AGILE MANUFACTURING: THE 21ST CENTURY COMPETITIVE STRATEGY

A. Gunasekaran

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2001

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AMSTERDAM · LONDON · NEW YORK · OXFORD · PARIS · SHANNON · TOKYO

ELSEVIER SCIENCE Ltd
The Boulevard, Langford Lane
Kidlington, Oxford OX5 1GB, UK

First edition 2001

Library of Congress Cataloging in Publication Data
A catalog record from the Library of Congress has been applied for.

British Library Cataloguing in Publication Data
A catalogue record from the British Library has been applied for.

Transferred to digital format 2006

ISBN: 0-08-043667-X

♾ The paper used in this publication meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).
Printed and bound in Antony Rowe Ltd, Chippenham

PREFACE

Manufacturing has undergone many evolutionary stages and paradigm shifts. The paradigm shifts in going from a craft industry to mass production, then to lean manufacturing, and finally, to agile manufacturing (AM). The concept of agility (flexible and quick responsive manufacturing) will reduce time to reach market with appropriate products/services.

Businesses are restructuring and re-engineering themselves in response to the challenges and demands of the 21st century. The businesses of the 21st century will have to overcome the challenges of demanding customers who will seek high-quality, low-cost products that are relevant to their specific and rapidly changing needs. The time during which many companies competed based primarily on price tag has gone. Now is the time for companies to compete in the global marketplace, and "push the envelope" in delivery-response, product quality, and overall excellence in customer service and customer satisfaction. Agility addresses new ways of running companies to meet these challenges.

Agile manufacturing is defined as the capability of surviving and prospering in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-designed products and services. Critical to successfully accomplishing AM are a few enabling technologies such as the standard for the exchange of products (STEP), concurrent engineering, virtual manufacturing, component-based Hierarchical shop floor control system, information and communication infrastructure, etc.

The aim of the book is to help the students at the undergraduate and graduate levels, senior managers and researchers in understanding and appreciating the concepts, design and implementation of Agile Manufacturing systems (AMS). One should be able to understand, develop and implement appropriate agile manufacturing strategies after reading this book.

The scope of the book is to present the undergraduate and graduate students, senior managers and researchers in manufacturing systems design and management, industrial engineering and information technology with the conceptual and theoretical basis for the design and implementation of AMS. The book emphasizes on systems methodology approach for the design and implementation of AMS. Also, the book focuses on broad policy directives and plans of agile manufacturing that guide the monitoring and evaluating the manufacturing strategies and their performance. A problem solving approach is taken throughout the book, emphasizing the context of agile manufacturing and the complexities to be addressed.

This book provides a much needed comprehensive coverage of materials required developing and implementing agile manufacturing strategies and systems. The book includes the concept, theory, modelling, and architecture of agile manufacturing system. It covers the state-of-the-art, concepts and methodologies of manufacturing strategy development taking into account the current development in information technologies and the overall trend in agile manufacturing. The book is expected to assist the companies in formulating 21st century manufacturing strategies to flourish in the competitiveness of manufacturing.

The book presents original works and interesting case studies arising from research with the evolving technologies and production concepts of agile manufacturing. The book aims to promote the ideas and technologies that promote agile manufacturing as company wide strategies to reduce the lead times at all stages of manufacturing. The chapters offer ideas on lowering manufacturing costs, increasing market share, satisfying the customer requirements, rapid introduction of new products, eliminating non-value added activities and enhancing manufacturing competitiveness. The book is organized into six parts to cover the introduction, design and development, information technology/systems, supply chain management, operations management and strategies of agile manufacturing. The chapters deal with the following areas as a part of agile manufacturing system development: concepts, strategies and enablers of agile manufacturing, virtual enterprise, managing people in agile organizations, product development in agile environment, application of Information Technology/Systems in agile manufacturing, supply chain management in agile environment, operations planning and control in agile manufacturing enterprise and some strategic approach for the development of agile manufacturing.

The Editor of this book acknowledges Dr. Martin Rack, Publishing Editor for Industrial Engineering and Control, and the staff of Elsevier Science Ltd (UK) for their great support in completing this book.

