"LASTING IMPROVEMENT IN MANUFACTURING PERFORMANCE: In Search of New Theory"

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Abstract

The fundamental premise of production management is one of focus. To be successful, a manufacturer has to choose between the capabilities of cost efficiency, quality, dependability and flexibility, and focus all its attention and resources on pursuing this capability. Yet one sees more and more world class manufacturers who seem to be successful by pursuing a strategy based on a combination of two or more of these capabilities. How can one explain this divergence between the prevailing paradigm and practice. It is our contention that the nature of the trade-offs among manufacturing capabilities is more complex than has been assumed. We propose an alternative theory, namely that those manufacturers who create deep and lasting manufacturing capabilities follow a pattern of allocation of efforts and resources that is built on the assumption that these capabilities are cumulative: lasting capabilities are not built at the expense of each other, but upon each other, following a specific pattern of quality, followed by dependability, then reaction speed and finally cost efficiency. If one accepts this then we should re-examine traditional managerial approaches for improving manufacturing performance and the long-term role of manufacturing in the competitive strategy of the firm. The belief that costs can come down quickly and at the same time lastingly has
to be reviewed. Lasting cost efficiency is not a prerequisite to the other manufacturing capabilities but is the result of improvement in the other capabilities.
LASTING IMPROVEMENT IN MANUFACTURING PERFORMANCE:

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Some manufacturers seem to be able to defy the commonly accepted production logic. Compared to their competitors, they have better quality, are more dependable, respond faster to changing market requirements and, in spite of all that, achieve lower costs. How do they manage to do that? The prevailing production management paradigm, set forth by Skinner (1966) and refined by scholars who followed him, seem to imply that this should not be possible. Achieving competitive strength along one of these yardsticks should come at the expense of the rest.

Yet increasingly we are witnessing the emergence of manufacturers who seem not to have traded off one capability to develop another. Many companies engaged in quality improvement programmes report also lower costs. Deming (1982), Juran, Gryna and Bingham (1974), Crosby (1979), Garvin (1987), and many others including Skinner himself (1986), have offered explanations of how and why this occurs. They show that improvements in cost efficiency and quality are not necessarily mutually exclusive, but that better cost efficiency can, in fact, be a consequence of investment in quality improvement programmes. Interestingly enough, this does not seem to work in reverse--i.e., increasing cost efficiency does not seem to improve quality. So the trade-off seems to work in one way but not the other.
New insights about the relationship between other capabilities are more scarce. The practitioner's literature describes many examples of cases where a high variety of end products can be offered without becoming inefficient. Examples of automobile companies such as Toyota or the Ford Motor Company in Europe, which have for all practical purposes lot size of one in final assembly come to mind. But conclusive results which show that flexibility can be obtained without trading in efficiency are not yet available. Jaikumar (1986) offers some indication for the relationship between flexibility and dependability of the production process. His comparison of flexible machining systems in the United States and Japan revealed that higher flexibility was associated with greater dependability: those companies that had made their production systems more reliable—essentially through increasing the level of knowledge about the production process in the company—could run their machines more flexibly. Again, the reverse does not appear to be true; that is, increasing flexibility does not seem to make the process more dependable.

In our own research in the last six years, comparing manufacturing practices of large companies in Europe, North America, and Japan (Ferdows, Miller, Nakane & Vollmann (1986), De Meyer, Nakane, Miller & Ferdows (1989), Miller, Amano, De Meyer, Ferdows, Nakane, Roth (1989)), we have noted that manufacturers use a multitude of different approaches for developing similar capabilities. Many of the Japanese manufacturers, in particular, seem to follow a distinct sequence of improvement programmes which aim at building one capability upon, and not instead of, another.
In short, we see growing evidence that the nature of tradeoffs among manufacturing capabilities is more complex than has been assumed. Even the fundamental premise of existence of tradeoffs under all conditions should be re-examined. We need a new theory to explain these observations. Our purpose in this paper is to propose one.

It will be our conclusion that those who create deep and lasting manufacturing capabilities follow a pattern of allocation of efforts and resources which instead of assuming a tradeoff between these capabilities, consider them to be cumulative. That lasting capabilities are not built at the expense of each other but upon each other following a specific pattern.

If we are right, then many current systems, procedures, and most important, mindsets in the management of manufacturing need to be revised. The very foundation of what is commonly considered as "common sense" in production is put under question. New theories of such scope are seldom "proved" quickly, and we do not claim to have done that in this paper. Our work here should be regarded as exploratory and our conclusion as a set of propositions. However, we hope we can convince you that these propositions merit careful attention.
The Research Base

To develop our arguments we use selected data available through the European Manufacturing Futures Project. Administered at INSEAD since 1983, this is a project in which a sample of large European manufacturing companies are surveyed once a year through a mailed questionnaire. For this paper, we have used the results of the 1988 survey (see Appendix 1 for a description of the sample). It should be mentioned that the sample is biased towards large, well performing manufacturing units and is not representative of Europe's manufacturing industry.

