4-1990

Lasting Improvements in Manufacturing Performance: In Search of a New Theory

Kasra Ferdows
INSEAD

Arnoud De Meyer
Singapore Management University, arnouddemeyer@smu.edu.sg

DOI: https://doi.org/10.1016/0272-6963(90)90094-T

Lasting Improvements in Manufacturing Performance: In Search of a New Theory

KASRA FERDOWS, *INSEAD, Fontainebleau, France, & Georgetown University, Washington, D.C. 20057*

ARNOUD DE MEYER, *INSEAD, Fontainebleau, France*

Published in Journal of Operations Management, April 1990, Volume 9, Issue 2, Pages 168-184. doi: 10.1016/0272-6963(90)90094-T

EXECUTIVE SUMMARY

Is there a way to avoid trading off one capability for another in manufacturing? The prevailing wisdom says no. But some manufacturers seem to have been able to defy that: compared to their competitors, they have better quality, are more dependable, respond faster to changing market conditions, and in spite of all that, achieve lower costs. How can this be explained?

Our aim here is to provide an explanation. We contend that the nature of the trade-offs among manufacturing capabilities is more complex than has been assumed. Depending on the *approach* taken for developing each capability, the nature of the trade-offs change. In certain cases not only can trade-offs be avoided altogether, but in fact one capability would enhance another. They become *cumulative.* Moreover, when a capability is developed in this way, it is likely to be more lasting and less fragile than if it were developed at the expense of other capabilities.

We go on to suggest a model which shows how this can be done: To build cumulative and lasting manufacturing capability, management attention and resources should go first toward enhancing quality, then-while the efforts to enhance *qualify* are further expanded-attention should be paid to improve also the *dependability* of the production system, then-and again while efforts on the previous two are further enhanced-production flexibility (or reaction speed) should also be improved, and finally, while all these efforts are further enlarged, direct attention can be paid to cost *efficiency.* We use data from 1988 European Manufacturing Futures Survey (167 respondents) to test and illustrate our model.

While we cannot "prove" our model, nevertheless, we believe there is enough evidence for a critical reexamination of traditional managerial approaches for improving manufacturing performance. For example, except for the cases when there are obvious slacks in the production system, the belief that costs can come down quickly and lastingly needs to be questioned. Lasting cost efficiency in production can be achieved only through improvements in other capabilities.

INTRODUCTION

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, seems 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 programs, particularly in their manufacturing systems, also report 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 performance in manufacturing are not necessarily mutually exclusive, but that better cost efficiency can, in fact, be a consequence of investment in quality improvement programs. 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 factories which are capable of producing a variety of products quickly and efficiently. Yamazaki machine tool factory in the United Kingdom, for example, offers four times more models in the third of the time normal to the industry, while the quality of their products "matches or beats" the high Japanese standard (Jones, et al. (1988)). Nippon Denso's radiator factory in Japan can shift from one model to another with no appreciable loss of efficiency. Apple Computer's Cork factory (in Ireland) can assemble various models of computers simultaneously on the same assembly line without changeover penalty.

These, plus many other examples, call for a fresh reexamination of whether there is a way to avoid the common trade-offs in production. Jaikumar (1986) offers an 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, et al. (1986); De Meyer, et al. (1989); Miller, et al. (1989)), we have noted that manufacturers use a multitude of different approaches for developing similar capabilities. Many of the excellent manufacturers in Europe, North America, and particularly Japan seem to follow a distinct sequence of improvement programs which aim at building one capability upon, and not instead of, another.

Do these observations invalidate the trade-off theory completely? The answer is no; there are clearly many cases where the trade-off theory applies forcefully. What these observations suggest, simply, is that this theory is not valid under all contingencies. In other words, the nature of the trade-offs depends on certain other factors. In the examples cited above, as we shall explain further, it is more reasonable to assume that the different capabilities have been *cumulative* and not the result of compromises and *trade-*

offs. We need, therefore, a more comprehensive theory which explains the achievements of these excellent manufacturers.