I am most grateful to my wife, Latha Parameswari and my son Rangarajan for their generous support and permission for staying away during family time in order to complete this edited book. I appreciate the countless hours spent by my wife for proof reading of all the chapters. My heartfelt thanks go to all the authors who have contributed chapter(s) to this book. Without their contribution and overall support, this book should have been hardly realized.

A. Gunasekaran
Editor
June 6, 2000

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Part I

INTRODUCTION TO AGILE MANUFACTURING

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Agile Manufacturing as the 21st Century Strategy for Improving Manufacturing Competitiveness

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1. DEFINITION OF MANUFACTURING STRATEGY

Manufacturing strategy has increasingly been regarded by academics and practitioners as having an important contribution to make to enhance competitiveness. The growth of the literature in manufacturing strategy has matched the growth of interest in the area. Within the literature three main reasons are identified for this newly found importance.

The first is the increased pressure owing to the growing international manufacturing competitiveness made more intense by the recent movement towards globalisation. The second is the increased potential to be gained from the development of new manufacturing technologies, the potential of which grows much faster than our ability to use it for competitive benefits and, the third is the development of a better understanding of the strategic role of manufacturing. Five characteristics can be listed to help understand the need for a strategic management of the manufacturing function:

- Manufacturing in general involves the bulk of the company's assets and human resources
- Many decisions regarding manufacturing resources require a long time to take effect therefore requiring a long term outlook of the future to support them
- Once made, many of these decisions will normally take a long time and substantial amounts of resources to revert
- Manufacturing decisions directly affect the way companies can compete in the market place because it is increasingly accepted that there is not such a thing as a "best way" to manage manufacturing resources - different configurations of manufacturing resources will result in different levels of manufacturing performance in different aspects (e.g. delivery, flexibility, quality and cost)
- Manufacturing decisions have to support and be supported by other functions in order to properly support the business strategy of the company, therefore requiring strategic orientation

Manufacturing strategy can be defined as a framework whose objective is the increased competitiveness of the organisation; to achieve this it should aim at designing, organising, managing and developing the company's manufacturing resources and shape a consistent pattern of manufacturing decisions in order that they can result in an adequate mix of

performance characteristics which will allow the company to compete effectively in the future.

2. THE CHANGING INTERNATIONAL MANUFACTURING COMPETITION IN THE '60s, '70s AND '80s

During the 60s, 70s and 80s, the relative competitive positions occupied by the formerly leading industrial countries changed substantially. Some traditional industrial nations were outperformed by other countries, of which Japan was the most evident example. The United States and the United Kingdom had their leading positions challenged and in many cases lost them, e.g. in the automobile market, long dominated by American companies.

Considering the Japanese manufacturing industry, Buffa (1984) notices that the industries in which they excelled during that period – motor cycles, domestic appliances, automobiles, cameras, hi-fi, and steel production – there were already developed markets with established market leaders. According to the author, Japanese companies may have succeeded, partially because of their Finance and Marketing related skills, but largely because of the high quality and low cost which they achieved through a sharp manufacturing practice which most of the Western manufacturers initially were not able to match. Japanese companies were using the improvements which they had been achieving in manufacturing as their main competitive advantage, as opposed to the Western companies, which had considered manufacturing as a 'solved problem', focusing their attention on getting competitive advantage through achieving excellence in marketing their products and managing their financial issues.

Not only were Japanese companies on average more cost efficient than most Western companies (though there were many exceptions of Western companies which had maintained or improved their competitive position in the world market during those decades), but they were competing and winning based also on their better quality and reliability performance as well as on their better responsiveness to the market needs and opportunities. In the introduction of new products, for instance, Japanese car manufacturers had cut their product development times (the period between the earliest stages of design and the manufacture of a new model) to an average of less than four years compared to six to eight years in Europe and America of the '70s.

There is, in general, agreement that (initially, at least) Western companies lacked an effective response to the Japanese challenge. According to the literature, the reasons behind this lack of an effective response are various. Hayes and Wheelwright (1984), in their now classic book, summarize some of them in five main points:

Financial considerations: The assessment of companies and their manager's performance based predominantly on short term considerations may have induced managers to avoid long term investments which might have resulted in a more effective manufacturing. Managers may not have decided to invest in improvements whose results would only show in the long term because they needed short term performance.

