition, the firm uses strategic decisions to realize its target market share and to prevent competition from controlling the market. As shown in Figure 21, (Arafa and ElMaraghy 2011b) used four macro feedback indicators to the strategic choices of the firm namely; market share, net profit, production capacity utilization and volume flexibility. The firm target is to maximize its profit and market shares through max matching with the market variables by either adjusting its capacity, adjusting prices, increasing advertising strength, focusing on labour training or introducing new product.

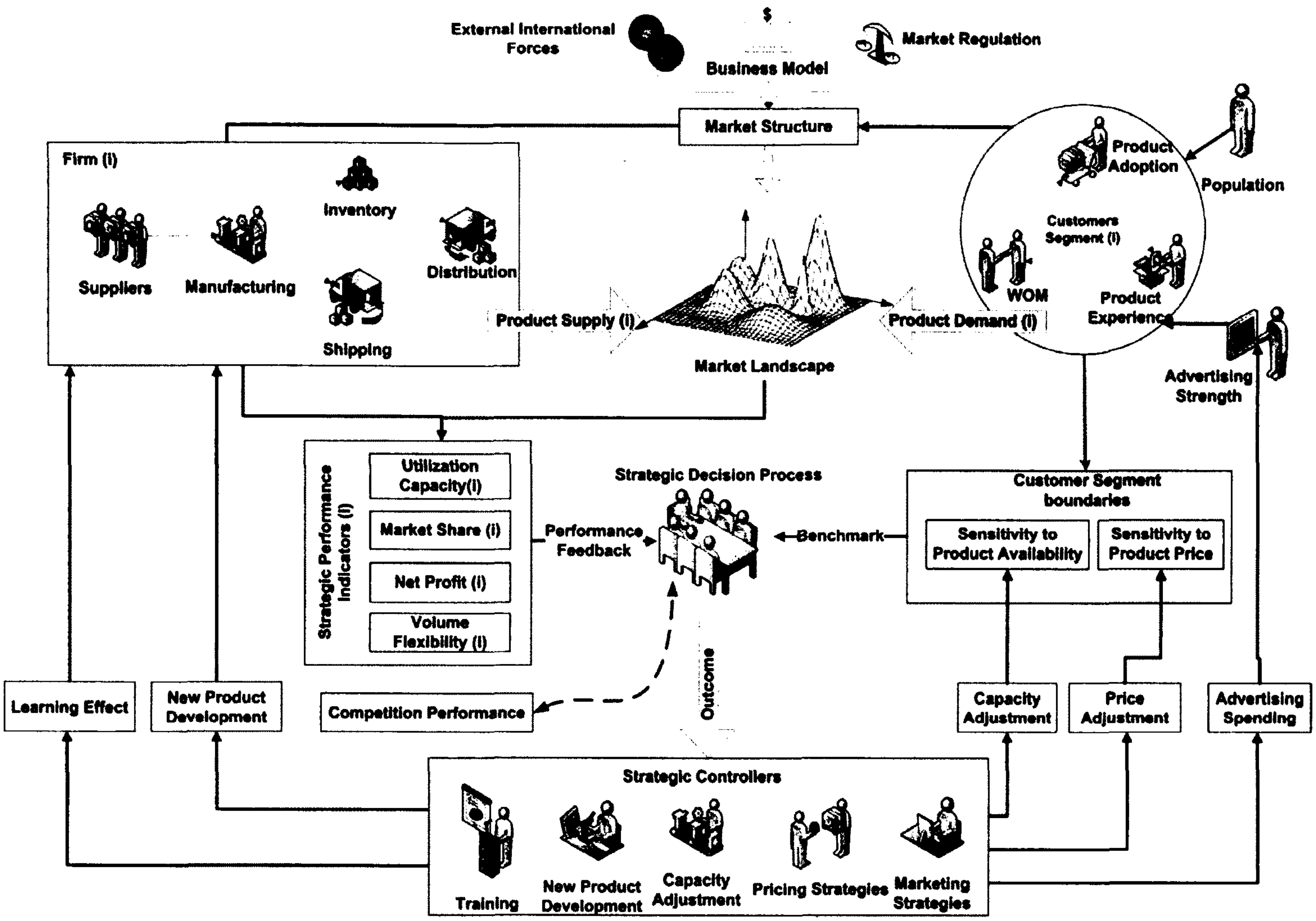


Figure 21 Conceptual model structure (Arafa and ElMaraghy 2011b)

The constraints that govern the market such as governmental regulation, culture, similar products from competition, individual behaviour, product availability and so forth, are the variables that form the manufacturing fitness function of any market. The priorities and weights of these variables may change from market to another and from time to time based on the customer's preferences and capability. As a result, one of the major preliminary tasks for any industrial organization is to identify the landscape variables, its priority and competition performance (i.e. benchmarking) and adapt their strategies using their available capabilities to "max match" with the market fitness function at any point of time to maximize its payoff (i.e. profitability and market share) as shown in Figure 22.

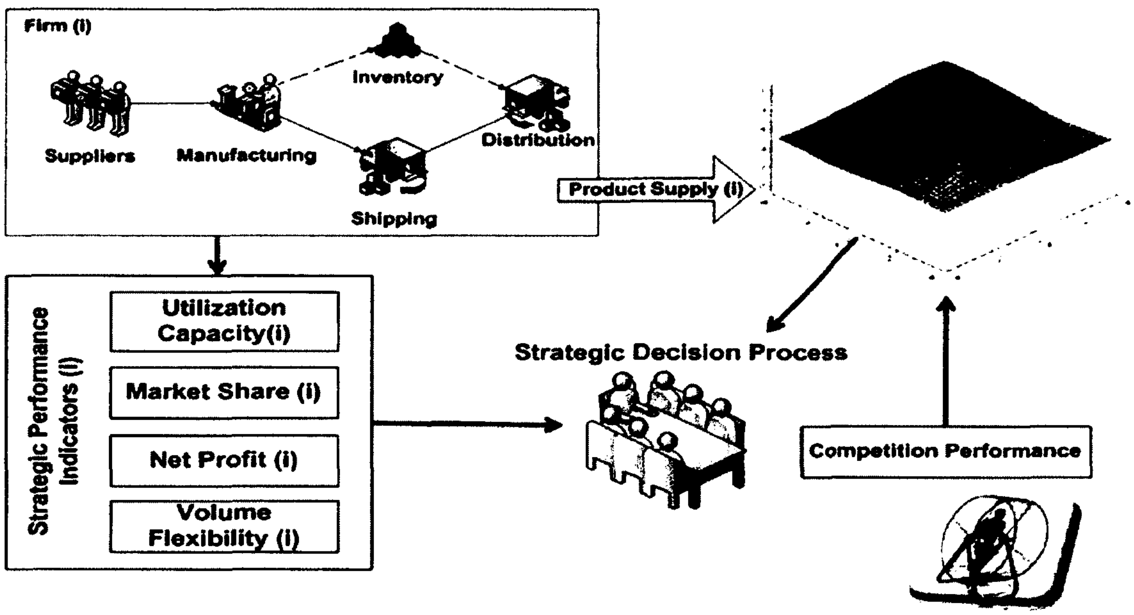


Figure 22 Strategic decisions based on industry benchmark

The continuous max matching process between dynamic market needs and the firm's dynamic capability is the key factor for success. Therefore, the firm that can design its manufacturing capabilities to "fit" with the current fitness function at certain time and satisfy customer needs will be rewarded by providing its products and services to the market. During any changes in the market fitness function, firms with high responsiveness and flexible dynamic capabilities may be able to provide its business solution to the market faster than its rivals and capture all the benefits of the first mover (i.e. first mover advantage (Kerin *et al.* 1992)).

In open ended competition, customers in global markets are becoming more sophisticated in their preferences for products. Firms, using different types of competitive strategies, are creating more products to segment markets using low cost or differentiation strategies against their competition. Due to this competition, market segmentation and dynamics is changing faster than ever. Uncertainty and forecasting errors eliminate the ability of any individual industrial enterprise to stand alone to match with the fast evolving industry benchmarks and customer preferences rate of change and that can explain the importance of strategic alliance for businesses. The performance feedback measure defined in this model is the market share, utilization capacity, net profit and volume flexibility. These are indicators to test the organizational capabilities fit with market segment benchmark. In our case the benchmark is assumed to be the product availability and product prices as shown in Figure 23. Quality is assumed to be given and will be excluded from the product attractiveness factor due to the fact that low quality products will not have the chance to stand in the market for long terms.

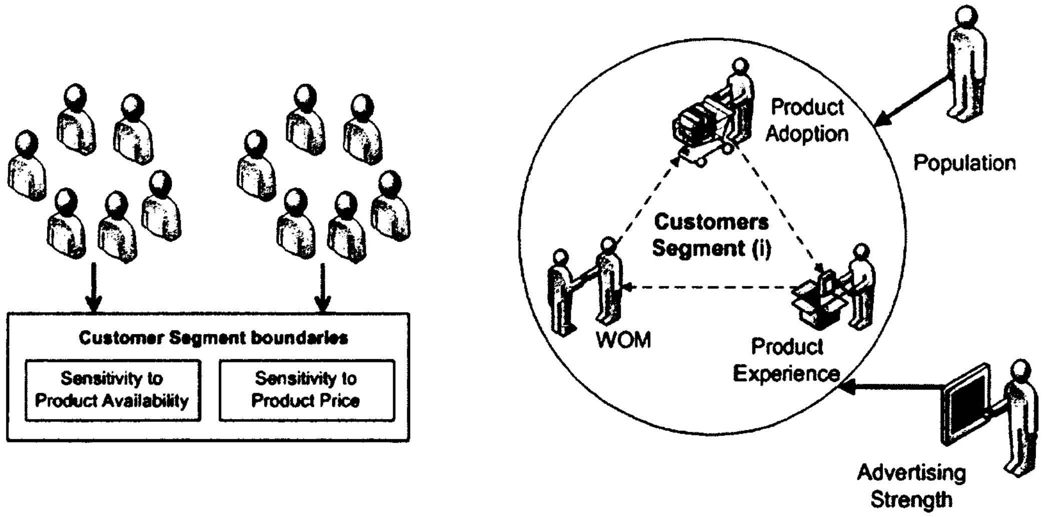


Figure 23 Market Segmentation

The available strategic controllers for the firm to select from as shown in Figure 24 are as follows:

- Intensive training to enhance the returns from the learning curve.
- Capacity adjustment through expansion, outsourcing or strategic alliance.
- Prices adjustment.
- Concentration in marketing activities.
- New product development through research and development.

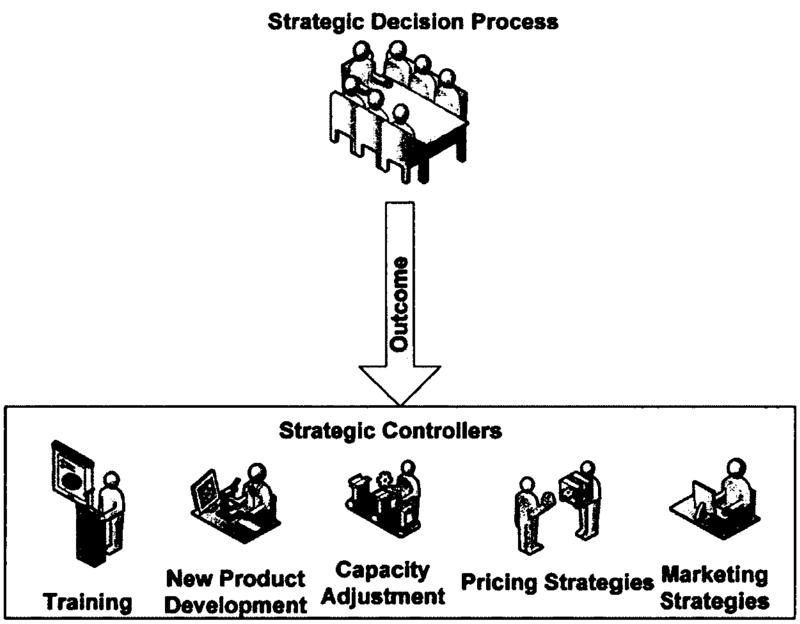


Figure 24 Strategic Controllers Available to the Enterprise

4.2.1. Variables Definitions

The following table present the definitions for the model variables. A detailed mathematical representation and variables relationship mapping are shown in Appendix B and Appendix C respectively.

Table 3 Model variables definitions

Variable	Definition
Industry Demand	The number of household in the population who will choose to purchase the product as a function of the minimum price.
Adoption Rate	The rate at which customers adopt the product.
Potential Adopters	The number of customers in the population who have not adopted the product.
WOM Strength	The strength of the word of mouth effect; probability per year of adoption by meeting with adaptors and exchange product experience.
Strength of Advertising	Advertising spending that affect the WOM strength probability.
Availability Attractiveness	Effect of availability depends on delivery delay benchmark.
Product Attractiveness	Attractiveness of each firm is product of effects of price and availability.
Order Share	Fraction of orders going to firm.
Backlog	The unfulfilled orders for the firm's product.
Industry Order Rate	Total order rate for the product.
Desired Shipments	Rate of shipments needed to deliver orders with average delay to match with the industry normal delivery delay.
Production	Production = Shipments as there are no inventories in this model.
Learning	Fractional cost reduction from learning curve.
LC Strength	Strength of Learning Curve, expressed as fractional reduction in unit costs per doubling of cumulative production.
Initial Production Experience	Initial cumulative output level resulted from hiring experienced labour force.
Market Share	Share of shipments in units going to each firm.
Normal Profit Margin	The normal mark-up on unit costs.
Industry Shipments	Total Rate of Industry Shipments to express fulfilled orders.
Discard Rate	A fraction of the installed base is discarded each year.
Demand Supply Balance	Ratio of desired shipments to capacity, adjusted for normal capacity utilization.
Capacity Acquisition Delay	The average delay in acquiring or discharging capacity.
Minimum Efficient Scale	Minimum efficient scale for operations.

4.2.2. Product Attractiveness Sub-model

The demand for the firms' product depends on overall industry demand and the firm's share of that demand. The share depends on product attractiveness, which in turn depends on other factors. To increase firm attractiveness, the firm can lower the price, improve product functionality through R&D investment, build up brand equity through marketing, increase product availability, or increase the installed base of products. Not all these factors are active together and valid for success in all markets. The order demand is represented mainly as function of two forces; the product attractiveness and product adoption. These two forces shape the market segmentation. The market is represented by two segments of customers; one attracted to price and the other attracted to availability.

Product attractiveness influences the sales growth and as attractiveness increases, the firm's market share in the market will increase as well. In the model, the level of product attractiveness is adjusted through two different driving factors: price reduction and performance in delivery represented as time to market. The attractiveness of product through price is a comparison between product price given by the firm and the lowest market price at any time. Advancement in information technology makes it easy to do so. This increases the effect of price competitiveness in the market. Attractiveness from the availability is assumed to be depended on the firm's delivery performance compared to the normal delivery delay benchmark of the industry. The two variables, A_V and A_P, represent the weight of availability attractiveness and price attractiveness respectively assigned by the customers in each market segment. The attractiveness to price and availability affect the total attractiveness of customer to the product and can be calculated as follows:

$$A_T(i) = A_P(i) * A_V(i) \qquad (4.1)$$

Where A_T is the product total attractiveness, A_P is the attractiveness from price and A_v is the attractiveness from Availability. The attractiveness from availability and price are calculated as follows:

$$A_V(i) = \exp(S_V * D_P(i)) \qquad (4.2)$$

$$D_P(i) = \left(\frac{D_d\,(i)}{RD_d}\right) \quad (4.3)$$

$$D_d\,(i) = \left(\frac{B(i)}{S(i)}\right) \quad (4.4)$$

$$A_P(i) = \exp(S_P * \left(\frac{P\,(i)}{LP}\right)) \quad (4.5)$$

The two variables, S_V and S_P, represent the customers' sensitivity to availability and price respectively. The firm delivery performance, D_P, is the delivery delay D_d compared to the reference delivery delay benchmark, RD_d, known by the customer in the market. Delivery delay is the ratio of backlog, B, to shipments, S. Finally, due to advancement in advertising and information technology, the customer compares the price, P, in reference to the lowest available price, LP, at any point of time. As a result competition over price and/or product availability will change customer expectation for both, and hence will set customer preference for product selection up to certain benchmark. Figure 25 presents the flow diagram of the product attractiveness sub-model.

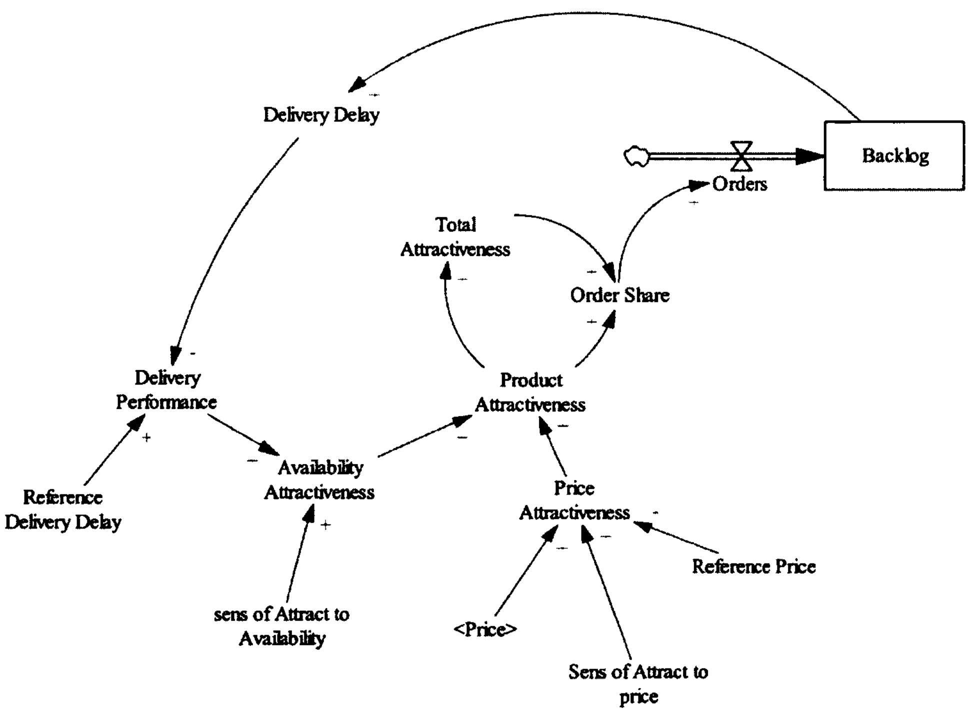


Figure 25 Product attractiveness sub-model

$$LP = VMIN\left(P(i)\right) \quad (4.6)$$

The total attractiveness to the product the firm scores limits its share from the total industry orders placed by the customer and is calculated as follows:

$$\frac{dO(i)}{dt} = A_T(i) * \left(\frac{dO_T}{dt}\right) \quad (4.7)$$

Where O (i) is the orders received to the firm.

4.2.3. Order Demand Sub-model

The total industry order rate (dO_r/dt) depends on the initial industry orders for the product and the reorder rate for product replacement is shown in Figure 26. Industry orders evolve according to Bass diffusion model (Mahajan *et al.* 1990) where potential customers adopt the new product with adoption rate (dA/dt). The customer's attitude towards products provides a main driving force for diffusion.

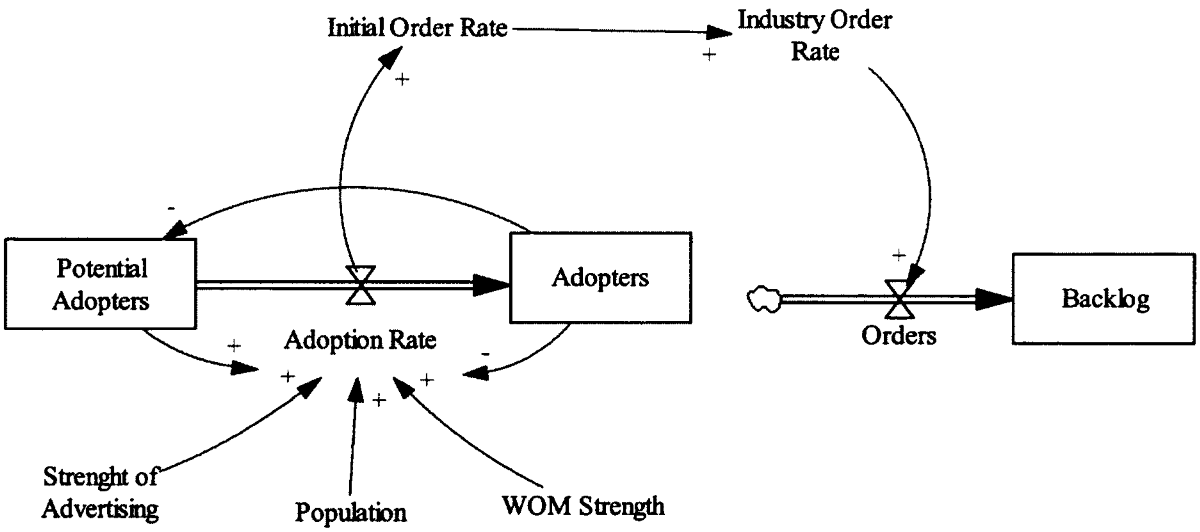


Figure 26 Order rate and product adoption sub-model

The modeling of the diffusion will start by having a "contagion" view of adoption. The basic idea is that the potential adopters of the product catch the desire of purchasing the new product from those who have already purchased the product. The adoption rate depends on number of adopters who have already purchased the product, number of potential adopters, how effective the adopters are in presenting the product, how often adopters meet with the potential adopters and the advertising spending that raise the product awareness among potential customers. This type of model can be interpreted as "word of mouth" introduced in Bass model, which implies that, positive word of mouth from happy adopters leads the potential adopters to make a purchase. The adoption rate is function of the word of mouth (WOM), number of customers who adopt the product, A_P, and other external factors such as advertising strength (ADV) in reference to the market population, POP, and is calculated as follows:

$$\frac{dA}{dt} = P_A\left(ADV + \frac{WOM * A_P}{POP}\right) \tag{4.8}$$

$$\frac{dO_r}{dt} = \sigma\left(\frac{dA}{dt}\right) + \sum(I_B\left(\frac{dD}{dt}\right)) \tag{4.9}$$

Where, σ is the number of products per customer, I_B is the installed base of the product and $\frac{dD}{dt}$ is the discard rate due to the end of product life cycle. To capture the re-purchase of the product is to assume that adopters, who have already discarded the product, are assumed to move back to the potential adopters stock. In this case the rate at which the product is discarded and, hence the rate at which adopter move back to the stock of potential adopters, depends on the number of adopters and the average product life time. Higher competition may increase the rate of product adoption to reach the market saturation state faster. This decreases the product life cycle. Considering the discarded product, the stock of potential adopters always contains some fraction of the population that can influence the adoption rate of the product. Since the discarded products are coming back to the pool of potential adopters, they are going to be treated exactly as the first-time purchase of the product. This implies that they have to become aware and being persuaded by adopters to buy the product.

4.2.4. Capacity Planning and Control Sub-Model

Capacity planning can be described as an iterative process between capacity expansion, identifying the required manufacturing technologies and their capacity levels to be physically expanded or outsourced. The overall objective is to meet the desired market share and maximize the return on investment based on the firm's strategic intent. Capacity configuration decisions are subject to adjustment throughout the forecasted period τ to accommodate demand and capacity variations.

Although change in capacity configuration is modeled as irreversible decision to the strategic planning decision, the model allows a positive and a negative capacity configuration change under different market scenarios. Since the instantaneous capacity adjustment and perfect foresight is excluded from the model, changing capacity configurations is unavoidable causing disruption in the regular flow of manufacturing, and may result in accumulated backlog and increased manufacturing cycle times.

To avoid the "bullwhip effect" (Lee *et al.* 1997b), the firm is assumed to maintain no inventory policy. As a result, production is equal to shipments. Although it is desirable to satisfy all demand from in-house production, for a certain type of capacity shortfall, the outsourcing could be more economical and/or tactical option to preserve the firm strategic position in its market(s) through enhancing its responsiveness to demand variations. The responsiveness of order fulfillment through production and outsourcing is presented in Figure 27 and calculated as follows:

$$B\,(i) = O_r\,(i) - S_A\,(i) - S_o\,(i) \tag{4.10}$$

$$S_A\,(i) = MIN\,(S_d\,(i),\,C\,(i)) + S_o \tag{4.11}$$

$$S_o(i) = DELAY1\,(B\,(i),\,O_D\,(i)) \tag{4.12}$$

$$S_d(i) = \frac{B\,(i)}{NDD\,(i)} \tag{4.13}$$

Where B is the backlog, S_A is the actual shipment the firm successfully fulfilled, S_d is the desired shipment needed to deliver orders with average delay equal or less to the market benchmark of normal delivery delay NDD , C is the firm's production capacity and S_o is the outsourced shipments. The firm starts outsourcing once the backlog start to accumulate with outsourcing performance delay O_D.

The lag in capacity expansion is due to the time lag between the request, the delivery and the installation of the machinery and the training of the employees. The delay in capacity adjustment is expressed as a third order exponential smooth with a capacity acquisition delay C_{AD} and starts the average industry order rate normalized over the normal capacity utilization of the industry, NCU, as follows:

$$C\ (i) = SMOOTH3I\left(C_T\ (i), C_{AD}\ (i), 0.5 * \frac{O_T\ (i)}{NCU(i)}\right) \qquad (4.14)$$

$$C_T = MAX\ \left(MES\ (i), MS_T(i) * \frac{EID\ (i)}{NCU\ (i)}\right) \qquad (4.15)$$

Where C_T is the target capacity by the firm, MES is the minimum efficient scale of production and EID is the expected industry demand.