The essence of our thesis in this paper is that excellence in manufacturing is perhaps built on a common set of fundamental principles which are easier to get in place starting with one particular type of activity, and then pursuing other activities that expand and enrich this set of principles. The sequence is important because it is the combination of organizational priorities which form the best vehicle for enhancing the appropriate foundation principles. The appropriate sequence would help the organization to go after *substance,* and not just *form.*

The sequence we suggest in this paper is one which puts the quality at the base; then-while the efforts on quality improvement continue and expand-focuses also on improving the dependability of the production process; next, again while the previous efforts are expanded, also pays attention to improving the reaction speed and flexibility of the production system. It is then, while all previous efforts continue to expand, that direct attention to cost efficiency is justified.

We shall explain all this in greater detail in the following pages, but we hope that this short introduction shows the implications of what we suggest. If our arguments are convincing, then many current practices and, more important, mindsets in the management of production must be reexamined. New theories of such scope are seldom "proved" quickly, and we do not claim to have done that in this paper. We realize that this paper does not put this issue to rest, but our conclusions can serve as propositions for future debate and research.

THE RESEARCH BASE

To develop our arguments we use selected data available through the European Manufacturing Futures Project.7 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 entirely 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 each had changed by the end of 1987. Table 1 shows the sample means and standard deviations for each of the eight indicators. 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.

Second, we used the data on specific improvement programs in manufacturing recently implemented by the respondents. A list of 39 specific improvement programs was given in the questionnaire and the respondents were asked to indicate those which they had greatly emphasized in the previous year. The full list of these programs is shown in Appendix 2.

THE TRADE-OFF MODEL

In his seminal work, Skinner (1966) made several important contributions. Foremost among them was the need to identify the "manufacturing mission," i.e., what should manufacturing do to enhance the competitive strategy of the company. He questioned the prevailing narrow view of the strategic role of manufacturing in many companies – a view which reduced the role to merely being cost efficient. Instead, he suggested a broad list of strategically useful capabilities that could be developed in manufacturing. A company could choose the one(s) which best fitted its business strategy. The generic capabilities often mentioned in his work and other contributors such as Hayes and Wheelwright (1984), Hill (1985), Schmenner (1987), to name a few, have been cost efficiency, quality, dependability, and flexibility. More recent authors have expanded and refined this list, but their suggestions can still be classified within these four generic manufacturing capabilities.

We do not question the need for identifying the manufacturing mission in the company and for choosing among the many possibilities which are available. That is not the trade-off we are referring to here. Our focus here is on how *the specific capability(ies) demanded by the manufacturing mission is (are) developed.* The literature suggests that in this process there are trade-offs among these capabilities, that a factory cannot do well on many yardsticks. It is the theory behind this trade-off that we are examining in this paper.

According to this theory, unless there is slack in the system, improvement of one of the generic capabilities is possible only at the expense of the others: a company which is operating its manufacturing system at industry standards (what the economists refer to as being close to “the efficient frontier” of its resource utilization), cannot be expected to improve two or more capabilities simultaneously. For example, a company which opts for flexibility of its production, if successful, would improve the flexibility but its cost efficiency or dependability of its deliveries might fall behind industry standards. The only way a company can improve in more than one generic capability simultaneously is when it has been operating with slack – e.g., poor layout, obsolete machinery, poor suppliers, wrong production scale, etc.

We turn to our data to test the hypotheses based on the trade-off theory: the number of manufacturers in our sample that have improved only one of these generic capabilities is likely to be greater than those that have improved any two capabilities simultaneously; those that have improved two are likely to be more than those that have improved three capabilities simultaneously, and so on. These hypotheses can be expressed more generally: the frequency of the number of performance indicators simultaneously improved should follow a negative exponential distribution.

The data analyzed were the changes in the eight performance measures from 1985 to 1987 (Table 1). Since, as mentioned previously, our sample is biased towards large, well performing manufacturing units, we have assumed that most of them were not operating with slacks in their production systems in 1985.

