"THE MANUFACTURING CONTRIBUTION TO INNOVATION"

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Abstract

The description of the contribution of manufacturing to the innovation process is often limited to the task of providing the necessary information to enable the development function to create a design which is easy to manufacture, and to be instrumental in the fast ramp-up of the production process Though these are important tasks, it is argued in this paper that there is a third aspect of manufacturing's contribution to innovation, namely the creation of a manufacturing system which is favourable to product innovation. This goes far beyond the design of an appropriate production process, but requires the creation of a general manufacturing environment which is amenable to product innovation. This thesis will be tested with data from a large survey of senior manufacturing managers.

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Innovation, it has been argued, is an activity which is by definition a common task and challenge for the development, marketing and manufacturing functions in the company. Quite a few studies **have focused** on the importance of the R&D-marketing interface. Already in the early studies on innovation the importance of a good collaboration between R&D and marketing had been stressed (Rothwell, Freeman, Horlsey, Jervis, Robertson and Townsend, 1974). The literature provides a number of suggestions of how to improve the interface between R&D and marketing (Desphande and Zaltman, 1984; Gupta, Raj and Wilemon, 1985; Moenaert and Souder, 1990; Souder and Chakrabarti, 1978). Less numerous however are studies on the R&D-manufacturing interface. Only more recently this particular aspect of the innovation process has received more attention. Yet this interface has to play an important role in determining whether an innovation will be profitable or not. A good R&D-manufacturing interface can lead to a cost efficient innovation and timely availability of the product for introduction in the market (Bergen, 1983). It has been said that difficulties in the interface between manufacturing and R&D are one of the most important causes of delay in the development process. Studies have focused on the importance of an integrated type of organisation (Epton, Pearson and Payne, 1984; Imai, Nonaka and Takeuchi, 1984; Rubenstein and Ginn, 1985), educational systems for manufacturing employees (Bergen, 1982; Bergen and Miyajima, 1986), supplier involvement in the design and production process (Imai et al., 1984; Clark, 1989), and radically different approaches to problem-solving activities (Clark and Fujimoto; 1989).

The question which is studied in most of these studies is : what can be done to the existing R&D-manufacturing interface to improve the innovation process. Much attention is paid to the improvement of the integration in design and manufacturing in order to install design for manufacture methodologies (Stoll, 1986). The idea behind this approach is that costs can be significantly reduced during the production stage by designing a product that takes into account the constraints imposed by the firm's manufacturing system. To put it in a somewhat extreme way, the issue at stake is how design can make live 'easier' for manufacturing. Since design costs are often small compared to process design and production start-up costs such an approach makes a lot of sense. The task of manufacturing in this is to provide and actively transfer the necessary information to the design and development groups.

A second aspect which received a lot of attention is the ability of manufacturing to quickly start up and ramp up the production of the new product. Close integration between the design and manufacturing to smoothen the transfer of the technology from the development group to the production team is advocated (Roberts and Frohman, 1980). Solutions such as joint planning, execution and control between development and manufacturing were suggested.

We want to propose here that manufactuirng has an additional role to play in the firm's innovation process. Rather than asking the important question what the design function can do to improve the manufacturability of the product, we want to address the question what kind of manufacturing system is needed to enhance the firm's capability to carry out product innovation. In other words, is there a typical manufacturing environment that is more adapted to product innovation.-- It will be clear that we want to go beyond the production process which has been designed to manufacture the product. The environment we refer to includes the manufacturing strategy, the misson of the plant, the general investments in the plant and the infrastructural options pursued.-- The goal behind answering this question is then to suggest that to become product innovative, it is not sufficient to create an innovative atmosphere within the company, or to create closer contacts between different groups, so that they share information. The innovative firm needs also to conceive a different approach to the management of its manufacturing function, one that is adapted to innovation.

Rather than inductively design such a manufacturing environment, which is favourable to product innovation, we will ask ourselves whether the manufacturing system in a large number of innovative firms is different from the one in firms where product innovation is less emphasized. If we can establish such a difference, one can argue that this provides complementary evidence to case-based studies, that indeed innovation is enhanced by specific forms of manufacturing environments.

Most of the studies, with exception of the automobile study by Clark and Fujimoto (1989) use small samples, and look at best practice in the firms. To study the research question at hand we propose to use a large sample of European manufacturing firms to analyse whether the degree of product innovativeness differentiates the manufacturing practices in the firm. Our study is limited to product innovation. Whenever we talk about innovation, or innovative in the next sections we mean product innovation or innovative with respect to products.