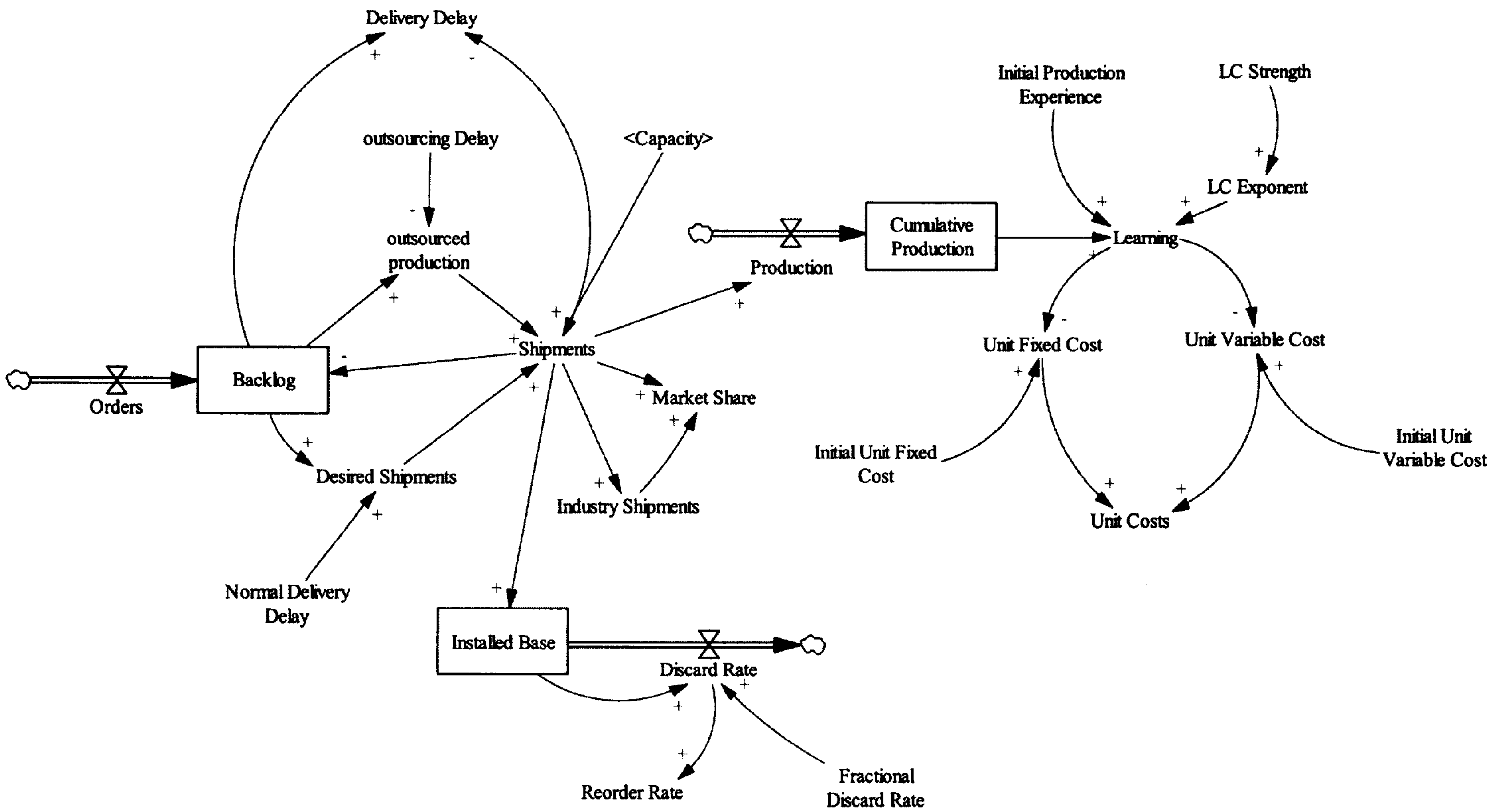


Figure 27 Order Fulfillment sub-model

The lag in capacity expansion is due to the time lag between the request, the delivery and the installation of the machinery and the training of the employees. The delay in capacity adjustment is expressed as a third order exponential smooth with a capacity acquisition delay C_{AD} and starts the average industry order rate normalized over the normal capacity utilization of the industry, NCU, as follows:

$$C\ (i) = SMOOTH3I\left(C_T\ (i), C_{AD}\ (i), 0.5 * \frac{O_T\ (i)}{NCU(i)}\right) \qquad (4.16)$$

$$C_T = MAX\ \left(MES\ (i), MS_T(i) * \frac{EID\ (i)}{NCU\ (i)}\right) \qquad (4.17)$$

Where C_T is the target capacity by the firm, MES is the minimum efficient scale of production and EID is the expected industry demand.

4.2.5. New Product Introduction Sub-Model

Investment decisions are propositional to the firm financial performance. Following the path dependent concept presented in the dynamic capability theory, resources for investments come from a reserve of the generated profits. The total profits – or losses – are obtained from production. In a situation of profits, a percentage of the total profits make up a reserve for future investments in capacity expansion (if needed), new product development and advertising. The time for introducing new product to the market is represented as step function which triggers the effect of the new product on the market. Figure 28 shows the flow diagram for introducing new product development.

$$NPI(i) = Step\ (1, NPD(i)) \qquad (4.18)$$

Where NPI is the new product introduction and NPD is the total time required for the new product development.

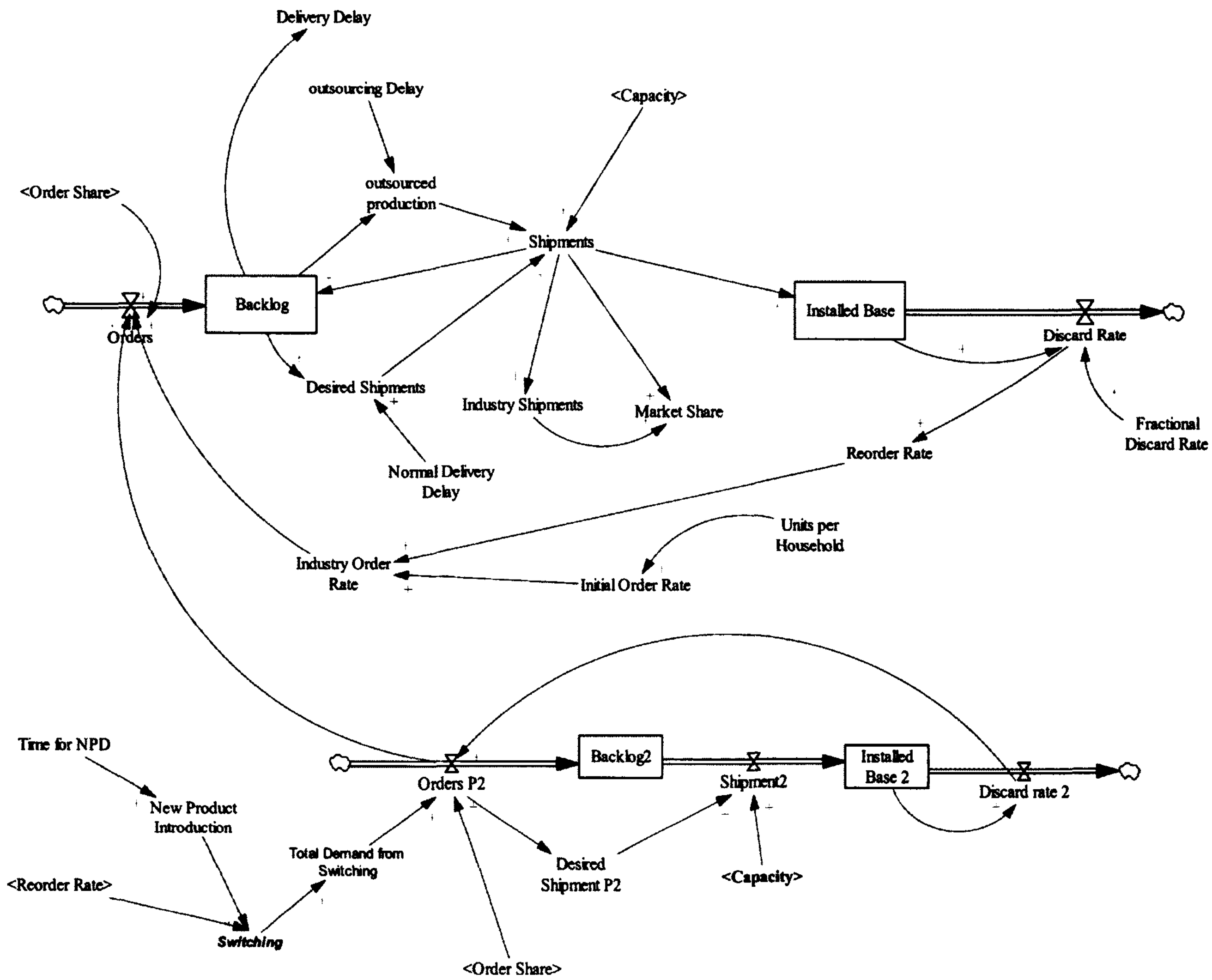


Figure 28 New Product Development sub model

4.2.6. Manufacturing Flexibility Sub Model

(Das 1996) derived a measure of flexibility by computing either, the change effort expended in moving between states, the drop in system performance in moving between states, a general or physical scale of difference between two successive states, or a combining all three. The study introduced 5 levels of flexibility measurement presented as follows:

- *Level 1* is the necessary flexibility, which is a function of the set of states which the system needs to attain if it is to successfully counter all of the expected environmental changes.
- *Level 2* is capability flexibility, which is a function of the set of states which the system is equipped to attain.
- *Level 3* is the actual flexibility exhibited by the system, and is always described with reference to sometime interval.
- *Level 4* is the inflexibility of the system, which is a function of the gap between the necessary flexibility and capability flexibility.
- *Level 5* is the optimality of the flexibility. This level is a measure of the difference between the optimal state of the system under specific conditions, and the state actually attained by the system in response to these conditions.

From a manufacturing perspective the dynamic capability for enterprise organizations is known as manufacturing flexibility. Flexibility in manufacturing systems is defined as the ability of a system or facility to adjust to the changes in its internal or external environment with little penalty in time, effort, cost, or performance. Review of the literature identifies 10 types of manufacturing systems' flexibilities (ElMaraghy 2009): machine, material handling, operation, process, product, routing, volume, expansion, control program, and production flexibility. Volume flexibility was defined as the ability to operate efficiently, effectively, and profitability over a range of volumes (Parker and Wirth 1999a). The importance of the volume flexibility measure lies in the need to evaluate the strategic decisions involving the acquisition of greater production capacity.

Flexibility measure attempts represented a basic property of the system components and its structure without reference to the operating environment (Giachetti *et al.* 2003). Deif and ElMaraghy (2007) proposed various performance measures to examine the best scaling policy under different demand scenarios. They demonstrated that the best scalability policy would be based on both the marketing strategy as well as the operational production objectives (Deif and ElMaraghy 2007). The strategic value of volume flexibility to firms is well documented (Son and Park 1987, Olhager 1993, Slack 1993, Parker and Wirth 1999b, Jack and Raturi 2002, Jack and Raturi 2003, Francas *et al.* 2009, Goyal and Netessine 2010). In this model, volume flexibility, VF, is considered to be the ability to operate efficiently, effectively and profitably over a range of volumes and is expressed by (Parker and Wirth 1999a) as:

$$VF(i) = 1 - \frac{aF_c(i)}{b(i)*C(i)} \tag{4.19}$$

$$F_c(i) = C(i) * UF_c(i) \tag{4.20}$$

$$b(i) = P(i) - UV_c(i) \tag{4.21}$$

Where Fc is the total fixed cost, UFc and UVc are the unit fixed and variable cost respectively, a is the number of capacity units required per part produced, b is the contribution margin for the product and P is the product price. Both the firm's fixed and variable costs are affected by the learning effect the organization has as shown in Figure 29. Unit indirect costs include product development, marketing, and subsidies to complementary asset producers. Unit direct costs are composed of unit fixed and variable costs. The model includes the classic learning curve through which greater sales and production accumulation experience lead to learning that lowers unit costs. Unit direct costs can be reduced either by the concept of learning by doing as manufacturing experience accumulates or by investment in process development which enhance the product delivery to the market. The learning effect is captured by adjusting the strength of learning curve that directly affects the learning curve exponent. The relation is expressed as fractional reduction in unit costs per doubling of cumulative production. The firm's learning strength, LS, on the market share may differ from one organization to another due to different managerial practices and/or some cultural considerations, such as the working environment and customer feedbacks for instance. Key parameters values are shown in Table 4.

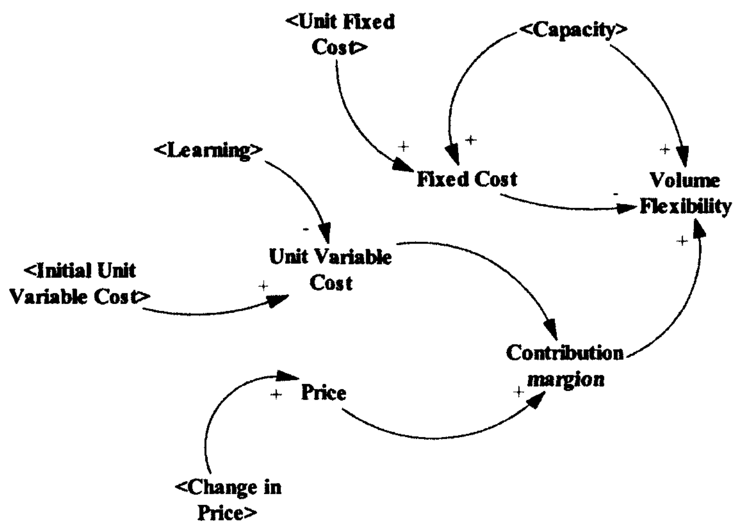


Figure 29 Volume flexibility sub model

Table 4 Initial Parameters for the Base Case

Parameters		Value	Unit
Preference for price	S_P	-8	Dimensionless
Preference for availability	S_V	-4	Dimensionless
Normal delivery delay	NDD	4	Month
Outsourcing delay	OD	0.25	Year
Product Price	P	1000	$ / Unit
Normal capacity utilization	NCU	80	%
Capacity acquisition delay	C_{AD}	1	Year
Minimum efficient scale	MES	10,000	Units
Learning curve strength	LS	$\log_2 0.7$	Dimensionless
Capacity units per part	a	1	Dimensionless
Ratio of fixed to variable cost	UF_c / UV_c	3	Dimensionless
Target Market share	MS_T	50	%

4.3. Base Case Simulation Results

This section present the results of the two competing firms in three market scenarios namely; low, medium and fast product adoption rates. The change in adoption rate due to change in the strength of the word of mouth (WOM) is shown in Figure 30. The total industry demand for these three scenarios is shown in Figure 31.

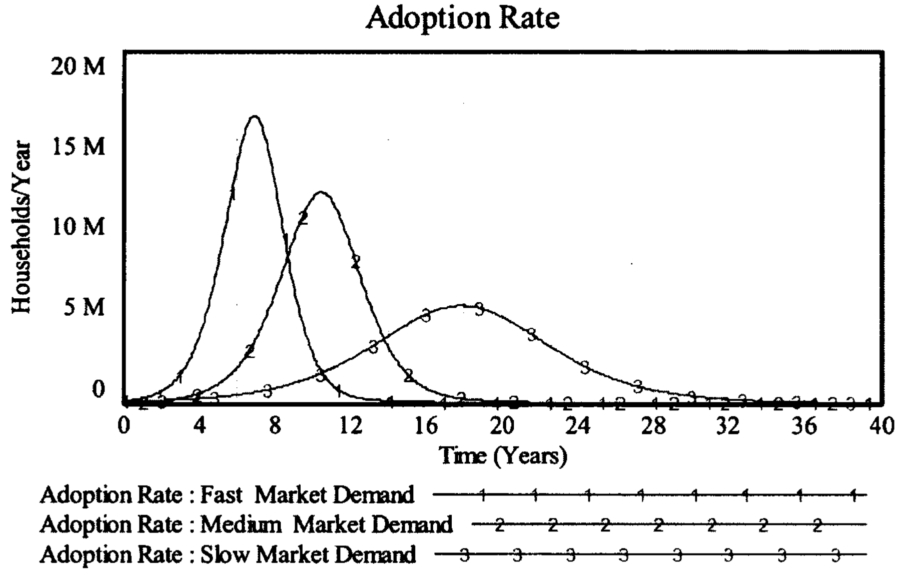


Figure 30 Adoption Rate for the 3 scenarios

From both figure it's clear that faster market scenario cause higher product demand during early stages of the product life cycle. Yet the product growth is limited by the market size as it reached a saturation level at the end of the product life cycle. The adoption rate, which represents the amount of product being adopted, has been sustained to a constant value before decaying. This value indicates the market saturation level. As the contact rate increases between customers, the speed of diffusion also increases and the total number of adopters will increase as a result. Also, depending on the technology life time, the behaviour of adoption rate, which also corresponds to the amount of firms' production per year, will differ from scenario to another.

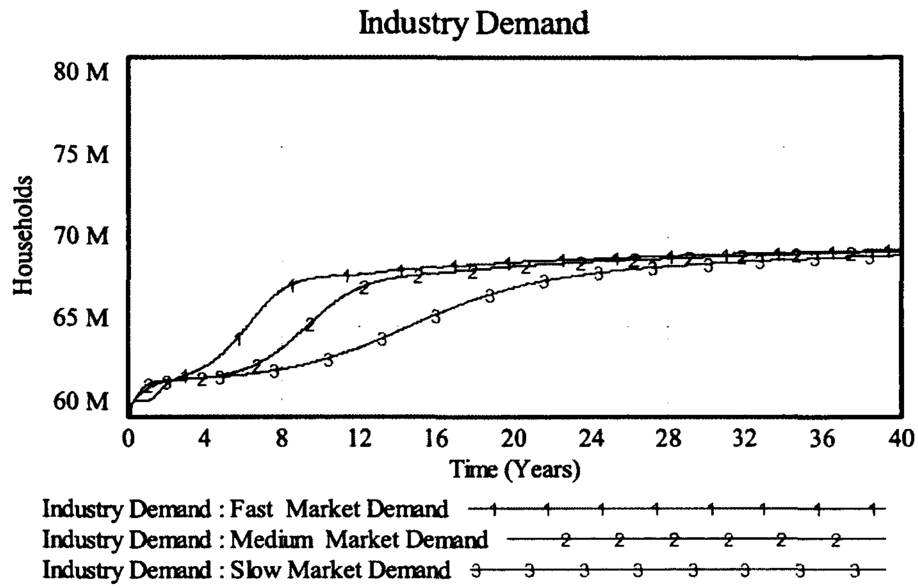


Figure 31 Total industry demand for the 3 scenarios

To ease the comparison, firm F1 and F2 desired market share is set to 50% for both during this scenario as shown in Figure 32. This suggests that both firms are willing to share the market together without trying to dominate greater shares than the other.

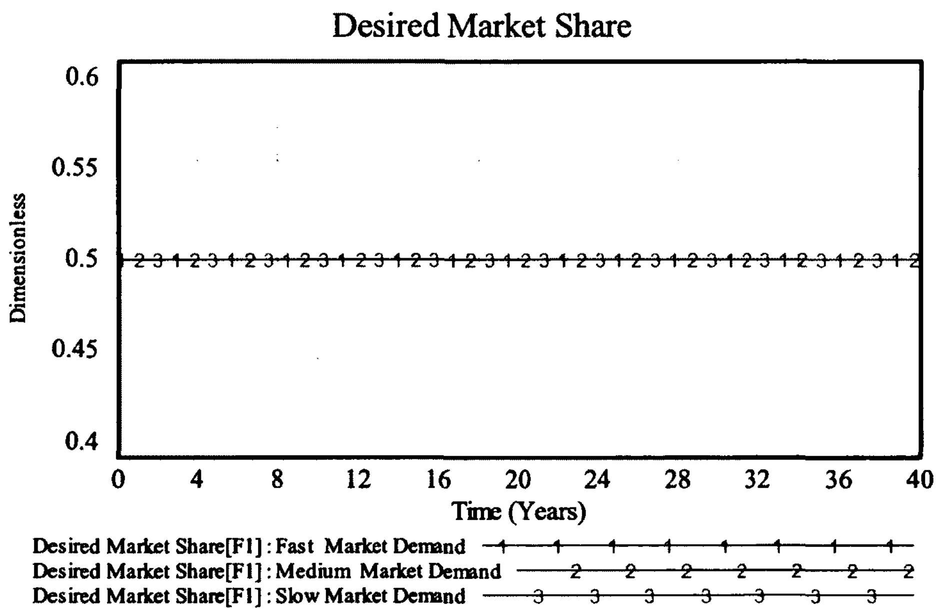


Figure 32 Firm F1 & F2 desire the same market share.

Also throughout the base case, results will be based on medium demand scenario only to highlight the significance of the selected variables under study. The actual market share for both firms is shown in Figure 33. Capacity utilization for both firms is shown in Figure 34. The backlog and product prices are shown in Figure 35 and Figure 36 respectively. Finally volume flexibility capability for both firms is shown in Figure 37.

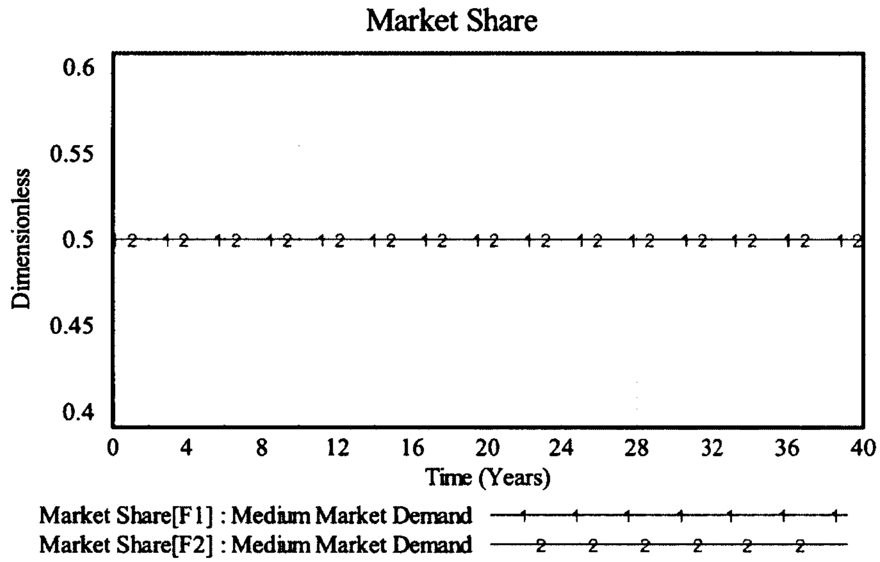


Figure 33 Market share for firm F1 and F2 in the base case

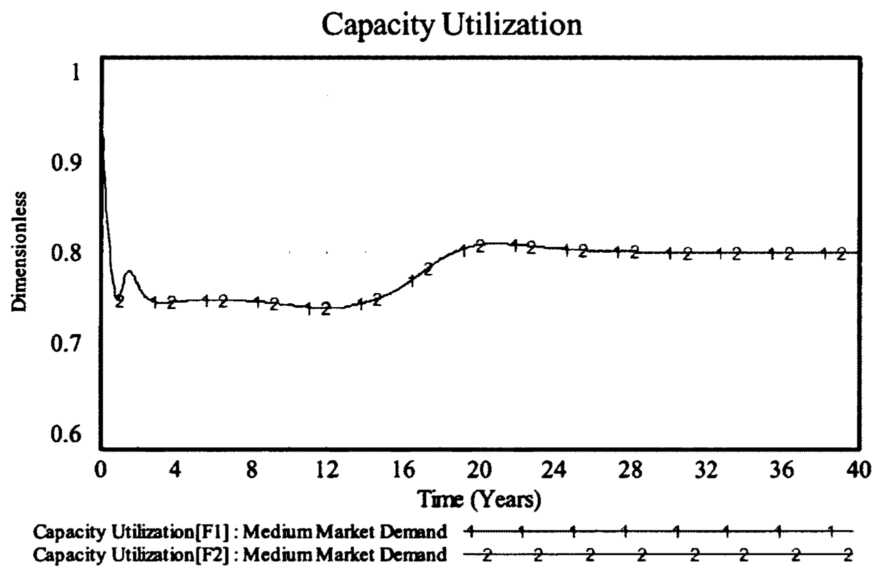


Figure 34 Capacity utilization for firm F1 and F2 in the base case

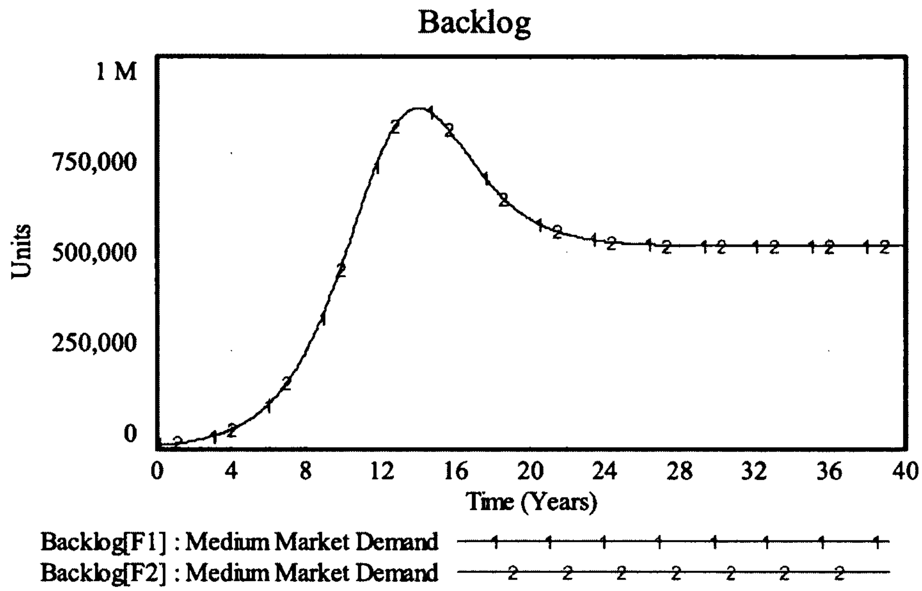


Figure 35 Backlog for firm F1 and F2 in the base case

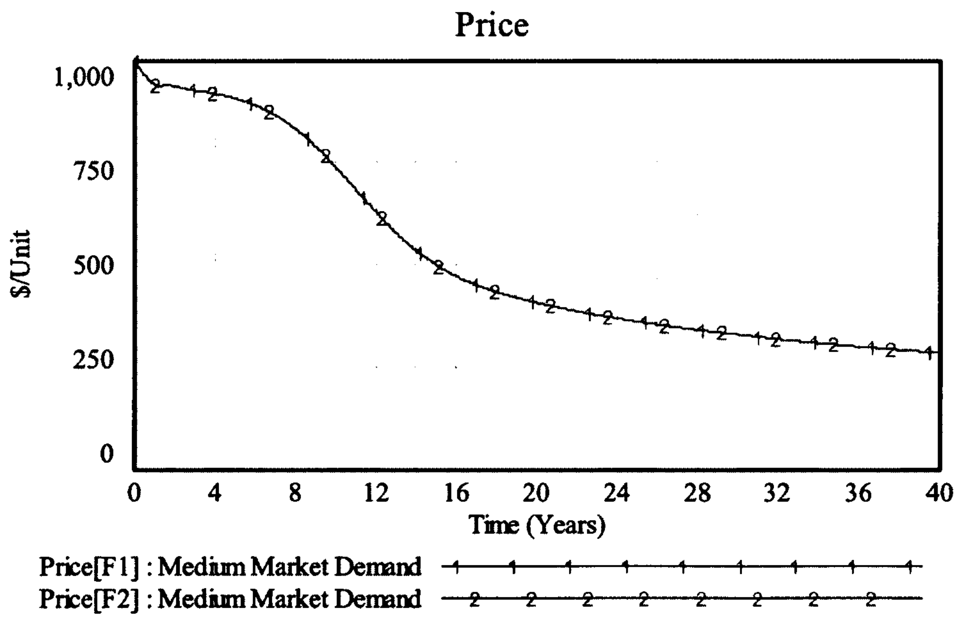


Figure 36 Product Price for firm F1 and F2 in the base case

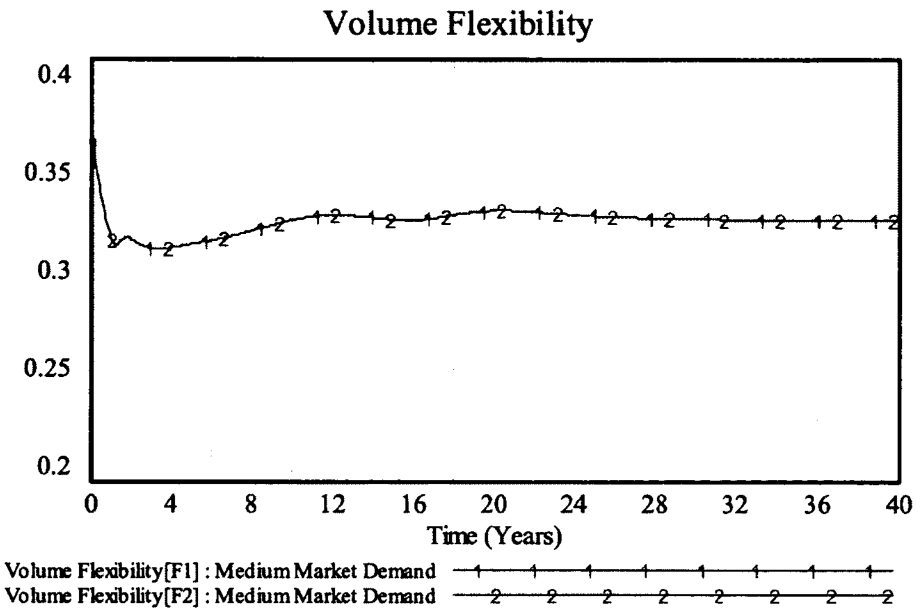


Figure 37 Volume flexibility for firm F1 and F2 in the base case

The above figures shows that the initial conditions for the both firm F1 and F2 are similar in the base case analysis. The variables vary based on changes that occur in the market due to changes in the installed base that follows the typical product life cycle shape. During this Process, prices lowers over time as the market reach its saturation levels due to reduction in cost gained from learning by doing and this affect the evolution of customer preferences over time although competition were assumed to act similarly all the time by assuming the same market share for both.