The first thing to do was to translate these eight measures to the four generic capabilities. This turned out to be a rather straightforward task because we found that performance indicators *within* the four broad categories are indeed highly correlated (Table 2). Improvements in unit cost and overhead cost, for example, are highly correlated (coefficient = .28, significance more than 99%). More examples can be seen in Table 2.

Table 1: Changes in Performance Indicators 1985-87

Indices for 1987 (1985 – 100)

	Mean Standard	Deviation
Quality conformance	109	17
Unit production cost	100	14
Inventory turnover	113	27
Development speed	106	19
On-time delivery	108	17
Delivery speed	108	19
Overhead costs	100	15
Batch sizes	98	29

Source: 1988 European Manufacturing Futures Survey (De Meyer and Ferdows, 1988)

Table 2: CORRELATION BETWEEN THE PERFORMANCE INDICES

	Unit Production	Inventory Turnover	Development speed	On-time delivery	Delivery Speed	Overhead costs	Batch sizes
Quality conformance	.04	.08	.19**	.17*	.09	.06	
Unit production cost	-	-.0l	-.08	-0.14	-.10	.28**	-.07
Inventory turnover		-	.01	.21**	.22**	.08	-.11
Development speed			-	.29**	.27**	.05	.18*
On-time Delivery					.51**	.02	.03
Delivery speed						.03	.16*
Overhead costs							.06

** $p < 0.01$ *$p < 0.05$

Source: 1988 European Manufacturing Futures Survey (De Meyer and Ferdows, 1988)

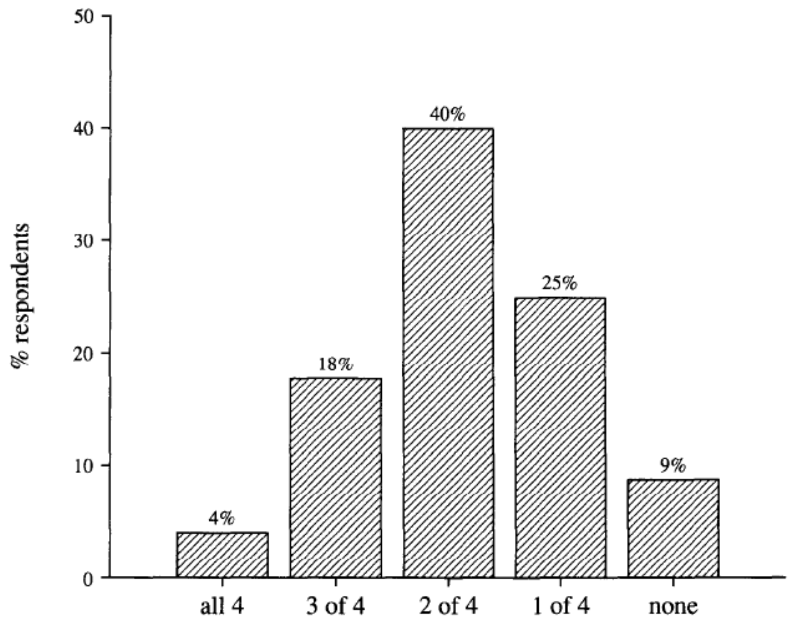
So, to test the hypothesis derived from the "trade-off theory," we chose four indicators which are close to the traditional four categories of cost efficiency, quality, flexibility and dependability. The four were unit manufacturing cost, quality conformance (i.e., producing according to the specifications), *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 trade-off theory would have predicted that the group of companies which have improved only one of the four measures would be the most numerous. This hypothesis has to be rejected! A large majority (62%) improved more than one capability. Although the subsequent hypotheses – e.g., those that improved two would be more numerous than those that improved three or four capabilities – cannot be rejected, the general hypothesis of negative exponential distribution of the number of simultaneously improved measures should also be rejected.

Given our assumption about the absence of slack (discussed previously), only two possible explanations remain. 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 is not supported by the additional data collected in our survey on the responding companies. As seen in Appendix 1, our sample seems to be biased toward well performing companies in terms of growth and profit. While it is of course possible that the penalties are incurring elsewhere, unknown to us, we believe it is prudent to consider the second explanation seriously and question the trade-off theory itself.