SHORT LITERATURE REVIEW

In their work on technological life cycles Abernathy (1978) and Utterback and Abernathy (1975) distinguish between a product and process oriented stage in the evolution of a technology and its applications. They identify specific production processes with each of these stages. In the fluid stage, where product innovation is the dominant form of innovation, the manufacturing will be less integrated and more flexible, with relatively less investments in production technology. In the more mature, stable state, where process innovation dominates, investments in production technology will be more significant and dedicated, rules and operating procedures will become more important and efficiency will become the main goal, as opposed to flexibility in the fluid stage. Consequently one can hypothesize that :

h1 : the more innovative firm will put more emphasis on flexibility and less on production efficiency and dependability than the less innovative firm

Bergen (1984) has analysed the differences in the R&D-manufacturing interface between German, British and Japanese firms, and he attributes a lot of the differences to differences in on the job as well as formal training. Also Fruin (1989) in his analysis of what he calls Toshiba's 'development factory' emphasizes strongly the employee related aspects. The development factory is a factory specialised in developing, introducing, and ramping up of new products. Among the characteristics which differentiate this development factory from other factories he sees : a high specialisation by function and product area ; centrality of the organisation; high leverage of the companies' skills in the factory; a tremendous feeling of community; liveliness ("it is pleasant to work here"); management of effort rather than of resources; an emphasis on state-of-the art automation. Apart from the automation, most of these programmes are people-oriented. Managing the human resources in a less Taylorian way seems to be positive for the innovation in the company. This leads us to a second hypothesis :

h2: more innovative companies will put more responsability with the individual manufacturing employees

The issue of automation deserves some more attention. Based on Abernathy the position would be that less innovative firms would be more heavily automated. Fruin's in-depth case study points in the opposite direction. The contradiction between the two studies can be explained by the fact that both talk about a different type of automation. Abernathy still described in 1978 hard automation, while the automation Fruin refers to is probably the flexible automation of CAD-CAM, FMS and CIM. Ettlie and Reifeis (1987) see as a result of nine case studies that an integrated CADCAM system can be a beneficial effort to improve the design-manufacturing interface. Adler (1989) warns that expectations about flexible automation are very high, but that getting the benefits out of CADCAM integration is very difficult. He suggests that CADCAM is not a solution to design-manufacturing coordination, but at best an opportunity. Cautiously we would propose a third hypothesis :

h3a: more innovative companies invest more in flexible automation technologies than less innovative companies

h3b : more innovative companies invest more heavily in integration of information systems across the different business functions.

The need to integrate internally in the organisation has been emphasized by many authors (Rubenstein and Ginn, 1985). But this integration does not have to be limited to the internal organisation. **Clark** (1989) demonstrates with data from ca. 75% of the world's automobile industry that involving suppliers in the design of the product improves the development time and development cost of the product considerably. He stresses that the companies which are more successful in doing so, are not simply downloading part of the design process on the supplier. In fact there is no ground whatsoever to suppose that suppliers would be either more, or less efficient in carrying out the development task. No, he clearly argues that to reap the benefits of involving the supplier, one has to create a relationship with the supplier, which is very different from the adversary relationship many companies all over the world are still used to. Development is of course no innovation. But Clark's results, which are limited to development of automobiles are strongly supported by the case studies on which Imai et al. (1985) report. They too argue in their analysis of the 'Japanese' innovation process that the sharing of information and the longstanding relationships in the supplier network contribute to the quick responsiveness of Japanese companies in terms of developing and launching new products. On the basis of these results we would propose the following hypothesis :

> h4 : more innovative companies take a more systems-oriented view of the procurement function than less innovative companies

The willingness to collaborate with suppliers in the design of new products can be combined with the emphasis on flexibility which was stressed by Abernathy (1978). If companies want to keep their flexibility, and manoeverability to react to changes in the market place, one would expect them to be less vertically integrated. Indeed a high degree of vertical integration creates a lot of fixed assets which will become sources of resistance against introducing new products. To keep the production efficient one will strive for a full capacity utilisation of the different steps in the production process. This will again constrain the innovation process. As a consequence one would expect :

h5 : more innovative companies are less vertically integrated than less innovative companies.

