"INFLUENCE OF MANUFACTURING IMPROVEMENT PROGRAMMES ON PERFORMANCE"

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Abstract

Today, to improve productivity in manufacturing, one has a large varity of improvement programmes at one's disposal. Zero defects, value analysis, Just-in-Time, manufacturing lead time reduction are just a few of a long list of potential action programmes. Their real impact is not always clearly described, and manufacturing managers often have to start implementation on the basis of belief. In this paper we use the database of the European Manufacturing Futures Survey to explore some of the medium-term effects of these improvement programmes on manufacturing performance. The conclusions show that there are no simple cause-effect relationships between single improvement programmes and manufacturing performance. Tenacity in implementation is required since some programmes have negative effects in the short term, but can have positive effects in the long term.

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Arnoud De Meyer & Kasra Ferdows

1. Introduction

Descriptions of manufacturing improvement programmes are abundant in the production management literature. Zero defect, integration of information systems, value analysis, manufacturing lead time reduction or flexible manufacturing systems are a few examples of a long list of action programmes which are proposed or described in the literature. In many cases, these action programmes are illustrated by successful case studies and/or accompanied by normative prescriptions of how and under which conditions one can successfully implement them (for example, see Garvin (1988), Schonberger (1986), Voss (1988)). Rarely, one finds studies which go beyond a small sample of case studies. Yet there are valid questions, which can only be answered comprehensively by studying a larger group of programmes. These are questions such as:

- Which programmes contribute to improvement of manufacturing performance along specific measures?

- What is the delay between implementation of a specific programme and its effect on performance?

- What is the relationship between the effect of an improvement programme and the extent of the efforts and resources dedicated to its implementation?

- Are there synergies between different improvement programmes?

- Which programmes are fashionable, but lack lasting impact on performance improvement?

We are not completely devoid of large sample studies. Whybark and Rho (1988) have reported on an effort to gather manufacturing data on a worldwide scale, but up until now no tangible results have been published. Schmenner (1988) reports on a productivity survey in the US and Europe and has strongly emphasized the causal effect betweenn the attention paid to throughput analysis and productivity improvements across the board in manufacturing. Cusumano (1988) has studied the effect of robotics and technology investment in the worldwide study of the automobile industry.

This paper explores the answers to some of these questions by using the data provided by the European Manufacturing Futures Survey. The European Manufacturing Futures Survey is a research programme in which selected data has been collected annually from a sample of large European manufacturers.(*) Every year for the last six years, between 145 and 200 large European manufacturers have completed the extensive questionnaire of this Survey. A description of the sample is given in Appendix A. (For more details see Ferdows et al, 1986; De Meyer et al, 1989; Ferdows and De Meyer, 1987).

(*) The European Manufacturing Futures Survey is part of a larger research project, the Global Manufacturing Futures Project, carried out by J. G. Miller and A. Roth at Boston University, J. Nakane et Waseda University (Tokyo), and the authors at INSEAD.

It should be stressed that the work described in this paper is of an exploratory nature. Our answers to the questions above should be regarded as propositions for further research and not as definitive conclusions.

2. Research Basis

To develop our arguments, we will make use of two sets of data. The first set consists of data on specific action programmes in manufacturing. A major part of the questionnaire was dedicated to gauging the degree of emphasis placed by the respondents on various action programmes. In 1986, 1987 and 1988 a list of 36 to 39 action programmes were offered to the respondents for which they could indicate on a Lickert scale their degree of emphasis on each of them.

These lists were of course not exhaustive. The fact that they grew from 36 to 39, and that some of the programmes themselves were changed over the three years, is an indication that one can never describe the full set of feasible action programmes in manufacturing. Nevertheless, being the result of cumulative experience of an international team of production researchers in the U.S., Japan and Europe, the list is credible. Furthermore, the list has gone through recursive examinations of being presented to a large number of executives and being modified over several years. For our purpose, we assume the list adequately reflects the generally accepted improvement programmes in manufacturing.

As has been said before, for the 1986 and 1987 survey, we have data on a Lickert scale (ranging from 1 to 5 in 1986, and from 1 to 7 in 1987), indicating how the respondents intended to emphasize the particular action programme. In the 1988 survey, we also have data on past action programmes, i.e. not only what they intended to do, but which action programmes they had emphasized in the previous year. In this case, we have only binary data, in the sense that the respondents were asked to tick off those action programmes which they had greatly emphasized.