Two specific sets of data from this survey are analyzed here. The first set is the change in eight performance indicators between 1985 and 1987. The respondents were asked to take 1985 as a base year for each of the performance indicators listed in Table 1 and give their perception of how much it changed by the end of 1987. Table 1 shows the sample means and standard deviations for each of the eight. For example, a score of 109 for quality (conformance to design) means that from 1985 to 1987 quality was perceived to have improved by 9%. In total 167 respondents filled out this question.

1. The European Manufacturing Futures project is part of a larger project, the "Global Manufacturing Futures Project", administered in North America by J.G. Miller and A. Roth (Boston University), in Japan by J. Nakane (Waseda University, Tokyo), and in Europe by K. Ferdows and A. De Meyer (INSEAD, Fontainebleau).
Second, we used the data on specific improvement programmes in manufacturing recently implemented by the respondents. A list of 39 specific improvement programmes was given in the questionnaire and the respondents were asked to indicate the ones which they had greatly emphasized in the previous year. The full list of these programmes is shown in Appendix 2.

The Tradeoff Model

As mentioned earlier, most of the literature on the development of strategic manufacturing capabilities is based on the paradigm of necessity to focus on a particular capability out of the many possible. The generic capabilities often mentioned in the early works of Skinner (1966, 1978), Hayes & Wheelwright (1984), Schmenner (1987), among others, have been cost efficiency, quality, dependability, and flexibility. More recent authors have redefined or expanded the list of alternative capabilities, but the necessity to choose and to focus one's efforts and resources on a limited set of capabilities (essentially one of the generic four) has remained unchanged.

According to this paradigm, the high performing manufacturing companies would obtain a higher improvement for one of the manufacturing capabilities, while remaining at a stable level (or an even deteriorated level) for the rest. For example, a well performing manufacturing company which opts for a strategy based on flexibility, would improve its flexibility, eventually to the detriment of its cost efficiency or its delivery dependability. Similarly, an emphasis on quality would lead to an improvement on a quality indicator, but might work out negatively when it comes to design or volume flexibility.
If this "tradeoff theory" is correct, then one should find most manufacturers improving only one type of capability and smaller numbers two or more. More specifically, the frequency of the number of performance indicators simultaneously improved should follow a negative exponential distribution.

To test this hypothesis, we turn to the data on the change of eight performance indicators in 1985-87 (Table 1). The first thing to do is to translate these eight measures to the four generic capabilities. This turns out to be a rather straightforward task because we find that performance indicators within the four broad categories are indeed highly correlated (Table 2). Improvements in delivery speed and delivery dependability, for example, are highly correlated. The same is true for improvements in unit cost and overhead cost. One would expect companies which have focused on cost efficiency as their key manufacturing capability to have improved on both unit cost and overhead costs. The rest of the correlations can be seen in Table 2.

Insert Tables 1 & 2 here

So to test the hypothesis derived from the "trade-off theory", we chose four mutually independent indicators which represent the total group of eight indicators, and which are also close to the traditional four categories of cost efficiency, quality, flexibility and delivery dependability. The four were unit manufacturing cost, quality conformance, speed of new product introduction, and delivery dependability.
Figure 1 shows the number of respondents corresponding to improvement in none, one, two, three or all four of these performance indicators. If we leave out the category of companies which improved none of the four indicators, the tradeoff theory would have predicted that the group of companies which have improved on one out of four measures would be the most numerous. This hypothesis has to be rejected! Indeed, a large majority (62%) improved on more than one indicator, most of them having ameliorated their performance on two of the mutually independent indicators.

We can see two possible explanations for these results. Either the companies which improved performance on more than one measure are paying for that elsewhere (and we are not capturing where in our analysis), or the trade off theory itself has to be modified. The first explanation does not fit the rest of the data. As it is clear from Appendix 1, the companies which participate in the survey tend to be biased towards the better performing companies in terms of growth and profits. Their departure from conventional practices should raise new questions and not be written off against unknown or unmeasured factors. So it would be prudent to question the trade-off theory itself.
The Cumulative Model

A few years ago Jinichiro Nakane proposed that the Japanese manufacturers follow a rather specific sequence for building manufacturing capabilities (Nakane (1986)): "In general, if some [Japanese] companies want to offer 'Flexibility' as a competitive priority, it is necessary that at least they have already qualified for a minimum level of abilities on quality, dependability and cost improvement. If they have not such an ability, they get a chaos condition and end tragically." On the basis of his experience with Japanese companies and a survey similar to the European Manufacturing Futures administered in Japan, he suggested a cumulative model with quality improvement as the basis of all other improvements, followed by dependability (see also Ferdows, et al (1986)). Accordingly to this model, one should only improve on dependability if the quality level in the company has reached a critical level. His sequence continues by asserting that quality and dependability improvements are pre-conditions to cost efficiency improvements; cost efficiency becomes almost a consequence of quality and dependability improvements; finally, flexibility improvements can only be obtained if a company has its quality, dependability and cost efficiency under control. This model has been documented further in De Meyer, et al (1989).