4.3.1. <u>Lower Initial prices</u>

To test the assumption that the competitive advantage is competitive when it is unique to the company and matches with the market requirements. Firm F1 is assumed to lower its initial prices by 10% than firm F2 to respond to the market segment that focuses on prices as a base for its product adoption decision. The market share and volume flexibility for both firms in this case are shown in Figure 38 and Figure 39 respectively.

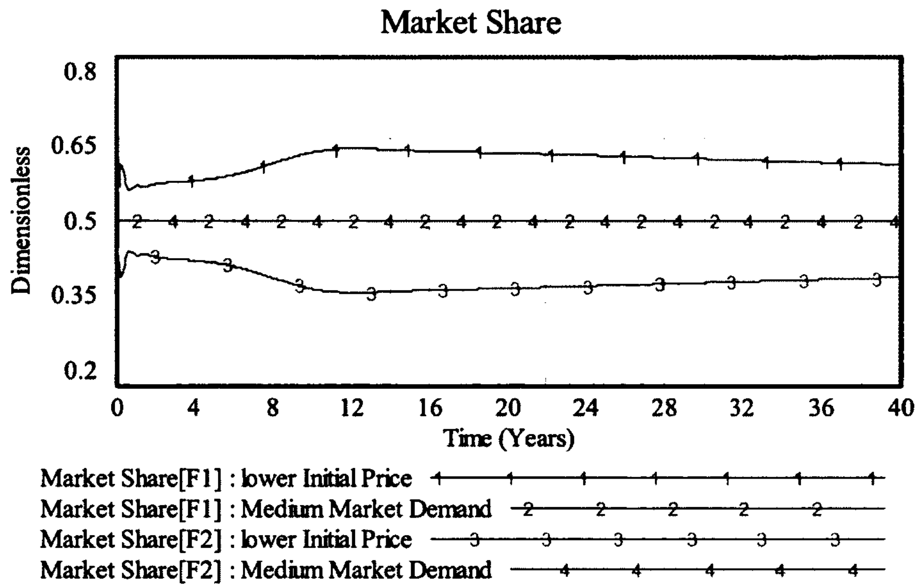


Figure 38 Market share for firm F1 and F2 with lower prices scenario

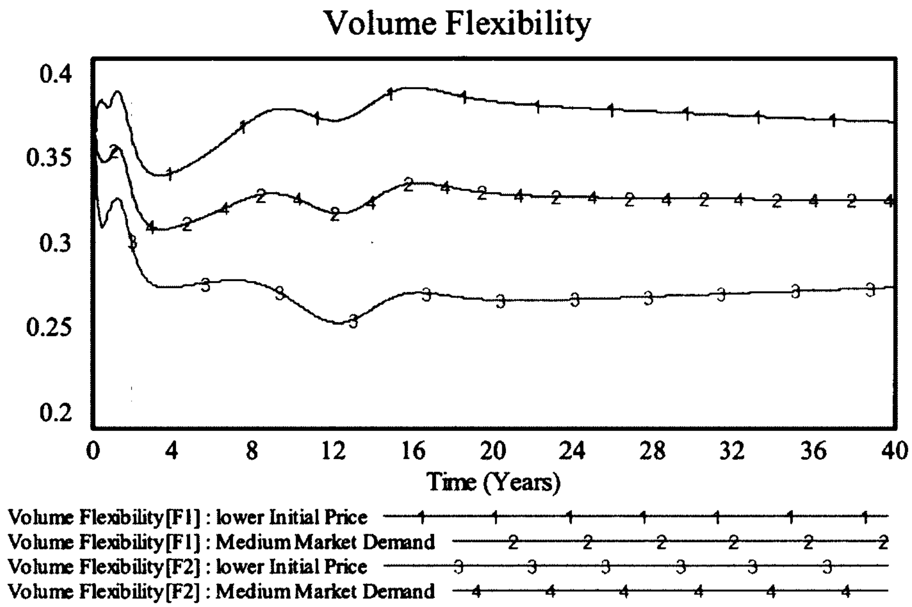


Figure 39 The relative importance of volume flexibility with lower prices

As shown from the results, when firm F1 lowered its initial price by 10 %, this generated a higher market share as a result of capturing the market segment attracted to price. The volume flexibility relative importance increased for firm F1 as well although there were no physical changes in the production capacity. This suggests that the volume flexibility capability is affected in relative to the market conditions and its effectiveness differs based on simultaneous actions from competition and how the market respond to these actions.

4.3.2. New Product Development

In this scenario firm F2 outperformed F1 in its prices and normal delivery delay. That resulted on a greater installed based that allowed firm F2 to get a higher market share. After 5 years of competition both firms launched the second version of its product in a trial to divert customers to its side. Customers followed the same rules of product price and availability attractiveness. While the same competitive advantage levels for both firms remains, the installed base for the second version of the product kept firm F2 leading the market as shown in Figure 40.

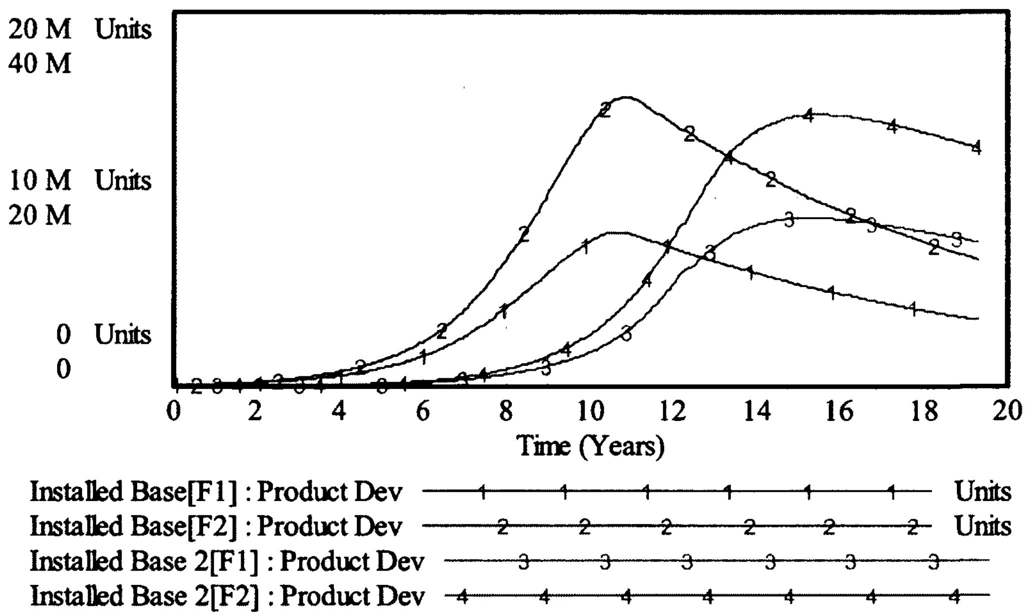


Figure 40 New Product Development for firm F1 and F2

It is noted from the above results, the adoption pattern for the product life cycle followed the typical known S-curve shape for product life cycle.

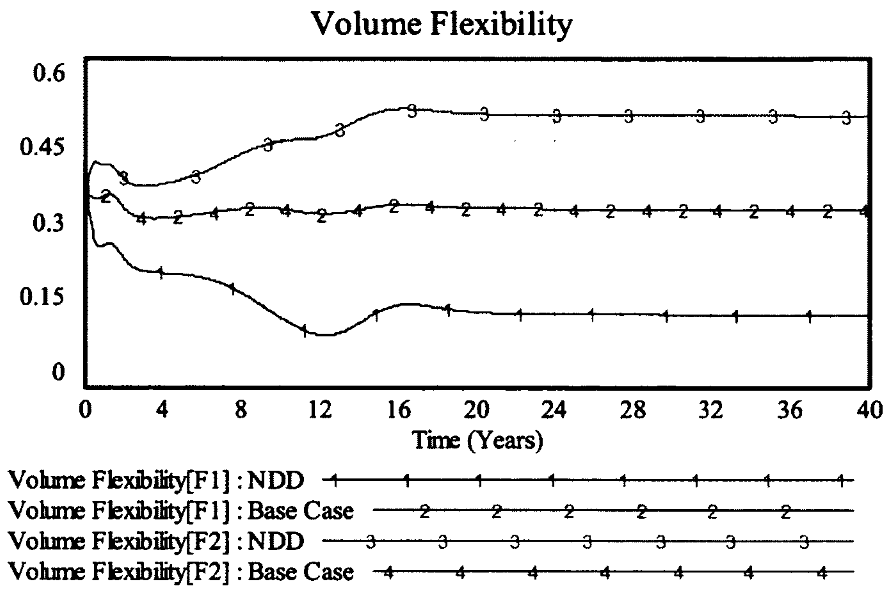
4.4. Strategic Flexibility Simulation Results

A firm can adapt its resource base to environmental change within the industry through its strategic flexibility capability. In this sense flexibility is critically important, because the firm capability to transform itself is essential for sustained growth and economic profitability in competitive environment. In this section, comparative results from various simulation experiments conducted to investigate the impact of volume flexibility on the firm's performance are reported to confirm the above assumption. The market share % is selected in this analysis as the main performance indicator that can offer insight into decisions concerning infrastructural and irreversible actions such as capacity expansion, strategic alliance, and intensive labour training.

To explore the behaviour of enterprise strategic flexibility as a capability (Arafa and ElMaraghy 2011a) developed, analyzed and compared three scenarios. The learning effect, the order fulfillment capability, and the outsourcing performance are the major three themes of competition between firm F1 and F2 in the following three scenarios. Each scenario will be conducted separately to highlight the significance of the assumption that caused performance difference. Then the three scenarios will be compared together to conclude the relative importance of the strategic actions taken by the enterprise in relative to each other.

4.4.1. Order Fulfilment Competition

The first scenario shows the effect of volume flexibility due to differences in order fulfillment responsiveness and its impact on market share. The differences in achieving the industry order fulfillment benchmark is captured by the normal delivery delay (NDD). The second firm F2 outperformed F1 in the order fulfillment responsiveness by 25%, which is one month earlier than the assumed average normal delivery delay benchmark in this scenario (4 month) as shown in Figure 41. Results shows that the capability of 25 % faster in order responsiveness resulted in more than 25% higher market share for F2.



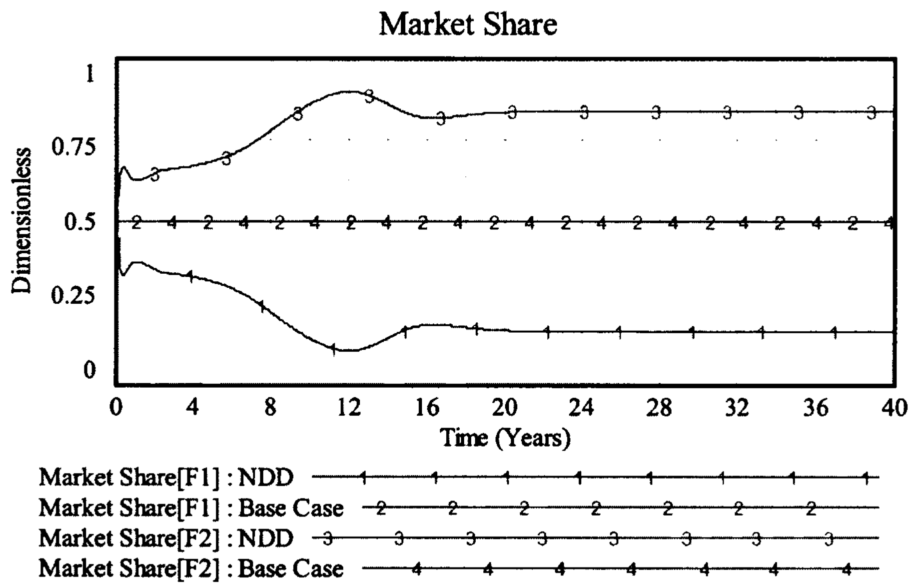


Figure 41 Firm F2 outperforms F1 in order fulfilment (40 Years).

Figure 42 show the same results for 5 years time horizon.

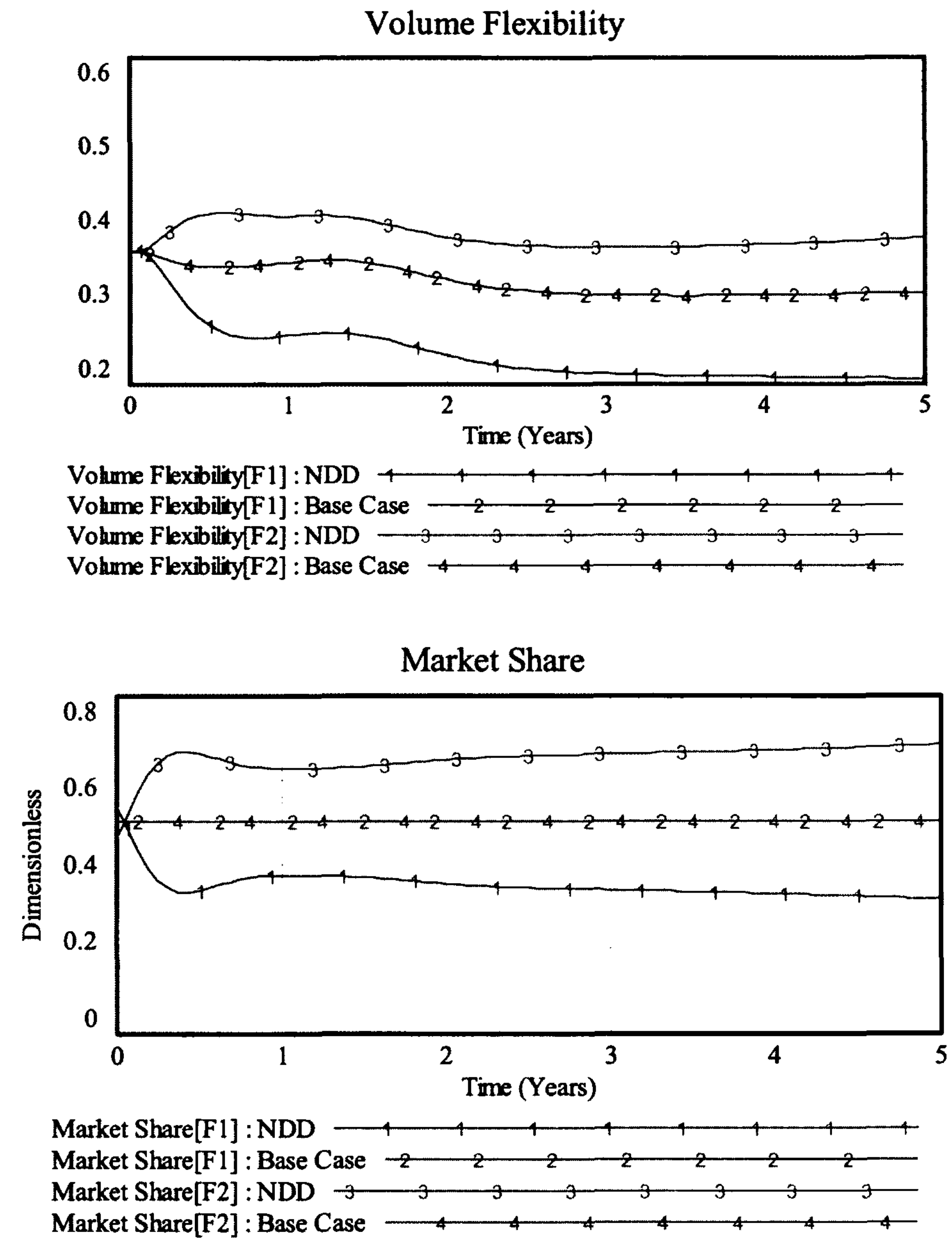


Figure 42 Firm F2 outperforms F1 in order fulfilment (5 Years).

4.4.2. Outsourcing Performance Competition

The second analysis explores the case where firm F2 responds to the backlog accumulation by outsourcing 3 months earlier than firm F1, which represents 25 % better performance in this case. Outsourcing delay (OD), causes differences in volume flexibility and market share that favour firm F2 as shown in Figure 43.

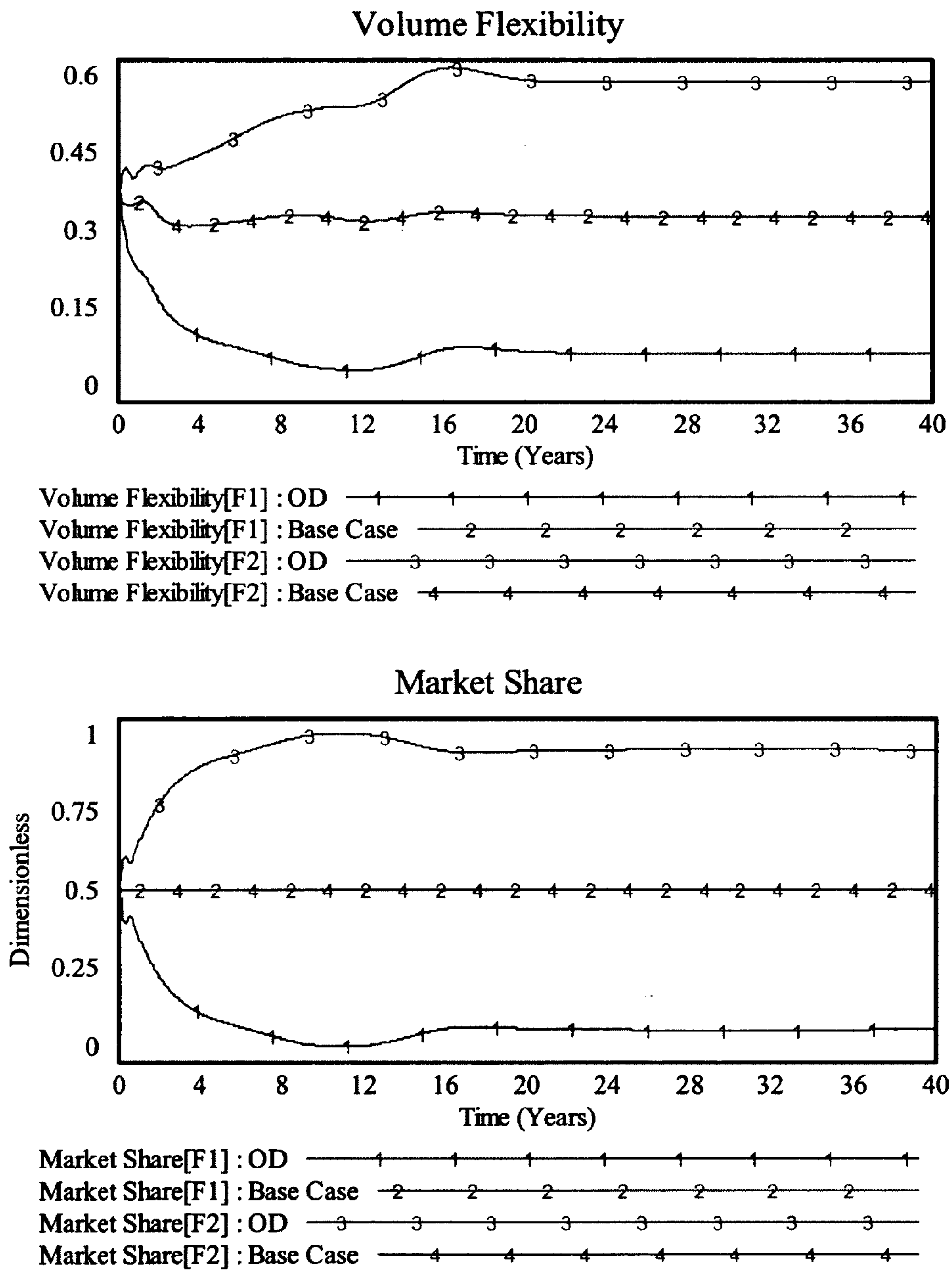
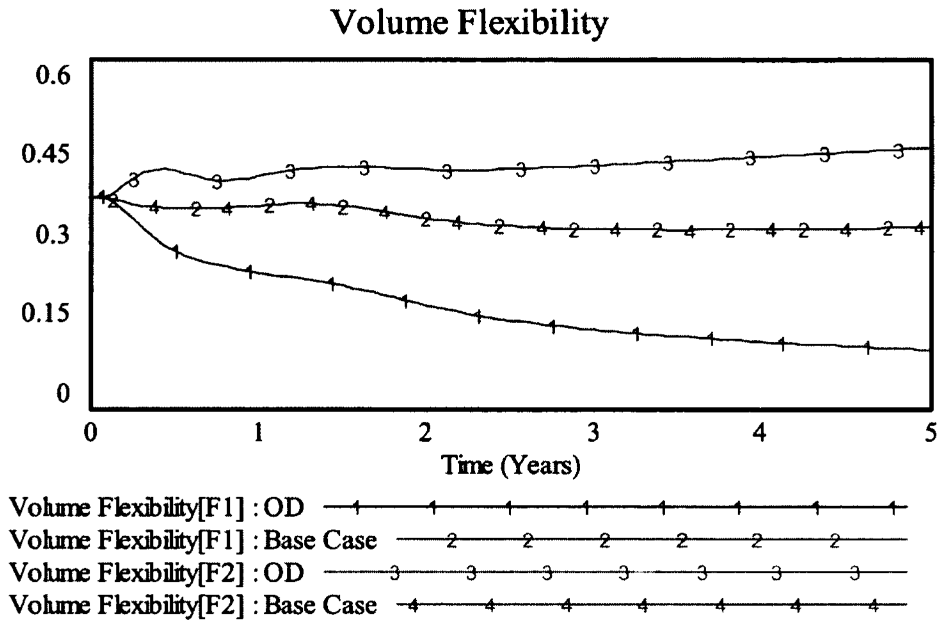


Figure 43 Firm F2 outperforms F1 in outsourcing (40 Years).

Figure 44 shows the same results for 5 years time horizon.



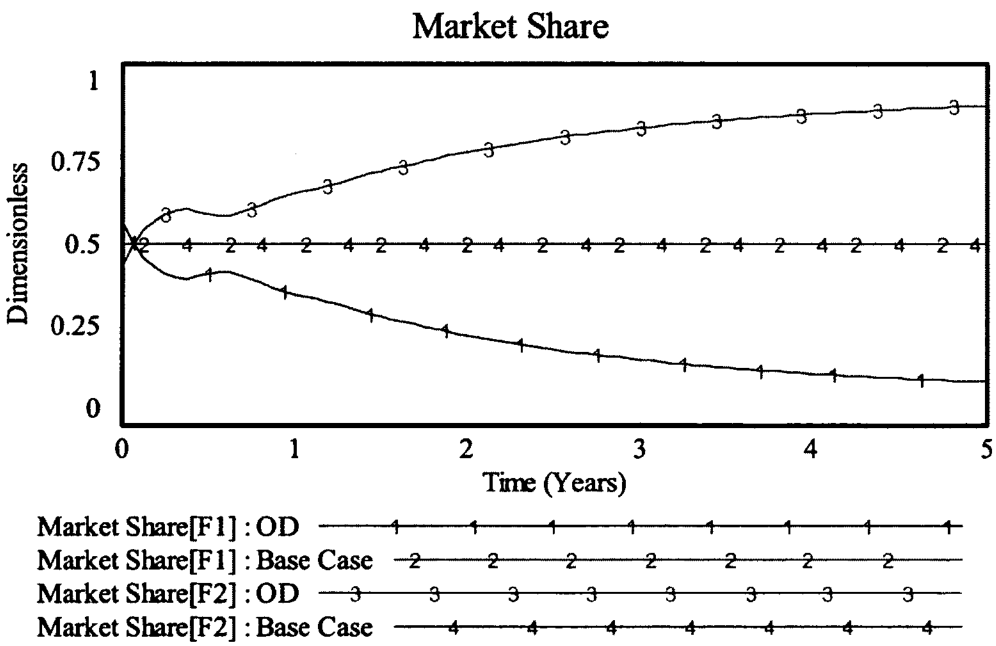


Figure 44 Firm F2 outperforms F1 in outsourcing (5 Years).

4.4.3. Learning Effect Competition

As suggested by the resource base view (Barney 1991), there are differences in the resource options available to the firm during the implementation of capability as competitive advantage. To test this assumption over the volume flexibility capability, the following scenario assumes changes in the learning effect of the organization. The third analysis explores the case where firm F2 focuses on labour training that affects both variable and fixed costs for the product more than firm F1.