Technological considerations: Western managers would have been less sophisticated, imaginative and even less interested in dealing with technological considerations than the overseas competitors, focusing attention predominantly on financial and marketing issues.

Excessive specialization and/or lack of proper integration: Western managers would have tended to separate complicated issues into simpler, specialized ones to a greater degree than their foreign counterparts without having developed proper integration to pull the differentiated responsibilities together and to be able to deal with the total picture.

Lack of focus The separating and specializing mentality would have led many Western firms to diversify away from their core technologies and markets. They would have tended to adopt the *portfolio* approach, used by stocks and bonds investors. This approach considers that diversifying is the best way to hedge against random setbacks. Manufacturing, however, would not be subject only to random setbacks but, more significantly, to carefully orchestrated attacks from competitors who focus their resources and energy on one particular set of activities. Focused manufacturing is based on the idea that simplicity, repetition, experience and homogeneity in manufacturing tasks breed competence (Skinner, 1974).

Inertia Skinner (1985) observed that most factories in the Western world were not managed very differently in the 1970s from the way they were in the 1940s or 1950s. Such practices might have been adequate when production management issues centered largely on efficiency and productivity. However, the problems of operations managers moved far beyond mere physical efficiency. On top of this, managers considered that the production problems were solved, directing attention and resources toward other issues such as distribution, packaging and advertising. According to Hill (1995), there had been a failure, conscious or otherwise, of Western industries and the society at large to recognize the size of the foreign competitive challenge, its impact on their way of life, and consequently to recognize the need for change.

The result of the concurrence of the five factors above is that Western plants and equipment were allowed to age in all senses. What one day had been technological advantage, was eroded by the decline in expenditure and attention to issues such as new products research and development and new process technologies (Hayes and Wheelwright, 1984). Then, Hayes and Wheelwright conclude, "in the beginning of the 1970s, US companies found themselves pitted against companies that did compete on dimensions such as defect-free products, process innovation and delivery dependability. Increasingly, they found themselves displaced first in international markets and then in their home market as well".

2.1. The development of a better understanding of the strategic role of manufacturing

Since the seminal work of Skinner (see e.g. Skinner, 1969), a number of authors have addressed the strategic role of the manufacturing function. Hayes and Wheelwright (1984) and later Hayes et al. (1988) called attention to the need to transform the manufacturing role from being primarily reactive to being *proactive*, where the manufacturing function contributes actively to the achievement of competitive advantage.

Another point which some authors make, e.g. Slack (1991) refers to the fact that the complexity of the manufacturing function calls for strategic management. According to Slack, manufacturing is almost certainly the largest (both in terms of people and capital employed), and probably the most complex and arguably the most difficult of all the functions within the organization to manage.

Hill (1995) argues that the need for a manufacturing strategy to be developed and shared by the business has to do not only with the critical nature of manufacturing within the corporate strategy but also with a realization that many of the decisions in manufacturing are structural in nature. Therefore, unless the issues and consequences are fully appreciated by the business, then it can be locked into a number of manufacturing decisions, which may take years to change. Changing them is costly and time consuming, but even more significantly, the changes will possibly come too late.

More recently some authors (Hayes and Pisano, 1996; Teece and Pisano, 1994; Pisano, 1997; Altier, 1998) have added to the debate by arguing that the recently developed resource-based view of strategic management should play an important role in the development of

manufacturing strategy - the resource-based view would help manufacturing strategies to be more difficult to copy resulting in more sustainable competitive advantages. This concept will be further developed later in this chapter.

2.2. Focused manufacturing: a controversial concept

Although the manufacturing function is regarded as one of the most complex to manage within the organization, what creates the complexity is not the technology dimension but the number of aspects and issues involved, the interrelated nature of these and the level of fit between the manufacturing task and its internal capability (Hill, 1995). The level of complexity involved depends largely on corporate and marketing strategy decisions, made within the business, where the competitive priorities are established. These competitive priorities are established because a manufacturing system cannot excel in all aspects of performance at the same time. Trade-offs must be made. Different types of performance demand different manufacturing resources organized in different ways (Slack, 1991; Skinner, 1996). An organization which competes predominantly on cost efficiency, for instance, by manufacturing in high volumes, would need different resources (possibly more dedicated machines) in order to compete effectively if compared to an organization competing on product customization, making products to order (which would possibly call for more general purpose flexible equipment).