In our own research, we have modified this model. Though we accept that cost improvements will remain the ultimate goal of most manufacturers, we see these cost improvements also as an ultimate consequence of resources and management efforts invested in the improvement of quality, dependability and reaction speed of the company. The sequence we see is the following. A precondition to all lasting improvements are improvements in the quality performance of the company. Once the company has reached a critical level of improvement in quality, it can tackle issues of dependability. However,
this should not constrain further improvements in quality. In other words, improvements in dependability will require continuous improvement in quality. Once a critical level of dependability is reached, the company can attempt to improve its manufacturing reaction speed. This reaction speed is to us the symptom of a company’s flexibility. It can be the company’s ability to react quickly to new customer requirements, change production volumes rapidly, introduce new products faster, etc. Again, investments of management efforts and resources in reaction speed should not lead to a loss of attention in the areas of quality and dependability. Improvements in speed should be built cumulatively upon the foundations of quality and dependability. Once, and only once, the company has obtained a critical mass of improvements in these three areas, can it improve in a lasting way its cost positions. Lasting cost improvement programmes ultimately should and can only be built upon improvements in the other areas.

We have sometimes depicted this cumulative model as a sandcone with different layers (Figure 2). The sand is, in this case, a stand-in for management effort and resources. To obtain a stable sandcone, one has to create first a stable foundation of quality improvements. Upon such a foundation, one can put layers of dependability, speed and cost improvements. This analogy helps us explain two characteristics of our model. It shows the cumulative character of the capabilities: one can build only a second layer if the foundation is there. It also clarifies the fact that working on speed or cost efficiency does not reduce the need to work on quality. Indeed, to improve cost efficiency (i.e. building a higher cone), it is necessary to put a lot more resources at the base capabilities.

Insert Figure 2 here
An obvious criticism of this model is that we seem to throw overboard all contingencies. The model seems to suggest that there is only one best way to achieve a multiple set of manufacturing capabilities. To some extent, this is indeed our belief. Our model is based on the general theory that manufacturing capabilities can be developed cumulatively, and when they do they are more lasting. We propose that there is a preferred sequence of allocating resources to achieve that. This may seem to be calling for too much uniformity in managing manufacturing, but the concepts of quality (Garvin, 1987), flexibility (Swamidass and Newell, 1987) or dependability (Jaikumar, 1986) are so broad that the individual company can clearly differentiate itself from its competitors by choosing its own combination of quality, dependability, speed and cost efficiency programmes.

**Applying the Sandcone Model**

If our sandcone model is true, then the programmes for improvement of quality should be associated with improvements in the largest number of performance indicators—not only with those directly related to quality itself, but also those related to dependability, flexibility and cost efficiency. The programmes related to improving the dependability of the production process—making deliveries more reliable, learning more about the process and generally making the production more reliable and predictable—should have the second most, and so on with the cost improvement programmes to show only results in improved cost efficiency and not the other capabilities.

To test this hypothesis, for each performance indicator we first compared the improvement programmes undertaken by two groups of companies: those which had achieved above average improvement for that indicator, with those
who had not improved performance along that indicator at all. (To sharpen the analysis, we excluded the middle group, i.e., those companies which had improved performance on the indicator below sample average.)

Let us take the quality conformance as an example. The first group consisted of those companies who had a 1987 rating of above 109 (average); the second group consisted of those with 1987 conformance indicator of equal or less than 100. (The excluded group consisted of companies with ratings between 100 and 109).

Turning to the second set of data described earlier, we then examined the recent improvement programmes undertaken by each group. The objective was to identify along which of the 39 specific improvement programmes (list in Appendix 2) the two groups differed. And this was to be done for each of the eight performance indicators.

Table 3 shows for each performance indicator the list of the programmes in which the two groups had significant differences. By "significant" we mean a confidence level of at least 95% that each of these programmes had been emphasized by one group more than the other (as shown). It is reasonable to assume that better or worse performance on the specific indicator was (partly) due to the emphasis (or its lack) of the particular programmes listed in Table 3. These are the programmes which "made a difference".
Careful reading of Table 3 provides support for the cumulative theory. The programme which shows an impact on the largest number of performance indicators is the "zero defect". The "better-than-average" performers in quality conformance, in on-time delivery, in speed of new product development, and in inventory turnover have all emphasised zero-defect programmes significantly more than the "worse-than-before" group. The effect of this clearly quality improvement programme is not just in improving quality conformance, but also in a dimension of dependability (on-time delivery), and flexibility (development speed, and one may include inventory turnover here as well as a measure somewhere between flexibility and cost efficiency).

Other quality improvement programmes also exhibit the same multiple impact, although not as much as zero-defect. Statistical quality control of process not only improves quality conformance (as one would expect) but it also improves unit production cost. Programmes for improving vendor quality, not only improve quality conformance, but also the speed of new product development.