The second set of data concerns manufacturing performance. In the 1988 survey, we measured the changes in eight performance measures between 1985 and 1987. The respondents were asked to take 1985 as a base year for each of the performance measures listed in Table 1 and indicate how much it changed by the end of 1987. 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%. A total of 167 participants filled this out in the 1987 questionnaire.

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insert Table 1 here

The eight performance indicators are again not exhaustive. Moreover they are not independent of each other. For example, as one may expect, on-time delivery and speed of delivery are correlated. But neither incompleteness nor interdependence causes problems for our analysis. We believe these indicators measure the performance of manufacturing more directly than some of the more common performance indicators such as growth, return on investments, return on assets, or profit margin.

With the action programmes and performance indicators thus defined, we can explore some of the questions we have raised in the introduction of the paper. Note that we have delved into the data collected in three consecutive surveys in 1986, 1987, and 1988; hence, we can take into account the lag in the effects of particular action programmes.

We examined the relationship between action programmes and performance indicators by two types of analysis. First, a stepwise regression analysis was carried out, using the 1988 performance indicators as dependent variable and the intended action programmes from the 1986 and 1987 surveys as independent variables. For this analysis, of course only those subsamples of business units which had responded both a) in 1986 and 1988, and b) in 1987 and 1988 were considered. Second, we used the binary data for the "past" action programmes for 1988 to form two groups for each of the programmes (i.e., those which emphasized the particular programme versus those which did not), and by means of a t-test we determined whether there was a significant difference in the achievements of the groups along each of the performance indicators. To avoid the influence of outliers, the data on action programmes and performance indicators were limited to those within two standard deviations around the mean of the total sample.

3. Results

The results are summarized in Table 2, in which the results of both the stepwise regression analyses and the t-test are presented. The programmes for which the coefficient in the regression analysis is significantly different from zero are given, each time with the sign indicating their effect. For the t-test, the sign indicates whether the group which emphasized the particular action programme has a significantly higher mean score for the performance indicator concerned. Granted, the two techniques are not fully comparable, but in both cases they show the effect of the particular action programmes.

Insert Table 2 here

3.1 Influence of individual programmes

The associations of the specific action programmes with specific performance indicators observed in Table 2, on the whole, are as one might expect. One sees, for example, that the quality index has been positively influenced by specific quality programmes such as zero defects, vendor quality or statistical quality control of the process. More general programmes such as direct labour motivation, improving new product development capabilites have also generally positive roles.

On-time delivery is positively influenced by better purchasing, integration of information systems, capacity expansion or plant relocation and all this with a two-year time lag. Though some of these effects may seem somewhat unexpected, each of them can be explained. A combined effort on materials flow programmes is, indeed, what one would expect for the improvement of delivery speed.

Another example of the face validity of the results is the positive effect of capacity expansion. It is probably the consequence of the higher slack created in the system by having more capacity available. This higher slack facilitates the production scheduling, and enables the company to live up to its delivery promises.

Investments in new technologies seem to have a negative effect on the quality index, at least at the time scale on which we carry out this analysis. The negative impact on quality performance of quality circles is less obvious. (We offer an explanation later why quality circles may lead to negative results).

There is no action programme that has a significant explanatory effect on the reduction of overhead costs. Though this is not necessarily what one would expect, explanations can be found. One could argue that the relation between manufacturing action programmes and the company's overhead costs is indirect; furthermore, reduction of overhead costs might require more than two years (i.e. the time scale of our analysis).

It is not our intention to go over all the entries in Table 2. The reader is encouraged to examine the table and draw his/her own conclusions which may be supplementary to what we have described in this paper. Some of the effects may remain an enigma. On the whole, however, the relationships indicated in these two tables have sufficient face validity to warrant further analysis.

3.2 Influence of portfolios of programmes

An interesting analysis is to see how many different action programmes seem to be leading to improvement in each performance indicator.

Table 3 presents a summary: for each performance indicator, it shows how many action programmes in 1986, 1987 and 1988 turned out to show significant positive influence.

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insert Table 3 here

It is clear that for most of the performance indicators, there is a portfolio of action programmes leading to improvement. Quality, for example, is positively influenced by eight action programmes emphasized in 1986, two in 1987 and three in 1988.