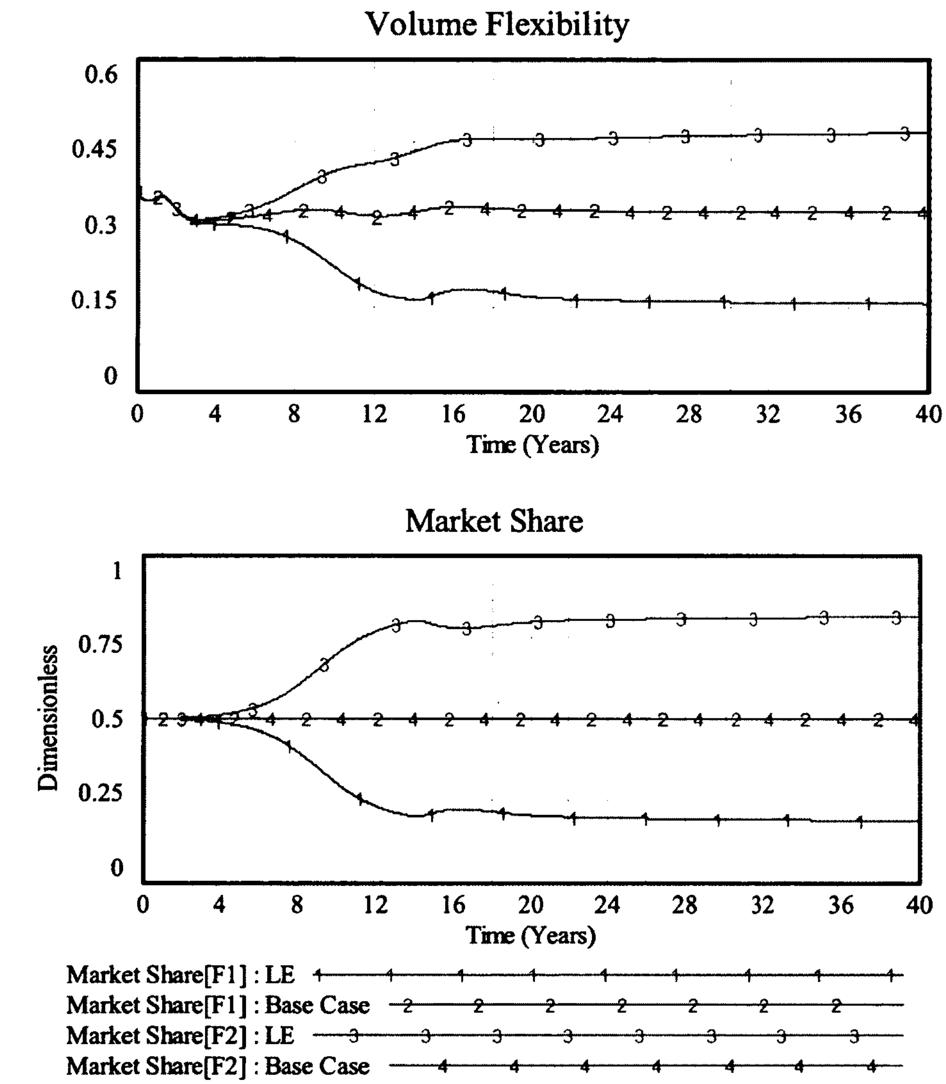
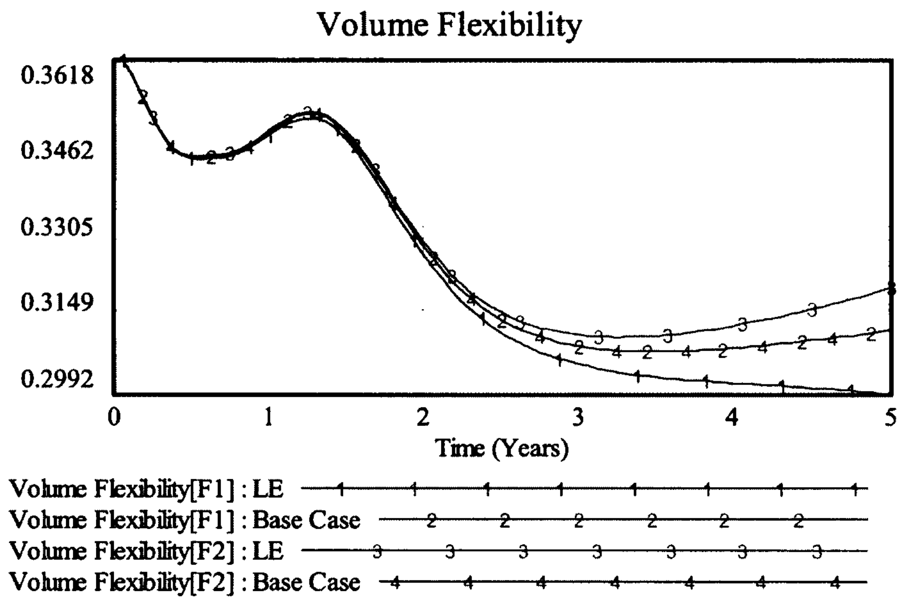


Figure 45 Firm F2 outperforms F1 in learning effect (40 Years).

The learning effect caused a decrease in the unit cost by 30% and 15% for F2 and F1 respectively after each production cycle (20,000 units). The learning effect was captured by changing the learning strength weights for F2 to outperform F1 by 25%. The market share performance for both firms is reported in Figure 45. The growth trajectories become a source of further organizational learning and "locked in" the organization development path. Figure 46 shows the same results for 5 years time horizon.



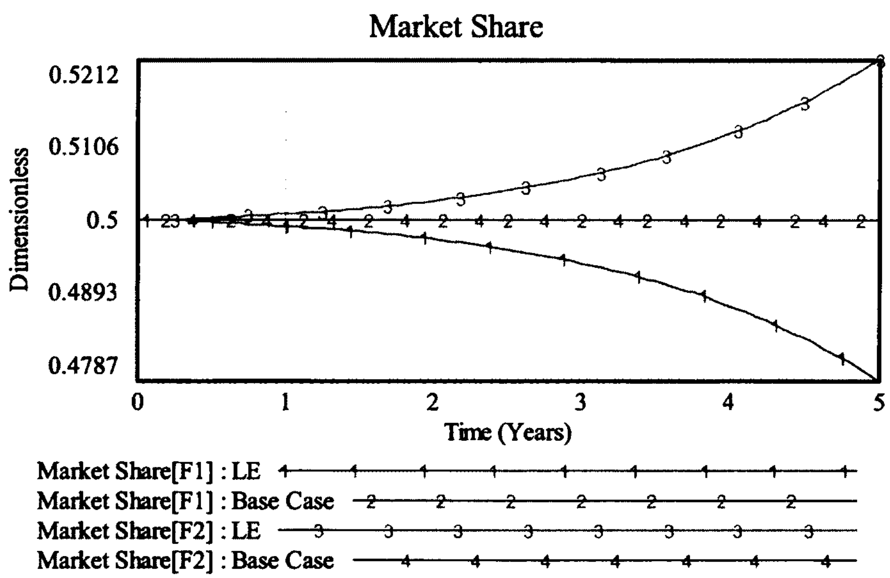


Figure 46 Firm F2 outperforms F1 in learning effect (5 Years).

4.4.4. Three Scenarios Comparison

By comparing all three scenarios representing the order fulfillment performance, the outsourcing and strategic alliances performance, and the learning curve performance together, as shown in Figure 47, the following observations are revealed.

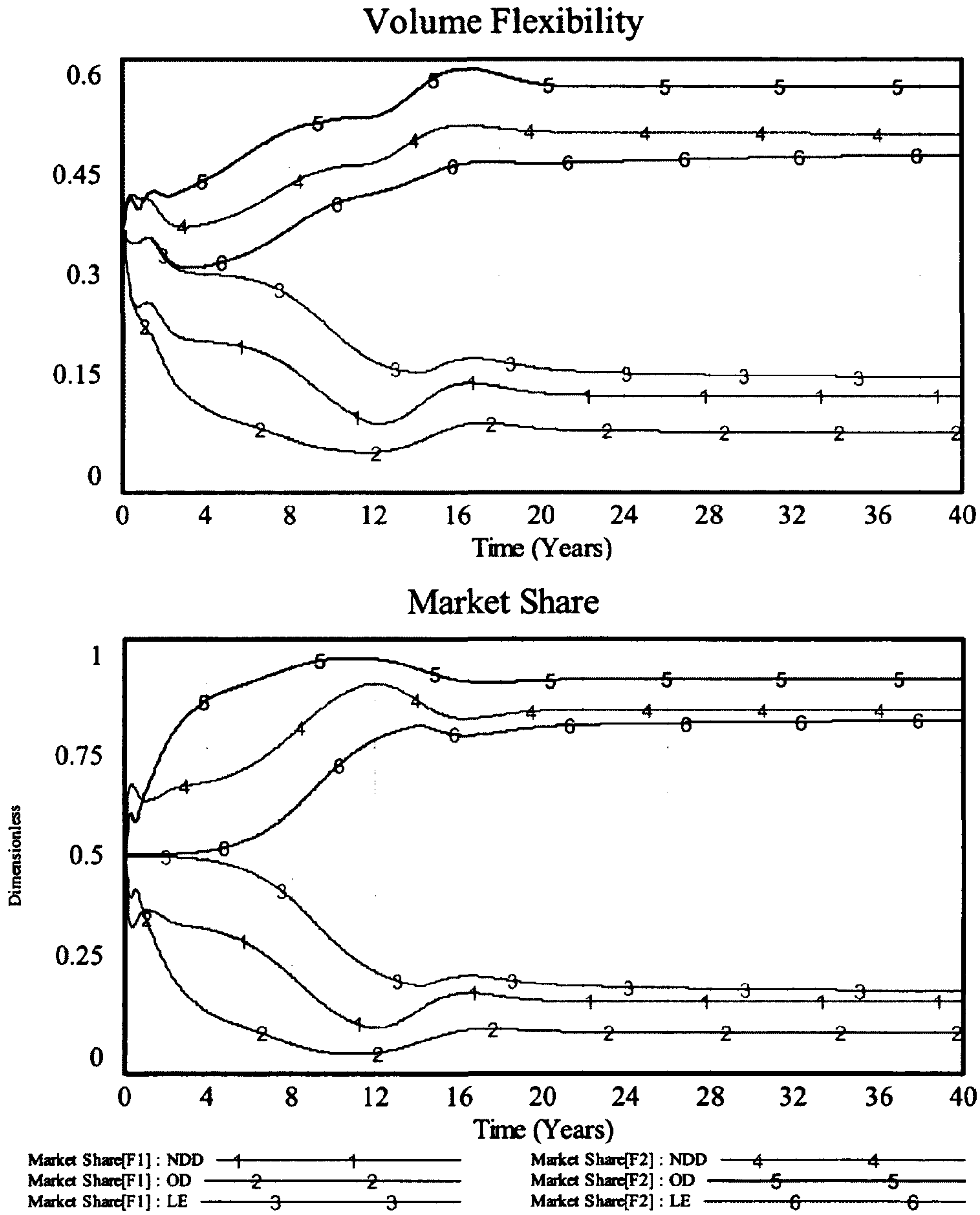


Figure 47 The Three scenarios comparison (40 Years).

Supply chain management practices, such as outsourcing and strategic alliances, lead to the greatest source of volume flexibility if compared to other internal sources of flexibility, such as order fulfillment performance or the learning curve's positive effect on fixed and variable unit costs. The Second best managerial practice for firms, in the presented market structure and scenarios, is to focus on achieving the normal delivery delay standards of the industry. Due to the exponential characteristic of the learning effect and its impact on business performance, the performance difference in market share is delayed for approximately 1 year, as shown in Figure 45. The three scenarios compared and zoomed over a 5 year time horizon for volume flexibility and market share is shown in Figure 48.

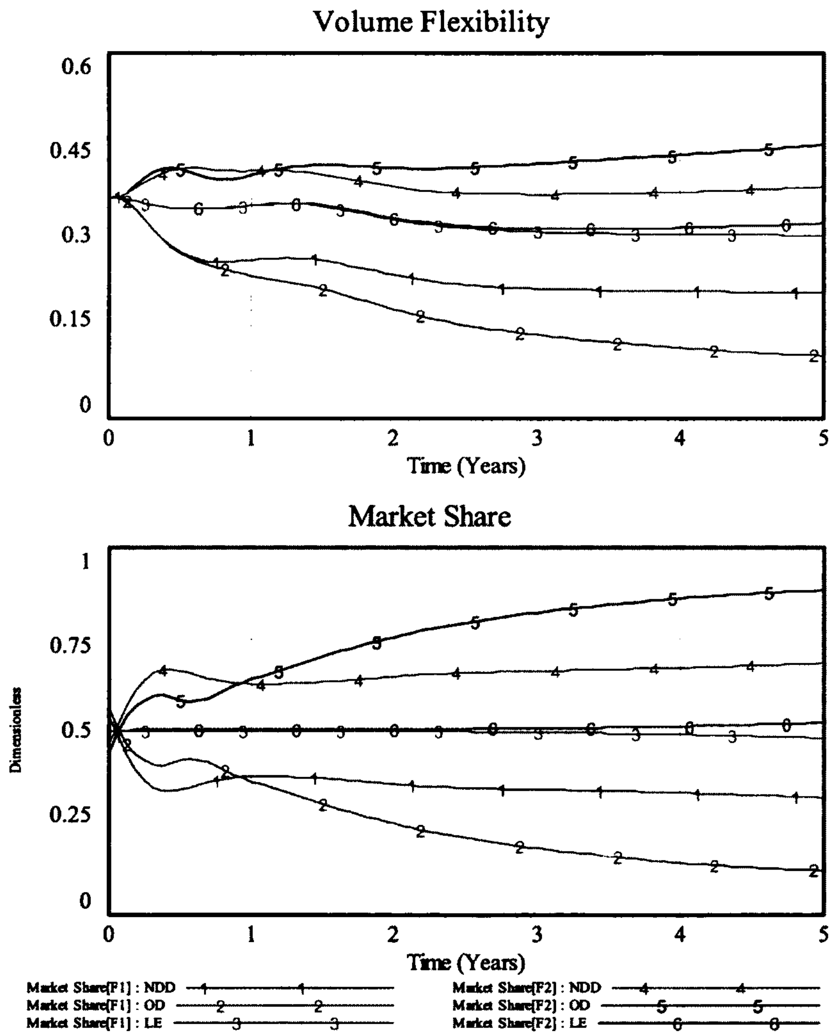


Figure 48 The Three scenarios comparison (5 Years).

4.5. External Environment Simulation Results

This section is focused to prove the hypotheses that any change in the external environment conditions may change the weights of the activated capability and accordingly will change the organization market position and the relative importance of its developed capability. First the same set of strategies adopted by the firm in the last case study, presented in section 4.4, will be explored but in different industry setup to test the robustness of this assumption as well. Then a change in the market weights will be introduced to the external environment by changing the weights of the attractiveness to product availability. As a result, this will cause changes in the adoption rate for potential adopters by valuating the product availability as a key factor to their decision making and hence will favour the enterprise that will focus to develop such capability. After that a comparison of the relative importance of the volume flexibility capability is conducted for the three assumed strategies; the learning effect capability, the order fulfillment capability and the outsourcing performance capability.

Due to the fact that various industries may operate at different speeds, the following scenario will also examine the effectiveness of outperforming the competition in volume flexibility in shorter industry cycle. The advancement in technology and the assumption that customer preference rate of change evolve over time as discussed earlier may affect the cycle time of the product life cycle. For instance, as in the mobile phones industry, the time horizon of this cycle may be limited to 2 years only. Also in this case the market population is assumed to be limited to 1 million customers. The product adoption rate follows medium market speed rate.

In the base case of this scenario, the adoption rate is assumed to be distributed over the 2 years period of the assumed cycle time as shown in Figure 49 so that the market saturate at the end of each cycle as shown in Figure 50 forming the regular S curve for product saturation.

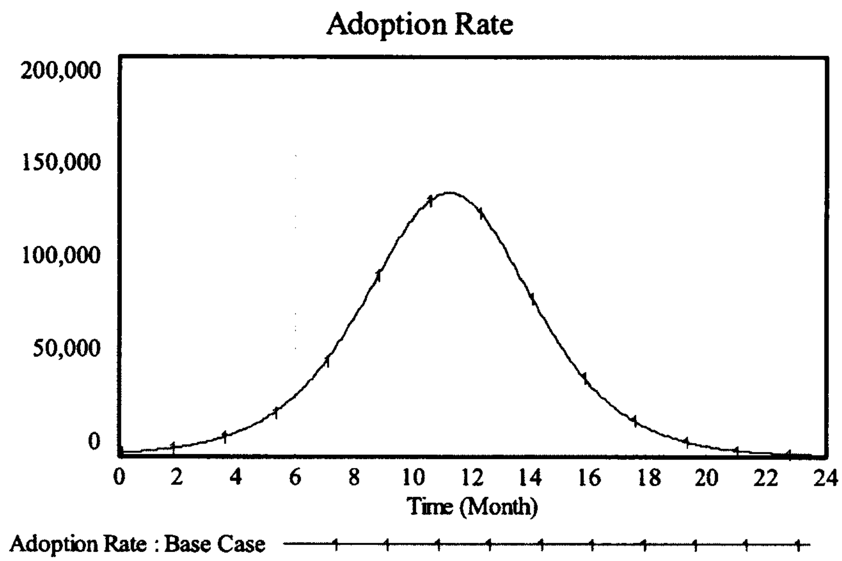


Figure 49 The adoption rate for the base case.

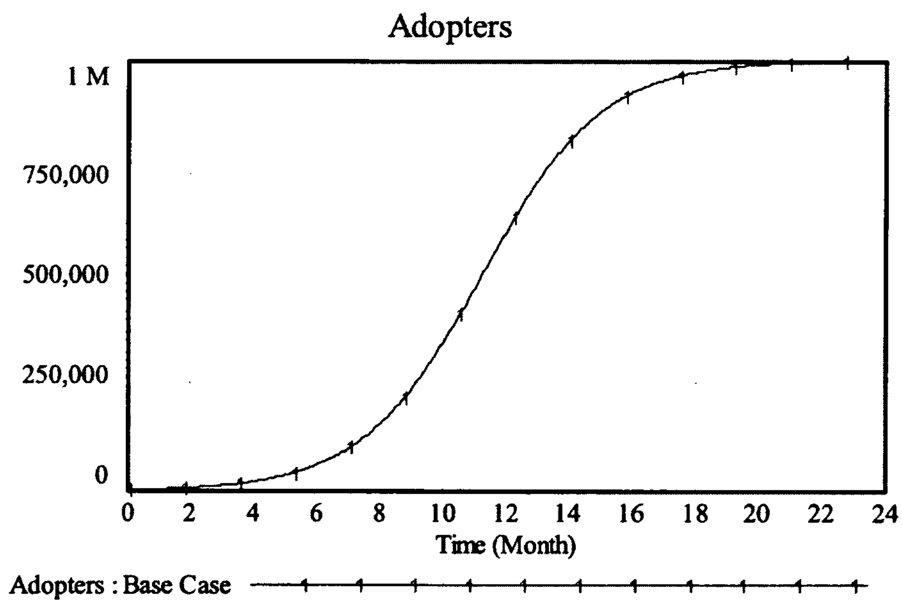


Figure 50 The accumulated adopters for the base case.

The initial conditions for firms F1 and F2 market share and volume flexibility capability in the base case are shown in Figure 51 and Figure 52 respectively.

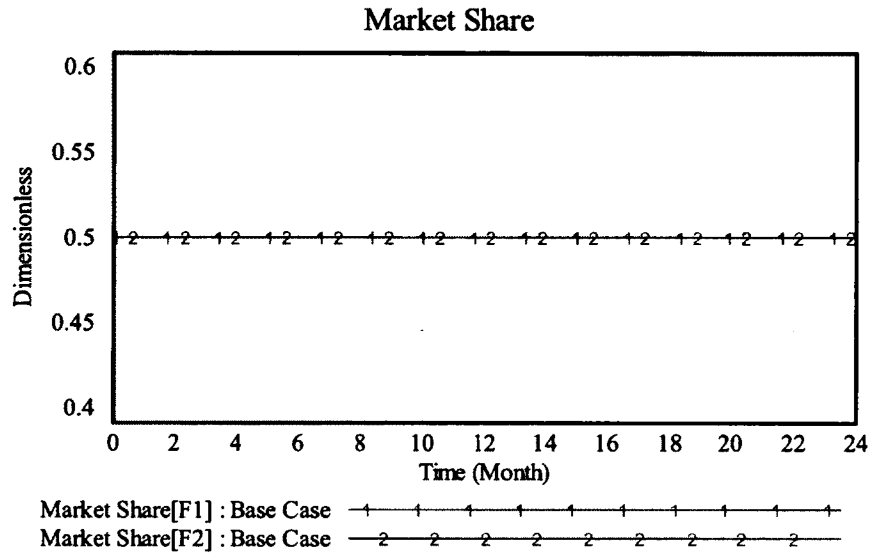


Figure 51 Firm F1 and F2 market share for the base case.

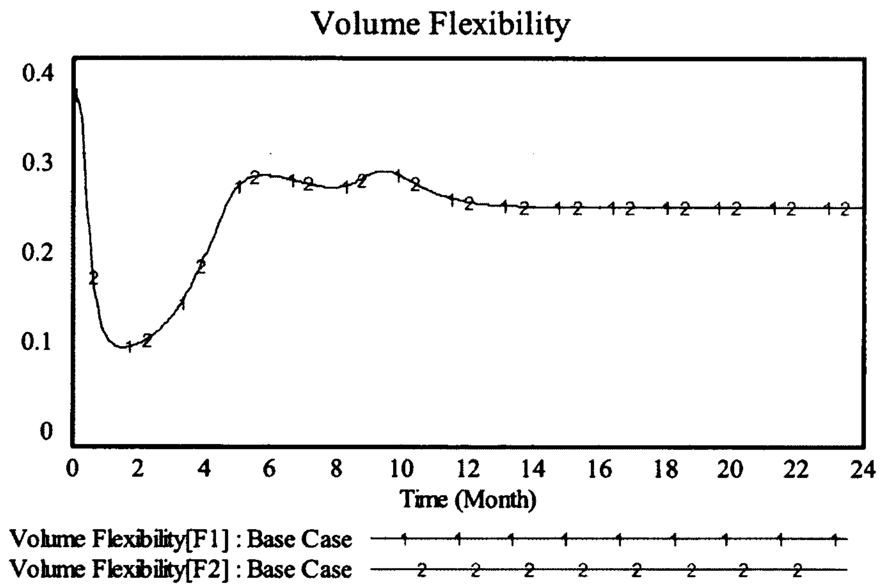


Figure 52 Firm F1 and F2 volume flexibility for the base case.

To explore the effect of selecting the following three strategies on volume flexibility and market share in a short cycle industry setup, the competition between the two firms will select one strategy at a time:

- The learning effect
- The order fulfilment capability
- The outsourcing performance

4.5.1. The Learning Effect

The following scenario assume changes in the learning effect of the organization where firm F2 focuses on labour training that affects both variable and fixed costs for the product more than firm F1. Due to the shorter cycle in this industry setup, the learning difference between the two firms is limited to 10% only. Results in Figure 53 and Figure 54 representing the volume flexibility and the market share respectively shows that the effect of using such strategy is very limited in industries described by short product life cycle due to the limitation of time and market population, i.e. the production experience accumulation cannot pay off in such short setup.

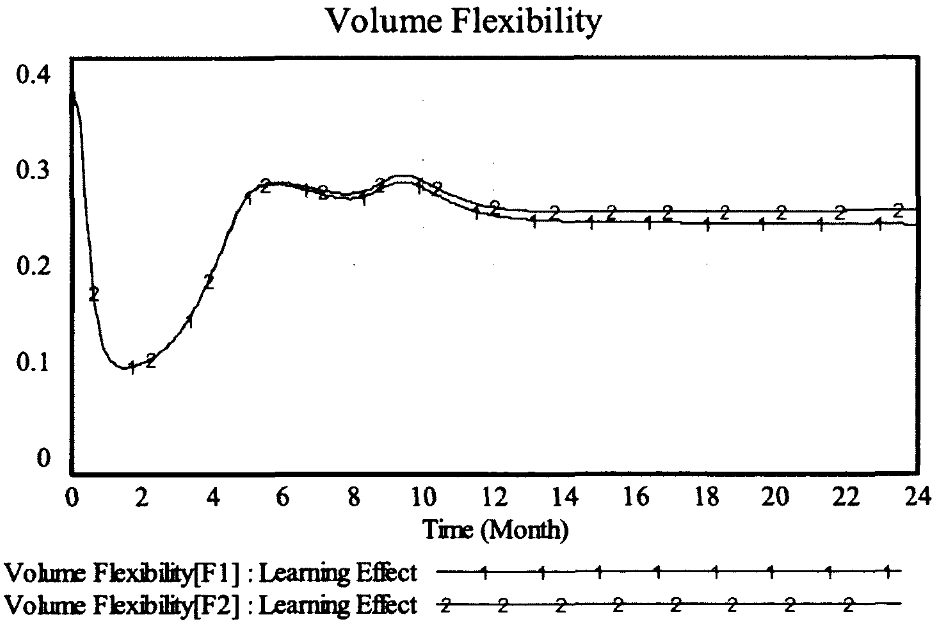


Figure 53 The effect of organization learning curve on volume flexibility

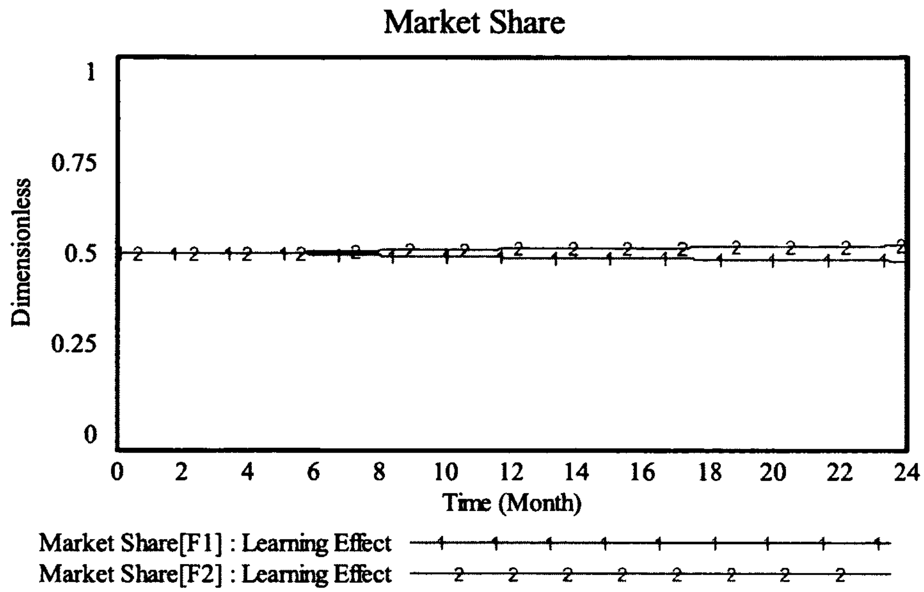


Figure 54 Market share due to change in the organization learning curve

4.5.2. Order Fulfillment Capability

Firm F2 is assumed to outperform F1 in the order fulfillment responsiveness by 50%, which is two weeks earlier than the assumed average normal delivery delay benchmark in this scenario (1 month). Results shows that the capability of 50 % faster in order responsiveness resulted in average 10% higher market share for F2 when market stabilize. Both volume flexibility and market share for firm F1 and F2 are shown in Figure 55 and Figure 56 respectively.