These are evidence that the quality improvement programmes have far reaching effects; they allow the company to achieve better performance along several measures--some of which, like improving development speed, could have been considered as unlikely according to the tradeoff theory.
Our evidence for the remaining layers, unfortunately, is scant. This is partly due to the fact that our questionnaire was not really designed for testing our cumulative model; most of the other 39 improvement programmes listed there can be interpreted to aim for a hybrid of quality, dependability, flexibility, and cost-efficiency. A second problem is that there may be a long time lag between embarking on some of the improvement programmes and the time they show actual performance improvements.

Nevertheless, certain patterns can still be discerned. For example, "giving workers more planning responsibility" can be argued to aim at a hybrid of quality and dependability. The results in Table 3 show that both quality and on-time delivery improve when this programme is emphasized, but interestingly enough, not the unit production cost. This may look disappointing, unless we take the interpretation offered by our model. According to this interpretation, giving the workers more planning responsibilities has more immediate effects on quality and dependability (two adjacent base layers of our model), but it will be a while before it works its way up to cost efficiency. This interpretation implies that those who are emphasizing this programme are doing so, not because they have accepted a bit of inefficiency in costs, but because they are convinced that in the long-run costs will come down.

Another pair of programmes in Table 3, "integration of information systems in manufacturing" and "integration of information systems across functions", deserve attention. Emphasis of the former seems to improve the speed of new product introduction; emphasis of the latter seems to reduce delivery speed and inventory turnover.
How can this be explained? Why should delivery speed and inventory turnover, which are usually a more direct aim of such programmes, be decreased and speed of new product introduction, which is a more indirect aim, be increased? We can try many explanations ranging from poor project management and irrational choice of computerized systems—resulting in information overload and confusion in certain areas—to attributing the oddity of these observations to the limitations inherent in questionnaire surveys and small samples. But a partial explanation—albeit that is has small plausibility—can also be provided by our sandcone model. Perhaps what we are observing is an indication that the average company in our sample engaged in implementation of these information systems, having achieved some flexibility (i.e. faster introduction of new products), must now wait for cost efficiency results (proxied by inventory turnover ratio) to improve. If one accepts this explanation, there is an interesting corollary. Though performance improvements are cumulative, it does not mean that they are simultaneous. To see the cumulative effects of improvements in quality or dependability or reaction speed on cost efficiency, one needs time. One needs to have some tolerance for the cost efficiency improvement to come through.

The interested reader might make other observations from Table 3, some of which may not be directly relevant to the thesis of this paper. Our own conclusion is that, although we are far short of "proving" the universal applicability of our sandcone model, there is enough evidence to justify questioning the existing tradeoff paradigm and searching for a new cumulative theory in the direction we are suggesting.
New Perspective on Manufacturing Performance

The cumulative theory provides a new perspective with which to judge achievements in manufacturing performance. Let us examine two cases as examples. First, if a company reports better manufacturing costs but worse quality, delivery dependability and/or flexibility, our sandcone model suggests, a priori, that this cost reduction has not been due to lasting improvements in the manufacturing capabilities of the company. It suggests that the cost reduction may have been due to other reasons such as increased out-sourcing, benefits from foreign exchange fluctuations, temporary cuts in overheads and investment programmes, "milking" the existing resources without rejuvenating them, or changes in accounting practices. All these have essentially little to do with how well production is managed in the company. The trade-off theory, in contrast, would raise no such questions a priori.

Second, assume two companies report faster introduction of new products through manufacturing; one does that with lower production costs but poorer quality, and the other with better quality but poorer costs. Everything else is the same for the two companies. Which one is building more lasting manufacturing capabilities? Our sandcone model suggests the latter, whereas the tradeoff model takes no position, a priori. Again, the reason is in the specific sequence of improvements proposed in the model.

These examples are illustrations of many other situations where the same observation interpreted by the tradeoff or cumulative theories can lead to almost opposite conclusions.
We realise that what we are asserting is fairly radical. Therefore, to avoid any possible confusion, perhaps it is useful to point out once again exactly what our sandcone model proposes. To begin with, it does not deny existence of tradeoff among generic manufacturing capabilities; all it suggests is that the nature of tradeoff relationships is contingent upon the approach. For example, cost and quality are traded off against each other if the attention is put on the cost; however, they both improve if the attention is put on quality.

Next, with our sandcone model we suggest a specific pattern of capability enhancement which changes the traditional tradeoffs among the generic manufacturing capabilities—in fact, reverses them. Indeed, if one goes back to some of the older paradigms of production management, or "common sense" theories in management, one will discover that implicitly cost efficiency was often seen as a prerequisite to allowing investments in quality, dependability or flexibility. Our sandcone model proposes precisely that lasting cost improvements can only be the result of cumulative improvements in the other areas. By reversing the order of cumulative manufacturing capabilities, deeper, more lasting manufacturing capabilities are built up.