This confirms the widely held view that **success in manufacturing does not come easily and seems to require investment in a wide portfolio of programmes.**

Examining Table 3 more carefully, one notes that some performance indicators are positively influenced by a larger group of action programmes than others. For example, far less action programmes are associated with improvements in unit production cost than with quality or on-time delivery. Why should this be? One explanation may be that for quality or on-time delivery the relationship between actions and performance are perhaps complex (i.e. many actions) but straightforward; for other performance indicators, for example, unit production cost or overhead costs, the relationship might be indirect, in that other measures should improve first before they are improved.

This is a subtle but important point which deserves some explanation.

In a previous paper, we have argued that:

> "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 pre-condition 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... Once a critical level of dependability is reached, the company can attempt to improve its manufacturing reaction speed... 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 position." (Ferdows and De Meyer, 1989).

Let us analyse Table 2 again with this model in mind. If quality is the basis of improvements, dependability and reaction speed at a second level, and cost improvements at a third level of improvement efforts, one would expect that many action programmes and management efforts would be deployed for obtaining improvements in quality, less so to obtain improvements in dependability or reaction speed and least to obtain improvements in costs. The logic would be that cost improvements would result from improvements in quality performance, enhanced by a few supplementary actions.

Though our data is of course limited, we can derive from Table 2 that quality is positively influenced by twelve different programmes (of course, with varying time lags); on-time delivery (i.e; part of dependability) by five different programmes; reduction of batch sizes or speed of new product development, as indicators of reaction speed, by nine and eight programmes respectively; while unit cost reduction or overhead costs are significantly influenced only by three and zero action programmes respectively.

We can go one step further. If cost improvements are influenced by improvements in quality and dependability, and if dependability is influenced by improvements in quality, then the explanatory power of a regression with cost efficiency as a dependent variable, and some of the action programmes plus the quality performance indicator and a dependability performance indicator as independent variables should be higher than a regression with only the action programmes as independent variables. Similarly one would expect that the regression with dependability as a dependent variable, and the quality indicator plus the action programmes as independent variable would have a higher explanatory power, than without the quality indicator as an independent variable.

The results of these regression analyses are presented in Table 4. The evidence is mixed.

insert Table 4 here

According to our model, for every row in Table 4, the coefficient of determination (R^2) should increase as we move to the right of the table and none of the variables should have a negative influence. This happens in some cases but not all. Inclusion of the quality performance indicator increases considerably the explanatory power for the dependability performance indicator. (And quality has the right sign!) That is, improvements in quality explains improvements in on-time delivery. However, for the cost indicators, the results do not support our thesis. For reduction of unit costs, inclusion of quality and/or delivery performance indicators do not change the R^2. For reduction of overhead costs, indeed, dependability has a large explanatory power (R^2 has increased), but with the wrong sign.

This does not necessarily reject our model. There might be short-term negative effects of dependability improvements on overhead costs, whereas the long-term effects might be positive. Clearly more investigation is needed to come up with clear proof. Meanwhile, we would like to continue with the proposition that the **tradeoff between manufacturing capabilities does not apply in all cases**. The trade-off relationship between quality, dependability, flexibility, and cost efficiency can be transformed into a cumulative one where cost efficiency is the ultimate consequence of investments in quality, dependability and reaction speed.

3.3 Influence of the time lag

A close look at Table 2 can help us understand some of the time lags in the implementation of action programmes. Take, for example, the effect of 'integration of information systems': it is intriguing to see that this programme has generally negative effects in the short term and positive effects over a two-year period. However, most of the other technology-driven programmes-- such as c.a.d., reconditioning physical plants, f.m.s.-- seem to continue to have a negative influence over the two-year period analysed by us.

The fact that the negative impact persists for so long is quite disturbing, particularly since it contradicts many of the promises of these technology-driven programmes (see, for example, Voss (1986), or Bolwijn, Kumpe et al (1986)). The usual explanation of this effect has been **that some action programmes have a negative effect in the short term, while their impact in the long term can be positive.** Traditional production management literature recognises the non-linear effect of some of the action programmes, that the performance effect as a function of the investment in resources follows an S-curve. What we observe here is more than an S-curve: we see the initial effect of some action programmes to be actually negative.

Let us return to the example of the integration of information systems. In this case, it is reasonable to assume that the short term confusion created by the systems integration, and the effort needed to install appropriate software and hardware, outweigh the beneficial effects of the better available information. However, after the organisation goes through the adjustment, the advantages become larger, and the negative effects are reduced. The existence of such a "short-term negative, long-term positive" influence is not unexpected, but the duration of the negative impact is often under-estimated. If the same explanation is to be offered for the other technology-driven programmes, such as c.a.d and f.m.s, our data suggests that the time lag before one sees positive effects can be more than two years.