This is the rationale behind the concept of *focused manufacturing*. According to this view, for the effective support of competitive business strategy the manufacturing function should focus each part of its manufacturing system on a restricted and manageable set of products, technologies, volumes and markets so as to limit the manufacturing objectives in which it is trying to excel. This means that if an organization has different products or product groups competing in different ways, then its manufacturing function should reflect this in the way it is subdivided and organised so as to maintain focus on what is most important for its competitiveness in the market place.

If a company competes on a broad range of products, the decision to adopt the concept of focused manufacturing can have the disturbing implication of calling for major investments in new plants and new equipment to break down the existing complexity. One alternative approach, which helps to avoid major investments, is a solution that does not involve selling big multipurpose facilities and decentralizing them into small ones. The solution could be the more practical approach of the 'plant-within-a-plant', where the existing facility is divided both organizationally and physically into plants within the original plant. Each of them would have its own facilities. Each plant-within-the-plant can in this way concentrate on its particular manufacturing task, using its own work force management approaches, production control systems, organizational structure and so forth. Each plant-within-the-plant would quickly gain experience by focusing and concentrating every element of its work on those limited essential objectives which constitute its manufacturing task or focus.

The idea of focus should thus permeate all the process of formulation and execution of the business and manufacturing strategies. The establishment of competitive priorities and the decision making process should also take the idea of focus into consideration, in order to make sure that the manufacturing function can really excel in what it is expected to.

Although it is intuitive and appealing, having gained broad support among academics and practitioners, a number of authors (see e.g. Schonberger, 1986) have challenged the idea of focus in manufacturing strategy. Inspired by the Toyota-developed Japanese just-in-time system, the "lean production" system advocates argue that trade-offs do not exist (since at a

certain point in time some Japanese companies outperformed western competitor companies in all aspects of performance) and that the principles on which "lean manufacturing" rests:

- broadly trained rather than specialised people;
- people empowered to identify and solve production problems in teams;
- horizontal and informal communication rather than through hierarchical paths;
- emphasis on production throughput flow rather than resource utilisation;
- production flows pulled by demand rather than pushed by centrally defined schedules;
- product based rather than process based layout;
- no acceptable level of defective production;
- inventory is considered as waste and set-ups should be minimised;
- continuous improvement and waste fighting initiatives are central;
- cooperative and long term rather than adversarial supplier relationships; and,
- product development related activities done concurrently by cross functional teams

Would be the "one best way" to organise and manage manufacturing. But is it? Many authors disagree. Hayes and Pisano (1996) for example argue that although many companies experienced improvements by implementing one or more of the "lean manufacturing" principles, "this does not assure that it will be successful financially. For example, the winners of the [American] national Baldridge Award, which recognises American companies that have been unusually successful in improving their quality, productivity and customer satisfaction, have done well on average - however, some of them entered Chapter 11 soon after receiving the Baldridge, and others (like General Motors, IBM and Westinghouse) soon thereafter began experiencing highly visible problems.

Even more disturbing, a number of Japanese companies are beginning to question many of the same approaches [...] Toyota's newest factory in Japan utilizes neither the JIT system nor mixed model assembly".

Arguments about the trade-offs in manufacturing have sometimes been polarised in two approaches - some of the advocates of "lean manufacturing" argue that trade-offs do not exist. Contrary to this some of the more radical advocates of the trade-off idea sometimes ignore the fact that even considering that trade-offs exist, they are dynamic rather than static in nature and that trade-off relationships can be altered in a number of ways. One of the interesting models to describe trade-offs in manufacturing is Slack's see-saw analogy. According to Slack's (1991) manufacturing management is sometimes portrayed as consisting almost entirely of handling trade-off's. Trading off high finished goods inventory against good product availability, trading off expensive preventative maintenance against the reliable provision of capacity are some examples. Improvement in one place should be paid for elsewhere. Schematically this idea can be seen in Figure 1.