Finally, our model is dynamic in nature. It focuses on continuous changes in the performance and not on the base value. Even if a company might be producing already at a high quality, to continue to enhance its manufacturing capability, it will have to continue to improve its quality performance. The model suggests that for every increase in cost efficiency or flexibility, a supplementary effort in quality will be needed. Regardless of its level, for every lasting marginal improvement in one capability, a similar improvement in the underlying capabilities will be required.
In practice, probably only a few companies follow the pattern of resource allocation prescribed by our sandcone model exactly. Even the performing manufacturing companies, such as the respondents to our 1988 European Manufacturing Futures Survey (Appendix 1), are probably following a hybrid of various patterns. Using our model as a gauge, we can make a rough assessment of the build up of lasting manufacturing capabilities.

To illustrate this point, we performed another analysis on the first set of data from the 1988 European Manufacturing Futures Survey. We went back to the four mutually independent performance measures described earlier. These four were quality conformance, delivery dependability, speed of new production development, and unit manufacturing cost. You may recall that we chose these four because they represented the available eight performance indicators well and because each corresponded rather closely to the generic manufacturing capabilities of quality, dependability, flexibility and cost efficiency.

For our analysis, we chose to examine the group of respondents who had reported improvement in performance for at least two of the four quality, delivery, speed, and cost indicators. This group consisted of 102 companies (62% of the sample). We then calculated the frequency which each of the four indicators happened to be among those improved. If quality was the most frequent, followed by delivery, followed by speed, and with cost improvements the least frequent, then this sample of European companies would be building up lasting manufacturing capabilities according to our model.

Insert Figure 3 here
The results are shown in Figure 3. Cost and Delivery happen to be more frequently the measures improved and in fact quality the least frequent. Looking at this positively, one may conclude that at least some work towards the build up of lasting capabilities by companies in this sample is going on; however, viewing it negatively, one has to conclude that until the proportions change--with quality improving more frequently than the rest, etc., many of the achievements are not based on deep and lasting enhancement of manufacturing capabilities.

CONCLUSION

If we accept that the development of one manufacturing capability need not be necessarily at the expense of another, then we should re-examine a) traditional managerial approaches for improving manufacturing performance, and b) the long-term role of manufacturing in the competitive strategy of the firm.

Most of the traditional managerial approaches for improving manufacturing performance is based on the tradeoff theory. We are suggesting the tradeoff theory does not apply in all cases. Certain approaches change the tradeoff relationship into a cumulative one--i.e., one capability is built upon another, not in its place.

Moreover, we are suggesting that under these conditions, every layer of capability requires continuous attention; one never leaves the necessity of investing in the "basics" of production. In fact, the higher and fancier the capability sought, the more enhancement from the bottom layer of capability up is required. (It is like building up bigger sandcones by pouring on more sand).
All this stands even if we have erred on the last part of what our model prescribes. We suggest that the approach which avoids tradeoffs and ensures cumulative buildup of manufacturing capabilities in the long run is one which in broad terms focuses on quality first, then quality and dependability, then quality, dependability and flexibility, and finally on all three plus cost efficiency. This sequence builds up lasting and deep manufacturing capabilities.

Applying this model requires a long-term approach, tolerance, and patience. It requires believing that costs will eventually come down. The important thing is to have benchmarks to check whether the company is on the right track. Our model is rather specific in this respect. If performance in the generic capabilities of quality, delivery, flexibility and cost efficiency is progressively improving (i.e., none of the earlier ones regress or stay stagnant when a later one improves), then the company is on the right track in building lasting manufacturing strength.

Capabilities built in this way become formidable competitive weapons; they cannot be easily or quickly matched by competitors. Embarking on this course requires a commitment to expand the role of manufacturing in the competitive strategy of the company.
REFERENCES


APPENDIX 1: DESCRIPTION OF THE SAMPLE

In 1988, we received 187 answers out of 850 questionnaires mailed. The 187 responding companies are from 14 European countries, and, on the basis of a two-digit Standard Industrial Code, can be classified in 19 industrial groups. The responding sample is therefore from a large variety of industries and countries but it is not biased towards a particular industry nor geographical region.

The unit of analysis (called "business unit"), for which most of the questions were answered, was chosen by the respondents: 39% answered for an entire company, 41% for a division or group and 20% for a plant.

The average European respondent is from a large, profitable, growing, internationally operating business unit which tends to be the market leader for its primary product or product family (Table A1).

Not all respondents were profitable and growing; 6% reported a loss for the last fiscal year, and 8% a negative growth.

The typical business unit makes 55% of its sales through its primary product or product family. A large share of its total sales, 28%, is coming from products which are on offer for less than two years; in three years' time this proportion is expected to reach 33%.
Manufacturing is important to the respondents: on the average, the current manufacturing cost is 65% of the business unit's sales. The medians of the components of these costs are shown in Table A2. (We show the medians to minimise the bias caused by the "outliers").