In the analysis of generic manufacturing strategies of North American manufacturing firms Roth and Miller (1989) conclude that their group of 'innovators' are characterised by an emphasis on CAD and the development of new processes, the improvement of lead times in production and a willingness to make structural (as opposed to infrastructural) changes in manufacturing. Hayes, Wheelwright and Clark (1988) see as one of the elements contributing to high performance development projects the capability of companies to have high-performance manufacturing organisations. They define these organisations as companies which have their processes under control, where confusion is minimal, everybody is continually learning, and where the process is characterised by low work-in-process, short cycle times, and high quality. This leads us to a further characteristic of the innovative company :

h6 : more innovative companies will invest more in production programmes which are characteristic for high-performance manufacturers.

RESEARCH METHOD

To test these hypotheses we will use the data provided by the European Manufacturing Futures Project (1). This is a biyearly survey which is administered to senior manufacturing managers of large European companies. The data which will be used here, was obtained in 1987 (Ferdows and De Meyer, 1988) and 1988 (De Meyer and Ferdows, 1990). The unit of analysis of the questionnaire is a business unit. This can be a plant, a subsidiary or strategic business unit in a larger group, or a company. The questionnaire which is used to collect the data has three sections which are relevant to this analysis.

The first set relates to the competitive priorities or capabilities, which the respondents think will be important in their industry. The importance is measured on a seven point self-anchoring scale, going from not important to extremely important. The set of nine competitive priorities are similar to the manufacturing capabilities which are proposed in any book on manufacturing strategy (Buffa, 1984; Hayes and Wheelwright, 1984; Skinner, 1978). They include the ability to offer low prices; to make rapid design changes and/or introduce new products quickly; to offer consistent quality; to offer high performance products; to offer a broad product line; to offer fast delivery; to offer dependable delivery: to change production volume quickly; and to change the production plan quickly. Since one can argue that the external environment in which these senior manufacturing managers are working is rather low in terms of analysability, the interpretation they have of the environment is probably more the way they will attempt to shape the industry than a true picture of the competitive priorities in the industry (Daft and Weick, 1984). One should interpret these answers as how these senior manufacturing managers interpret their environment and want to shape their industry from their company's point of view, rather than as a true reflection of the strategies which will objectively be needed in that particular industry.

In the same section of the questionnaire we also requested the senior manufacturing managers to judge their business unit's capability against that of their best competitor, and this for each of the nine competitive priorities. With 'best' we did not mean largest, but best in terms of manufacturing practices. The question was asked somewhat differently in 1987 and 1988. In 1987 we asked for their perception of the gap vis-a-vis their competitors, and in 1988 we asked them to judge their current strength vis-a-vis their competitors.

The second set of data are a number of characteristics of the company, such as source of process knowhow, value added as a % of sales, investments in R&D, growth rates, and the share of new products as a % of sales.

The third set of data is a closed list of 37 action plans in manufacturing. They cover a broad range of structural and infrastructural programmes. This list is the result of brain-storming by the researchers, and has been checked over the years with practitioners on its validity. It is of course not exhaustive, but it is probably a satisfactory list of action programmes which manufacturers considered during the years covered by the survey.

For each of the action plans we asked the senior manufacturing manager to indicate what kind of emphasis the company would place on it over the next five years. Again the repondents were asked to indicate their emphasis on a seven point self anchoring scale, where 1 stood for no emphasis , and 7 indicated a very significant emphasis. An identical list was used to ask the respondents to indicate which action programmes they had invested in over the last years. In 1987 we used a similar seven point scale. In 1988 we asked the respondents simply to tick off the programmes on which they had put a significant emphasis. Thus for the past actions in 1988 we have only binary data. In contrast to the competitive priorities which are heavily influenced by the external environment, the action programmes are concrete internal plans. Action programmes in manufacturing are often long term, require considerable investments, and involve large groups of people. For these reasons one can safely assume that the action programmes which are planned for the next two years, are very concrete plans which are on the desk of the senior manager. In that sense they are no dreams of what the company would be supposed to do in case it were an ideal company. There remains of course a certain degree of wishful thinking in these answers.

