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AGILE OR ADAPTABLE? FINDING A PARADIGM FOR AN UNCERTAIN WORLD

David Bennett

Aston Business School,
Aston University, Birmingham B4 7ET, UK

This paper looks at the way in which, over recent years, paradigms for manufacturing management have evolved as a result of changing economic and environmental circumstances. The lean production concept, devised during the 1980s, proved robust only until the end of the bubble economy in Japan caused firms to re-examine the underlying principles of the lean production paradigm and redesign their production systems to suit the changing circumstances they were facing. Since that time a plethora of new concepts have emerged, most of which have been based on improving the way that firms are able to respond to the uncertainties of the new environment in which they have found themselves operating. The main question today is whether firms should be agile or adaptable. Both concepts imply a measure of responsiveness, but recent changes in the nature of the uncertainties have heightened the debate about what strategies should be adopted in the future.

1. INTRODUCTION

The publication, in 1990, of the book *The Machine that Changed the World* by Womack, Jones and Roos, with its advocacy of "lean production", was timely in that its appearance coincided with a period when the concept could be sustained due to the business circumstances that prevailed at that time. In Japan, where the researchers from the MIT International Motor Vehicle Programme (IMVP) identified the concept, there were very special conditions. The post World War 2 period, with its severe shortages of materials, had forced Japanese manufacturers to manage with limited inventories simply to survive. This consequently served them well during the 1980s when they were able to apply what they had learned about manufacturing with few resources within the context of high, stable, demand for their products, fuelled by a low value of the Yen, which made exports competitive, and low interest rates, which boosted domestic sales.

The essential elements of lean production are shown in Figure 1. A key feature is the idea that fewer resource inputs are required by the manufacturing system (less materials, fewer parts, shorter production operations, less unproductive time due to set-ups etc). At the same time there is pressure for higher output performance to be achieved (better quality, higher technical specifications, greater product variety etc.) This should result in greater customer satisfaction, which in turn provides the opportunity for the lean company to gain a larger market share than its competitors.

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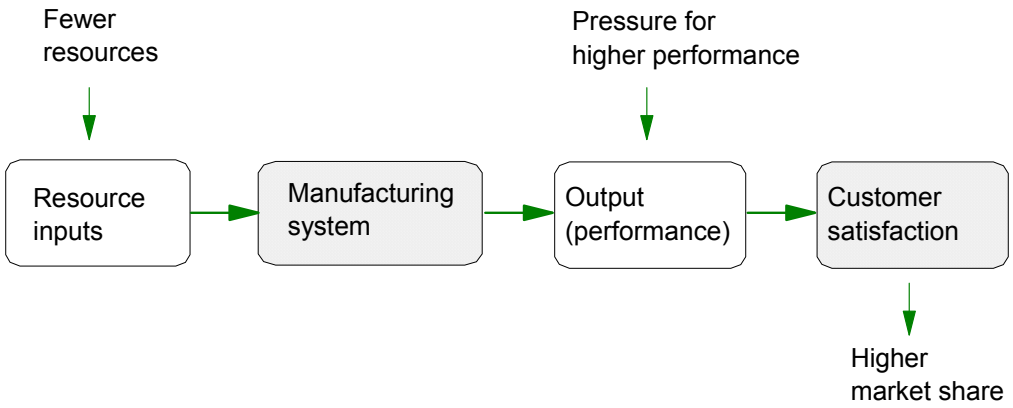


Figure 1. The essential elements of lean production

Within the automobile industry the consequence of creating a lean system of production has best been demonstrated by Toyota. Since starting to introduce lean principles around 1950 Toyota has transformed from being a minor producer of just a few thousand vehicles into one that now ranks among the world's leading automotive manufacturers.

