SWP 14/95 COMPATIBILITY AND TRADE-OFF BETWEEN PERFORMANCE: AN ALTERNATIVE VIEW

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Compatibility and Trade-off Between Performance: An Alternative View

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Abstract

An issue on which opinions still differ concerns the presence or absence of trade-offs between different types of manufacturing performance. In an attempt to provide some empirical evidence to resolve this argument, a recent conference paper [3] examined the relationships between different types of performance for a sample of plants in the metal/mechanical industry. The authors concluded that trade-offs between several performance types still exist. This paper provides a different interpretation of the data presented, using statistical analysis to demonstrate that the evidence for trade-offs is not significant. However, there is evidence that some types of performance are mutually supportive. The results obtained are compared with the results predicted by each of the available trade-off models and some empirical support for the sand cone model is obtained.

Introduction

Since Skinner [7] first published his seminal work on the nature of manufacturing trade-offs it has been assumed by most manufacturers that improved performance on one factor can only be achieved by trading this off against reduced performance on one or more other factors.

Since then a number of authors [1, 6, 7, 9], notably Schonberger have argued that some companies are able to simultaneously improve on all aspects of performance. For these companies there are no trade-offs.

Skinner [8] and New [4] have responded to this argument by saying that although the nature of trade-offs is constantly changing, some trade-offs still remain. Ferdows and De Meyer [2] have developed what they refer to as the sand cone model. This is based on the proposition that competences are cumulative rather than mutually exclusive.

Filippini, Forza and Vinelli [3] have tried to provide some empirical data regarding the trade-off issue by analysing the compatibility/trade-off between different types of performance for a sample of 42 plants drawn from the metal mechanical industries. They define trade-off as the impossibility of reaching high level performance over several types of performance and compatibility as the possibility of obtaining high level performance over several types of performance. The following 3 research questions were addressed.

1. On consideration of n different performance areas (where n is ≥ 2), it is possible to find companies in which there is compatibility between a number (k) of these performance types.

2. On consideration of n different performance areas (when n is ≥ 2), are there sets of performance types where a compatibility situation prevails and others where a trade-off situation prevails?

3. Do high levels of compatibility between performance areas go hand in hand with high overall levels of distinctive competences?

The sample was selected to include equal numbers of traditional and world class manufacturing (WCM) plants. Classification was based on the opinions of experts in the field. WCM plants were defined as plants with a reputation for excellence in several areas. Traditional plants were defined as plants focusing on one or a few performance areas. There was no discussion of whether the sample was representative of the population from which they were drawn. There was also no discussion of the problems associated with using a sample carefully selected to meet their definition of compatibility in combination with another sample of equal size carefully selected so that it was less likely to meet their definition of compatibility.

It is not stated whether the data was collected by self-administered questionnaire or by interview. A series of objective and subjective questions were asked and these were used to construct a set of measures of performance and distinctive competence. The measures obtained were tested for reliability and validity using Crombach's alpha coefficient, factorial analysis and analysis of variance. Although the results of this analysis are not presented it is stated that only measures with high validity and reliability were used. The criteria used are not stated. The performance measures selected were as follows,

Delivery time - The time which elapses between receipt of the order and delivery to the customer.
Delivery punctuality - The percentage of orders delivered on time.
Quality consistency - The average percentage of rejects and re-processing and of finished products that are defective.
Quality capability - Quality of the product in terms of its characteristics and performance capabilities compared with those of the competitors.
Invested capital turnover - average invested capital turnover and relative trend.
Production cost over turnover - average production cost of sales over turnover and relative trend.

The companies were then divided into 4 quartiles for each performance measure with equal numbers of companies in each quartile. Then the following measures of compatibility and trade-off were determined.

$CT_1(j, i_1, i_2)$

This measure compares performance types i_1 and i_2 for plant j. For compatibility (C) the plant must be in the top 2 quartiles on both types of performance. For a trade-off plant performance on the 2 measures must be in non-adjacent quartiles. Otherwise the measure is classified as neither a compatibility or a trade-off situation (NTC).

$SCT_1(j, i_1, I_2)$

This is a more stringent measure comparing performance types i_1 and i_2 for plant j. For compatibility (C) the plant must be in the top quartile on both performance types. For a trade-off the plant must be in the extreme opposite quartiles for the 2 types of performance.

C(j, G)

This measures the performance of plant j across a sub-set G of k different performance measures taken from the n performance types being studied. For compatibility (C) the plant must be in the upper 2 quartiles for all k performance types.

SC(j,G)

This is a more stringent measure of the performance of plant j across a sub-set G of k different performance measures taken from the n performance types being studied. For compatibility (C) the plant must be in the top quartile for all k performance types.

The first step in the authors' analysis of the data collected was to carry out a correlation analysis between the various performance types. Although they do not present the results of this analysis they state that the performance types examined are tendentially independent. Although they do not develop this further it could be an extremely important conclusion. If it is correct it suggests that, for the industry being studied, trade-offs do not exist. High performance on any of the measures being studied can be achieved without any effect, positive or negative, on any of the other performance measures.

The next stage in their analysis was to count the number of companies in which compatibility between at least k performance types was confirmed. This was done using both the function C(j,G) and the more restrictive function SC(j,G). As none of the companies in the sample achieved compatibility between all 6 performance types they conclude that some trade-offs must still exist. In fact their results provide striking support for the hypothesis that all of the performance types being studied are independent. Under this hypothesis the measure based on C(j,G) would be binomial with n=6 and p=0.5 and the measure based on SC(j,G) would be binomial with n=6 and p=0.25. The observed and theoretical results are compared in Table 1.