When performance objective 2 is improved, performance objective 1 suffers, at least in the short term (B). One example in the field of inventory management would be the trade-off between cost efficiency (associated with lower inventories) and customer service defined as good product availability. If in the short term a company decides to improve service level, one way of doing it is by increasing finished goods inventory. Having done that, it then may be possible to re-gain the lost level of cost efficiency (by reducing inventory levels) without jeopardising the newly acquired improved level of customer service (C) - for example by reducing lead times or improving future demand knowledge (via e.g. improving forecasting

systems or better coordinating with the customer and this way, with less uncertainty, less buffer inventory would be needed), represented by the movement of the see-saw pivot.

Figure 1. Slack's (1991) see-saw represents the dynamic nature of trade-offs

None of this pivot moving alternatives however can normally be achieved in the very short term. They are initiatives, which normally take longer than simply increasing inventory levels. This means that managing the trade-offs between performance aspects of manufacturing performance does not mean only managing the position of a static see-saw (which in many situations can be altered in the short term), but it also means managing the movements of the see saw pivot (which normally takes longer). Hayes and Pisano (1996) add to Slack's point arguing that trade-offs should be managed considering not only the improvements in each of the performance objectives but also the knowledge and learning that each of different possible dynamic improvement paths will bring to the organisation. The idea of dynamic improvement paths is interesting. Let us use another form of representation for the idea of dynamic trade-offs in relation to the trade-off between service level and inventory level. One of the simplest models used to dimension safety stocks of inventory items (the demand of, which is approximately constant, is):

$$SS = SF \times \sigma_{LT} \tag{1}$$

Where:
SS = safety stock level
SF = safety factor
σ_{LT} = standard deviation of demand (compared to forecast) during replenishment lead time

The SF (safety factor) is defined as a function of the service level intended to be offered to the customer (see Chase et al., 1998 for a detailed treatment of safety stocks - the idea here is just to use this simple model as an illustration). Assuming that demand forecast errors behave normally and with some help from statistics, the plotting of a graph relating safety stock level and service level, results in something like what is shown in Figure 2.

This somewhat simplistic model can be used to show the idea of dynamic paths. Movements along the trade-off borders 1 and 2 represent Slack's "static" pivot see-saw movements - if one wants to increase service levels one way to do it is surely to increase the levels of inventory (therefore jeopardising the objective of cost efficiency). However, as it can be seen by the formula (1), one can alter the level of service without changing the level of inventory - by changing the other factor of the right hand side term - the standard deviation of the demand forecast during replenishment lead time.