2. LEAN PRODUCTION QUESTIONED

Despite the apparent superiority of lean production compared with conventional mass production systems, however, questions started being asked in Japan during the 1990s concerning its robustness as an approach to cope with future economic and market conditions. There are several factors to bear in mind concerning the apparent dominance of lean production. The first is that Womack and his colleagues conducted their research at the time of Japan's 'bubble economy' of the late 1980s during conditions of a bull stock market and low interest rates. Domestic demand for consumer products was at an all time high level and the output from Japan's factories also could remain high. The main competitive objective of companies, therefore, was to increase market share by reducing costs, and thereby prices, as well as offering a greater variety of products with more features. The second point is that Japan has a severe *"shaken"* vehicle inspection system which encourages owners to scrap their cars and buy new ones. There is little demand for second hand vehicles and cars more than a few years old are a rare sight on Japanese roads. This has enabled automobile manufacturers to rely on a large domestic market which has been willing to readily accept the latest models, thereby increasing the rate of new product development. Domestic sales in Japan, at around 8 million per year, account for about one quarter of total world production and are two and a half to three times larger than the market size in Germany, the United Kingdom or France, where sales are between 2 million and 3 million per year. Also, the average model age of Japanese cars is less than two years compared with around four to five for a typical European or North American producer. The effect of the phenomenon just described is shown in Figure 2.

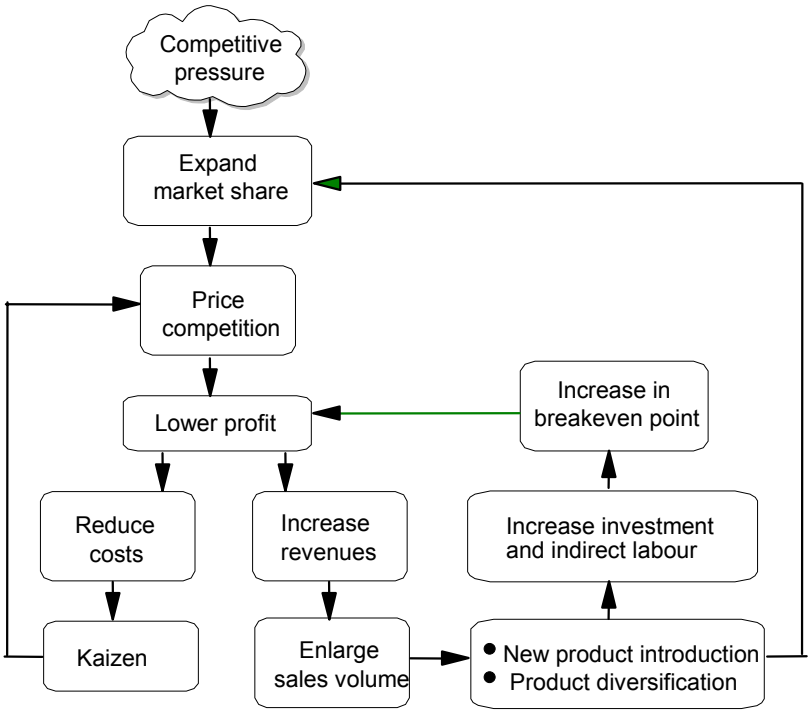


Figure 2. The past trend in Japanese manufacturing

The main competitive pressure on companies was to expand market share, the principal means of achieving which was through price competition. This in turn reduced profits, thereby necessitating cost reductions and increased revenues. Cost reductions were achieved through "*kaizen*" (continuous improvement) activities, which further stimulated price competition, while increased revenues necessitated larger sales volumes and required new products to be introduced and products to be diversified. This required increased investment and more indirect labour, so increasing the breakeven point and reducing profit.

Japanese industry was able to maintain this continuous cycle during the bubble economy of the late 1980s and early 1990s but then the chain of events in Figure 2 was broken. In particular the increase in revenues through larger sales volumes could no longer be a presumed step in the cycle with the increase in interest rates and levelling of disposable incomes. Moreover the increasing value of the Yen, brought about by the strength of the industrial economy, reduced the opportunity for Japanese companies to rely on exports as a means of compensating for lower domestic sales.

3. THE EMERGENCE OF AGILITY

The paradigm that subsequently emerged during the 1990s was that of 'agility'. The term 'agile manufacturing' was coined by a U.S. government sponsored research programme at Lehigh University and, latterly, MIT [2]. It seeks to cope with demand volatility by allowing changes to be made in an economically viable and timely manner [3]. Although the word 'manufacturing' is used with this concept, the principles of agility can equally apply to other functions of a business and to service industries.

Agility relates to the interface between the company and the market. Essentially it is a set of abilities for meeting widely varied customer requirements in terms of price, specification, quality, quantity and delivery. Agility has been expressed as having four underlying principles [4]. These are:

i) delivering value to the customer,
ii) being ready for change,
iii) valuing human knowledge and skills, and
iv) forming virtual partnerships.