The sample consists of 225 responses in 1987 and 184 in 1988. The original panel for the study consisted of the 100 largest manufacturing companies in the four biggest economies in Western Europe, and the 50 largest manufacturing companies in the smaller Western European countries. About 850 questionnaires were sent out to these companies. The sample is biased by selfselection. But as is analysed elsewhere, there is no systematic bias in favour of a particular industry or country. The sample is however biased towards the larger, more profitable companies (De Meyer and Ferdows, 1990; Ferdows and De Meyer; 1988). There are no start up companies in the sample. Some of the questionnaires were discarded due to incomplete or unreliable data.

To test the hypotheses the following approach was used. The first task was to separate the more innovative companies from the less innovative. To do so we used the answers to the question what the proportion of new products, introduced over the last five years, was as a percentage of total sales. The advantage of using this variable is that we measure commercial success in product innovation. We do not measure the number of innovations. The risk exists that in that way we include those companies which are not really product innovative, but which have had luck, and derive a large part of their sales from a recently introduced product. Since we use a larger sample, one can argue that this 'luck' factor will cause no more than some noise in the data. Moreover, by looking at two years of data we reduce the influence of random noise somewhat.

On the average in 1988 the proportion of new products as a percentage of sales (further to be called '% past new sales') was 27.7% with a standard deviation of 27.5. In 1987 the percentages are lower : the average is 17.1%, while the standard deviation is 17.7. This increase from 1987 to 1988 in the % of past new sales has been explained (De Meyer and Ferdows, 1990) by some differences in the composition of the sample, but also by a strong improvement in the European manufacturing industry over the period concerned. To separate the high from the low innovators we decided to categorise every company with a % of past new sales less than the average as a 'low innovator', while every company with a higher % of past new sales than the average plus one standard deviation, as a **'high innovator'**. This may seem a somewhat arbitrary separation, but in that way we reach our objective of clearly singling out the innovators : in 1988 more than 55% of their sales come from products which have been introduced during the last five years. This procedure has been proposed under different conditions to single out high performers (Allen, 1977). The separation leads in 1988 to 106 low innovators and 28 high innovators, and in 1987 to 122 low innovators and 23 high innovators. These numbers of course do not add up to the total sample. First of all we discarded a group in the middle, and secondly not all questionnaires were usable. From now on the analysis will be limited to these groups.

One final remark on the sample : there is of course an extensive overlap between the sample of 1987 and 1988. 95 companies answered in both years. We took advantage of this to look for the 1988 high and low performers which have answered in both years to see what their future and past action plans had been in 1987. The rationale for doing this is that the good record as product innovator may be influenced by the manufacturing choices which have been implemented in the past. Compared to the larger group average % of past sales(27.2%) and standard deviation (27.5) do not really change for this more limited group. There are 59 low innovators and 16 high innovators in the common sample.

Once we have the samples on can look at the differences between the high and low innovators in terms of competitive priorities, action plans and business unit characteristics. For this we used a simple t-test, assuming pooled variance.

RESULTS

Before analysing the results it seems necessary to find out whether our separation is not simply a separation of industries. Since we considered the Standard Industrial Code to be inadequate to verify this on a relatively small sample like this, we decided to use a self-selected categorisation which is part of the questionnaire (table 1). Although there are some differences between the group of high and low innovators, they are not significant. There are proportionally a few more consumer product companies in the group of high innovators, and a few more producers of raw and semi-finished goods in the group of low innovators, but the overall picture is one of no large bias towards one or the other group.

Insert table 1 about here

A first quick glance at the results can give some confidence in the instrument. Programmes which were emphasized in the 1987 future programmes are mentioned in the 1988 past action programmes. And high innovators emphasize new processes for new products, while low innovators emphasize the development of new processes for old products. High innovaotors seem to emphasize more the improvement of their capability to introduce new products.

The group of high and low innovators do not differ from each other in terms of their business characteristics. The only strong differences are that in 1987 the high innovators spent more on R&D as a % of sales, and they have a significantly higher growth rate. There is in 1988 a weak indication that low innovators turn less to internal sources for their process know how, and that in 1987 the high innovators have relatively speaking somewhat more engineering personnel as a % of the total personnel than the low innovators. But there are no differences in the value added created in manufacturing. The fifth hypothesis cannot be supported. If one takes the lower internal sourcing for process know how by low innovators into account the hypothesis has to be rejected on the basis of this data.