FIGURE 1: Simultaneous Improvements in Performance Indicators

Measuring Quality Conformance, Delivery Dependability, Development Speed, and Unit Production Cost



Source: 1988 European Manufacturing Futures Survey (De Meyer and Ferdows, 1988)

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.

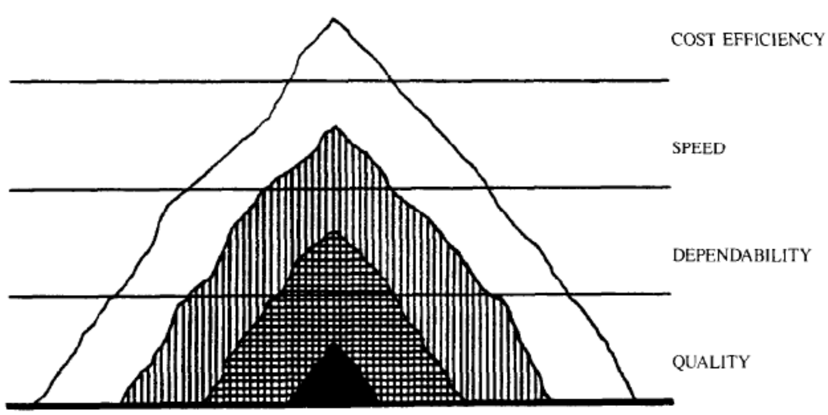
On the basis of his experience with Japanese companies and a survey similar to the European Manufacturing Futures administered in Japan, he suggested a cumulative model with *quality* improvement as the basis of all other improvements, followed by *dependability.* According to this model, one should 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 preconditions 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 Ferdows, et al. (1986) and De Meyer, et al. (1989).

In our own research, we have modified this model. Though we accept that cost improvements 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 in manufacturing capabilities is improvements in the *quality* performance of the company. Once the efforts in improvements in quality get underway and some results are obtained, while the efforts to improve the quality continue to expand, some efforts should be focused on making the production process more *dependable.* Next, improvement of *speed* should be added to these efforts-again, while the activities aimed at improving the quality and dependability are further enhanced and expanded. (Speed of response in manufacturing is essentially the way manufacturing flexibility can be gauged-i.e., how fast production can react to new customer requirements, changing production volumes, introduction of new product, etc.) Improvements in speed should be built cumulatively upon the foundations of quality and dependability. It is after these efforts are put in place that the company should start programs which are aimed directly at cost efficiency improvements, and again, do that while all the previous efforts continue to expand at increasingly higher rates. Cost improvements which result from this pattern of allocation of management attention and resources will be more lasting, and ultimately the company will be able to enjoy improved performance in quality, dependability, flexibility, and cost efficiency *simultaneously.*

We have sometimes depicted this cumulative model as a sand cone with different layers (Figure 2). The sand is, in this case, a stand-in for management effort and resources. To obtain a sand cone, one has to create first a stable foundation of quality improvements. Pouring more sand, one enlarges the quality foundation while starting also tackling the dependability of the production system. To build a taller sand cone, an increasing amount of sand needs to be poured, thereby while enhancing the quality and dependability layers, building the foundation for improving the speed of response of manufacturing. By pouring still more sand, and enhancing the foundation layers of quality, dependability, and speed still further, one can start building stable and well-founded cost improvement programs.

FIGURE 2: Development Of Lasting Manufacturing Capabilities

The Sand Cone Model



This analogy helps us explain an important characteristic of our model: that moving up each step in the path towards development of *lusting* manufacturing capabilities requires exponentially more efforts to go for the earlier steps. For example, to improve the cost *efficiency* by 10%, it will be necessary to improve the *speed* by a larger percentage, say 15, *dependability* by yet a larger percentage, say 25, and *quality* by still larger, say 40%. Once again, we should clarify that we are not saying that this is the only way to reduce costs; what we are saying is that even when there are no slacks in the system, costs can be reduced at no expense in terms of other capabilities-in fact by enhancing the other capabilities. Moreover, improvements obtained in this manner, being essentially due to deeper penetration of good manufacturing management practices in the organization, would be more stable and likely to last.