Of course, there also need to be some concrete technological changes to realise agility [5] and there are many examples of hardware and software technologies that can enable agility to be realised [6]. In order to determine the strategic importance of agility to companies an analysis of strategic priorities and action programmes has been carried out among Japanese domestic companies using data collected through an extension to the "Manufacturing Futures" project [7]. There were 182 respondents, with 157 from the manufacturing sector. They were all relatively large companies or business units. A company's strategic priorities can be defined in terms of the emphasis assigned to each element of its business strategy. In the survey sixteen such priorities were identified, among which seven could be regarded as being agility-related. These are:

- Making rapid design changes
- Introducing new products quickly
- Making rapid volume changes
- Making rapid product mix changes
- Providing fast delivery
- Making a product easily available
- Customising products

In order to assess their strategic priorities respondents were asked to indicate on a scale of 1 to 7 the current strength of each priority relative to their main competitor and the importance of each priority for their organisation when competing in over the next five years. The results are shown in Figure 3.

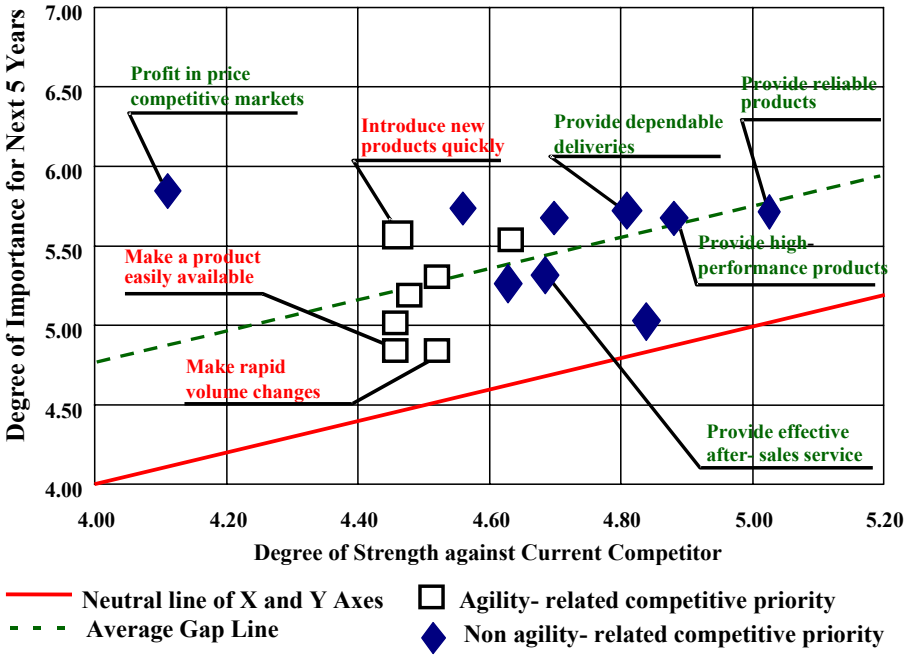


Figure 3. Gap analysis between current strength and future importance of strategic priorities

In the analysis, competitive priorities are categorised into two types, i.e. agility-related (as listed above) and non agility-related priorities. It is noticeable that the average scores of current

strength for the agility-related priorities, which are plotted on the horizontal axis, are relatively low and concentrated between 4.45 and 4.65, whereas those for the non agility-related direction are significantly higher, being mainly between 4.55 and 5.05 with the exception of the priority of "profit making in price competitive markets" which has a relatively low score of 4.1. On the other hand, scores of future importance for the priorities are widely varied between 5.0 and 6.0 without any significant distinction between the two categories. This means that companies now tend to be more clearly aware of the importance of agility than in the past and conflicts of priority with conventional issues seem to be occurring. The distinctive agility-related priorities are "introduction of new products quickly" and "offering a broad product range", which could be summarised as a 'product-focused direction'.

A further analysis related to the action programmes used by companies towards accomplishing the objectives defined by their strategy. Here a total of forty-four such action programmes were identified among which the following nineteen were assessed as being related to agility:

- Giving workers a broad range of tasks
- Reorganising plant networks
- Worker training
- Management training
- Supervisor training
- CAD/CAE
- CIM
- Cross- functional teams
- Functional teamwork
- Integrating manufacturing information systems
- Integrating systems across business functions
- Integrating information systems with suppliers and distributors
- JIT
- FMC/FMS
- Concurrent engineering
- Reengineering business processes
- Outsourcing manufacturing
- Supplier partnerships
- Customer partnerships

Again, respondents were asked to indicate on the same scale as for their strategic priorities the extent of any payoff resulting from these programmes or activities in the last two years, together with the relative degree of emphasis their organisation will place on each action programme over the next two years.