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insert table 2 about here

The differences in how the competitive environment is perceived are not very strong either (table 3). But they tend to support the first hypothesis. In 1988 the high innovators see less need for dependability of the delivery, and the low innovators consider that their product line is well performing in terms of its breadth. This does not mean that they have necessarily a very broad product line, but they consider themselves strong enough vis-a-vis the competition. They see no need for increasing the number of products. Consequently they probably feel less the need to innovate. If we look at the influence of the categorisation in 1988 on the opinions expressed in 1987, then we see that the low innovators emphasize more the need for low prices, while the high innovators emphasize more the need for production plan flexibility. In 1987 the high innovators emphasize more the ability to rapidly design new products. And if we look at the gaps vis-a-vis the competition, the list of significant differences is quite long. Both on flexibility issues and low prices the low innovators feel they have a bigger gap than the high innovators. These results provide support for the first hypothesis, and there is no reason to reject it.

Insert table 3 about here

Looking at the list of action plans (table 4), one will observe that the action plans related to the employees and on which the two categories differ significantly is very limited. In fact there is only worker safety and supervisor training in the 1987 data. And in both cases they are more heavily emphasized by the low innovators. One could perhaps make a case that the higher attention paid to supervisors as opposed to giving workers a broader range of tasks, or more planning responsability, is an expression of a more hierarchical management system, but the evidence seems to be very weak. We have to conclude that we cannot find any real differences in the way manufacturing employees will be managed.

Insert table 4 about here

Both in 1988 and 1987 the degree of intention to automate the design and the manufacturing function are different for the two groups. In 1987 CAD and Production and Inventory Control Systems (PICS) belong to the past action programmes of the high innovators, and CAD, introduction of robots, and integration of manufacturing information systems belong to their more heavily emphasized future programmes. In 1988 the high innovators have emphasized more heavily CAM, CAD and the development of new processes for new products, and will keep on emphasizing CAM in the future. Looking at the influence of the 1988 categorisation on the 1987 data one can see the CAM and PICS was more emphasized by high innovators, and CAM would be equally emphasized in the future. The concept of CAM is a constant throughout the two years, and combining the two years. And aspects of integration (both integration of information systems, and PICS, which assumes an integration between sales, procurement, manufacturing and design), come back in both years. The third hypothesis seems to find quite some support.

In the past and future actions of 1987 we find the reduction of vendor lead times more heavily emphasized by the high innovators. Combined with the attention paid to PICS, this would support that the relation with the vendors is more important to the high innovators. Indeed shortening the lead time of vendors, is difficult to obtain without having a more modern collaborative view on the supplier relationships. Although the support is limited, the fourth hypothesis seems to withstand the test.

Finally, we find that high innovators emphasize more heavily items like manufacturing reorganisation in both 1988 past and 1987 future action plans; the improvement of the capability to introduce new products in 1987 future and 1988 past action plans; defining a manufacturing strategy in past and future action plans in 1987, manufacturing lead time reduction in 1987 past and future action plans, the development of new processes for new products in 1988 past actions. Low innovators emphasized on the contrary new processes for old products in 1987 future and 1988 past actions, preventive maintenance and capacity expansion in 1988 future actions, plant relocation in both 1987 past and future action plans (for the respondents who answered both years). They are a varied set of programmes, and there is definitely no indication that the high innovators are modern manufacturers, as opposed to the low inovators. But the combination of redefining a manufacturing strategy with lead time reduction, integration of info systems, PICS, improvement of capabilities to launch new products (better introduction in the production process as well as development of new processes), CAD and CAM seems to indicate that the high innovators have indeed some of the characteristics of what Hayes et al. (1988) called the high performance manufacturers. Support for the sixth hypothesis is available.

DISCUSSION

We do not pretend that the results we have presented here are a conclusive test of the hypotheses. They should be seen in the context of the case-based work that was referred to in the literature review. But we would like to propose the following summary. Our results, based on a relatively large but somewhat biased sample indicate that indeed companies which emphasize product innovation pursue a different portfolio of manufacturing priorities and action programmes than companies which emphasize less product innovation. If they succeed, one would expect these more innovative companies to develop a manufacturing system which is different from the one of companies which are less product innovation oriented. In particular we find evidence to support the hypotheses that high innovators invest more in flexible automation technologies, and attempt to integrate the information systems in manufacturing. They are working on a different relationship with vendors and suppliers, probably less emphasizing lowest purchasing cost, but rather investing in speedy delivery and a close introduction in the production process as well as development of new processes), CAD and CAM seems to indicate that the high innovators have indeed some of the characteristics of what **Hayes et al.** (1988) called the high performance manufacturers. Support for the sixth hypothesis is available.