3.4 Influence of fads versus deep commitments

Some of the improvement programmes seem to become fashionable for a while without leaving a lasting impact. As Makridakis (1989) indicates, many management theories and tools developed over the last 20 years have come into being, received high attention, and have consequently disappeared into oblivion. The same might be true with manufacturing action programmes. Let us look at some examples.

The case of quality circles is an interesting one. Quality circles have been praised by many as a way of involving workers in the problem-solving process leading to the continuous improvement of the manufacturing organisation. But our data shows that, except for the improvement in inventory turnover, quality circle programmes seem to have a negative influence on performance! The explanation that quality circles have only an impact at the lowest level of the factory floor, hence are less likely to influence higher-level parameters such as delivery speed or new product development, is not satisfactory. If so, one would expect quality circles to remain neutral--not to have a negative impact. Perhaps a more acceptable explanation is that impact is **highly dependent on the way the quality circle programme is implemented!** Perhaps quality circles have been implemented without adequate preparations, under adverse conditions, or worse, as a substitute for facing the problems openly.

The second example we want to take out of the list is f.m.s. (flexible machining systems). This comes up three times, and exclusively with a negative influence! As we explained before, this can be partly due to the "short-term negative, long-term positive" syndrome. The negative impact of f.m.s., particularly on delivery speed and quality improvement can be attributed to inappropriate implementation. An implementation which is too technologically oriented, and which loses sight of the organisational requirements to make the f.m.s. work, can lead to a disruptive impact. Paradoxically, the very performance measures which it aims to improve seem to deteriorate.

A third example is c.a.m. (computer aided manufacturing). Although c.a.m. has been on the list since the start of the surveys, it does not seem to have a significant impact on any of the eight performance indicators studied here. A cursory glance through journals for production practitioners, convinces one immediately that c.a.m is in, and is expected to lead to faster and better manufacturing. But why is it absent from our list?

Again, several explanations are possible. Either one can say that everybody is emphasizing c.a.m. at the same high level, so there is no variation in the data to flag out the influence of c.a.m. A quick analysis shows that this is not the case. The variance of the emphasis placed on c.a.m. is of the same magnitude as for the other action programmes. So, we are back to the explanation that either the time lag of c.a.m implementation is too long to be measured through our data, or that the impact of c.a.m. is highly dependent on its implementation.

The last two examples point in the same direction. Some of the technology-driven programmes which are supposed to provide a beneficial effect on manufacturing performance, have no effects or worse, negative effects over the time span of two years we have studied. These observations lead us more convincingly towards the hypothesis that **the technology-driven programmes generally require a long time and an appropriate set of complementary action programmes to turn out positive results.** Too often, technology is deployed as a magic tool to change the company. What our data suggest is that technology can have, in fact, a negative effect for a long time.

An interesting question can be raised at this stage: is it possible to speed up the success of the introduction of FMS? To explore this question, the following exercise was carried out. We isolated the group of respondents who had put a strong emphasis on FMS in 1986 and 1987. For these groups we separated the ones with a higher than average performance on delivery speed in 1988 from the ones with a lower than average performance on delivery speed. After the separation, we checked whether the high performers had put more emphasis on other programmes than the low performers. The objective of this exercise is obvious. The question we try to answer is whether there are other programmes which have a synergistic and positive effect on the introduction of FMS. It turns out that in 1986, the better than average performing group put less emphasis than the worse than average performers on reorganisation of manufacturing but more on purchasing and the development of new processes for new products. In 1987, the better than average performing group put a significantly higher emphasis on integration of information systems across functions, production and inventory control systems and just-in-time programmes. These results are of course very limited, and cannot do more than confirm a hypothesis that success with FMS seems to be positively influenced if its introduction is accompanied by a systems view with emphasis on logistics and production linkages.

4. Conclusion

Our data, analyses, and observations, tentative as they are, lead to or confirm four propositions:

One: There are no simple cause-effect relationships between single improvement programmes and manufacturing performance. Success in manufacturing requires an investment in a carefully selected set of complementary action programmes.

Two: Lasting cost improvements in manufacturing result from improvements in quality, dependability and fast reaction capabilities, and only rarely as the direct result of specific action programmes.

Three: Certain manufacturing action programmes require tenacity in implementation. The extent of resources committed to the implementation of these programmes and persistence seem to have significant effects on their outcomes. Indeed, some have short-term negative results and may only become effective after a fairly long transition period.