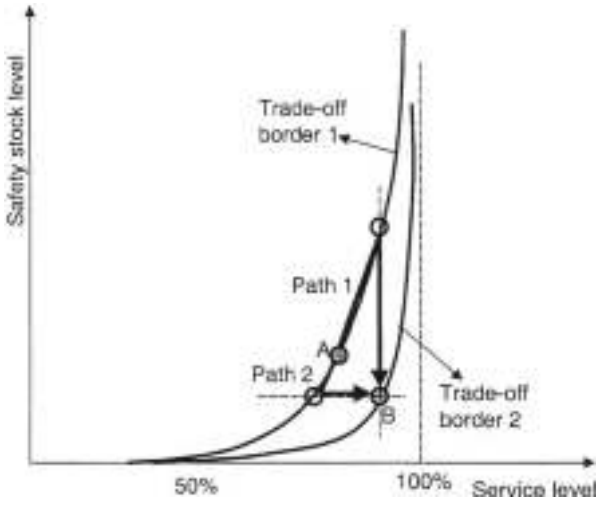

Figure 2. Graph representing Hayes and Pisano (1996) dynamic trade-off paths

If the standard deviation is reduced for example, the trade-off border changes from trade-off border 1 to trade-off border 2. To illustrate Hayes and Pisano (1996) dynamic path idea, one can imagine a manager intending to go from status A to status B, in figure 2, therefore improving both aspects - service level and inventory-related cost efficiency. Several paths of improvement could be chosen. Among them, two are used to illustrate the point; path 1 and path 2. Path 1 would mean first to increase inventory levels (which can be done relatively quickly) to achieve increased service level ("static" pivot see-saw movement) and then to set off efforts to reduce inventory levels without reducing service level through e.g. improving forecasting methods (which takes longer and requires a particular set of capabilities development). The other path which could be used to achieve the same status B (coming from status A) which is path 2, means a different sequence of actions. First, the inventory levels would be reduced and then efforts would be made to increase service levels without increasing inventory levels again, by for example, using JIT-type techniques of identifying production problems by reducing inventory levels and then acting selectively and constantly to tackle such problems (which will result in a rather different set of capabilities being developed). Path 1 is more centred in the traditional methods whereas path 2 is more towards JIT-type management. The final status (B) is the same, but Hayes and Pisano (1996) argue that depending on the path chosen the learning experience which the hypothetical company would go through would differ considerably and therefore the ability of the company to face future competitive challenges would also differ considerably. The conclusion is: trade off analysis is not as simple as the radical advocates of "lean manufacturing" (one best way) would have liked and they are not as simple as a "static" analysis would have us believe either. Trade-offs exist and will probably always exist but their treatment requires an in depth understanding of the dynamics and dynamic paths involved in each particular situation under analysis.

2.3. Why Manufacturing Strategies for Improving Productivity and Quality

Basically the whole movement set off by Skinner's seminal articles in the beginning of the '70s was basically an attempt of western astonished manufacturing academics and practitioners to understand and respond to the competitive challenged posed by the suddenly successful Japanese companies who had quickly taken a substantial share of the world export market from them. In terms of Slack's see-saw model, Japanese companies had found out how to move the pivots while western companies had been complacently managing the "static" pivot see-saw movements only. One of the formerly accepted trade-offs which the Japanese companies challenged was one between high levels of conformance quality (the ability of the production system to produce outputs according to specifications) and cost efficiency. In the traditional manufacturing systems inspectors would sort good from bad products at the end of the production line - if a company wanted more quality, more inspectors (with the corresponding increased inspection cost) would be needed. Quality used to cost. Japanese companies changed this paradigm (they moved the pivot), by giving operators the responsibility and the ability to detect and solve quality problems, redirecting the attention from product quality to process quality. More conformance quality therefore would not necessarily mean more costs. Quality started to be considered as free (Crosby, 1979).

Western managers started to realise that their role should change: the traditional mass production approach which had reduced the manufacturing strategic contribution to "reducing costs" to something more complex and relevant: the purpose of the strategic management of manufacturing would have to change to specifying the kind of competitive advantage that a company is seeking in the market place and to articulate how that advantage is to be achieved (Hayes and Pisano, 1996). However, the challenge in the '80s was basically one of catching up with the Japanese companies and the most important trade-off involved was the one between cost efficiency and quality: Western companies had to manage better the things which were under their control e.g. levels of defect and wasted manufacturing resources. The '90s brought a different environment. Japanese companies used the lead they had simultaneously achieved in quality and cost and while the western companies spent all their efforts to catch up with them, they had started directing efforts towards moving more pivots - e.g. that between flexibility and cost efficiency, for example, based on set-up time reductions via both technology (flexible automation) and methodology (quick changeover techniques based on different more rational non-technology based methods - see for e.g. Shingo, 1985). At the same time, markets had became increasingly turbulent, globalisation had taken place and technology had reached unprecedented development rates. The challenge then was not only to manage things better which were under control (such as product quality variability) but to manage things better which were not completely under control - to manage better the unexpected change.

3. THE NEW MANUFACTURING ENVIRONMENTS OF THE '90s AND THE 2000s

The manufacturing environments of the '90s and the 2000s have been and will be considerably different from those of previous decades.