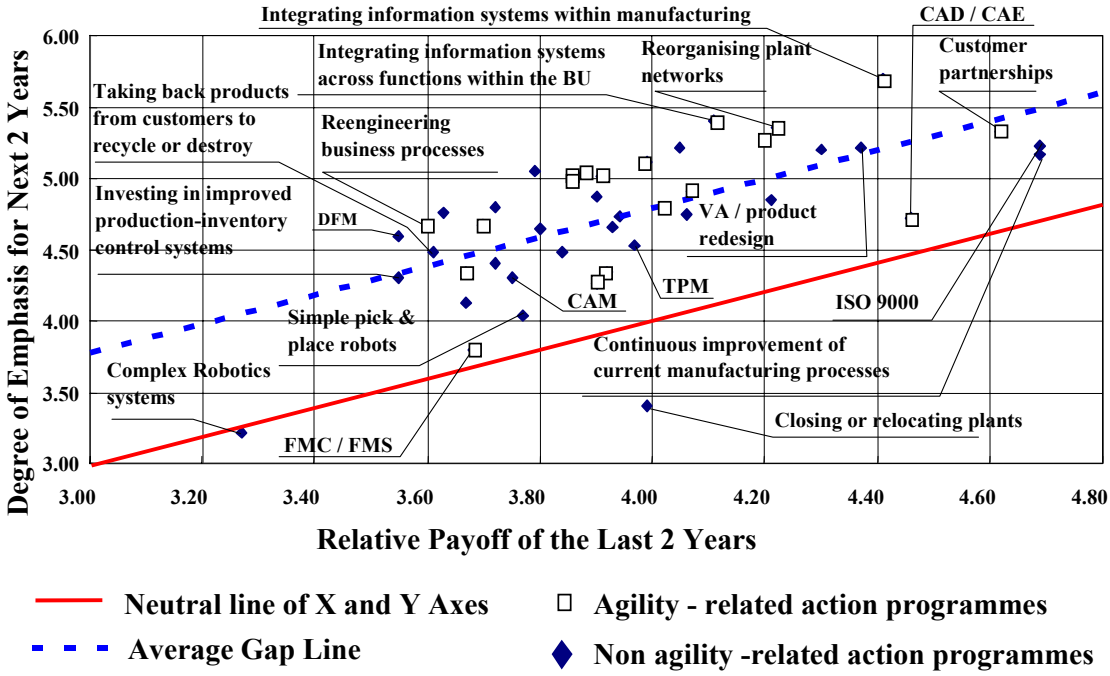


Figure 4. Gap analysis for action programmes used to accomplish objectives

From the gap analysis for the action programmes sown in Figure 4 it was found that scores for both agility-related and non agility-related action programmes were widely dispersed with no significant difference between the two categories. This implies that the respondents' action policies were still item-by-item investments which focused on separate improvement islands, e.g. customer partnerships, CAD/CAE, integration of information systems etc. Although the companies had already experienced many successes in implementing various action programmes this way of working is not very effective for agility realisation This is because the critical issue for agility is a company-wide ability to respond quickly and efficiently to customer requirements rather than the implementation of specific measures.

4. THE NEED FOR ADAPTABILITY

Although the agility paradigm has been seen as a means of overcoming many of the rigidities associated with lean production there are still many other related problems that have been experienced in Japan. Some of these relate to the external environment of companies, while others relate to the internal production environment. Some of these have recently been documented [8].

4.1 External Environment

One of the most apparent effects relating to the external environment, that was reported widely in the popular Japanese press, was the increase in traffic brought about by the pressure for smaller, and thereby more frequent, deliveries of materials to factories. Not only was this the cause of urban congestion, but at times it also created long queues of delivery vehicles on the country's main highways, particularly the most important arterial route linking the industrial centres of Tokyo, Nagoya, Osaka, Kobe, Hiroshima etc. This situation gave rise to accusations that it resulted in pollution and unnecessary energy consumption as well as being the cause of inconvenience for other road users.