Four: Deployment of technology in manufacturing can easily have a negative influence on performance for a long period. To reduce this period, as it has been suggested by many, these programmes should be accompanied by proportional investments in human and organisational resources.

We are aware that these propositions are tentative and that neither our sample nor our methodology can provide definite proof for them. Still, we hope that our arguments are strong enough to stimulate further work.

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: Performance indicators as a function of action programmes

	Stepwise Regression analysis (1986 future action programmes) (n = 32)	Stepwise regression analysis (1987 future action programmes)	T-test (1988 past action programmes (p< 5%)
Improvement of <u>Quality</u> index of conformance to design	R^2 = .92 + direct labour motivation + manufacturing reorganisation - worker safety (*) + automating jobs + zero defects (*) + vendor quality + group technology - developing new processes for new products - reconditioning physical plants - F.M.S. + closing plants + statistical quality control (process)	R^2 = .34 - capacity expansion - reconditioning physical plants (*) - F.M.S. + improving new product introduction capability + reducing the size of the manufacturing workforce	+ value analysis/product redesign + group technology + vendor quality
Reduction of <u>Unit Production Cost</u>	R^2 = .47 + giving workers a broader range of tasks - giving workers more planning responsibility - quality circles (*) + integration of information systems across functions	R^2 = .13 - manufacturing reorganisation - introducing robots (*)	+ plant relocation
Increase of <u>Inventory Turnover</u>	R^2 = .18 - manufacturing reorganisation	R^2 = .18 + integration of information systems across functions - reconditioning of physical plants + quality circles (*)	+ zero defects - plant relocation - integration of information systems across functions - closing plants - reducing the size of the manufacturing workforce
Increase the <u>speed of new product development</u>	R^2 = .49 - giving workers a broader range of tasks - manufacturing reorganisation + supervisor training + purchasing management	R^2 =.19 - giving workers a broader range of tasks + giving workers more planning responsibilities + reducing set-up time	+ integrating information systems within manufacturing + vendor quality + improving new product introduction capability + PICS - reducing the size of the manufacturing workforce

Improvement of on-time delivery	$R^2 = .54$ - quality circles + purchasing management - CAD + capacity expansion (*) + plant relocation + integration of information systems across functions	$R^2 = .06$ + J.I.T. (*)	- closing plants
Increase of delivery speed	-	$R^2 = .50$ - worker safety - CAD + group technology (*) + J.I.T. + closing plants - quality circles + PICS	- integration of information systems across functions - F.M.S.
Reduction of overhead costs	-	-	-
Reduction of batch sizes	$R^2 = .57$ - changing labour/management relationships + value analysis/product redesign - developing new processes for old products + integration of information systems	$R^2 = .71$ + giving workers more planning responsibility - changing labour/management relationships + supervisor training - preventive maintenance + vendor lead time reduction - capacity expansion + reduction of size of manufacturing units - narrowing product lines/ standardisation - integration of manufacturing information systems + integration of information systems across functions (*) + introducing robots + improving new product introduction capability + quality circles	+ manufacturing lead time reduction + PICS

Note: - Since the regression analysis are exploratory, we included all variables for which the coefficient are significantly different from zero on a 10% level. The coefficient for which 5% < p < 10% are indicated with an asterix.

- The negative and positive signs indicate the effect of the independent variables on the dependent variables for the regression. For the t-test, the sign indicates whether the average performance indicator is lower or higher for the group which has greatly emphasized the particular action plan.

Table 3: Number of action programmes with a positive effect

	1986	1987	1988
Quality conformance	8	2	3
Unit production cost	2	0	0
Inventory turnover	0	2	1
Speed of new product development	2	2	4
On-time delivery	4	1	0
Speed of delivery	0	4	0
Overhead costs	0	0	0
Batch sizes	2	6	2

Table 4: Regression results with varying sets of independent variables

Independent	Dependent variables		
	Action plans 1987 only	Action plans 1987 plus quality performance indicator	Action plans 1987 plus quality & delivery performance indicators
On-time delivery	R^2 = .06	R^2 = .21	-
Unit production	R^2 = .13	R^2 = .13	R^2 = .13
Overhead costs	No variables enter the equation	No variables enter the equation	R^2 = .22

APPENDIX

Characteristics of the respondents to the 1988 European Manufacturing Survey

(N° = 167)

<u>Median</u> of annual sales revenues	ECU 1,219,929,000
Average pre-tax 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

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