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The conclusion that the manufacturing system of a high innovator differs from that of a low innovator is an important one. It implies that if the manufacturing system is not appropriate, that the innovator can be inhibited by the manufacturing. Indeed, Abernathy (1978) already suggested that the manufacturing process could be a serious obstacle in the process of technological renewal. He coined the term 'Productivity Dilemma' to indicate that the efficiency of the production process, associated with a mature technology, could become a major hindrance for the company to internalise a new technology. Engineers, he suggested, do not like to give up the efficiency of the old production system in favour of the flexibility and messiness of the production system associated with new technologies. And Hayes et al, (1988:326) argue that ' a company can improve its development effectiveness only about as fast as it improves its manufacturing capabilities'. They see a close link, not only between product and process, but equally between more generic design and manufacturing capabilities.

Our argument is somewhat similar. Manufacturing systems of high and low innovators are different in their objectives and in the emphasis on action programmes. However there is some difference with Abernathy's productivity dilemma. Some interpretations of the technological life-cycle tend to suggest a certain predestination. According to these arguments as a company's manufacturing system becomes more efficient, it will become automatically less hospitable to innovation. This we would like to reject here. One can create a manufacturing system which is favourable to product innovation, and this under a large variety of boundary constraints. Indeed as De Meyer, Nakane, Miller and Ferdows (1989) have described, with modern manufacturing methods a contradiction between efficiency and flexibility does not have to exist. The combination of flexible automation technologies, integrated information systems, and an emphasis on lean production systems where speed of reaction, low inventories and high quality as a result of process control have become major targets for manufacturing management, should enable the modern company to create an efficient production system which can remain open to a rapid sequence of new products, but at the same time efficient enough to compete with its world competitors. The contribution of manufacturing to the innovation process is not only to provide information to the design group in order to increase the manufacturability of the product, or to be an instrument in the successful startup and launch of the product. Manufacturing has the supplementary task of conceiving a production system that is adapted to the company's innovation strategy. This is in agreement with recent literature on competitive advantage, which states that a bundle of assets, of which manufacturing capabilities are an example, are at the heart of a firm's competitive position, rather than a particular product market combination (Dierickx and Cool, 1989). A manufacturing system which is favourable to innovation can in the long run be more important to the company's innovation strategy than a particular new product.

The remaining question is of course : what does such a manufacturing system favourable to innovation look like ? According to our results both manufacturing's priorities and action plans play a role in creating a manufacturing environment hospitable to innovation. Hayes et al (1988) give some characteristics of these action programmes : an emphasis on speed in manufacturing; application of just-in-time principles on prototype construction; testing facilities in the workshop, rather than as a separate function; direct contacts between engineers and technical experts from the suppliers; the implementation of a low work-in-process, short-cycle, high-quality production system. Ettlie and Reiffeis (1987) discuss five mechanisms which are used to integrate Design and Manufacturing. These five machanisms are : the creation of a design-manufacturing team, CAD systems which are common to design and tooling, a common consolidating organisational reporting relationship which integrates design, manufacturing and other functions in the business unit, a philosophical shift to design for manufacture, and the introduction in manufacturing of engineering specialists. They warn however that what they have derived on the basis of case studies in heavy manufacturing, may not be applicable to other situations. Some of their results do coincide with the work of Hayes et al. Our analysis here is by its methodology less specific, but a bit more general. We find similar ideas such as an emphasis on shortening the lead times, flexible automation, and integration of information systems. Though we are convinced that a lot more empirical observations will be needed, this study gives some broader support to the characteristics of what a manufacturing system favourable to innovation can consist of.

CONCLUSION

Manufacturing has its own specific role to play in the innovation process. Most studies on manufacturing and innovation focus on the contribution of the R&D-manufacturing interface to improve the design for manufacturability. In some cases attention is also paid to the information that manufacturing can provide to design about new process capabilities which may enable the design team to experiment with new ideas. But we argue here that manufacturing has a very important additional role in the innovation process. The manufacturing function has to create a manufacturing system which is favourable to innovation, which can cope with the continuous release of new products. In order to support this assertion we have used the data of the European Manufacturing Futures Survey to see whether there are some differences between manufacturing practices in companies with a highly innovative track record, as opposed to companies which have a lower rate of product innovation. The results support the assertion that a different manufacturing system exists, and provides some suggestions of what the characteristics of such a product innovation favouring system may consist of.