Another effect relating to the external environment was the public's reaction to the plethora of new products and variants that have appeared at an ever increasing rate. While once this was an attraction to consumers the situation became one in which they were confused by the choice they were offered and they felt annoyed by the fact that new goods became obsolete almost as soon as they left the store in which they were purchased. Many customers of automobiles, for example, began to feel that despite the number of models on offer very few were attractive [9] and visible evidence of this could be found in the number of well established foreign models that were to be seen on Japanese roads despite their high price compared with domestically produced vehicles. For example the British made Austin (Rover) Mini, almost unchanged since its launch around 40 years ago, was a particularly popular model in Japan right up until its recent replacement in the UK.

An external influence of the global economy, the high value of the Yen, was mentioned earlier. Another influence has been the setting-up of Japanese owned factories abroad. This in turn has created a source of competition for Japanese parent plants in both foreign and domestic markets. For example a subsidiary factory in South East Asia typically can manufacture products at 50% of the cost in Japan while a European plant can manufacture at around 80% of the cost. The effect of this is that Japanese companies are increasingly importing products and parts from their overseas subsidiaries, causing a decrease in demand on domestic plants.

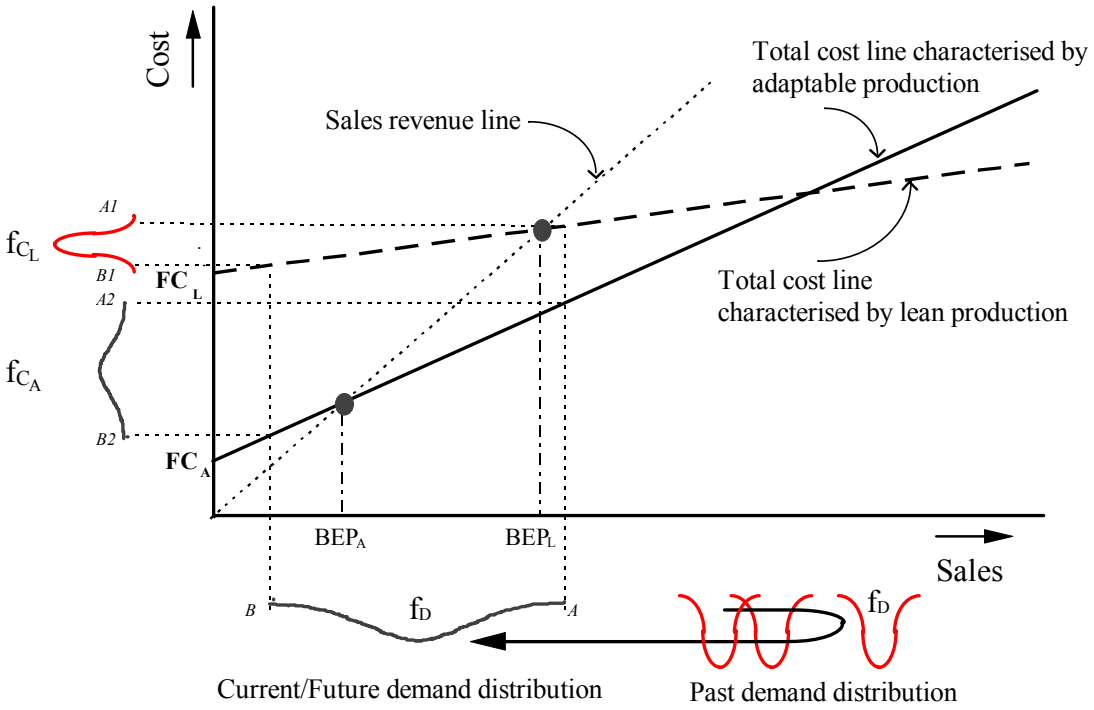
4.2 Internal Environment

The main internal environment factor affecting the application of lean production relates to the workforce. There is the question of the aging population, which means there are fewer younger workers employed in Japanese factories. In the past Japan had an abundant younger workforce that was adaptable to new technologies and, by virtue of the seniority based pay system, provided relatively cheap labour. Today, Japan has achieved the longest life expectancy in the world and the number of young workers entering the labour market is in decline. The total size of the Japanese workforce is also now reducing so Japan's problem is beginning to be one of labour shortages rather than unemployment [8]. A particularly difficult problem that is now becoming evident in many Japanese companies is the shortage of young workers and relatively large number of older employees. As well as being less productive and versatile these older workers also increase wage costs since there is a tendency to reward length of service in Japanese companies.