Information technology has remarkably changed the patterns of integration and communication within as well as between companies and between companies and consumers. The ERP-type integrated management systems have broadly been adopted and although one could argue that the results were not as spectacular as the consultancy companies and software houses had announced, the levels of integration and communication between

customers and suppliers (internal and external) which the companies have achieved so far are superior than the levels they used to work with without the integrated systems. With the integrated systems being connected with the Internet (a reality now) now virtually endless opportunities are available to the companies who are competent enough to use them for competitive benefit. However, one should not make the usual mistake - assuming that it is enough to *possess* the technology to ensure a *good use* of the technology. These are actually different things and anyone who has managed a manufacturing operation knows that. Sometimes some authors tend to neglect this fact considering that operational excellence is easily copied because manufacturing operations are increasingly technology oriented and technology is easily traded. They sometimes mix concepts. Having an integrated software system plugged in, for example, is in fact easy and increasingly cheap. However when one looks at how comparatively well companies use the resources made available by such systems one starts seeing huge differences. So having the same technology is easy; using that technology for the company's competitive benefit is not - and therefore it is not easily copied.

The rate at which technology has evolved requires, more than ever, that manufacturing managers are *proactive* in anticipating and understanding the newly available technologies and their impact on the company's competitive performance, both in terms of information, product and process technologies.

Customer requirements are increasingly demanding because competition is increasingly global and fierce and, competitors are increasingly competent. Customers already want it "here, now and customised" (McKenna, 1997) - that means achieving levels of agility never required before from the production systems. That means a level of ability to ensure consistency between manufacturing actions and strategic direction, which was never required before. Required changes in the strategic direction must be quickly mirrored by changes in the pattern of manufacturing decisions. In the same way, changes in the manufacturing resources, newly developed competencies and newly available technologies should also be able to quickly change the strategic direction of the company changing for example the marketing aim to market segments which better value the newly acquired or developed competencies.

4. ROLE OF NEW MANUFACTURING CONCEPTS AND TECHNOLOGIES

4.1. The development of new manufacturing technologies

Manufacturing Technology is regarded as one of the most important decision areas within the manufacturing management function. Traditionally, manufacturing management has influenced manufacturing technology to a much greater extent than the other way round.

Changes in the manufacturing technology were for a long time slow and gradual not calling for profound changes in its management methods and techniques. With the new microelectronics and information handling technology being quickly incorporated into the process technologies, the resulting changes were not gradual and did not follow the usual pattern. A new paradigm was established. Computer controlled flexible machines challenged the once well established concept of *economies of scale* because they have the potential of making changeover times negligible. The concept of *economies of scope* started to gain importance. Economies of scope (Goldhar and Jelinek, 1983) are said to occur when one production unit can produce a given level of outputs of a variety of products at no unitary cost which is lower than that obtained by a set of separated production units, each producing one product at the same level of output.

The new flexible technology made it possible to produce different products at the same rates, which had only been possible with mass production, with single, or a few products. The

strict one-to-one relationship between product and process life cycles would not apply any more (Stecke and Raman, 1986).

In summary, without a clear strategic direction with regard to manufacturing, the new manufacturing technologies can become an expensive 'solution in search of a problem'. In this sense, one of the aims of manufacturing strategy is to give the organization strategic direction with regard to manufacturing issues, technology included, making sure that not only the technologies but also the people and the infrastructure used are consistent with the strategic objectives of the business.

4.2. The resource-based view

The more popular paradigm for approaching competitive strategy has been based on the notion of strategic fit (Hayes & Pisano, 1996). Porter's (1980) book, "Competitive Strategy" became possibly the most celebrated book in the field. Recognising the existence of trade-offs, Porter argued that the goal of business strategy is to seek sustainable competitive advantage by positioning oneself within industries and businesses that are either structurally attractive or can be made so through deliberate actions. According to Porter, competitive advantage is strongly linked with the idea of good positioning. In the '90s, Prahalad and Hamel (1990) added to this debate challenging Porter's ideas by advocating that companies should focus on building "core competencies" that could create competitive advantages in a variety of markets. They argue that only competencies which are difficult to copy actually make a company sustainable competitive and therefore a company who positions itself and then develops the needed competencies will have their recently acquired competences easily copied and therefore the advantage will not be sustainable. Teece and Pisano (1994) called the attention to the dynamic aspects of the resource-based view, arguing that not only are the capabilities to be developed important but that the mechanisms by which new skills and capabilities are built have an important role to play because they influence the learning processes and knowledge base of the company and these will influence the ability of the company to compete in the future.