The average total number of people employed by the business units is 4,585. The distribution of this number is highly skewed. The median is only 840. This median is expected to rise to 943 in two years' time. Since we assume that this does not reflect a trend towards a reduction of the capital intensity of the business units, this must be an indication of the intention to grow, and perhaps of a general impression of optimism which characterises the average manufacturer in our sample this year. The median direct labour component of the workforce is 300 or 36% of the total labour force.

All these numbers tend to indicate that the average respondent is a large, profitable and growing business unit, for which the manufacturing function plays an important role now and is expected to do so in the future. It is depending primarily on its internal resources to introduce more new products and expand its market share. In general, it is fairly optimistic about future growth and markets.
Table A1: Characteristics of the respondents

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median of annual sales revenues</td>
<td>ECU 1,219,929,000</td>
</tr>
<tr>
<td>Average pre-tax return on assets</td>
<td>16.4%</td>
</tr>
<tr>
<td>Average pre-tax profit as a % of sales</td>
<td>7.8%</td>
</tr>
<tr>
<td>Average market share of primary product</td>
<td>26.5%</td>
</tr>
<tr>
<td>Average market share of main competition</td>
<td>22.8%</td>
</tr>
<tr>
<td>Average growth rate (units sold)</td>
<td>11.3%</td>
</tr>
<tr>
<td>Average number of countries in which the respondent has plants</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Table A2: Median current and expected cost structure

<table>
<thead>
<tr>
<th>Cost Structure</th>
<th>Current</th>
<th>Expected in 2 years' time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total manufacturing costs as a % of sales</td>
<td>65%</td>
<td>62%</td>
</tr>
<tr>
<td>R&amp;D expenses as a % of sales</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>Allocation of manufacturing costs to:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- materials</td>
<td>58%</td>
<td>56%</td>
</tr>
<tr>
<td>- direct labour</td>
<td>15%</td>
<td>15%</td>
</tr>
<tr>
<td>- energy</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>- manufacturing overheads</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>- of which:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- indirect salaries, wages, fringes</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>- depreciation &amp; facilities expenses</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>- corporate allocations</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>- other</td>
<td>16%</td>
<td></td>
</tr>
</tbody>
</table>

Note: Since these numbers are the medians, they do not necessarily add up to 100.
APPENDIX 2: LIST OF MANUFACTURING IMPROVEMENT PROGRAMMES

Included in 1988 European Manufacturing Futures Survey Questionnaire

- Giving workers a broad range of tasks
- Giving workers more planning responsibility
- Changing labour management relationships
- Manufacturing reorganisation
- Worker safety
- Worker training
- Management training
- Supervisor training
- Preventive maintenance
- Zero defects
- Manufacturing lead-time reduction
- Vendor lead-time reduction
- Computer-aided manufacturing
- Computer-aided design
- Reducing setup/changeover time
- Value analysis/product redesign
- Group technology
- Capacity expansion
- Reducing size of manufacturing units
- Plant relocation
- Developing new processes for new products
- Developing new processes for old products
- Narrowing product lines/standardising
- Defining a manufacturing strategy
- Integrating information systems between manufacturing and other functions
- Integrating information systems within manufacturing
- Vendor quality
- Reconditioning of physical plants
- Just-In-Time
- Robots
- Flexible manufacturing systems
- Closing plants
- Statistical quality control (product)
- Statistical quality control (process)
- Improving new product introduction capability
- Quality circles
- Automating jobs
- Production/inventory control systems
- Reducing the size of manufacturing workforce (including hourly and salaried)
<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality conformance</td>
<td>109</td>
<td>17</td>
</tr>
<tr>
<td>Unit production cost</td>
<td>100</td>
<td>14</td>
</tr>
<tr>
<td>Inventory turnover</td>
<td>113</td>
<td>27</td>
</tr>
<tr>
<td>Development speed</td>
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<td>19</td>
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<tr>
<td>On-time delivery</td>
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<tr>
<td>Delivery speed</td>
<td>108</td>
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<tr>
<td>Overhead costs</td>
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<td>Batch sizes</td>
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**Source:** 1988 European Manufacturing Futures Survey (De Meyer and Ferdows, 1988)
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<th>Unit Production</th>
<th>Inventory Turnover</th>
<th>Development Speed</th>
<th>On-time Delivery</th>
<th>Delivery Speed</th>
<th>Overhead Costs</th>
<th>Batch Sizes</th>
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<td>Quality conformance</td>
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<td>.19**</td>
<td>.17*</td>
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<td>Unit production cost</td>
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<td>.28**</td>
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<td>Inventory turnover</td>
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<td>.21**</td>
<td>.22**</td>
<td>.08</td>
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<td>.27**</td>
<td>.05</td>
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** p < 0.01
* p < 0.05

Table 3: Relationship between manufacturing improvement programmes and performance indicators