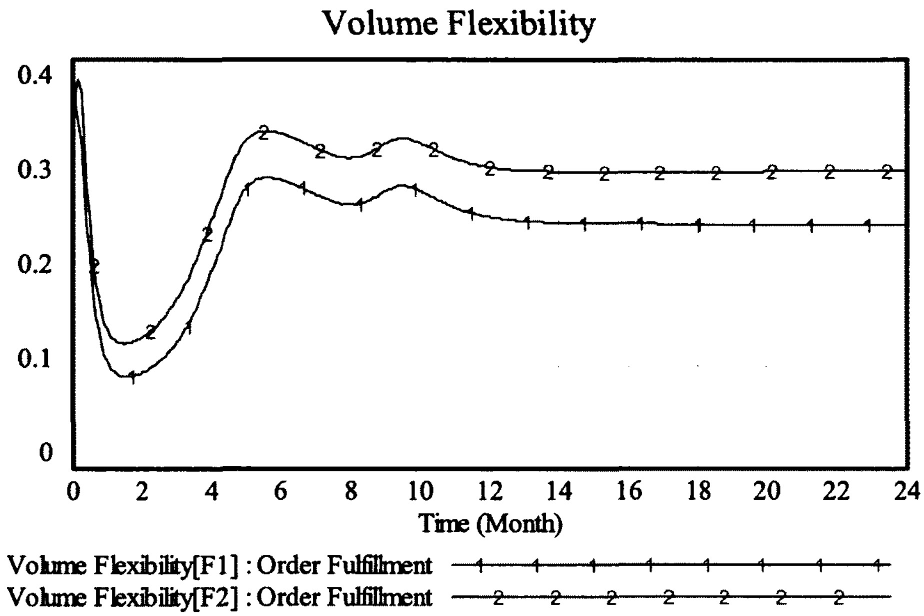


Figure 55 The effect of order fulfillment capability on volume flexibility

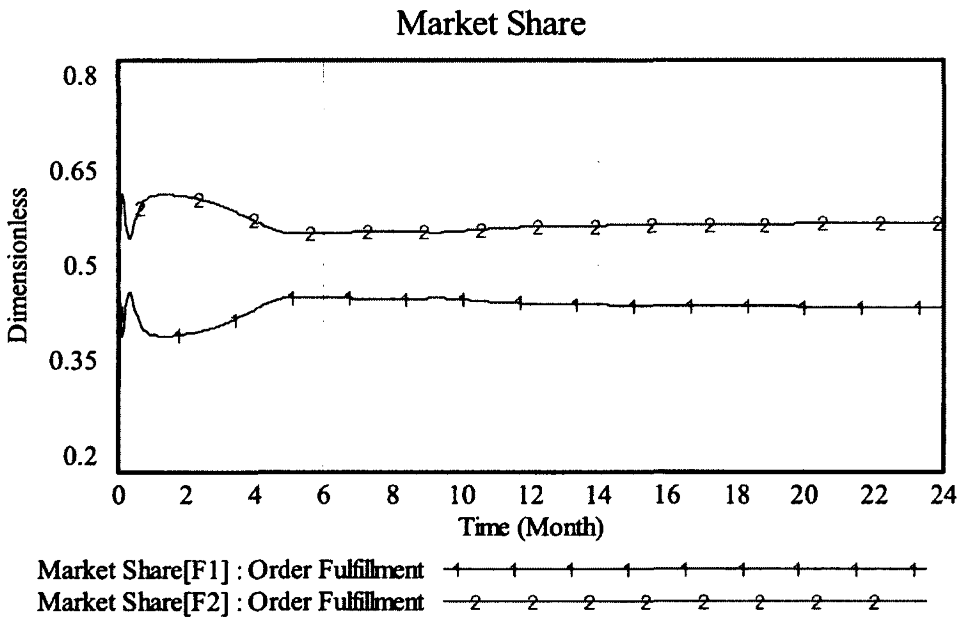


Figure 56 Market share due to change in order fulfillment capability

To show the effect of the relative importance of the developed capability with the external environment in this scenario, the attractiveness to availability is adjusted to zero in one case (Zero Attractiveness), meaning that it has no effect on attracting customers, and to 50% higher than the normal values in the second case (50% Attractiveness), meaning that customers are attracted to prices rather than any other factor. The effect on market share for both cases is shown in Figure 57.

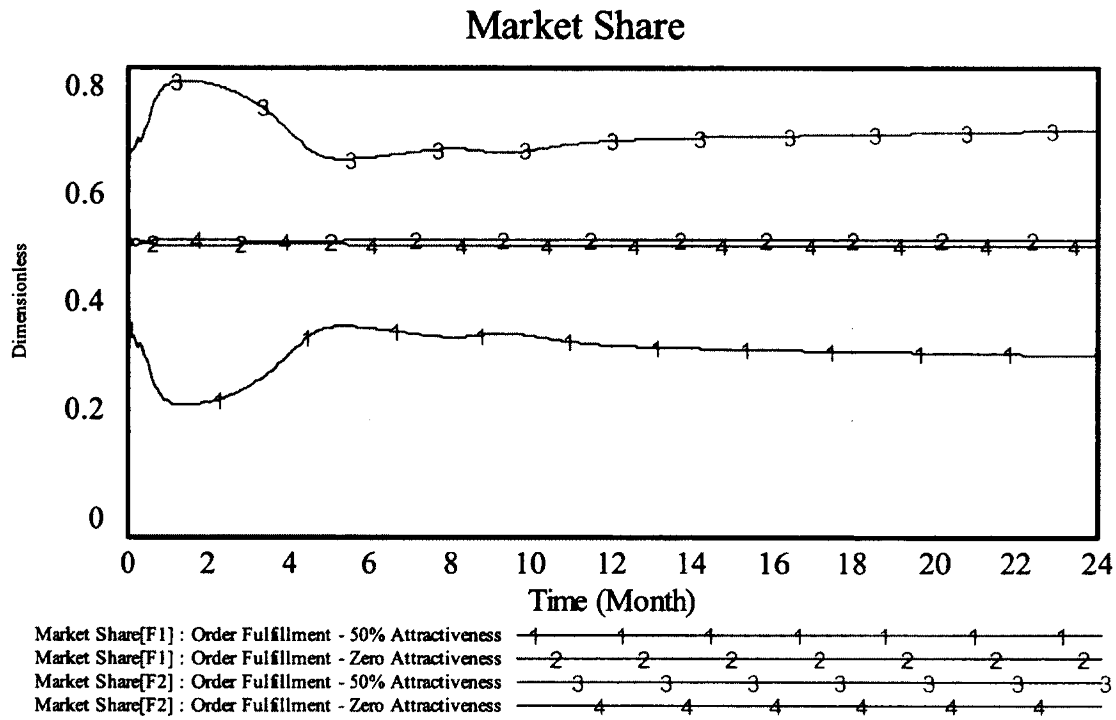


Figure 57 The relative importance of product availability capability

Although the order fulfillment capability for firm F2 remained physically unchanged (50% better deliver performance than the average normal deliver delay of the industry), yet the value and effect of this capability affected its market share differently when the customers valuated the availability of the product differently. This confirms the value theory of the dynamic capability as discussed in section 2.7 and confirms the hypotheses that any change in the external environment conditions may change the weights of the activated capability and accordingly will change the organization market position and the relative importance of its developed capability.

4.5.3. Outsourcing Performance

This analysis explores the case where firm F2 responds to the backlog accumulation by outsourcing 2 weeks earlier than firm F1, which represents 25 % better performance in this case. In fast markets with short product life cycles, outsourcing delay did not show a significance change in both the volume flexibility capability and the market share as shown in Figure 58 and Figure 59 respectively.

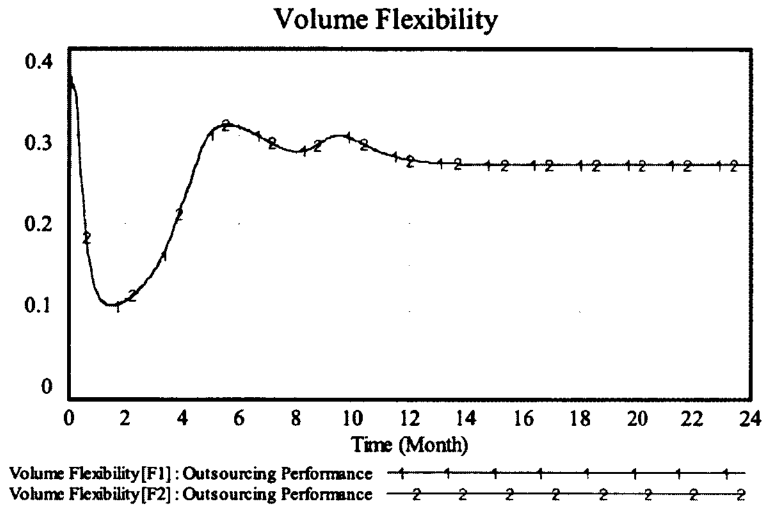


Figure 58 The effect of outsourcing performance on volume flexibility

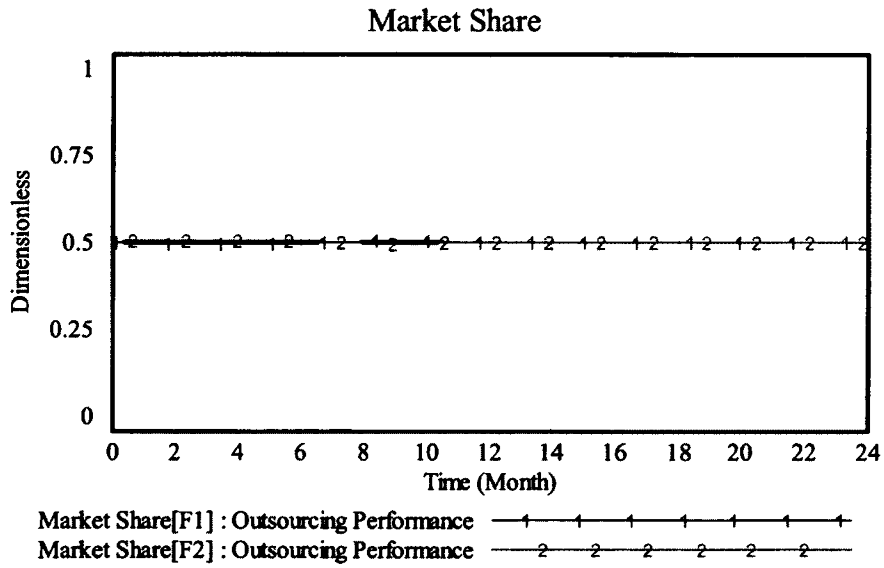


Figure 59 Market share due to change in outsourcing capability

Although market changes wasn't considered significant, yet it would be interesting to see the dynamics of change during this scenario. Market share for both firms with a zoom to the values shown earlier is shown in Figure 60. The limited change is due to both the limited size of market population and the relatively higher production capacity for both firms in this case.

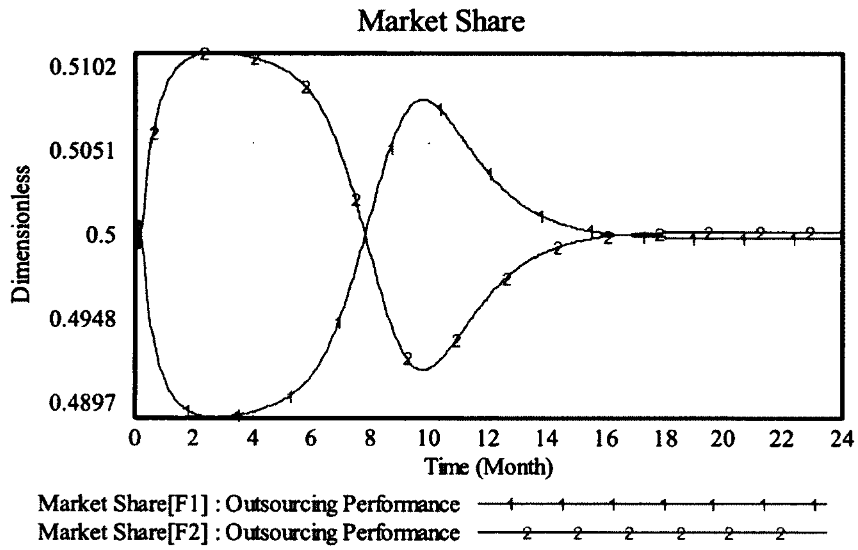


Figure 60 Market share for firm F1 and F2 (with vertical zoom)

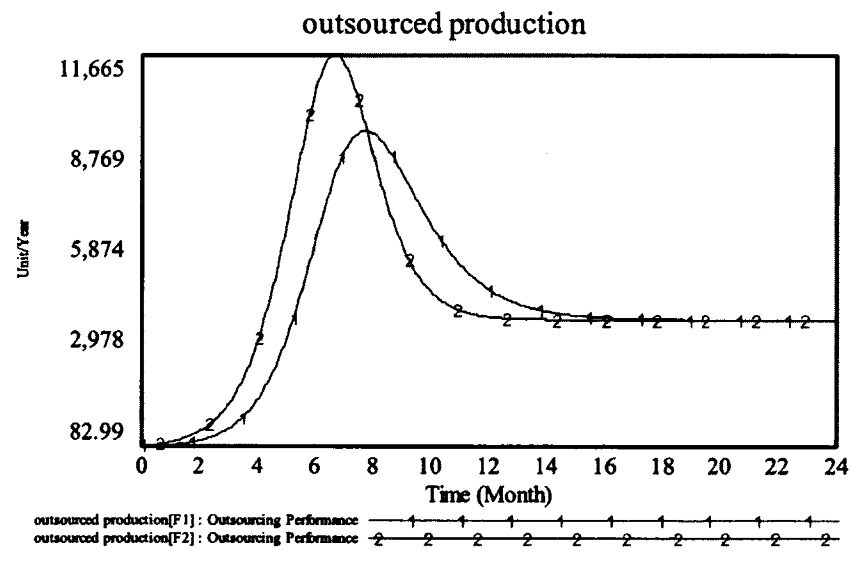


Figure 61 Outsourced production for firm F1 and F2

It should be noted that the return of investment construct a minimum production scale and that is why the backlog for both firms was limited. As a result both firms have a backlog that did not reached more than 10,000 units on its peak. Also due to the fact that the market is described as a fast market, the difference in outsourcing decisions is relatively close to each other (2 weeks). The outsourced production and market share for both firms with a zoom to the values shown earlier are shown in Figure 61.

4.5.4. Results Comparison

The comparison of the three scenarios as shown in Figure 62 shows that the winning strategy in this case is due to focusing on order fulfillment capability according to the normal delivery delay benchmark of this industry. The fast product life cycle (2 years) in this industry setup highlighted the relative importance and the weight of fulfilling orders in a market that is described by short term opportunity rather than the gains that may be achieved due to cost saving practices resulted from the learning effect or even due to faster strategic alliance to respond to market fluctuation due to a limitation suggested by the return of investment and market population.

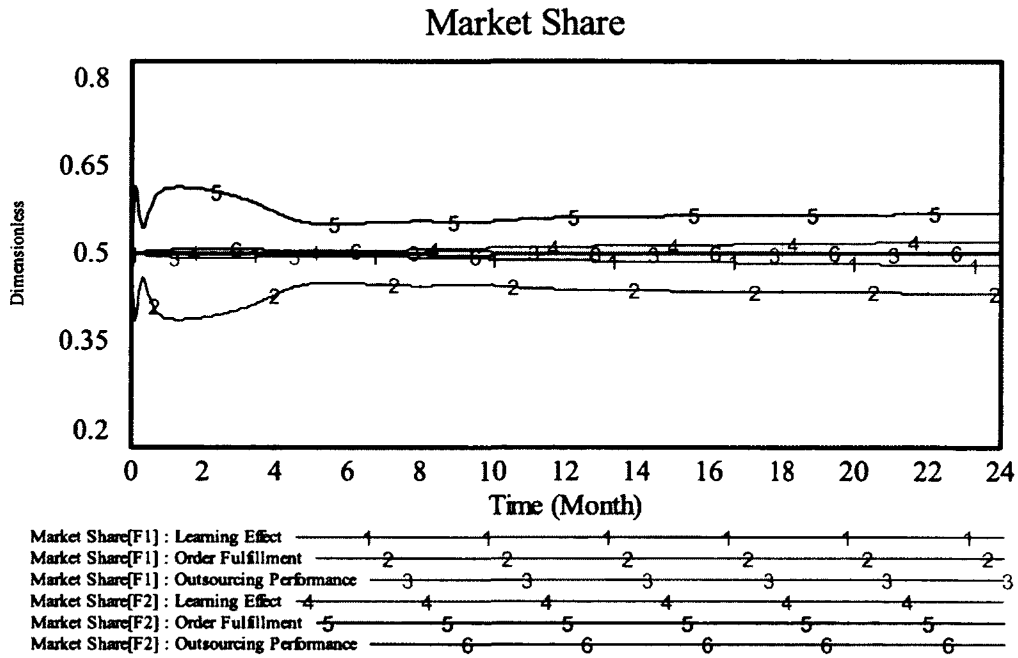


Figure 62 The market share for the 3 strategies

CHAPTER V

STRATEGIC FLEXIBILITY MODEL VALIDATION

5.1. Introduction

Model validation constitutes an important step in system dynamics methodology. Model validation may be defined as: "establishing confidence in the usefulness of a model with respect to its purpose" (Barlas 1994). This confidence building process is a gradual process starting with model conceptualization. Stages of the model building process are as follows:

1. Defining the purpose of the model
2. Identifying the model boundary
3. Identifying the key variables
4. Describing the behaviour of the key variables
5. Diagram the basic mechanisms of the system.

Although model validation does take place in every stage of modeling methodology, it is safe to state that a majority of formal validation is done after the initial model formulation and before the policy design step as illustrated in Figure 63. The validation is defined as the process of determining the simulation model based on an acceptably accurate representation of reality. Validation deals with the assessment of the comparison between 'sufficiently accurate' computational results from the simulation and the actual hypothetical data from the system (Martis 2006).

Following (Kleijnen 1995) in determining simulation accuracy, validation, verification and credibility were considered during different stage of model structuring.

- *Conceptual model validation:* the theories and assumptions underlying the conceptual model reasonably matched the intended purpose of the model discussed in section 4.2.
- *Model credibility:* by conducting a sensitivity analysis as will be discussed latter, the behaviour of the model output proved sufficient accuracy for the model's assumptions over the domain of the model's intended applicability; linking volume

flexibility to the decision making of the enterprise as a macro measure for long term strategic decisions.

- *Model verification*: by conducting extreme case analysis, as will be discussed latter, the model accurately represents the significance concluded through scenarios analysis.

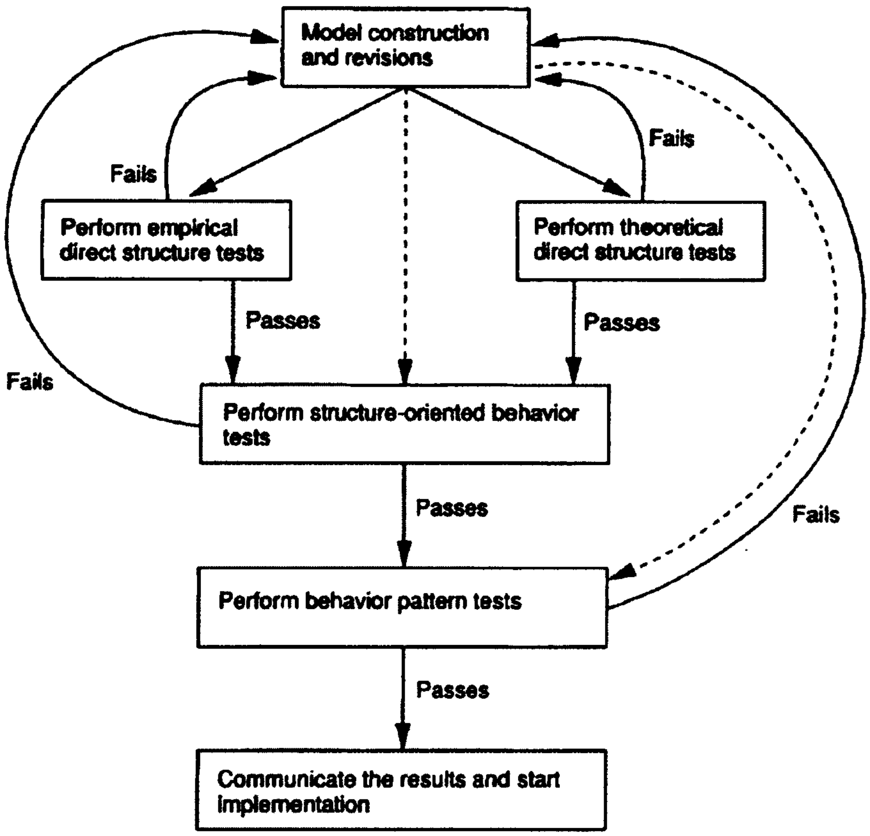


Figure 63 Logical sequence of model validation (Barlas 1994).

In system dynamics, the behaviour patterns of model variables are more important than their numerical values. For instance as in the case of introducing new product to the market, developing the S-shaped growth, the exact value of the variable at a specific time point may not important as much as the overall behaviour of the system. Instead, the specific characteristics of behaviour patterns, such as equilibrium levels, periods and amplitudes of oscillations make up the main interest. In conclusion, sensitivity analysis of system dynamics models should focus on the behaviour patterns' sensitivity to various model structures or different parameter values.

5.2. Monte Carlo Sensitivity Testing

Sensitivity testing is the process of changing the assumptions about the value of constants in the model and examining the resulting output. Manual sensitivity testing involves changing the value of a constant (or several constants at once) and simulating, then changing the value of the constant again and simulating again, and repeating this action many times to get a spread of output values.

Monte Carlo simulation (Mooney 1997) furnishes the decision-maker with a range of possible outcomes and the probabilities they will occur for any choice of action. It shows the extreme possibilities—the outcomes of going for broke and for the most conservative decision—along with all possible consequences for middle-of-the-road decisions. Monte Carlo simulation performs risk analysis by building models of possible results by substituting a range of values—a probability distribution—for any factor that has inherent uncertainty. It then calculates results over and over, each time using a different set of random values from the probability functions. Depending upon the number of uncertainties and the ranges specified for them, a Monte Carlo simulation could involve thousands or tens of thousands of recalculations before it is complete. Monte Carlo simulation produces distributions of possible outcome values.

Monte Carlo simulation, also known as multivariate sensitivity simulation (MVSS), makes this procedure automatic. Hundreds or even thousands of simulations can be performed, with constants sampled over a range of values, and output stored for later analysis. This study used Vensim software as a modeling tool. In this software package, Monte Carlo multivariate sensitivity works by sampling a set of numbers from within bounded domains. To perform one multivariate test, the distribution for each parameter specified is sampled, and the resulting values used in a simulation. Vensim also has the capability to do repeated simulations in which model parameters are changed for each simulation. This can be very helpful in understanding the behavioural boundaries of a model and testing the robustness of model-based policies to confirm the model credibility.

Uncertainty in Multiple Parameters

This analysis is focused for the three scenarios presented in section 4.4, known as outsourcing delay, learning effect and normal delivery delay. Since our research is focused towards the lags in capacity adjustment and its effect on volume flexibility as a capability, the capacity for both firms was selected to represent the validity of the model boundaries with major changes of the market adoption rate represented by the speed of the word of mouth. A multivariate test was conducted in this study.

The common effective parameters between in both the normal delivery delay and outsourcing delay scenarios share 5 constants that we can vary to examine their effect on simulation output. The exact values for two constants are assumed: price of item and revenue to sales (because these are policy decisions that managers can set). The uncertain parameters are production capacity, volume flexibility, and word of mouth. We will select these parameters and assign maximum and minimum values along with a random distribution over which to vary them to see their impact on model behaviour. Note that we could select only one parameter if we wanted to see how sensitive model behaviour is to one parameter but in our case the integrated dynamic behaviour of different variables is considered as more efficient in the cases presented.

The range for adoption rate and number of adaptors are presented in Figure 64 and Figure 65 respectively.

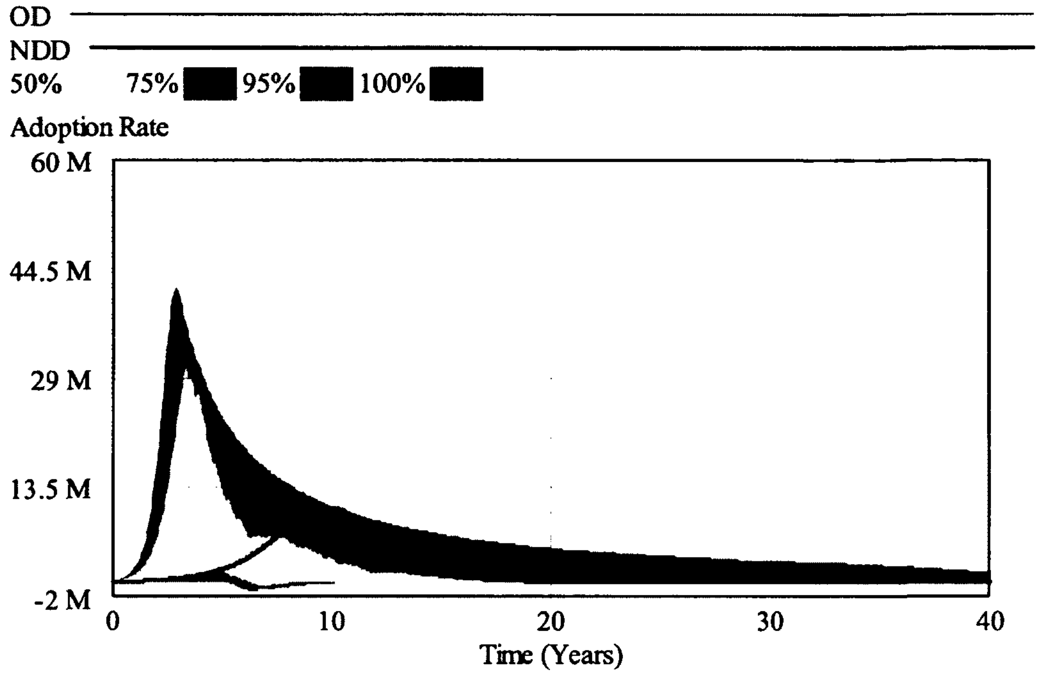


Figure 64 Adoption rate for the OD and NDD case scenarios.