An obvious criticism of this model is that we seem to throw all contingencies overboard. 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 shows the way for an organization to go after substance and avoid chasing *form*; it shows the best vehicle for putting the fundamental principles of good manufacturing in place and continually expanding and enriching that set of principles. We have not attempted to identify and list these principles here, but they can be attention to details, aggressive investment in increasing knowledge of the production process, allowing active experimentation, direct contribution by everyone in continuous improvements, looking beyond small production microcosms, blurring the organizational demarcation lines, etc. With our model, we are implying that by focusing on quality first, the seeds of these organizational abilities are nurtured more than if the emphasis had been say on cost efficiency. While the quality efforts get on their way, by focusing also on making the system more dependable, the organization identifies the gaps in its knowledge and the reliability of its systems. Again, it would be premature to push cost efficiency aggressively at this stage. The next stage, speed, nurtures these principles further. By focusing on time reduction, more improvement ideas can be generated and implemented. The organizational abilities are further nurtured, and by now most of the efforts in the organization are directed towards the cost drivers, knowing that if they can be improved, the costs will improve. So at this stage some direct attention to cost efficiency efforts will be justified. A manufacturing capability developed in such a cumulative manner is likely to be more deeply ingrained in deep organizational abilities, hence will be more lasting.

Once the essence of our suggested approach is understood, the specific things that a company might do to enhance quality, dependability, flexibility (speed), and cost efficiency of its manufacturing may of course be chosen from a wide range of possibilities. The concepts of quality (Garvin (1987)), dependability (Jaikumar (1986)), flexibility (Swamidass and Newell (1987)) and cost efficiency are so broad that the individual company can clearly differentiate itself from its competitors by choosing its own combination of programs. Therefore, even though different business strategies may call for different capabilities from the manufacturing function, there is still a similarity of approach among those who build lasting and stable capabilities.

Once again, we should emphasize that in all our arguments, we are referring to companies that are operating generally at industry standards. If, for example, a company’s factory is clearly below the minimum efficient size, then naturally it first must find a remedy for that before venturing on the road that we suggest.

APPLYING THE SAND CONE MODEL

If our sand cone model is valid, then the programs 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 programs 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 number of performance indicators, and so on with the cost improvement programs 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 programs 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 contrast, we excluded the middle group-i.e., those companies with improvements 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 (please refer to Table 1); the second group consisted of those with a 1987 conformance indicator less than or equal to 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 programs undertaken by each group. The objective was to identify along which of the 39 specific improvement programs (list in Appendix 2) the two groups differed. We did a similar analysis for each of the other seven performance indicators. The results are summarized in Table 3.

More specifically, Table 3 shows the differences in the activities of the high (i.e., better-than-average) and low (i.e., worse-than-before) performers for each of the eight indicators. We included only those programs which received significantly different emphasis by the two groups. By "significant" we mean a confidence level of at least 95% that each of these programs had been emphasized by one group more than the other. With this type of analysis, strictly speaking, one can only discern *association* and not *causality* – i.e., theoretically one cannot be sure whether the observed performance was the result of the action program, or conversely, the program was undertaken because of the observed performance. Going beyond the strict theoretical interpretation, we believe it is reasonable to assume that better or worse performance on the specific indicator was (at least partly) due to the emphasis (or its lack) of the particular programs listed in Table 3. These are the programs which "made a difference."

Careful reading of Table 3 provides support for the cumulative theory. The program 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 emphasized zero-defect programs significantly more than the "worse-than-before" group. The effect of this seemingly quality improvement program 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 programs 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. Programs for improving *vendor quality,* improve not only quality conformance, but also the speed of new product development.

These are evidence that the quality improvement programs 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 trade-off theory.