Notes

(1) The European Manufacturing Futures Survey is part of a larger research project, the Global manufacturing Futures Project. This was started in 1982 by J.G. Miller at Boston University and carried out in collaboration with J. Nakane, Waseda University, Tokyo, Japan and K.Ferdows and A. De Meyer, Insead, Fontainebleau, France.

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Table 1 : industry classification by category of innovators		
	low innovators	high innovators
consumer products	36.8%	44.4%
raw/semi-finished goods	16.0	11.1
components for consumer products	9.4	7.4
capital goods	23.6	22.2
industrial supplies	11.3	14.8
other	2.8	0.0

Table 2 : business unit characteristics			
1988 categorisation :	low	high	p-value
value added	39.1%	37.9	.74
growth as a % of sales	9.4%	8.2	.75
degree of internal process knowhow development(#)	4.9	4.4	.08
R&D as a % of sales	4.2%	3.3	.41
proportion of engineering personnel as a % of total	8.4%	3.7	.41
Share of new products 5 years from now as a % of sales	20.9	69.3	.0001
1987 categorisation			
value added	40.7	47.3	.19
growth as a % of sales	8.7	31.5	.0001
degree of internal process knowhow development(#)	4.7	4.9	.0024
R&D as a % of sales	3.7	7.4	.0024
proportion of engineering personnel as a % of total manufacturing personnel	18.4	32.3	.097
Share of new products 5 years from now as a % of sales	15.8	50.4	.0001

(#) on a scale from 1 to 7

Table 3 : Differences in competitive priorities			
ability to offer	high	low	p-value
1988 categorisation and 1988 priorities			
dependable delivery	5.8	6.2	.03
1988 categorisation and 1988 strengths			
broad product line	4.4	5.0	.06
1988 categorisation and 1987 priorities			
low prices	4.1	5.1	.02
change prod. plan quickly	6.1	5.2	.01
1987 categorisation and 1987 priorities			
change design rapidly	5.7	5.0	.08
1987 categorisation and 1987 gaps			
low prices	3.6	4.3	.06
change design quickly	3.3	4.0	.04
rapid volume changes	3.8	4.8	.004
fast deliveries	4.0	4.8	.015
dependable delivery promises	4.1	4.8	.05
change prod. plan quickly	4.1	4.8	.02

Table 4 : Differences between high and low innovators in terms of emphasis on action programmes(only significant different items)

Table 4a : 1988 past actions	low	high	p-value
manufacturing reorganisation	.41	.64	.03
manufacturing lead-time reduction	.44	.64	.06
CAM	.41	.68	.01
CAD	.39	.64	.02
developing new processes for new products	.44	.64	.06
developing new processes for old products	.41	.21	.05
improvement of capability to introduce new products	.33	.50	.10
Table 4b : 1988 future actions			
preventive maintenance	5.0	4.4	.06
CAM	4.4	5.5	.001
capacity expansion	4.1	3.3	.08
Table 4c : 1987 past actions			
worker safety	5.0	4.4	.05
supervisor training	4.6	4.0	.06
manufacturing leadtime reduction	4.3	5.1	.03
vendor lead time reduction	4.1	4.9	.01
CAD	3.3	4.1	.10
plant relocation	2.4	3.2	.04
narrowing product line /standardisation	3.5	4.1	.08
defining a manufacturing strategy	4.1	4.8	.07
Production and Inventory Control Systems	4.5	5.3	.02
Table 4d : 1987 future actions			
supervisor training	5.2	4.6	.07
manufacturing lead time reduction	4.8	6.0	.001
vendor lead time reduction	4.6	5.5	.003
CAD	4.2	5.1	.05
developing new processes for old products	4.6	3.7	.01
defining a manufacturing strategy	4.8	5.7	.005
integrating manufacturing information systems	5.3	5.7	.10
introduction of robots	3.2	3.9	.08
improving the capability to introduce new products	5.4	5.8	.09

Table 4e : 1987 past action plans for 1988 categorisation			
CAM	3.7	4.7	.06
plant relocation	2.8	1.9	.08
Production and Inventory Control Systems	4.7	5.4	.08

Table 4f : 1987 future action plans for 1988 categorisation			
manufacturing reorganisation	4.3	5.1	.08
CAM	4.7	5.4	.09
plant relocation	3.1	2.1	.10

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