The resource-based approach is markedly different from the traditional manufacturing strategy paradigm.

According to most of the early authors, the manufacturing strategy development should follow a predominantly top-down approach. Skinner (1985), Fine and Hax (1985), Gregory and Platts (1990), Slack (1991) and, to a certain extent, Hill (1995), suggest hierarchical models in which the corporate strategy drives the business strategy. This in turn drives the strategies of manufacturing and other functional areas within the business unit. In fact, the manufacturing strategy formulation process has not received as much attention as the manufacturing strategy contents - objectives and decision areas - in the literature (Leong et al., 1990). Among the pioneers in the field, Hill (1995) seems to have been one of the few who actually delved into a more detailed discussion on it, proposing a specific framework to guide the development process on a (also predominantly top-down) step-by-step basis. Rather, the authors in the field tend to focus their work primarily on the manufacturing strategy objectives and decision areas. This approach, according to Leong et al. (1990), seems to consider some sort of implicit process, which depends on breaking manufacturing down into a number of decision areas and making the goals of manufacturing explicit in terms of a number of performance criteria. The steps of identifying these criteria, prioritising them and relating the decision areas to them would form the implicit process. Hayes and Wheelwright (1984), for instance, although describing four stages along a "continuum", which represents the evolution of manufacturing's strategic role, where the key aspect of evolution is the

increasing, more proactive involvement of manufacturing in the firm's strategic needs, do not describe how a company should go about reaching the more advanced stages.

The exclusive top-down traditional planning approach does not seem to be adequate for the future - planning is only of use when a good level of stability is present. Otherwise it may easily become a futile exercise. In the future the only certainty companies will face is that changes will be larger, more sudden and quicker than ever before therefore requiring more agile manufacturing strategy development and implementation processes.

5. NEED FOR AGILE MANUFACTURING STRATEGY PROCESSES

The authors in the field of manufacturing strategy are more prolific in prescribing *what* to do than *how* to do it. There is however some authors whose work can help in the difficult task of developing a manufacturing strategy in real situations. Two examples are the worksheets developed by Gregory and Platts (1990), which are interesting tools for helping define the priorities for manufacturing and, the importance-performance matrix proposed by Slack (1991), which is both simple to understand and use and effective in giving managers a clear idea of what performance aspect needs urgent action in manufacturing. Both however are still predominantly top-down planning-based tools. As can be seen, although some very valuable contributions can already be found in the literature, some increasingly important aspects of the manufacturing strategy development process still lack proper operationalizing methods in the literature.

The proactivity of the manufacturing function is an example. Proactivity, particularly in turbulent environments, is not something that simply can give companies an edge. It is the only way to survive. In fact, manufacturing proactivity is suggested by a number of authors (Hayes and Wheelwright, 1994 is possibly the most eloquent example) but few of them actually prescribe how the function should be organized and managed to achieve it. Proactivity relates to the concept of the resource-based view - it is no doubt desirable, but actually how to go about reaching it? You will not find much about this in the current literature.

Breaking functional barriers is a second example. In turbulent environments, where change is not an exception, but the rule, inter-functional communication becomes essential in order to allow for rapid responses to frequent and sudden changes. The authors in the literature generally agree that for an effective manufacturing strategy to be put into practice it is necessary that functional barriers be broken down. Much of the reengineering discussion gravitates around this aspect. However, few authors in the field of manufacturing strategy deal specifically with methods to operationalize ways to break down or at least reduce the negative effects of the inter functional barriers.

The propositions described here aim to contribute to the manufacturing strategy process development debate addressing specifically aspects such as manufacturing proactivity and inter-functional integration, drawing some conclusions that may help companies operate under the turbulent conditions of the future when dealing with unexpected change is central.

5.1. Change is rule, not the exception

Change is a central concept in managing organizations in the future In recent years, the turbulent industrial/economic environment makes long-term planning a difficult task for many companies around the world. The high and unstable levels of inflation and exchange rates, the constantly changing government industrial policies, high interest rates, the political turmoil in which many countries have found themselves in recent years, the globalization with constant