Table 3: Relationship between Manufacturing Improvement Programs and Performance Indicators

Performance Measure	Programs emphasized more by better-than-average group	Programs emphasized more by worse-than-before group
Quality (conformance to design)	Giving workers more planning responsibility Zero defects Value analysis/product redesign Group technology Narrowing product lines/ standardization Vendor quality Reconditioning physical plants Flexible manufacturing systems Process Statistical Quality Control Quality circles	
Unit Production Cost	Developing new processes for existing products Process Statistical Quality Control	Giving workers more planning responsibility Plant relocation
Inventory turnover	Zero defects Just-in-Time	Capacity expansion Plant relocation Narrowing product lines/standardization Integration of information systems across functions Reducing size of manufacturing units
Speed of new product development	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	Reducing size of manufacturing units
On-time delivery	Giving workers more planning responsibility Zero defects	
Delivery speed		Manufacturing reorganization Integration of information systems across functions
Overhead costs	Value analysis/product redesign Capacity expansion Defining a manufacturing strategy	
Automating jobs		
Batch sizes	Manufacturing lead time reduction Reducing set-up times Closing plants Just-in-Time	

Source: 1988 European Manufacturing Futures Survey (De Meyer and Ferdows, 1988)

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 programs listed there can be interpreted to aim for a hybrid of quality, dependability, flexibility, and cost-efficiency. Another problem is the time lag: in our analysis we have not adjusted for the time lag between embarking on an improvement program and its effect on the 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 program 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 our model, 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 program 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 programs in Table 3, "integration of information systems in manufacturing" and "integration of information systems across functions," deserve attention. Emphasis on the former seems to improve the speed of new product introduction; emphasis on 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 programs, 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 can also be provided by our sand cone 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 sand cone model, there is enough evidence to justify questioning the existing trade-off 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 illustrate it by two examples. Suppose a company reports better manufacturing costs but worse quality, delivery dependability and/or flexibility. If there is no evidence that the company was operating with slacks before — e.g., its factory was not below the minimum efficient size, it was not poorly laid out, it did not suffer from severe under capacity utilization, its machinery was not obsolete, etc. — our sand cone 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 programs, "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.

In another example, 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 sand cone model suggests the latter, whereas the trade-off model takes no position, a priori. Again, the reason is in the specific sequence of improvements proposed in our model.

There are therefore many situations where the same observation interpreted by the trade-off or cumulative theories can lead to different conclusions.

Since our assertion can be considered radical, to avoid any possible confusion, perhaps it is useful to point out once again exactly what our sand cone model proposes. To begin with, it does not deny existence of trade-off among generic manufacturing capabilities; all it suggests is that *the nature of trade-off 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 sand cone model we suggest a specific pattern of capability enhancement which changes the traditional trade-offs among the generic manufacturing capabilities. The conventional paradigms of production, and the prevailing mindsets, when critically examined, often tend to put cost efficiency at the base and a prerequisite to allowing investments in quality, dependability or flexibility. Our sand cone model proposes precisely that lasting cost improvements can only be the result of cumulative improvements in the other areas. Hence, if a factory is gradually losing its cost efficiency, before needing tight financial discipline and control, it needs discipline and attention to enhancing quality, dependability, and flexibility of its production system.

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 is already producing at high quality, to continue to enhance its manufacturing capability, it will have to continue to improve its quality further. 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 somewhat larger improvement in the underlying capabilities will be required.