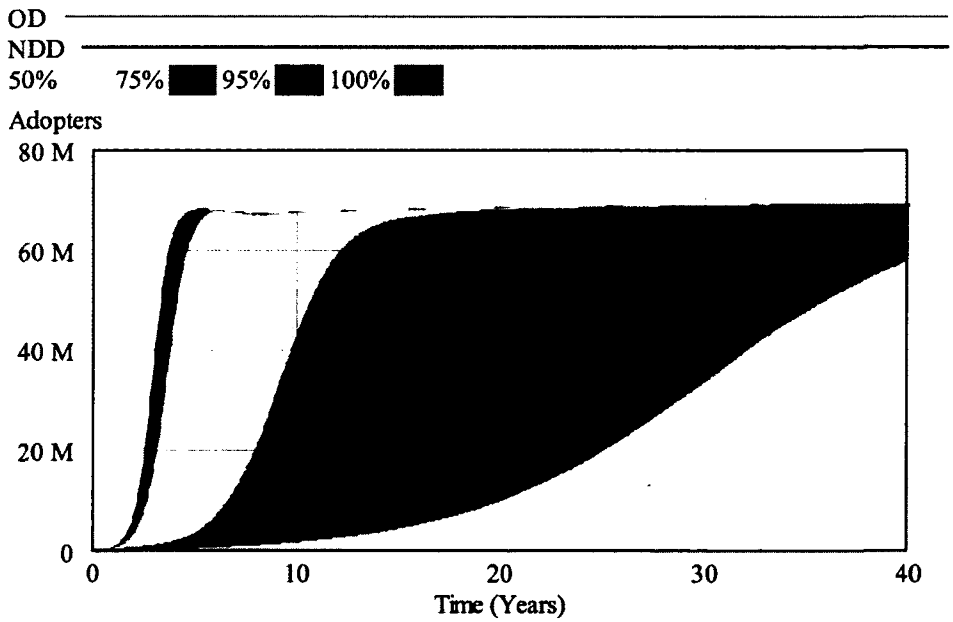


Figure 65 Adopters for the OD and NDD case scenarios.

The graph shows confidence bounds for all the output values of adoption rate that were generated when the three parameters were randomly varied about their distributions. The distribution for each parameter was specified as uniform distribution. The distribution function and range of the selected parameter ranged ± 40% of the parameter value. The resulting values used in a simulation were set to be repeated 500 times. The range of the word of mouth strength (WOM) started from 0.25 to 4. According to the

Accordingly the production capacity, volume flexibility, learning effect and outsourcing performance for both firm F1 and F2 shown in Figure 66 and Figure 67, shows that the selected scenarios are within the projected range of the 500 simulation performed in this test. The graph shows confidence bounds for all the output values that were generated when the selected parameters were randomly varied about their distributions range.

In the comparison between the learning effect, outsourcing delay and normal delivery delay, as mentioned before, the market speed is a central assumption to these scenarios that controls the output behaviour. Results are sensitive to the adoption rate of the market which in a sense represents the product life cycle speed. It is concluded that faster market scenarios, due to changes in the advertising strength or the strength of the market word of mouth (WOM) may change the sequence of effective strategic decisions. In our case, the training effect may overcome gains achieved from focusing on meeting the normal delivery delay benchmark of the industry. The analysis shows that faster accumulation of production experience in faster market scenarios may lead to more savings in production cost and therefore less prices and bigger market shares. Outperforming in outsourcing performance remains dominant strategy in the three presented scenarios even under fast market scenarios or short product life cycles shown in Figure 30.

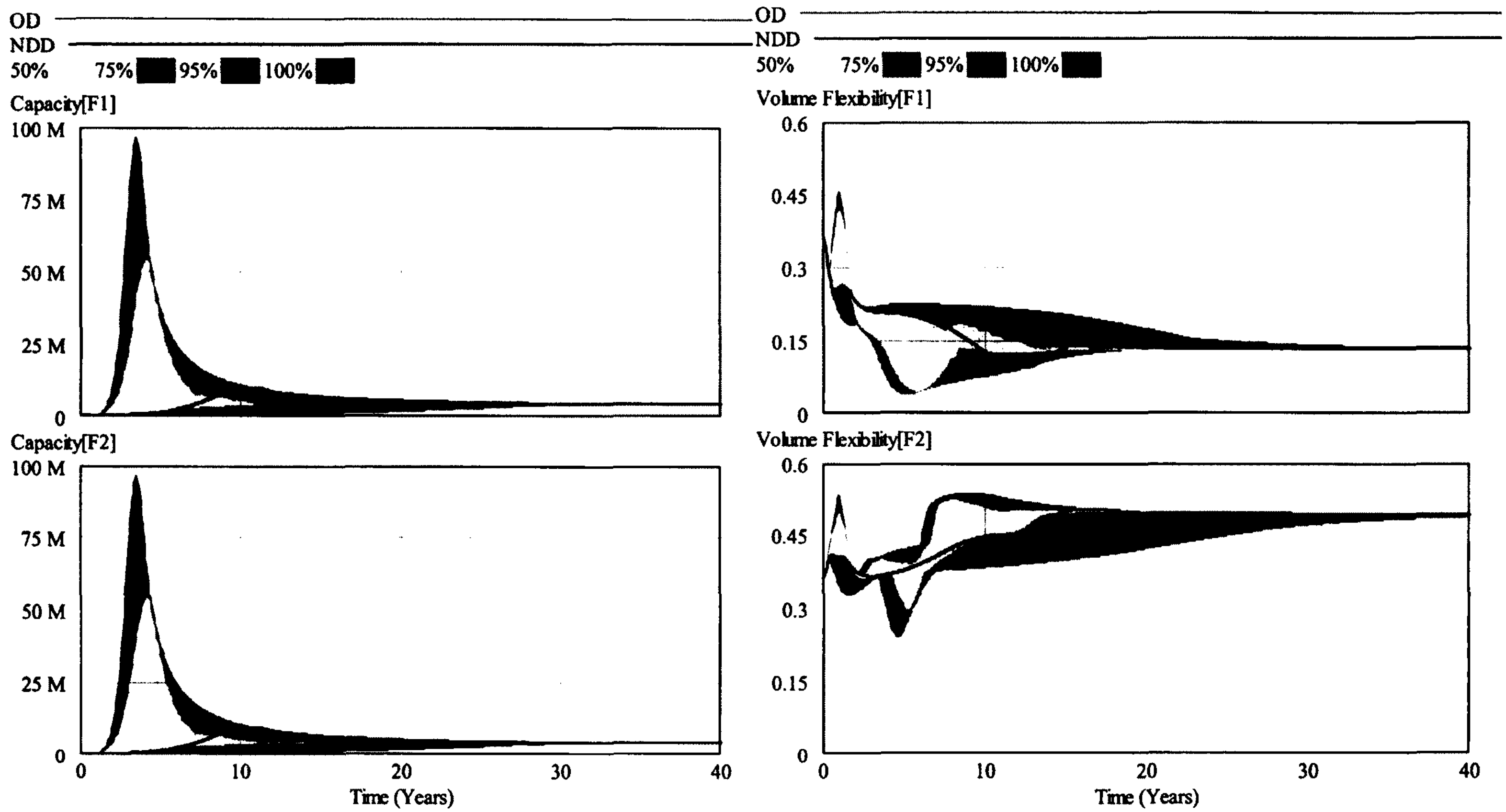


Figure 66 Capacity and volume flexibility analysis for firm F1 and F2.

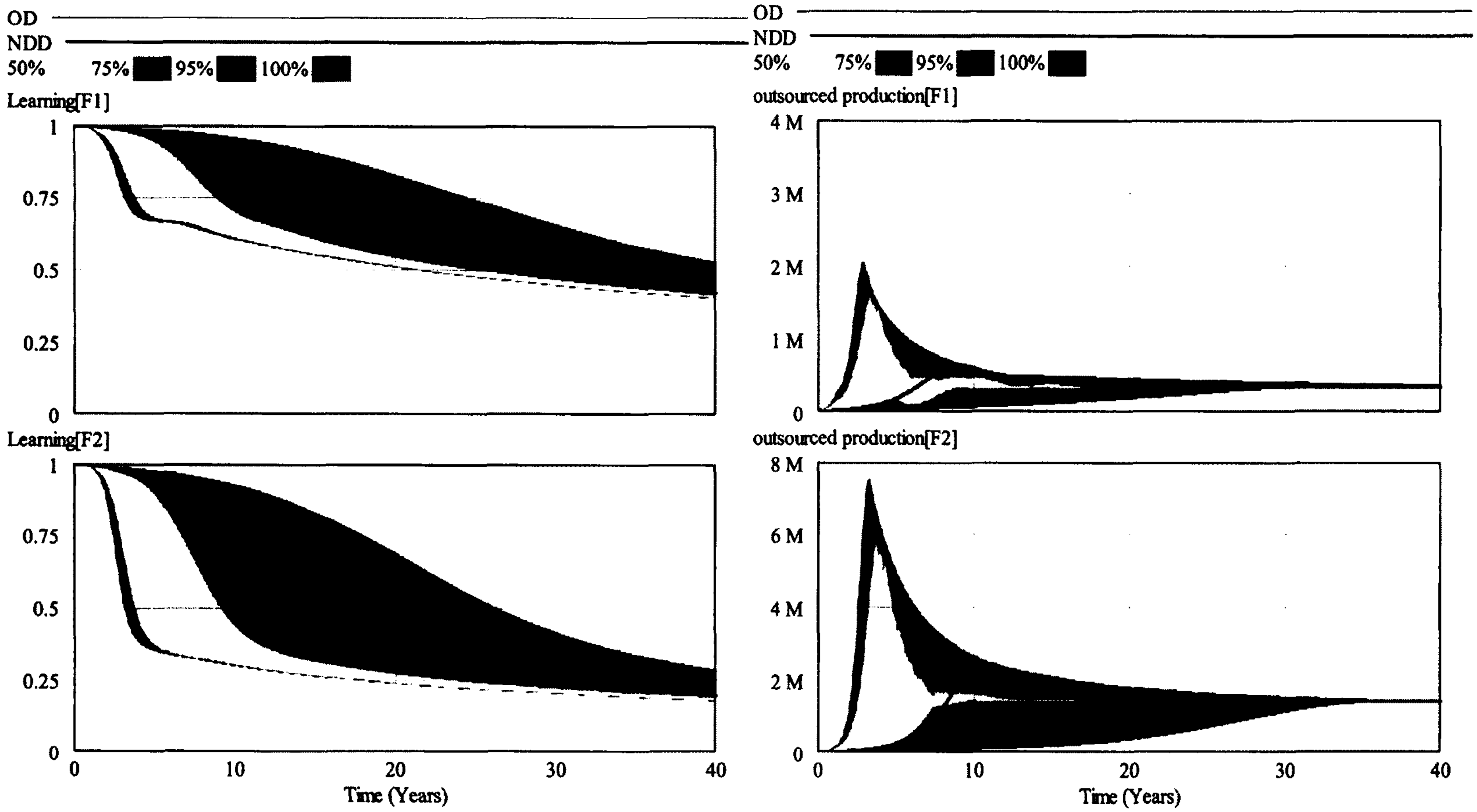


Figure 67 learning and outsourcing analysis for firm F1 and F2.

5.3. Extreme Case Analysis

To examine the extreme case, two firms were assumed to compete over market share to maximize the return on investment based on the firm's strategic intent. Capacity configuration decisions are subject to adjustment throughout the forecasted period to accommodate demand and capacity variations. Change in capacity configuration is modeled as resource to the strategic planning decision. In the base case conditions the target market share decision based on the type of strategy the firm possesses will differ based on the demand forecasted and adjusted by strategic considerations, the firm determines its target capacity. One strategy may consider its target capacity as the comparative maximization between its desired market share and the uncontested market share. Another strategy may consider its target capacity as the comparative minimization between its desired market share and the uncontested market share to make sure that it fills only the free space in the market. To examine the effect of considering volume flexibility as a macro measure in enterprise organization, the strategy for the firm will follow the intent to achieve the maximum returns of its volume flexibility capability without considering the uncontested market share or even the other firm adopted strategy in the market in the following case analysis. The logic of strategy selection is shown in Figure 68.

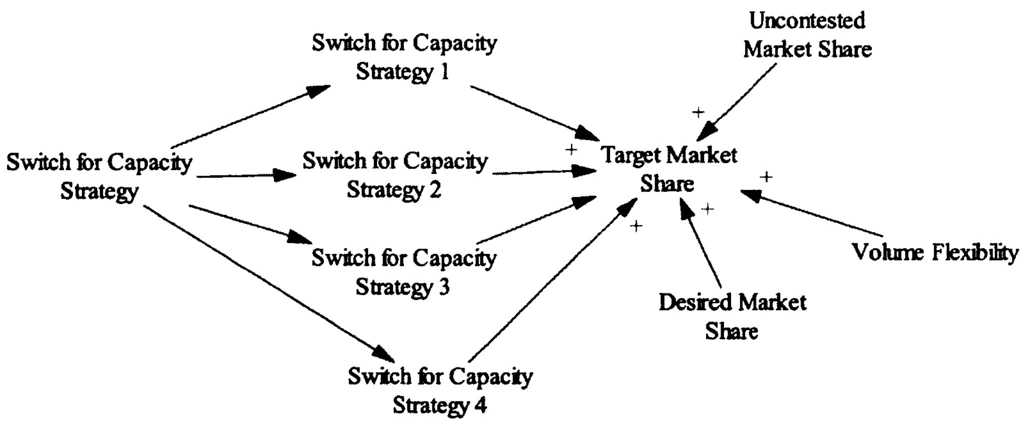


Figure 68 Strategic selection for firm F1 and F2.

The target market share decision logic follows the following rule:

*Switch for Capacity Strategy 1[i] * MAX (Desired Market Share[i], Uncontested Market Share[i]) + Switch for Capacity Strategy 2[i] * MIN (Desired Market Share[i], Uncontested Market Share[i]) + Switch for Capacity Strategy 3[i] * Desired Market Share[i] + Switch for Capacity Strategy 4[i] * Volume Flexibility[i])*

First, to show the significance of the volume flexibility as a strategic measure that may advance the final performance for the firm that will consider it, the two firms F1 and F2 were assumed to have identical intentions for the market share by targeting exactly 50 % in the base case. As shown in Figure 69, Figure 70 and Figure 71 the initial condition for both firms are identical at the beginning of the simulation. The target capacity is modeled to represent the firm's strategic intent. The volume flexibility and the market share show the initial condition for the setup of the base case.

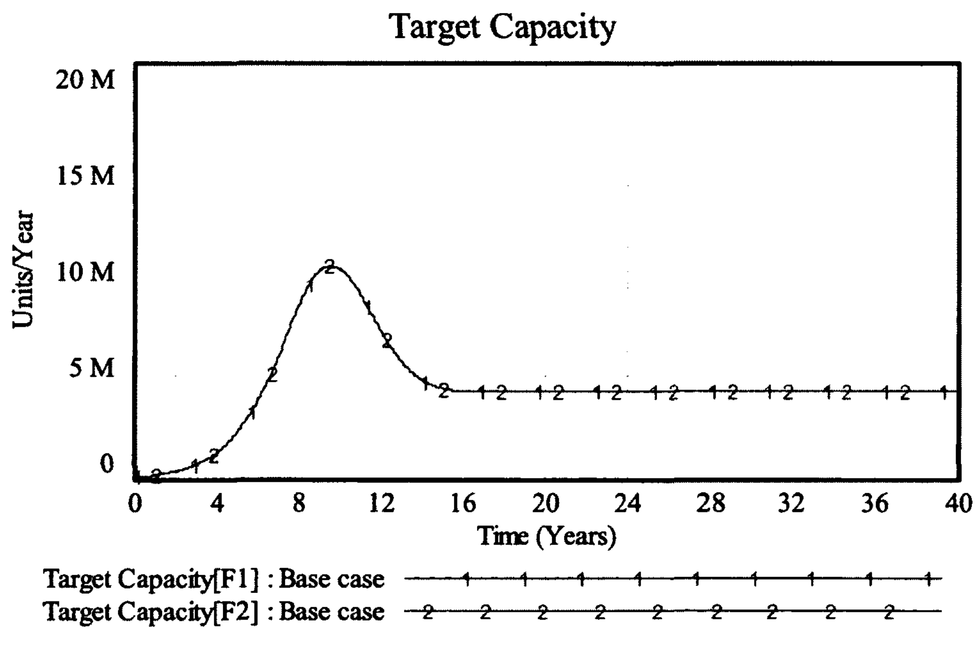


Figure 69 Target capacity for firm F1 and F2

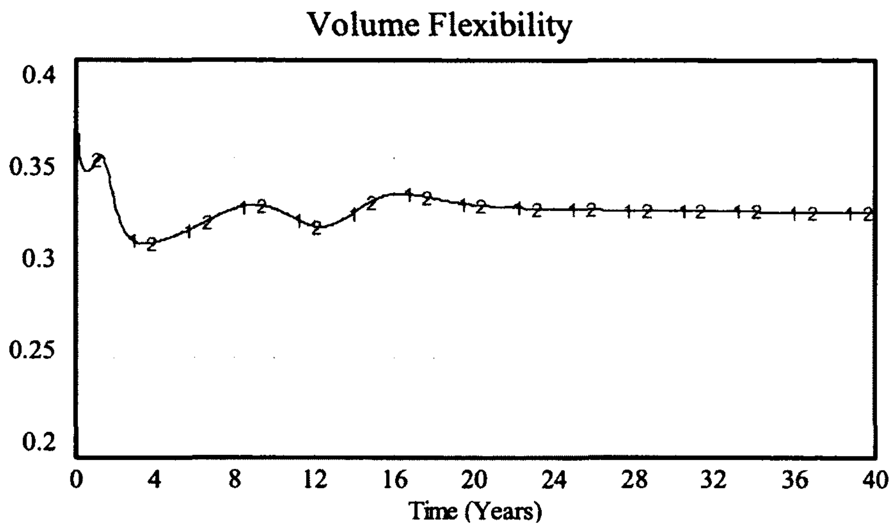


Figure 70 Volume Flexibility for firm F1 and F2

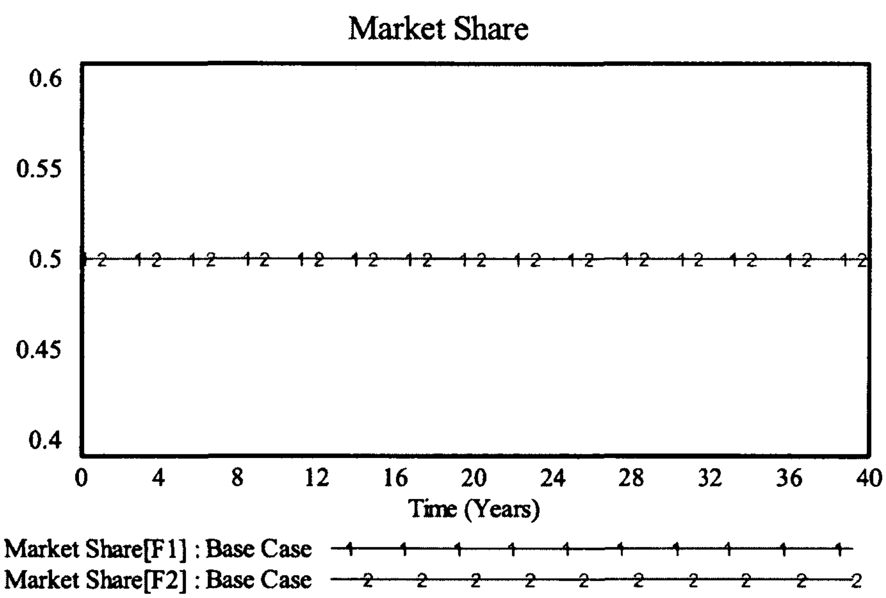


Figure 71 Market share for firm F1 and F2

Introducing volume flexibility measure

After extracting the base case results, firm F2 will consider the volume flexibility as strategic guidance for its capacity decisions to maximize the benefits from having such capability while firm F1 will consider the uncontested market share as a guide for their decisions. The effect on target capacity and volume flexibility is shown in Figure 72 and Figure 73 respectively. It is noted in this case that the firms' target capacity increase as its position advance in the market.

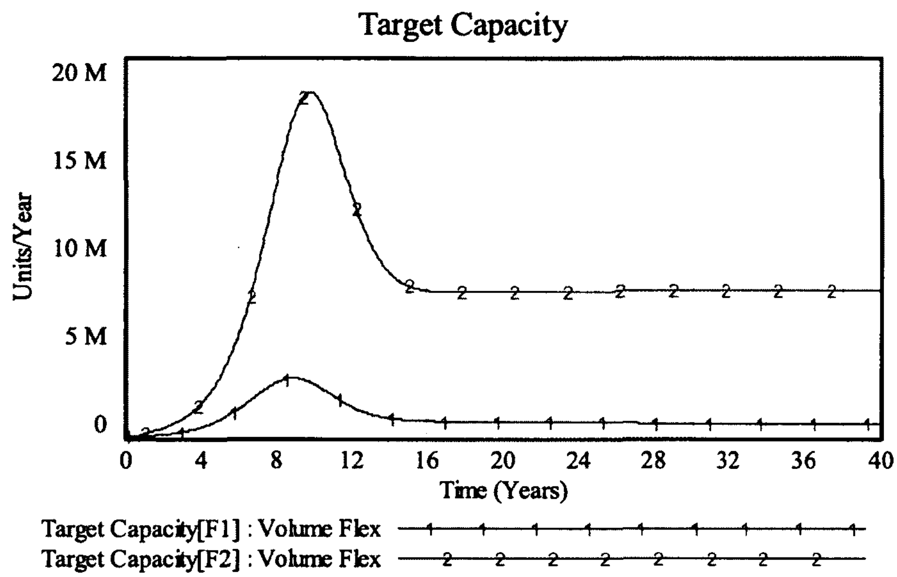


Figure 72 Target capacity for Firm F1 and F2.

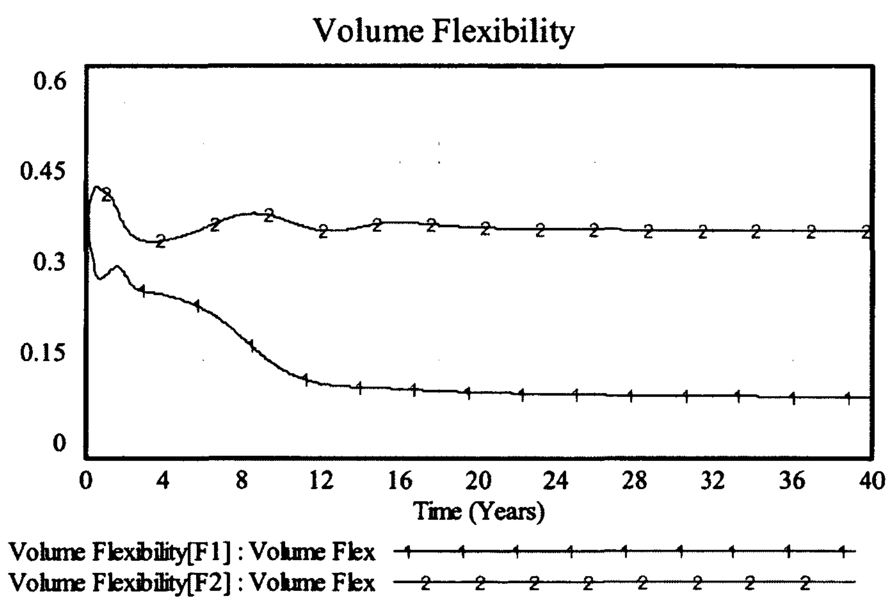


Figure 73 Volume flexibility for Firm F1 and F2.

As shown in the results, not only taking such feedback to the manager's strategic decision process gives a chance to maximize the flexibility benefits built in the system in terms of market share as shown in Figure 74, but also gives guidance to more beneficial future capacity development.

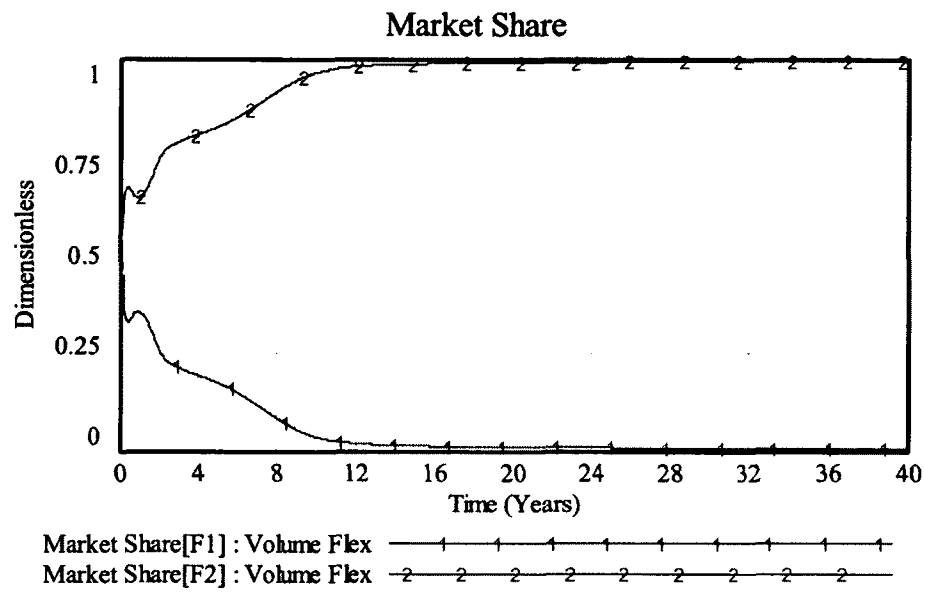


Figure 74 Market share for Firm F1 and F2.

From Figure 75, Figure 76 and Figure 77, results shows that considering the volume flexibility measure increase the target capacity for the organization from 2.5 million to 17.5 million units at the peak of its competition over market share. This leads firm F2 to dominate 300 % greater market share than firm F1 that didn't consider the volume flexibility measure in their capacity planning decisions even if they have it.

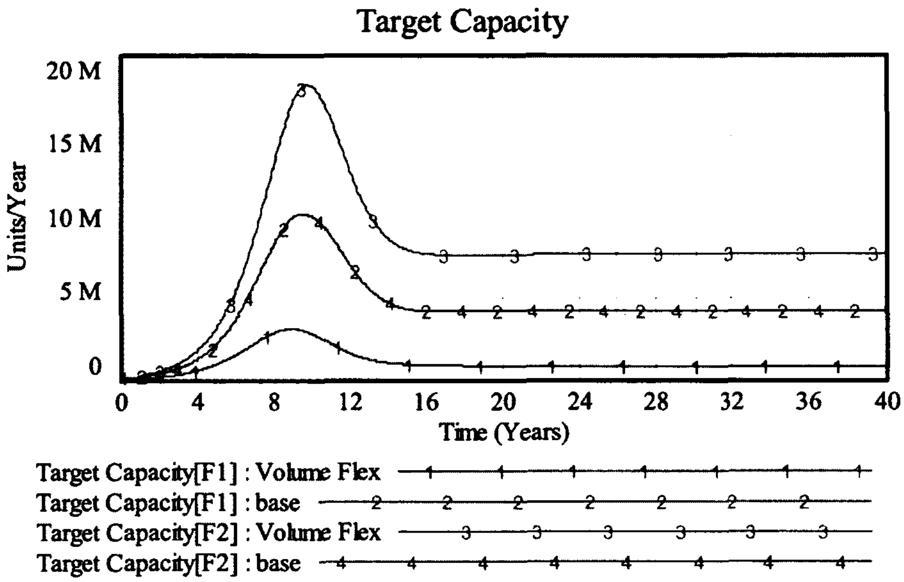


Figure 75 Target capacity comparison with the base case.