The aging population is not the only reason why fewer younger workers are going into Japanese factories. The work itself is also proving to be a disincentive, being seen as exhausting and involving long working hours. The automotive industry is especially notorious in this respect and a report by the Confederation of Japan Automobile Workers' Unions [9] recognised an "exhausted workplace" as being among the factors it considered were causing harm to the industry's competitiveness. Of particular significance in this report is the suggestion that the Japanese automobile industry may not be competitive in the true sense of the word when taking into consideration the fact that employees work 2,200 hours per year. These are much longer working hours than are common in European or American plants and the question is posed how competitive a Japanese plant would be if the work hours were shortened to a more typical 1,800.

Case studies of current practice in Japanese manufacturing plants, which focused specifically on these problems identified the need for a new approach [10]. Such an approach involves the company adopting the paradigm of "adaptability" rather than "agility". The main feature of adaptable production is the inherent ability of the production system to adjust or modify its cost performance according to demand. In the current competitive environment surrounding

manufacturing industries, a defensive approach in response to the pressure for survival is through changing the company's or factory's cost structure from being flat with a big fixed cost function to a small fixed cost function even though the variable cost element becomes steeper. Figure 5 shows the essential difference in cost structure between systems with high and low fixed costs.



Notation;
BEP_A = Break-even point (BEP) of adaptable production (AP)
BEP_L = BEP of lean production (LP)
f_D = Demand distribution
fC_A = Cost distribution of AP
fC_L = Cost distribution of LP
FC_A = Fixed cost of AP
FC_L = Fixed cost of LP

Figure 5. The cost structure and sensitivity for systems with high and low fixed costs

When demand is reduced adaptable production becomes more cost effective because it is characterised by a cost function with a lower break-even point (BEP_A) compared with lean production that has a higher break-even point (BEP_L).
Moreover, adaptable production is more cost sensitive than lean production. For example, for a particular distribution of demand (f_D) the cost distribution for lean production is narrow (fC_L), while that for adaptable production is much wider (fC_A). Adaptable production therefore has much greater flexibility in terms of cost than does lean production.

Adaptability may be realised through a number of different organisational and technological solutions. Studies have identified several features of adaptable production that can enable the cost structure to be modified. These are as follows:
• Production costs are more sensitive to changes in demand
• Systems enable production rate to be adjusted to accommodate changes in demand

• System software can support changes in production rate and product mix
• Lower fixed costs on new product development activities and the acquisition of new production facilities
• Use of human operators as a flexible resource
• Prevalence of mechanisms to support manual work
• Production systems support job enlargement and job rotation
• Use of technological solutions to increase the variety of upstream products and flexibility of upstream processes
• Grouping of parts and products into families to reduce work-in-process variety and shorten set- up times
• Modularisation of product designs to enable efficient production of greater product mixes
• Planned mixing of different product complexities to smooth production load
• Extensive use of kaizen activities and methodologies such as TQM, TPM etc.