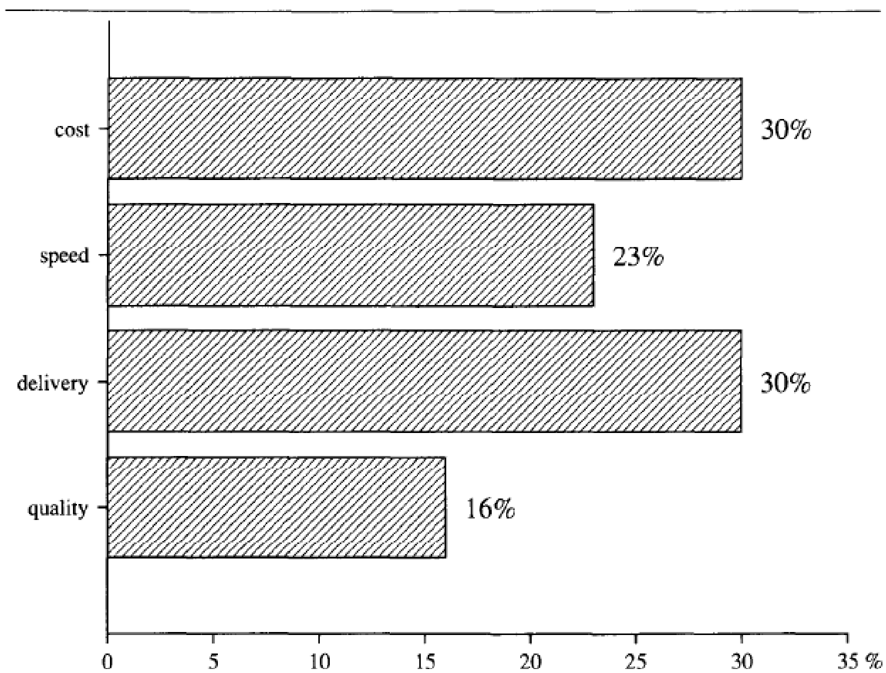
In practice, probably only a few companies follow the .pattern of resource allocation prescribed by our sand cone model exactly. Even the well performing manufacturing companies, such as the respondents to our 1988 European Manufacturing Futures Survey (Appendix l), are probably following a hybrid of 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 performance measures described earlier. They were *quality* conformance, *delivery* dependability, *speed* of new production development, and unit manufacturing *cost. You* will 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 in more than one capability—i.e., those who had improved performance in *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.

The results are shown in Figure 3. Cost and delivery have improved more frequently than quality. Looking at this positively, one may conclude that perhaps most of these European manufacturers are remedying the slacks in their production systems, bringing them at par with the global standards; however, if we assume that most of these large manufacturers in our sample were already at their industry standards, then our model sheds a negative light: that many of the achievements reported by our respondents might not be based on deep and lasting enhancement of the management of their manufacturing function.

Figure 3: Frequency of Simultaneous Improvements



Note: This chart shows the frequency of improvement of each indicator simultaneously with at least one of the other three indicators.

Source: 1988 European Manufacturing Futures Survey (De Meyer and Ferdows, 1988)

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 are based on the trade-off theory. We are suggesting the trade-off theory does not apply in all cases. Rather, certain approaches change the trade-off 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 sand cones by pouring on more sand).

All this stands even if we have erred on the last prescription of our model. We suggest that the approach which avoids trade-offs 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 establish milestones to ensure that the company stays 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 progressively improve (i.e., none of the earlier ones regress or stay stagnant when a later one improves), then the company is on the right track toward 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. Otherwise, the arguments for going directly after one capability at the expense of the others will prevail.

ACKNOWLEDGMENTS

The authors thank the three anonymous referees for their significant contributions

ENDNOTE

[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).

REFERENCES

Crosby, PB. *Quality is Free.* New York: McGraw-Hill, 1979.

De Meyer, A., and K. Ferdows. “Quality Up, Technology Down.” INSEAD Working Series No. 88165, 1988.

De Meyer, A., .I. Nakane, J.G. Miller, and K. Ferdows. “Flexibility, the Next Competitive Battle.” *Strategic Management Journal,* Vol. 10, 1989.

Deming, W.E. *Quality, Productivity and Competitive Position.* Cambridge: MIT Center for Advanced Engineering Study, 1982.

Ferdows, K., J.G. Miller, J. Nakane, and T.E. Vollmann. “Evolving Global Manufacturing Strategies: Projections into the 1990’s.” *International Journal of Operations and Production Management,* vol. *6, no. 4, 1986, 6-16.*

Garvin, D. *Managing Quality.* New York: Free Press, 1987.