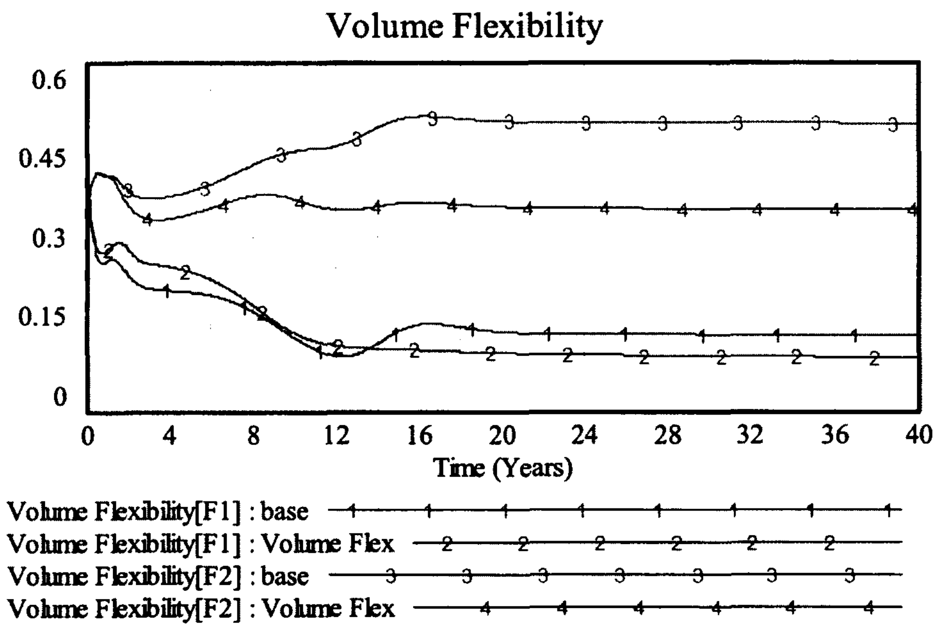


Figure 76 Volume flexibility comparison with the base case.

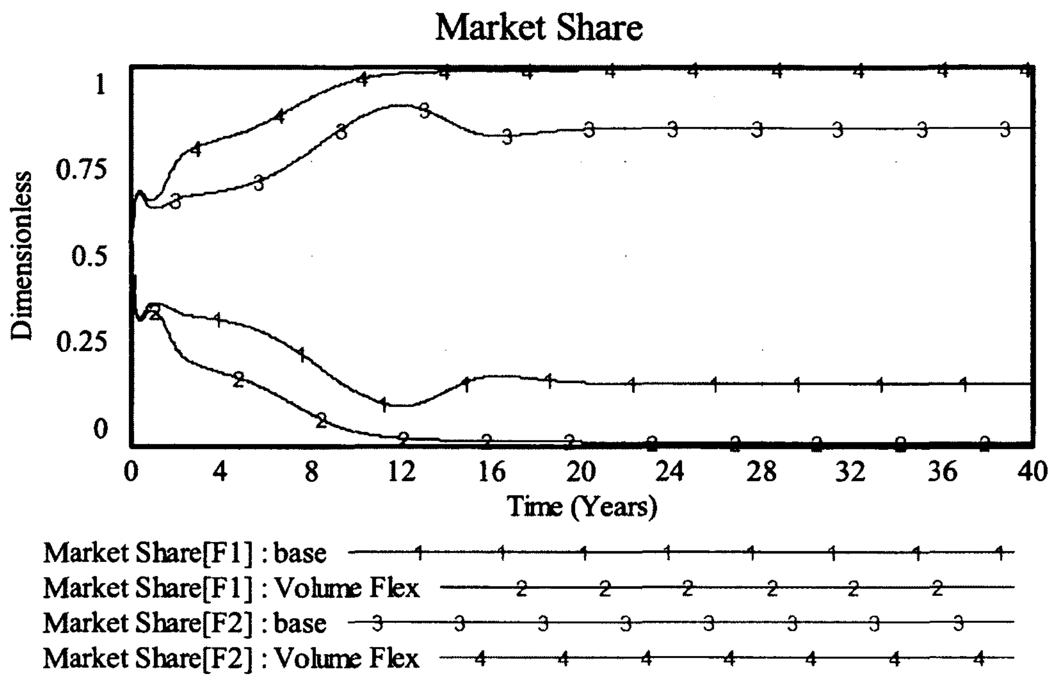


Figure 77 Market share comparison with the base case.

CHAPTER VI

CONCLUSION AND FUTURE WORK

6.1. Conclusion

This research explored how volume flexibility presented in the operations management theory can be linked to the dynamic capability theory to develop new macro measures for the enterprise manufacturing strategy. Model results show that there are differences in the resource options available to the firm, as suggested by the resource base view (Barney 1991), and this may limit the implementation of volume flexibility capability as competitive advantage.

Industrial enterprises will have to adapt their manufacturing capabilities to outperform the evolving industry benchmark. The benchmark evolution speed, either in market(s) or between industry members, is affected by the evolving customer preferences and the degree of allowed competition governed by policy makers. However, under different scenarios, given the universality of the uncertain environment, volume flexibility capability is commonly desirable by the enterprise to achieve a certain level of competitive advantage in its market(s) as shown in section 4.4.

It is also noted that more revenue allows more spending on marketing, which increases brand equity and drives up product attractiveness and therefore increases the targeted market segment as in the case shown in section 4.5.2. Greater attractiveness increases the relative weight of the capability and thus revenue to be spent on marketing. Also more revenue enables more investment in product development, which increases functionality and makes the product more attractive, leading to more sales and revenue to be invested in R&D as shown in section 4.3.2. More investment in process development leads to better process improvement, lowering unit costs. With lower costs the firm can lower its price while maintaining profit margins, which increases product attractiveness and provides more resources for process improvement.

Due to capacity acquisition and adjustment lags, if orders rise faster than capacity, the delivery delay for the product will rise, lowering attractiveness. The effect of availability on attractiveness forms a balancing feedback that can limit sales and market share during periods of growth when capacity lags orders. Market saturation occurs when more marketing drives up the adoption rate, which gradually exhausts the pool of potential adaptors. Also, more adopters cause more word of mouth, which drives up the adoption rate and leads to eventual market saturation as shown in section 4.3.

As shown in section 4.4, different product life cycle affects the industry speed and that may change the wining strategies adopted by the competing firms. In short industry cyclic time (2 years) the winner strategy was to match the industry demand as fast as possible and adopt a strategy that focus implicitly on order fulfilment while in long industry cyclic time the winning strategy was due to differences in outsourcing performance between the competing firms. This confirms the hypothesis that there is no absolute wining strategy and the key factor to success is to match the market requirements and dynamics.

Higher pricing leads to more profit per unit, but it also drives down product attractiveness and causes lower market share, which may lead to lower overall profitability as shown in section 4.5. For each strategic move the firm takes, its competitor can respond by either matching or even undercutting it. For example, when the firm spends more on R&D to improve product functionality and introduce new version, this may induce the competitor to invest more in R&D. Experience accumulation and knowledge lowers unit costs or improves product functionality as shown in section 4.4.3. And finally, global manufacturing networks that coordinate outsourcing, enhance responsiveness and share information fairly are expected to be dominant the next era of manufacturing practices on the strategic, tactical and operation levels.

6.2. Main Findings

a. Matching between the firm capabilities and its external environment is a critical factor for organizational success. Enterprises that focused on matching the industry normal delivery delay were able to capture the market segment attracted to product availability, while those who focused on cost reduction captured the market segment attracted to product price as shown in section 4.4.1. This confirms that the reconfiguration and transformation of the firm boundaries, resources and capabilities based on the industry benchmarking is critical to success.
b. Success level is relative to the competitor simultaneous actions and reactions while the effect differs from market to another. There are no ultimate right strategies for firms to follow as shown in section 4.4.4.
c. The process of creating a dynamic capabilities, as shown in section 4.2, is:
   - Built by continuous integration and coordination of all organizational activities
   - Internally, represented in process planning, information process and automation capabilities.
   - Externally, represented in strategic alliances, virtual cooperation and supplier relation.
d. The organizational learning ability is represented in skills and knowledge due to the effect of production experience accumulation over time as shown in section 4.4.3 and this confirms that the competitive advantage is competitive when it is unique to the company and matches with the market variables.
e. Empirical studies on the relationship between the manufacturing priorities that shapes the strategic direction of any indusial organization confirmed the tradeoffs between flexibility and cost as shown in the model section 4.2.
f. Innovation in physical technology and social technology are related and affect each other. And customer preferences evolve according to the available products or services that satisfy their needs as discussed in section 3.3.1.
g. The intense of competition govern the product life cycle duration and rate of change as discussed in section 3.4.

6.3. Study limitations

a. The model uses a set of differential equations over continuous time thus implies smooth transformation between different states of the system and that there is no step changes unless it is pre planned input.
b. The model does not include small market fluctuation which is normally captured as noise due to its stochastic nature. Short term sources of flexibility such as inventory or capacity buffers may respond to such small fluctuations in market demand while large market fluctuation is more controlled by the irreversible type of strategy the firm may possess and accumulate over long period of time for its production capability either by expanding its production line capacity or by strategic alliances which our focus in this research.
c. The model does not include product parts or supplementary services and assumes that the product is represented as one part to focus on the system level comparison stated in the scope of work.
d. Emotional decisions, natural disasters and unethical trading that cause step changes in the market are not included in the model.
e. Although the intra-industry relationship was not included yet the network effect can be represented through the installed base, which increases the customer and user network size.

6.4. Future Work

Before discussing the potential of future work, one shall consider the major forces that are affecting the world life as we know it. The struggling to cope with the aftermath of the recession and its consequences not only represent a problem in the developed world but also in the developing world. The major trend of the post-recession world is that there will be fewer people doing more work, with the demands of new technology and global competition unfavourably affecting their work and private lives. The pressure for more environmentally friendly sustainable industrial solutions and business models that integrate social responsibility are not an option any more. As a result, the major transformation from competition to cooperation is unavoidable for success in the future. From this the suggested potential work may be as follows:

a. Expanding the decision making process for the enterprise to consider the complete life cycle of the product including the recycling phase. This should affect the total cost and though allows the enterprise to introduce lower prices, more environmentally friendly products and that will increase the possibilities to control more market share.
b. Introduce to the model the minimum number of labors as constraint and study the effect of wages and quality of work. This attempt may help in exploring the social effect, labor social satisfaction and the firm's social responsibility with respect to the relative importance of the product utility.
c. Introduce small market fluctuation and inventory that target to dampen such fluctuation to test their effect on the long term strategic decisions of capacity adjustment.
d. The model can also be extended to include new domains such as knowledge management. Most knowledge management approaches developed so far rely on static processes as well as on documents indexed by formalized data. However, these approaches are inadequate for highly dynamic and volatile markets. Integrating knowledge management with the introduced strategic flexibility model to explore its effect on the organizational learning curve may shade some light for new standards for competition in knowledge based driven economy and foresee the economic benefits of global coordination mechanism for innovation.
e. Expanding the automation process to include the strategic decisions by integrating Artificial Intelligent Neural Network (AINN) methodology may be interesting to overcome the bounded rationality of managers taking decisions based on their personal perspectives and limits to risk.
f. Finally, studying both the evolution of customer preferences in adopting products and the evolution of competition strategic behavior using Agent Based Model simulators such as Robust and linking it to this model may lead to a leap in market dynamics studies for industrial enterprise.

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APPENDICES

Appendix A: Disequilibrium Dynamics Model Formulation

(Sterman et al. 2007) introduce the disequilibrium dynamic model as follows:

Mathematical Model Parameters

Q^o	Total Industry Order Rate
Q^I	Initial Orders
Q^R	Replacement Orders
μ	Number Of Units Ordered Per Household
M	Number Of Adopters
N	Potential Adopters
α	Strength Of External Influences
β	Strength Of Social Exposure And Word Of Mouth
POP	Total Number Of Households
M^*	People Who Will Eventually Choose To Adopt
σ	Slope Of The Demand Curve
P^{min}	Lowest Price Currently Available In The Market
P^r	Reference Price
POP^r	Reference Population
D_i	Discard Rate
I_i	Installed Base
Q_i	Shipments
O_i	Orders
S	Share
B_i	Backlog
A,	Attractiveness
P^r	Price Reference Values
τ^r	Delivery Delay Reference Values
R	Revenue
C^f	Fixed Costs
C^v	Variable Costs

P	Price
V	Order Book
U^f	Unit Fixed Costs
U^v	Unit Variable Costs
K	Capacity
Q	Production
£	Cumulative Production Experience
U_o^f	Initial Values Of Unit Fixed Costs
U_o^v	Initial Values Of Unit Variable Costs
Q^*	Desired Production
T^*	Target Delivery Delay
ℓ	Lag Operator
S^*	Market Share
D^e	Forecast Of Industry Demand
u_*	Normal Rate Of Capacity Utilization
D^e	Forecast Of Industry Demand
u_*	Normal Rate Of Capacity Utilization
K^{min}	Minimum Efficient Scale Of Production
g^e	Expected Growth Rate In Demand
D^r	Reported Industry Demand
h	Historical Horizon
T^r	Data-Reporting Time
S^{min}	Minimum Acceptable Market Share
S^{max}	Maximum Acceptable Market Share
S^u	Uncontested Share
D^u	Uncontested Demand
λ	Forecast Of Industry Demand
K^e	Expected Competitor Capacity
u^*	Normal Capacity Utilization
Kf	Estimate Of Competitor Target Capacity
T^C	Competitive Intelligence Delay
P	Price

Mathematical Representation

$$Q^{O}=Q^{1}+Q^{R} \quad \text{(A.1)}$$

$$Q^{1}=\mu(dM/dt) \quad \text{(A.2)}$$

$$dM/dt=n\ (\alpha+\beta M/pop) \quad \text{(A.3)}$$

$$N = MAX\ (0.M^{*} - M) \quad \text{(A.4)}$$

$$M^{*}=MIN\ (POP, POP^{r} * MAX\ (0.1+\sigma(P^{\min}-p^{r})/pop^{r})) \quad \text{(A.5)}$$

$$\sigma=-\varepsilon_{d}(POP^{r}/P^{r}) \quad \text{(A.6)}$$

$$Q\ R = \sum_{I} D_{i'} \quad \text{(A.7)}$$

$$Di=\delta 1_{i'} \quad \text{(A.8)}$$

$$dI_{i}/dt=Q_{i}-Di \quad \text{(A.9)}$$

$$O_{i} = S\overset{O}{i}\ Q^{o} \quad \text{(A.8)}$$

$$S\overset{O}{i}=A_{i}/\sum_{j} A_{j'} \quad \text{(A.10)}$$

$$A_{j}=\exp(\varepsilon_{p}P_{i}/P^{r})\exp(\varepsilon_{a}(B_{i}/Q_{i})/T^{r}) \quad \text{(A.11)}$$

$$S_{i}\ Q_{i}/\sum_{j} Q_{j'} \quad \text{(A.12)}$$

$$\pi = R - (C^f + C^v) \tag{A.13}$$

$$RQ(V/B) \tag{A.14}$$

$$dv/dt = PO - R \tag{A.15}$$

$$C^f U^f K_t \tag{A.16}$$

$$C^v = U^v Q_t \tag{A.17}$$

$$U^f = U_o^f (E/E0)^{y_f} \tag{A.18}$$

$$U^v = U_o^v (E/E0)^{y_v} \tag{A.19}$$

$$dE/dt = Q \tag{A.20}$$

$$Q = MIN(Q^*, K) \tag{A.21}$$

$$T = B/Q \tag{A.22}$$

$$Q^* = B/T^* \tag{A.23}$$

$$dB/dt = O - Q \tag{A.24}$$

$$k = \ell(K^*, \lambda) \tag{A.25}$$

$$K^* = MAX(K^{min}, S^* D^e / u^*) \tag{A.26}$$

$$D^e D^r \exp(\lambda g^e) \tag{A.27}$$

$$\theta^e = In(D_t^r / D_t^r -_h)/h \tag{A.28}$$

$$dD^r / dt(Q^O - D^r)/T^r \tag{A.29}$$

$$S^* = \begin{cases} MAX\,(S^{min}, S^u)\; if\; strategy = Aggressive \\ MIN\,(S\max, Su)\; if\; strategy = Conservative \end{cases} \tag{A.30}$$

$$S^u = MAX(0, D^u / D^e) \tag{A.31}$$

$$D^u = D^e - u^* \sum_{j \neq i} K_j^e \tag{A.32}$$

$$K_j^e = \omega \overset{e}{K_j^*} + (1-\omega)K_j \tag{A.33}$$

$$d\overset{e}{K_j^*} / dt = (K_j^* - \overset{e}{K_j^*})_T{}^C \tag{A.34}$$

$$dP / dt = (P^* - P) /_T{}^p \tag{A.35}$$

$$P^* = MAX\left[U^v, P\left(1 + \alpha^c\left(\frac{Pc}{P} - 1\right)\right)\left(1 + \alpha^d\left(\frac{Q^*}{u^* K} - 1\right)\right)(1 + \alpha^s (S^* - S)\right], \alpha^c \geq 0p; a^d \geq 0; \alpha^s \leq 0$$

(A.36)

Initial Conditions

Table 5 Parameters Initial Conditions and Definitions

Parameters:		***Value***
μ	Average number of units per Household (units/household)	*1*
a	Propensity for non adopters to adopt the product autonomously (I/years) 0.001	*0.001*
β	Propensity for non adopters to adopt the product through word of mouth (1/years)	*1*
POP	Total population (Households)	100e6
ε_d	Elasticity of demand at the reference price and population (dimension less)	-0.2
POP^r	Population that would adopt at the reference price P'	60e6
P^r	Price at which industry demand equals the reference population *POP'* ($/unit)	1.000
δ	Fractional discard ra1.000te of units from the installed base Clears) 0,100.10	0.10
ε_p	Sensitivity of product attractiveness to price	-8
ε_a	Sensitivity of product attractiveness to availability	-4
C	Ratio of fixes to variable costs (dimensionless)	3
y	Strength of the learning curve (dimensionless)	Log 2 (0,7)
T^r	Reference delivery delay (years)	0.25
T^*	Target delivery delay (years)	0.25
λ	Capacity-acquisition delay (years)	1
U^*	Target capacity utilization rate (dimensionless)	0.8
k^{min}	Minimum efficient scale (units/year)	1e5
T^d	Time delay for reporting industry order rate (years)	0. 25
λ^h	Historic horizon log estimating trend in demand (years)	1
T^c	Time delay for estimating competitor target capacity (years)	0.25
T^p	Adjustment time for price (years)	0.25
A^c	Weight on costs in target price (dimensionless) 1	1
a^d	Weight on demand/supply balance of target price (dimensionless)	0.5

Appendix B: Used Vensim Equations for the Base Case

Difference between capacity and desired capacity, given normal utilization, as percent of capacity:

Adequacy of Capacity[i] = (Capacity[i] - Desired Shipments[i]/Normal Capacity Utilization [i])/Capacity[i]

The cumulative number of adopters of the product:

Adopters= INTEG (Adoption Rate, Initial Cumulative Adopters)

The rate at which Customers adopt the product:

Adoption Rate = Potential adopters*(Strength of advertising + WOM*Adopters/Population)

Attractiveness of each firm is product of effects of price and availability:

Attractiveness[i] = Attractiveness from Price[i]*Attractiveness from Availability[i]

Effect of availability depends on delivery delay:

Attractiveness from Availability[i] = EXP (Sensitivity of Attractiveness to Availability*(Delivery Delay[i]/Reference Delivery Delay))

Effect of price on attractiveness of firm:

Attractiveness from Price[i] = EXP (Sensitivity of Attractiveness to price*(Price[i]/Reference Price))

Backlog of unfilled orders for the firm's product:

Backlog[i] = INTEG (Orders[i] - Shipments[i], 0.5*Industry Order Rate*Normal Delivery Delay[i])

Production Capacity of the firm:

Capacity[i] = IF THEN ELSE (Switch For Perfect Capacity = 1, Desired Shipments[i]/Normal Capacity Utilization[i], SMOOTH3I (Target Capacity[i], Capacity Acquisition Delay[i], 0.5*Industry Order Rate/Normal Capacity Utilization[i]))

Switch for Capacity Strategy 1[i] * MAX (Desired Market Share[i], Uncontested Market Share[i]) + Switch for Capacity Strategy 2[i] * MIN (Desired Market Share[i], Uncontested Market Share[i]) + Switch for Capacity Strategy 3[i] * Desired Market Share[i] + Switch for Capacity Strategy 4[i] * Volume Flexibility[i])

Target Capacity[i] = MAX (Minimum Efficient Scale[i], Target Market Share[i]*Expected Industry Demand[i]/Normal Capacity Utilization[i])

The average delay in acquiring or discharging capacity:

Capacity Acquisition Delay= 1year

Ratio of shipments to capacity:

Capacity Utilization[i] = Shipments[i]/Capacity[i]

Average time between placing and receiving an order:

Delivery Delay[i] = Backlog[i]/Shipments[i]

Industry demand:

Demand Curve Slope = (-Reference Population*Reference Industry Demand Elasticity) / (Reference Price)

Rate of shipments needed to deliver orders with average delay = normal delivery delay

Desired Shipments[i] = Backlog[i]/Normal Delivery Delay[i]

A fraction of the installed base is discarded and replaced each year.

The average life of the products in the installed base is 1/Fractional Discard Rate.

Discard Rate[i] =Installed Base[i]*Fractional Discard Rate

Fractional Discard Rate= 0.1

Industry Demand = MIN (Population, Reference Population*MAX (0, 1+Demand Curve Slope *(Lowest price -Reference Price)/Reference Population))

Industry normal production given industry capacity and normal capacity utilization rate

Industry Normal Production = SUM (Normal Production [i!])

Total order rate for the product:

Industry Order Rate = Initial Order Rate + Reorder Rate

Total Rate of Industry Shipments:

Industry Shipments = SUM (Shipments [i])

The initial cumulative number of adopters of the product:

Initial Cumulative Adopters = Initial Diffusion Fraction * Industry Demand

Initial fraction of Industry Demand who are adopters:

Initial Diffusion Fraction = 0.001

Rate of initial orders for product:

Initial Order Rate = Adoption Rate * Units per Household

Installed base of the market:

Installed Base[i] = INTEG (Shipments[i] - Discard Rate[i], 0.5*Units per Household*Adopters)

The lowest price available in the market:

Lowest price = VMIN (Price [i])

Share of shipments in units going to each firm:

Market Share[i] = Shipments[i]/Industry Shipments

Normal rate of production:

Normal Capacity Utilization[i] = 0.8, 0.8

Normal Delivery Delay[i] = 0.25, 0.25

Normal Production[i] = Capacity[i] * Normal Capacity Utilization[i]

Fraction of orders going to firm:

Order Share[i] = Attractiveness[i]/Total Attractiveness

Orders[i] = Industry Order Rate*Order Share[i]

The total population of potential adopters:

Population = 1e+008

The number of Customers in the population who have not adopted the product:

Potential adopters= Industry Demand - Adopters

Price[i] = INTEG (Change in Price[i], Initial Price[i])

Reference value of delivery delay used in attractiveness:

Reference Delivery Delay = 0.25

Demand elasticity at the reference price:

Reference Industry Demand Elasticity = 0.2

Reference Population = 6e+007

Reference Price = 1000

Price at which the potential adopter population = the Reference Population

Rate of re-entry into the market:

Reorder Rate = SUM (Discard Rate [i])

Sensitivity of Attractiveness to Availability = -4

Sensitivity of Attractiveness to price= -8

Shipments:

Shipments[i] = Switch for Capacity*MIN (Desired Shipments[i], Capacity[i]) + (1-Switch for Capacity)*Desired Shipments[i]

The fractional rate per year that non adopters adopt independent of WOM:

Strength of advertising= 0.001

Target Production:

Target Normal Production[i] = Normal Capacity Utilization[i] * Target Capacity[i]

Sum of attractiveness levels of all firms in market:

Total Attractiveness = SUM (Attractiveness [i])

Units per customer = 1

Volume Flexibility:

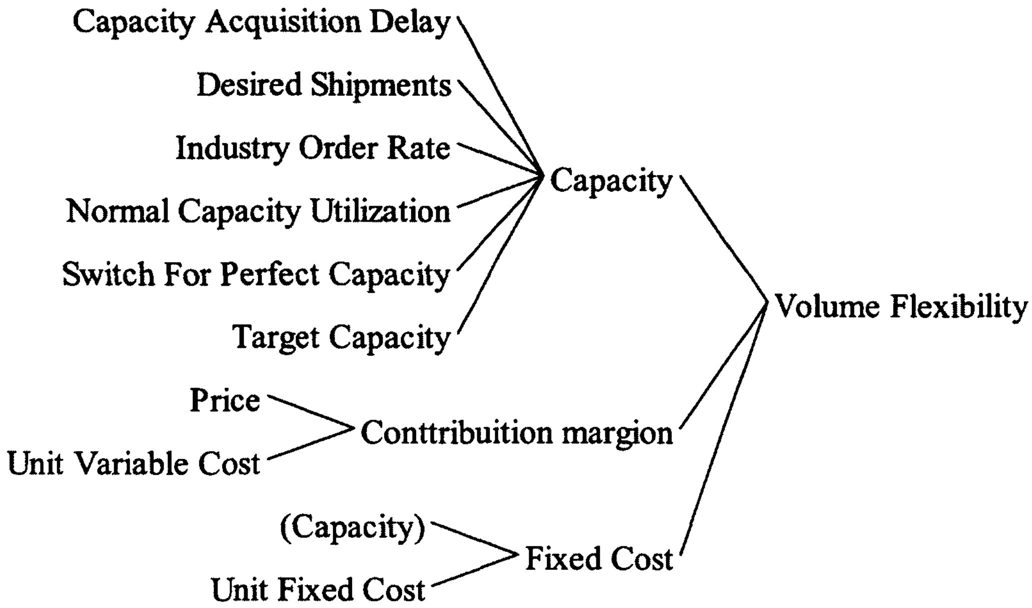
Volume Flexibility[i] = 1-(Fixed Cost[i]/ (Contribution margin[i]*Capacity[i]))

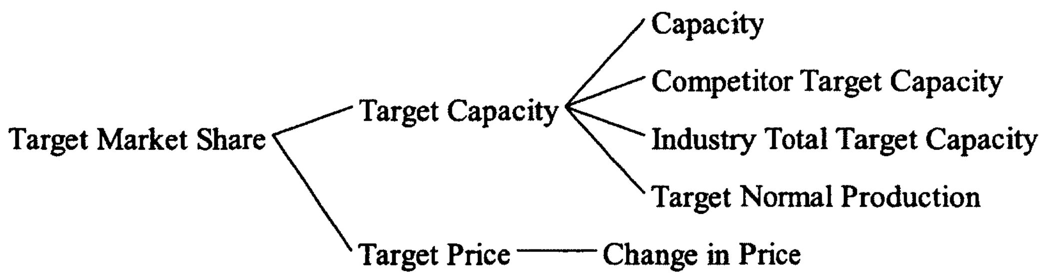
Unit Variable Cost[i] = Initial Unit Variable Cost[i] * Learning[i]