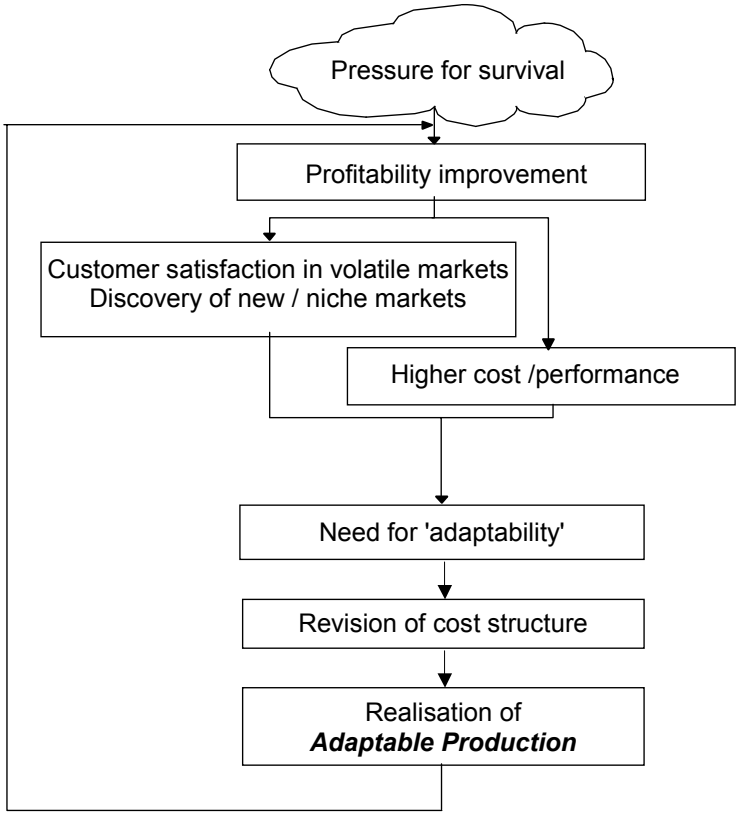


Figure 6. The cycle in manufacturing based on a strategy of survival

The above features were observed in the case studies of more than ten factories in Japan making products such as semiconductors, photocopy machines, personal handy-phone systems, refrigerators, air-conditioners, textiles, cement, televisions, automobiles, telecommunication equipment, household equipment (boilers, bath tubs, system kitchens), printed matter, steel, and machinery equipment. All the firms were trying to modify their cost structure in various ways using one or more of the adaptability features to maintain their competitive edge or market niche position. The new trend in Japanese manufacturing, which is based on a strategy of survival rather than expansion, is illustrated in Figure 6.

5. TODAY'S UNCERTAINTIES

The uncertainties of the 1990s were due to the turbulent economic and business conditions that existing after the ending of the bubble economy in Japan, and these conditions were reflected in many other parts of the world. Today's world, however, is even more uncertain. The September 11th 2001 events were not only tragic; they also gave rise to a range of additional problems for manufacturers. Apart from the adverse effect on business conditions they also relate to, for example, transport infrastructure, staff mobility, and the need to maintain security of supply. Some companies are also having to find new products and pursue new markets as their traditional ones are eroded. The survival orientation of the adaptability paradigm is well suited these new conditions because it is based on a cost structure that minimises exposure to heavy investments in fixed cost that cannot deal with such uncertainties.

The other uncertainty emerging in the new Century relates to the sustainability agenda. The World Summit on Sustainable Development (WSSD) held in Johannesburg in September 2002 identified three key areas (or dimensions) of sustainability. These are:

i) economic growth and equity;
ii) conservation of natural resources and the environment, and
iii) social development

Production is therefore subject to a number of pressures and influences as shown in Figure 7. The uncertainties these pressures create are wide ranging. The most obvious is the uncertain impact of environmental legislation relating to pollution prevention and cleaner production, which impacts on the energy demands of the production process as well as the outputs in the form of products and services [12].