Hayes, R.H., and SC. Wheelwright. *Restoring Our Competitive Edge: Competing through Manufacturing.* New York: John Wiley, 1984.

Hill, T. *Manufacturing Strategy.* London: MacMillan, 1985.

Jaikumar, R. “Postindustrial Manufacturing.” *Harvard Business Review, vol. 64,* no. 6, November-December 1986, 69-76.

Jones, B., P. Foy, J. Drury, and S. Young. “Britain’s Best Factories.” *Management Today,* September 1988.

Juran, J.M., FM. Gryna, and R.S. Bingham. *Quality Control Handbook.* New York: McGraw Hill, 1974.

Miller, J.G., A. Amano, A. De Meyer, K. Ferdows, J. Nakane, and A. Roth. “Closing the Competitive Gaps.” In *Managing International Manufacturing,* K. Ferdows. Amsterdam: North Holland, 1989.

Nakane, J. *Manufacturing Futures Survey in Japan, A Comparative Survey 1983-1986.* Tokyo: Waseda University, System Science Institute, May 1986.

Schmenner, R.W. *Production/Operations Management.* 3rd ed. Chicago: Science Research Associates, 1987.

Skinner, W. “Production under Pressure.” *Harvard Business Review,* vol. 44, no. 6, November-December 1966, 139-145.

Skinner, W. *Manufacturing in the Corporate Strategy.* New York: John Wiley, 1985.

Skinner, W. “The Productivity Paradox.” *Harvard Business Review, vol. 64,* no. 4, July-August 1986, 55-59.

Swamidass, PM., and W.I. Newell. “Manufacturing Strategy, Environmental Uncertainty and Performance: A Path Analytic Model.” *Management Science, vol. 33,* no. 4, April 1987.

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 and not biased towards a particular industry or a geographic 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 respondent was a *large, profitable and growing* business unit which operated internationally, and likely to be the market leader for its primary product or product family (Table A 1). Of course, 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 made 55% of its sales through its primary product or product family. A large share of its total sales, 28%, was coming from products which were on offer for less than two years; in three years' time this proportion was expected to reach 33%.

Manufacturing was 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 minimize the bias caused by the "outliers".)

The average total number of people employed by the business units was 4585. The distribution of this number was 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 characterized the average manufacturer in our sample this year. The median direct labor component of the work force was 300 or 36% of the total labor force.

All these numbers tend to indicate that our average respondent was a large, profitable and growing business unit, for which the manufacturing function plays an important role now and was expected to do so in the future. It was depending primarily on its internal resources to introduce more new products and expand its market share. In general, our respondents seemed to be optimistic about the future.

TABLE Al: Characteristics of the Respondents

Median of annual sales revenues	ECU 1.2 Billion
Average pretax return on assets	16.4%
Average pre-tax profit as a % of sales	7.8%
Average market share of primary product	26.5%
Average market share of main competition	22.8%
Average growth rate (units sold)	11.3%
Average number of countries in which the respondent has plants	2.3

Table A2: Median Current and Expected Cost Structure

	Current	Expected in 2 Years' Time
Total manufacturing costs as a % of sales	65%	62%
R&D expenses as a % of sales	3%	
Allocation of manufacturing costs to:		
- materials	58%	56%
- direct labor	15%	15%
- energy	3%	3%
- manufacturing overheads of which:	20%	20%
- indirect salaries, wages, fringes	50%	
- depreciation & facilities expenses	20%	
- corporate allocations	15%	
- other	16%	

Note: Since these numbers are the medians, they do not necessarily add up to 100.

APPENDIX 2

LIST OF MANUFACTURING IMPROVEMENT PROGRAMS

Included in 1988 European Manufacturing Futures Survey Questionnaire

Giving workers a broad range of tasks
Giving workers more planning responsibility
Changing labor management relationships
Manufacturing reorganization
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/standardizing
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 work force (including hourly and salaried)