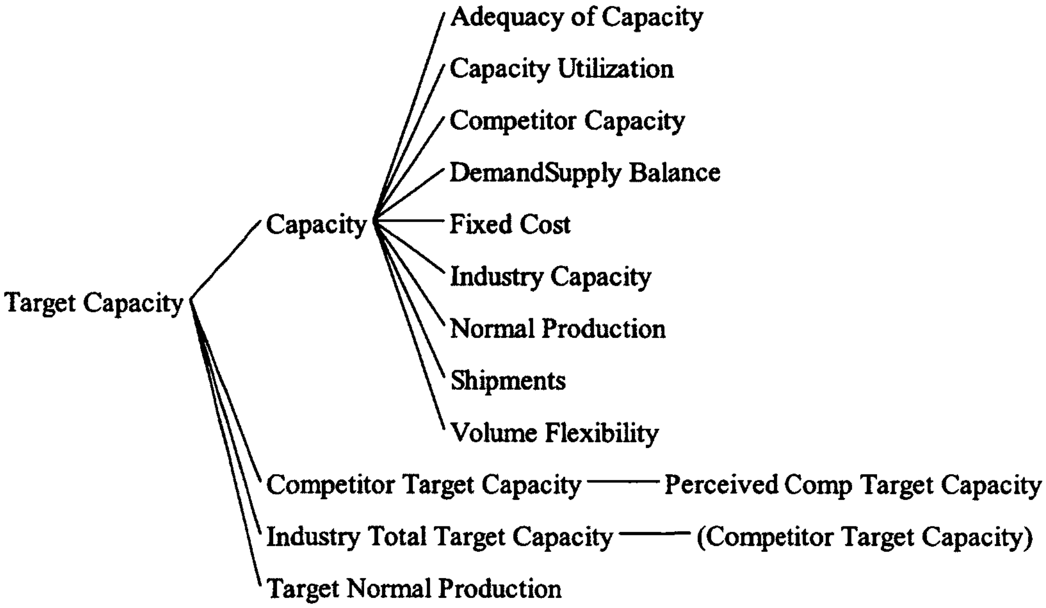
Contribution margin[i] = Price[i]-Unit Variable Cost[i]

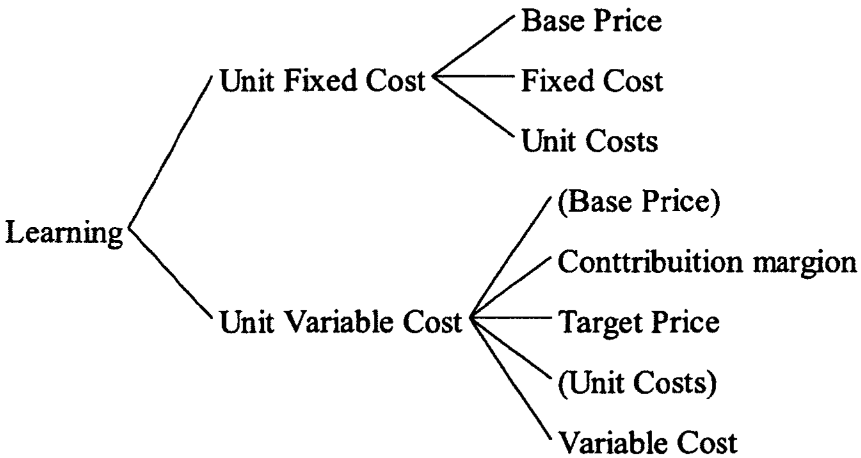
Outsourced production[i] = DELAY1 (Backlog[i], outsourcing Delay[i])

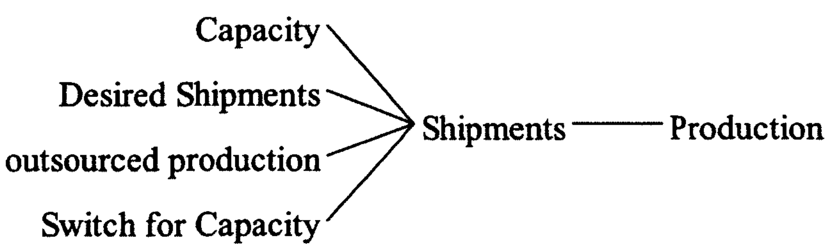
Appendix C: Mapping Key Parameters Relationship

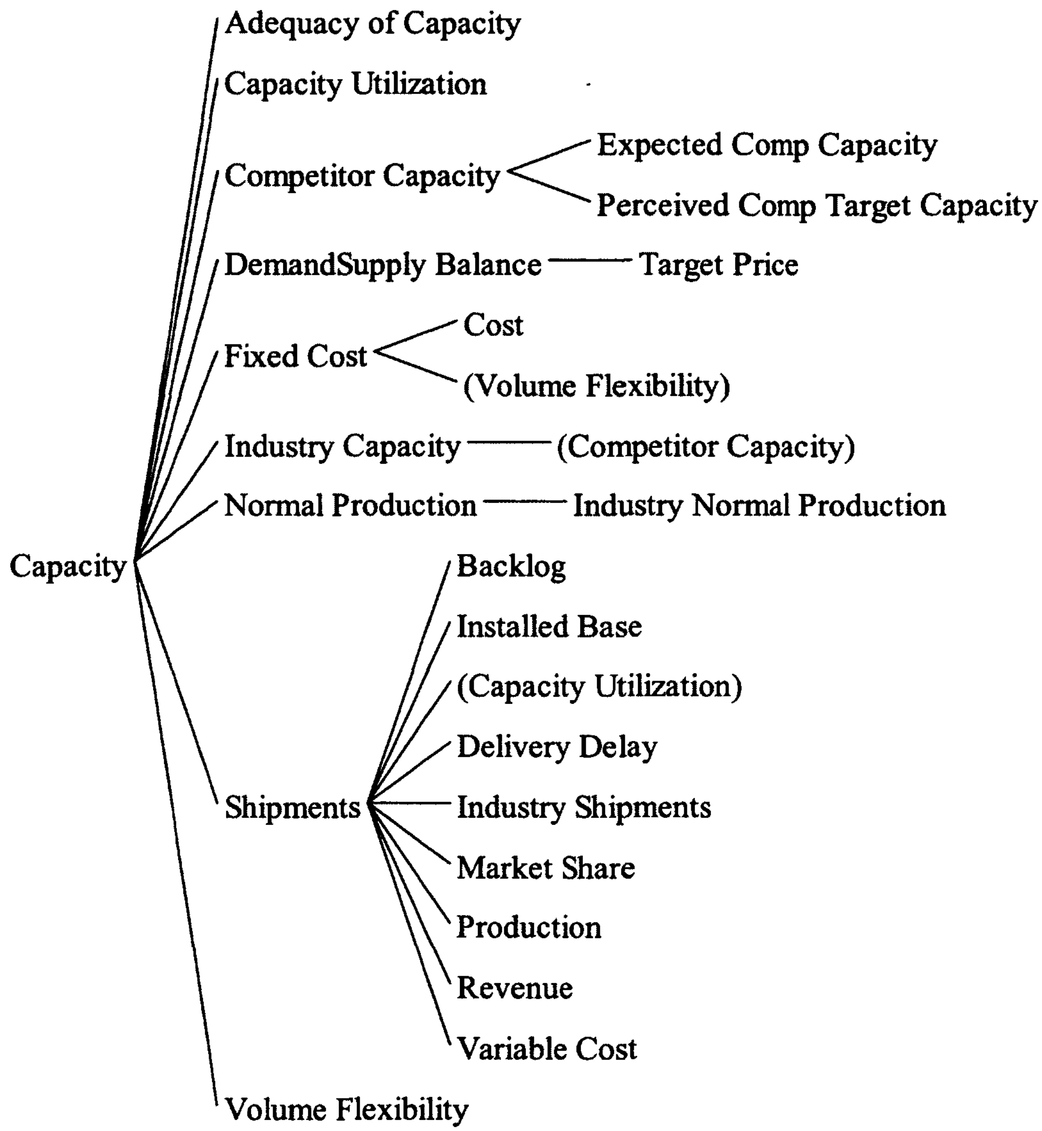


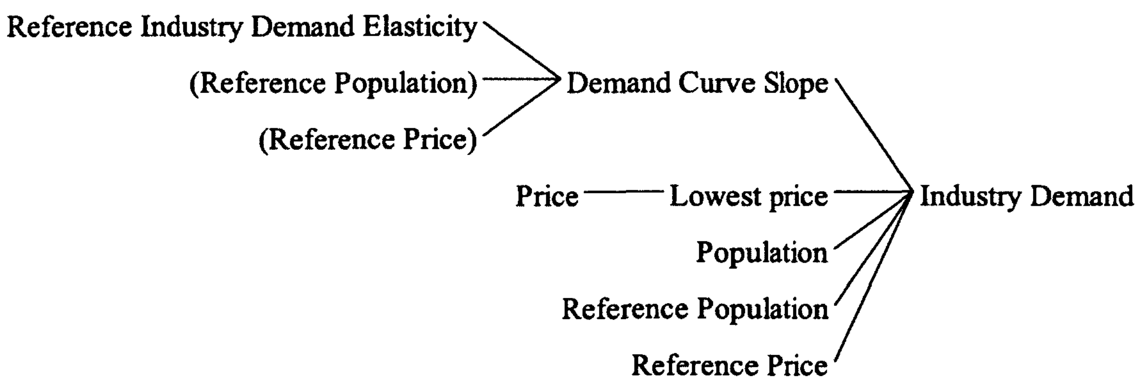


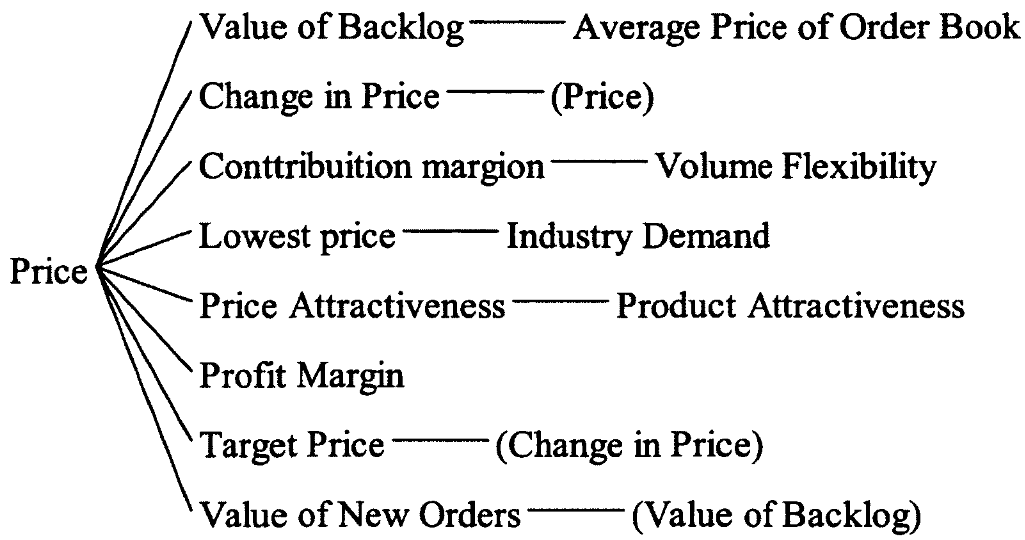

Target Capacity
Capacity
Adequacy of Capacity
Capacity Utilization
Competitor Capacity
DemandSupply Balance
Fixed Cost
Industry Capacity
Normal Production
Shipments
Volume Flexibility
Competitor Target Capacity
Perceived Comp Target Capacity
Industry Total Target Capacity
(Competitor Target Capacity)
Target Normal Production

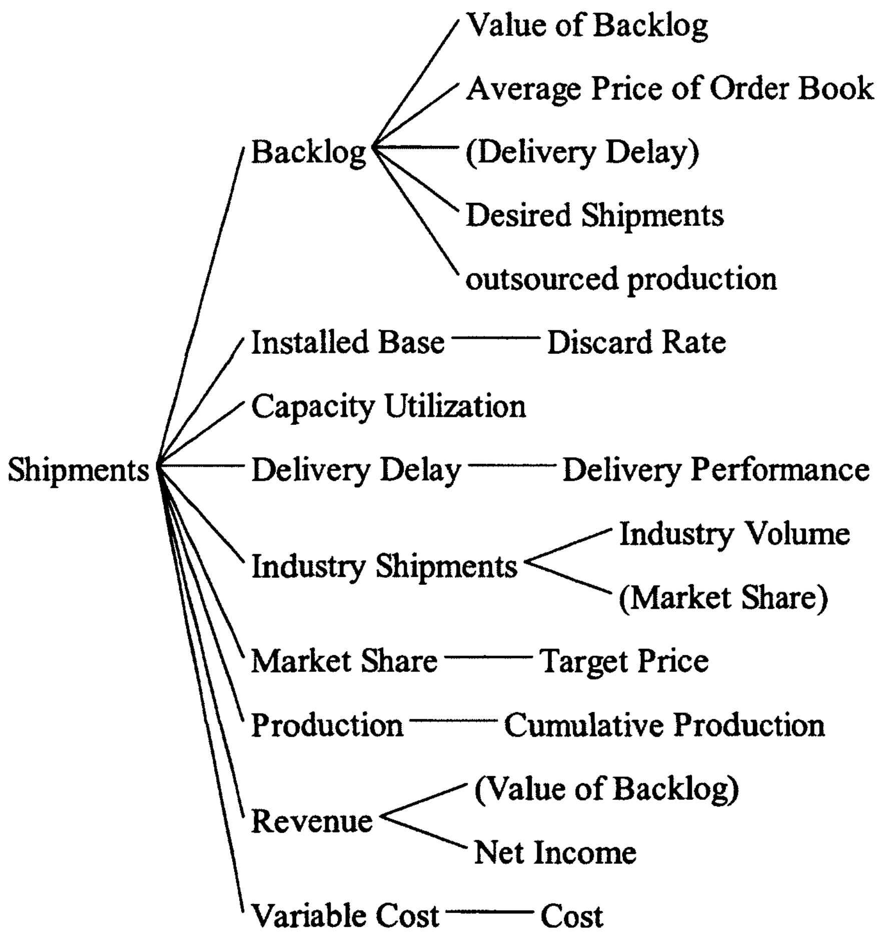

Learning
Unit Fixed Cost
Base Price
Fixed Cost
Unit Costs
Unit Variable Cost
(Base Price)
Conttribuition margion
Target Price
(Unit Costs)
Variable Cost

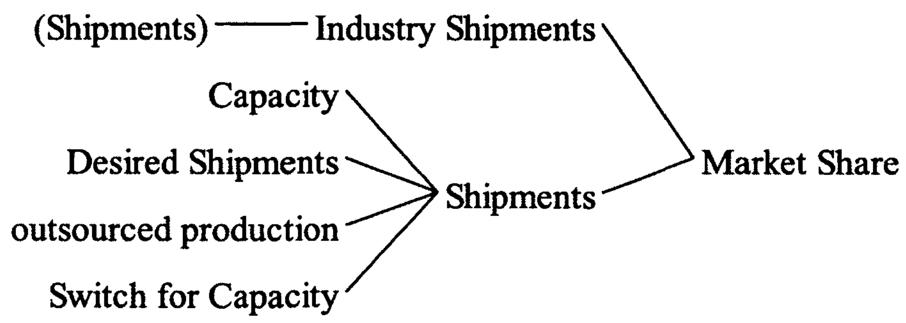

Capacity
Desired Shipments
outsourced production
Switch for Capacity
Shipments
Production

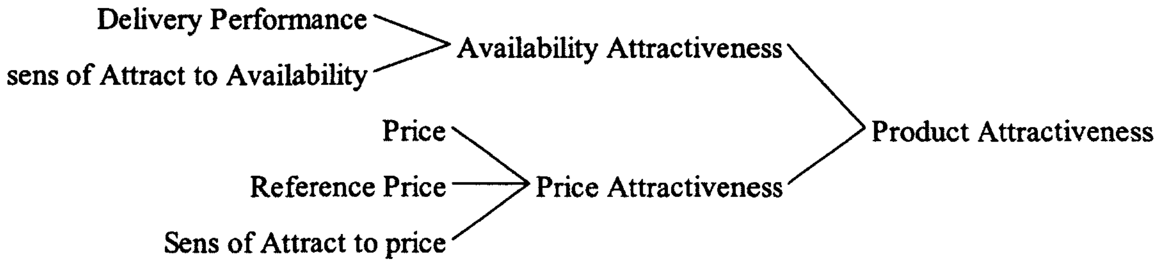

Adequacy of Capacity
Capacity Utilization
Competitor Capacity
Expected Comp Capacity
Perceived Comp Target Capacity
DemandSupply Balance
Target Price
Fixed Cost
Cost
(Volume Flexibility)
Industry Capacity
(Competitor Capacity)
Normal Production
Industry Normal Production
Capacity
Backlog
Installed Base
(Capacity Utilization)
Delivery Delay
Shipments
Industry Shipments
Market Share
Production
Revenue
Variable Cost
Volume Flexibility

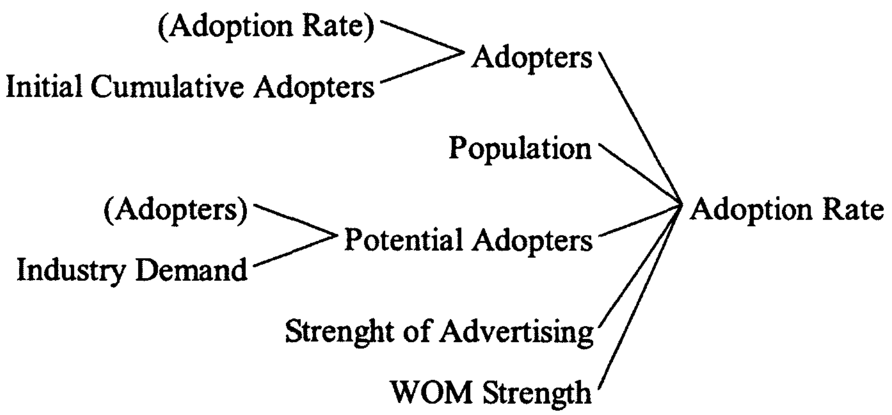

Reference Industry Demand Elasticity
(Reference Population)
(Reference Price)
Demand Curve Slope
Price
Lowest price
Industry Demand
Population
Reference Population
Reference Price


Price
Value of Backlog
Average Price of Order Book
Change in Price
(Price)
Conttribuition margion
Volume Flexibility
Lowest price
Industry Demand
Price Attractiveness
Product Attractiveness
Profit Margin
Target Price
(Change in Price)
Value of New Orders
(Value of Backlog)


Shipments
Backlog
Value of Backlog
Average Price of Order Book
(Delivery Delay)
Desired Shipments
outsourced production
Installed Base
Discard Rate
Capacity Utilization
Delivery Delay
Delivery Performance
Industry Shipments
Industry Volume
(Market Share)
Market Share
Target Price
Production
Cumulative Production
Revenue
(Value of Backlog)
Net Income
Variable Cost
Cost


(Shipments)
Industry Shipments
Capacity
Desired Shipments
outsourced production
Switch for Capacity
Shipments
Market Share


Delivery Performance
sens of Attract to Availability
Availability Attractiveness
Price
Reference Price
Sens of Attract to price
Price Attractiveness
Product Attractiveness


(Adoption Rate)
Initial Cumulative Adopters
Adopters
Population
(Adopters)
Industry Demand
Potential Adopters
Strenght of Advertising
WOM Strength
Adoption Rate

Appendix D: Detailed Manufacturing Strategy Research Survey

Table 6 Work Contributed to MS focusing on Manufacturing Capabilities

Researcher	Methodology	Contributions to research
(Skinner 1969a)	Conceptual	Originator of manufacturing strategy concept
(Skinner and Review 1974)	Conceptual	Focus provide power and clear goals and sense of direction
(Kotha and Orne 1989)	Conceptual	Framework for linking manufacturing strategy to business unit strategy
(Hayes and Wheelwright 1984b)	Descriptive	Various aspects of manufacturing strategy
(Hayes 1985)	Descriptive	Approach of managers for planning strategies
(Skinner 1996)	Descriptive	The "S" curves of manufacturing strategy
(Voss 1993)	Descriptive	Aspects of manufacturing function in manufacturing strategy
(Barney 1986)	Descriptive	Explanations about the future value of strategic resources by analyzing skills and capabilities under control
(Gerwin 1993)	Descriptive	Dimensions of manufacturing flexibility
(Schroeder *et al.* 1989)	Descriptive	A framework for innovation and its effect on manufacturing performance
(Ferdows and Lindberg 1987)	Descriptive	An empirical evidence for a cumulative "sand cone" model that helps to redefine the nature of tradeoffs among manufacturing capabilities
(Wheelwright and Bowen 1996)	Descriptive	Essential elements in successful search of manufacturing advantage
(Hayes and Pisano 1994)	Descriptive	Long-term success could be achieved by offering something unique to customers
(Hill and Chambers 1993)	Descriptive	Flexibility in manufacturing strategy
(Grant 1996)	Descriptive	A model for operating capabilities and competencies
(Sanchez 1996)	Descriptive	Technological innovations in modular product design and CAD/CIM systems have increased flexibilities
(Hall 1999)	Descriptive	Classification of intangible resources and capabilities
(De Toni *et al.* 1993)	Descriptive	A conceptual model for operations in presence of global strategies
(Gerwin 1993)	Descriptive	Highlighting flexibility as an important priority
(Collis and Montgomery 1995)	Descriptive	Strategy that blends two powerful sets of capabilities and competition represents an enduring logic

Researcher	Methodology	Contributions to research
(Berry *et al.* 1995)	Descriptive	Link between marketing and manufacturing to meet today s dynamic and market
(Collins and Cordon 1997)	Descriptive	Three levels of organizational capabilities
(Hum and Leow 1996)	Empirical	Assessment of Hayes and Wheelwright's framework
(Ahmed *et al.* 1996)	Empirical	Appropriate operation strategy leads to superior organizational performance
(Slack 1993)	Empirical	Flexibility has two dimensions, i.e. product and volume flexibility
(Corbett 1996)	Empirical	Operations strategy of New Zealand firms
(Kerr and Greenhalgh 1991)	Empirical	Various ways of manufacturing strategy contribution to an organization
(Sweeney 1993)	Empirical	Taxonomy of manufacturing strategy
(Chase *et al.* 1992)	Empirical	Attributes of service-based manufacturing
(Leonard-Barton 2003)	Empirical	Empowered individuals have the self-confidence, freedom, and motivation to solve problems
(Meredith and Vineyard 1993)	Empirical	Study of three FMS to highlight importance of manufacturing strategy
(Miller and Roth 1994)	Empirical	Detained taxonomy of manufacturing strategy practices
(Schmenner 1982)	Exploratory cross-sectional	Multiple plant strategies and their associated characteristics
(Schroeder *et al.* 1986)	Exploratory cross-sectional	Empirical study of manufacturing strategy
(Hörte *et al.* 1993)	Exploratory cross-sectional	Competitive priorities, concerns and programs for Swedish industries
(Lindberg 1993)	Exploratory cross-sectional	Impact of suppliers on manufacturing flexibility, empirical evidence of relationship of planning and workforce to manufacturing strategy
(De Meyer *et al.* 1989)	Exploratory cross-sectional	Competitive priorities among manufacturers worldwide and degree of consistency between priorities and manufacturing action plans
(De Meyer and Ferdows 1991)	Exploratory cross-sectional	Cost reduction in manufacturing results from improvements in quality
(Upton 1995a)	Exploratory cross-sectional	Careful, right mix of machine, people and computer system results, increased flexibility
(Hörte *et al.* 1993)	Exploratory cross-sectional	Strategic direction and competitive means of Swedish manufacturers

Researcher	Methodology	Contributions to research
(Upton 1995b)	Exploratory cross-sectional	Linkages between flexibility and factors such as computer integration, technology vintage and workforce management
(Kotha and Vadlamani 1995)	Exploratory cross-sectional	Comparison in Porter's strategy typologies
(Chikán and Demeter 1995)	Exploratory cross-sectional	Features of transition in manufacturing and tested Skinner s model in Hungarian industries
(Tunälv 1993)	Exploratory cross-sectional	Competitive priorities for Swedish manufacturers
(JOHN and YOUNG 1992)	Exploratory cross-sectional	Competitive priorities are related to long-run strategic trade-off decisions
(Ettlie and Penner-Hahn 1994)	Exploratory cross-sectional	Product focus and strategic focus are related
(MCDOUGALL *et al.* 1992)	Exploratory cross-sectional	Manufacturing strategy issues in computer and communication equipment companies

Table 7 Work Contributed to MS focusing on Strategic Choices

Researcher	Methodology	Contributions to research
(Golden and Powell 2000)	Descriptive	Information technology can enable flexibility
(Klassen 2000)	Descriptive	Linkage between investment in manufacturing and environmental technologies
(Kitazawa and Sarkis 2000)	Descriptive	Employee empowerment, their willingness to make suggestions for improvement is a critical element in managing continuous resource reduction program
(Grover and Malhotra 1999)	Descriptive	Framework for examining the interface between operations and information systems
(Gagnon 1999)	Descriptive	Resource-based competition has replaced the market-based competition
(Berry and Cooper 1999)	Empirical	Alignment between manufacturing and marketing strategies
(Li and Richard Ye 1999)	Exploratory cross-sectional	IT investments have stronger positive impact on financial performance
(Klassen and Whybark 1999)	Exploratory cross-sectional	Conceptual model of environmental management within operations
(Teo and Ang 1999)	Exploratory cross-sectional	Critical success factors in the alignment of information system plans with business plans
(McDermott 1999)	Exploratory longitudinal	Informal networks within a firm played a large role in the development of radical projects
(Brown and Bessant 2003)	Exploratory longitudinal	Mass customization and agile manufacturing are important in manufacturing strategy

VITA AUCTORIS

Amir Arafa was born in Cairo, Egypt in 1974. He graduated in Electrical engineering in 1997 from Military Technical College, Egypt, where he also received the M.Sc. degree in Artificial Intelligence Neural Network Control in 2002. In 2004, he successfully accomplished the International Register of Certificated Auditors (IRCA) examination and requirements to become ISO9000 Certified Lead Auditor. In 2005 he received a higher diploma in Business Administration followed by another higher diploma in Crisis Management in 2007, both from Ain Shams University, Cairo, Egypt. He joined the Intelligent Manufacturing systems Centre (IMSC) as a Ph.D. student in 2008, at the University of Windsor in Ontario, Canada. His research activities are focused on enterprise strategic management and synthesis of organizational flexibility and system complexity. He has published 3 journal papers and 2 conference papers.