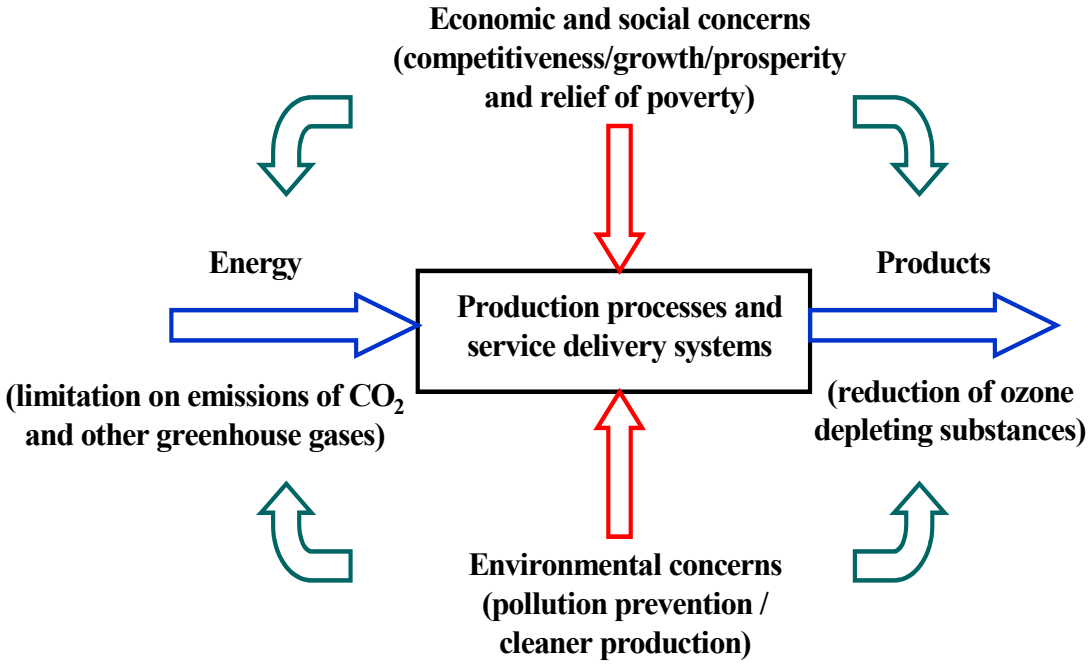


Figure 7. Production and the sustainability agenda

On the other hand, as a result of economic and social concerns and the need to relieve poverty in the under-developed world there is the pressure to re-align international manufacturing

networks so more investment is transferred to the slow and late industrialising countries. Adaptable systems are better suited here because of their lower fixed cost element and emphasis on manual operations supported by organisational and technological solutions to provide competitiveness.

They can help slow and late industrialising countries to climb from the bottom step of the ladder by enabling them to engage in more efficient production for domestic markets - through export oriented contracting and participation in the supply chain of international firms (see Figure 8). In certain cases it may also enable leapfrogging to take place from lower steps of the ladder - in much the same way the some industrialising countries, such as Korea, have leapfrogged the higher technology steps.

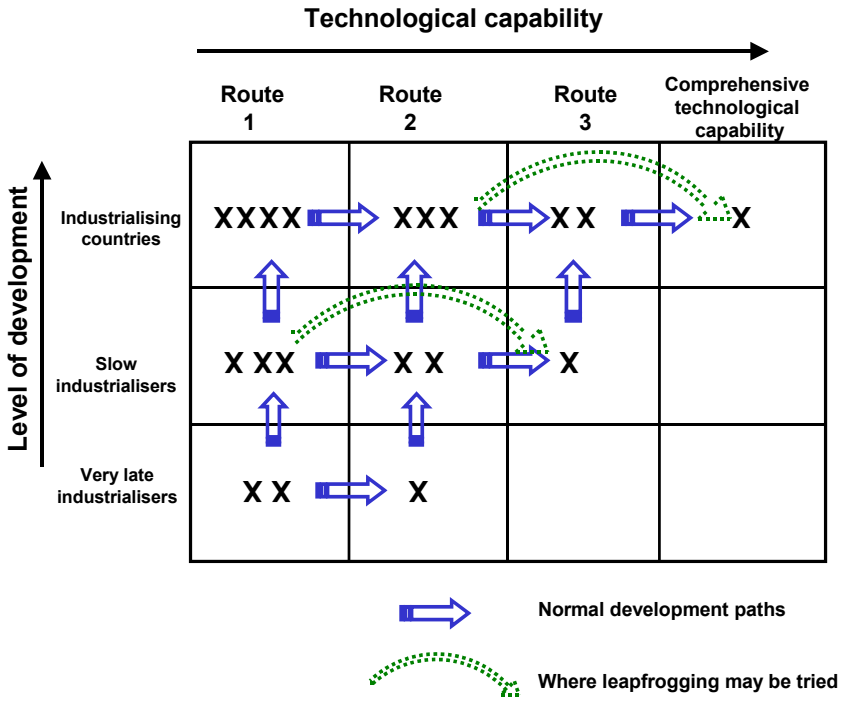


Figure 8. Paths to development and increasing technological capability

6. CONCLUSION

The drivers for new production paradigms have traditionally been closely related to the economic and business conditions within which companies have operated. They have also been based, in the main, on technological hardware and software solutions. However, since the early 1990s there has been a significant change in the uncertainties companies face so they now include a range of environmental and political considerations. As a consequence there has been a move towards more managerial solutions such as adaptable production, with its emphasis on changing the cost structure, and technology playing a supporting role rather than being a pivotal element of the paradigm. However, the final remark must be that there is no "one size fits all" paradigm - each one has a part to play and comprises a pillar that supports the ability of companies to respond to the modern competitive environment

7. ACKNOWLEDGEMENTS

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