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<th>Performance Measure</th>
<th>Programmes emphasized more by better-than-average group</th>
<th>Programmes emphasized more by more by worse-than-before group</th>
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<tr>
<td>Quality (conformance to design)</td>
<td>Giving workers more planning responsibility, Zero defects, Value analysis/product redesign, Group technology, Narrowing product lines/standardisation, Vendor quality, Reconditioning physical plants, Flexible manufacturing systems, Process Statistical Quality Control, Quality circles</td>
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<tr>
<td>Unit Production Cost</td>
<td>Developing new processes for existing products, Process Statistical Quality Control</td>
<td>Giving workers more planning responsibility, Plant relocation</td>
</tr>
<tr>
<td>Inventory turnover</td>
<td>Zero defects, Just-in-Time</td>
<td>Capacity expansion, Plant relocation, Narrowing product lines/standardisation, Integration of information systems across functions, Reducing size of manufacturing unit</td>
</tr>
<tr>
<td>Speed of new product development</td>
<td>Zero defects, Value analysis/product redesign, Developing new processes for new products, Integration of information systems in manufacturing, Vendor quality, Improving new product introduction capability</td>
<td>Reducing size of manufacturing unit</td>
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<tr>
<td>On-time delivery</td>
<td>Giving workers more planning responsibility, Zero defects</td>
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<tr>
<td>Delivery speed</td>
<td>Manufacturing reorganisation, Integration of information system across functions</td>
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<tr>
<td>Overhead costs</td>
<td>Value analysis/product redesign, Capacity expansion, Defining a manufacturing strategy, Automating jobs</td>
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<tr>
<td>Batch sizes</td>
<td>Manufacturing lead time reduction, Reducing set-up times, Closing plants, Just-in-Time</td>
<td></td>
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FIGURE 1: SIMULTANEOUS IMPROVEMENTS IN PERFORMANCE INDICATORS
Measuring Quality Conformance, Delivery Dependability, Development Speed, and Unit Production Cost

Source: 1988 European Manufacturing Futures Survey (Keiver and Ferdows (1988))
FIGURE 2: DEVELOPMENT OF LASTING MANUFACTURING CAPABILITIES

THE SANDCONE MODEL

COST EFFICIENCY

SPEED

DEPENDABILITY

QUALITY
FIGURE 3: FREQUENCY OF IMPROVEMENT IN EACH PERFORMANCE INDICATOR
if at least two measures improved chance of one being

Source: 1988 European Manufacturing Futures Survey
(Donovan and Wardow (1988))
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<table>
<thead>
<tr>
<th>Page</th>
<th>Authors</th>
<th>Title</th>
<th>Publication Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>88/12</td>
<td>Spyros MAKRIDAKIS</td>
<td>&quot;Business firms and managers in the 21st century&quot;, February 1988</td>
<td></td>
</tr>
<tr>
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<td>Manfred KETS DE VRIES</td>
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<td></td>
</tr>
<tr>
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<td>Alain NOEL</td>
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<td></td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
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<td>Michael BURDA</td>
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<td></td>
</tr>
<tr>
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<td>Michael BURDA</td>
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<td></td>
</tr>
<tr>
<td>88/19</td>
<td>M.J. LAVERENCE and Spyros MAKRIDAKIS</td>
<td>&quot;Individual bias in judgements of confidence&quot;, March 1988</td>
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<tr>
<td>88/20</td>
<td>Jean DERMINE, Damien NEVEN and J.F. THISSE</td>
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<td></td>
</tr>
<tr>
<td>88/21</td>
<td>James TEBOUL</td>
<td>&quot;De-industrialize service for quality&quot;, March 1988 (88/03 Revised)</td>
<td></td>
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<td>88/22</td>
<td>Lars-Hendrik ROLLER</td>
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<td></td>
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<tr>
<td>88/23</td>
<td>Sjur Didrik FLAM and Georges ZACCOEUR</td>
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<td></td>
</tr>
<tr>
<td>88/24</td>
<td>B. Espen ECKBO and Hervig LANGOER</td>
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<td></td>
</tr>
<tr>
<td>88/25</td>
<td>Everette S. GARDNER and Spyros MAKRIDAKIS</td>
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<td></td>
</tr>
<tr>
<td>88/26</td>
<td>Sjur Didrik FLAM and Georges ZACCOEUR</td>
<td>&quot;Semi-competitive Cournot equilibrium in multi-stage oligopolies&quot;, April 1988</td>
<td></td>
</tr>
<tr>
<td>88/27</td>
<td>Murugappa KRISHNAN and Lars-Hendrik ROLLER</td>
<td>&quot;Entry game with resellable capacity&quot;, April 1988</td>
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<tr>
<td>88/31</td>
<td>Sumantra GHOSHAL and Christopher BARTLETT</td>
<td>&quot;Creation, adoption, and diffusion of innovations by subsidiaries of multinational corporations&quot;, June 1988</td>
<td></td>
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<tr>
<td>88/32</td>
<td>Kasta FERDOVS and David SACKRIDER</td>
<td>&quot;International manufacturing: positioning plants for success&quot;, June 1988</td>
<td></td>
</tr>
<tr>
<td>88/33</td>
<td>Mihkel M. TOMBAK</td>
<td>&quot;The importance of flexibility in manufacturing&quot;, June 1988</td>
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<td>88/34</td>
<td>Mihkel M. TOMBAK</td>
<td>&quot;Flexibility: an important dimension in manufacturing&quot;, June 1988</td>
<td></td>
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<tr>
<td>88/35</td>
<td>Mihkel M. TOMBAK</td>
<td>&quot;A strategic analysis of investment in flexible manufacturing systems&quot;, July 1988</td>
<td></td>
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<tr>
<td>88/36</td>
<td>Vikas TIBREVALA and Bruce BUCHANAN</td>
<td>&quot;A Predictive Test of the NRD Model that Controls for Non-stationarity&quot;, June 1988</td>
<td></td>
</tr>
<tr>
<td>88/37</td>
<td>Murugappa KRISHNAN and Lars-Hendrik ROLLER</td>
<td>&quot;Regulating Price-Liability Competition To Improve Welfare&quot;, July 1988</td>
<td></td>
</tr>
<tr>
<td>88/38</td>
<td>Manfred KETS DE VRIES</td>
<td>&quot;The Motivating Role of Envy: A Forgotten Factor in Management&quot;, April 88</td>
<td></td>
</tr>
<tr>
<td>88/39</td>
<td>Manfred KETS DE VRIES</td>
<td>&quot;The Leader as Mirror: Clinical Reflections&quot;, July 1988</td>
<td></td>
</tr>
<tr>
<td>88/40</td>
<td>Josef LAKONISNOK and Theo VERMAELEN</td>
<td>&quot;Anomalous price behavior around repurchase tender offers&quot;, August 1988</td>
<td></td>
</tr>
<tr>
<td>88/41</td>
<td>Charles WYPLOSZ</td>
<td>&quot;Asymmetry in the EMS: Intentional or systemic?, August 1988</td>
<td></td>
</tr>
<tr>
<td>88/42</td>
<td>Paul EVANS</td>
<td>&quot;Organizational development in the transnational enterprise&quot;, June 1988</td>
<td></td>
</tr>
<tr>
<td>88/43</td>
<td>B. SINCLAIR-DESCAGNE</td>
<td>&quot;Group decision support systems implement Bayesian rationality&quot;, September 1988</td>
<td></td>
</tr>
<tr>
<td>88/44</td>
<td>Essam MAHMOUD and Spyros MAKRIDAKIS</td>
<td>&quot;The state of the art and future directions in combining forecasts&quot;, September 1988</td>
<td></td>
</tr>
<tr>
<td>88/46</td>
<td>Yves DOZ and Amy SHUEN</td>
<td>&quot;From intent to outcome: a process framework for partnerships&quot;, August 1988</td>
<td></td>
</tr>
</tbody>
</table>
88/47 Alain BULTEZ, Eli GJISBERGEN, Philippe NAERT and Piet VANDEN ABEELE

88/48 Michael BURDA

88/49 Nathalie DIERKENS

88/50 Rob WEITZ and Arnoud DE MEYER

88/51 Rob WEITZ

88/52 Susan SCHNEIDER and Reinhard ANCELMAR

88/53 Manfred KETS DE VRIES

88/54 Lars-Hendrik RÖLLER and Mihkel M. TOMBAK

88/55 Peter BOSSAERTS and Pierre HILLION

88/56 Pierre HILLION

88/57 Wilfried VANHONACKER and Lydia PRICE

88/58 B. SINCLAIR-DESGAGNE and Mihkel M. TOMBAK

88/59 Martin KILDUFF

88/60 Michael BURDA

88/61 Lars-Hendrik RÖLLER

88/62 Cynthia VAN HULLE, Theo VERMAELEN and Paul DE VOUTERS

88/63 Fernando NASCIMENTO and Wilfried R. VANHONACKER

88/64 Kasra FERDOVS

88/65 Arnoud DE MEYER and Kasra FERDOVS

88/66 Nathalie DIERKENS

88/67 Paul S. ADLER and Kasra FERDOVS

88/68 B. SINCLAIR-DESGAGNE and Mihkel M. TOMBAK

88/69 Michael BURDA

88/70 Nathalie DIERKENS

88/71 Rob WEITZ

88/72 Susan SCHNEIDER and Reinhard ANCELMAR

88/73 Manfred KETS DE VRIES

88/74 Lars-Hendrik RÖLLER and Mihkel M. TOMBAK

88/75 Peter BOSSAERTS and Pierre HILLION

88/76 Pierre HILLION

88/77 Wilfried VANHONACKER and Lydia PRICE

88/78 B. SINCLAIR-DESGAGNE and Mihkel M. TOMBAK

88/79 Martin KILDUFF

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88/83 Fernando NASCIMENTO and Wilfried R. VANHONACKER

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