Table 1: Number of companies showing compatibility between k or more performance areas

	Measure based on C(j,G)		Measure based on SC(j,G)	
k	Observed	Expected	Observed	Expected
0 or 1	42	42	42	42
2	31	37.3	16	19.6
3	27	27.5	8	7.1
4	15	14.4	3	1.6
5	6	4.6	1	0.2
6	0	0.7	0	0.0
chi-squared		0.709		0.739
p		0.95		0.86

The next stage in their analysis was to count the number of companies showing compatibility using the $CT_1(j, i_1, I_2)$ measure for each pair of performance areas. Even if the 2 performance areas show perfect correlation only half of the companies could be in the upper 2 quartiles and meet the compatibility criterion. For this reason the number of companies showing compatibility on each pair of measures was expressed as a percentage of the maximum number possible, 21. Even if a pair of performance measures is completely independent, Table 2 shows that 16 combinations could arise, all equally likely, of which 4 meet the compatibility criterion. The expected value of the calculated percentage will therefore be 0.25/0.5 = 50 %. The 95 per cent confidence limits for the actual sample percentage can easily be calculated to be 35 % - 65 %. Table 3 shows the observed results taken from the original paper. All lie within the 95 per cent confidence limits further supporting the hypothesis that all of the performance areas studied are independent of each other. The average value across all the cells is 52.2 % compared with an expected value of 50 % for independence. This difference is not statistically significant.

Table 2: Performance combinations meeting the compatibility/trade-off criteria

		Quartiles for performance area i_1			
		1	2	3	4
Quartiles for	1	SC	C	T	ST
performance	2	C	C	NCT	T
area i_2	3	T	NCT	NCT	NCT
	4	ST	T	NCT	NCT

Stringent compatibility = SC
Basic compatibility = SC or C
No compatibility or trade-off = NCT

Stringent trade-off = ST
Basic trade-off = ST or T

Table 3: Basic compatibility between performance areas
(the number of companies showing compatibility as a percentage of the maximum number possible)

	Punctuality	Q. Consist	Q. Capabil.	Inv. Capital Turnover	PCS/ Turnover
Delivery Time	55 %	45 %	50 %	53 %	50 %
Punctuality		55 %	40 %	37 %	55 %
Q. Consist.			55 %	63 %	65 %
Q. Capab.				47 %	50 %
Inv. Capital Turnover					63 %

The authors next considered the percentage of companies meeting the trade-off criteria for each pair of performance areas. Reference to Table 2 shows that if the performance areas are independent then the expected percentage of companies meeting the trade-off criteria will be 37.5 %. The 95 per cent confidence limits for the actual percentage will be 22.5 % - 52.4 %. Table 4 shows the results from the original paper. Again all of the results lie within the 95 per cent confidence limits. However, the average percentage across all performance area combinations is 31.2 % compared with an expected average of 37.5 %. This difference is significant at the 0.01 level and provides limited evidence that some pairs of performance areas are not independent but exhibit some positive correlation.

Table 4: Basic trade-off between performance areas
(the number of companies showing trade-off as a percentage of the maximum number possible)

	Punctuality	Q. Consist	Q. Capabil.	Inv. Capital Turnover	PCS/ Turnover
Delivery Time	37 %	31 %	28 %	24 %	29 %
Punctuality		31 %	38 %	42 %	37 %
Q. Consist.			25 %	26 %	31 %
Q. Capab.				29 %	36 %
Inv. Capital Turnover					24 %

The next stage of the authors' analysis was to look at compatibilities and trade-offs using their more restrictive definition SCT_1 . Table 5 shows the results using their stringent definition of compatibility. If the 2 performance areas are independent then, on average, 1 in 16 plants will meet the stringent compatibility criteria. The maximum percentage of plants that can meet the stringent compatability criterion is 25 per cent. Therefore, under the independence assumption, each cell in table 5 has an expected value of 6.25 %/25 % = 25 %. The 95 per cent confidence limits for the actual values are 12 % - 38 %.

Table 5: Stringent compatibility between performance areas
(the number of companies showing stringent compatibility as a percentage of the maximum number possible)

	Punctuality	Q. Consist	Q. Capabil.	Inv. Capital Turnover	PCS/ Turnover
Delivery Time	37 %	37 %	50 %	25 %	37 %
Punctuality		30 %	30 %	33 %	20 %
Q. Consist.			40 %	44 %	40 %
Q. Capab.				33 %	20 %
Inv. Capital Turnover					22 %

The average of these results is 33.2 % compared with an expected value of 25 %. This difference is significant at the 0.001 level and provides further support for compatibility between the performance areas being studied. The following pairs of performance areas show compatibility levels significantly higher than would be expected for independence.

Delivery time and quality capability
Quality consistency and quality capability
Quality consistency and the turnover of invested capital
Quality consistency and production cost over turnover

Table 6 shows the corresponding results using the stringent trade-off criterion. Under the independence assumption an average of 1 in 8 plants would meet the stringent trade-off criterion. The maximum number of plants that can meet the stringent trade-off criterion is 50 % and so the expected value for each cell in Table 6 is 12.5 %/50 % = 25 %. The 95 % confidence limits for the actual values are again 12 % - 38 %.

Table 6: Stringent trade-off between performance areas
(the number of companies showing stringent trade-off as a percentage of the maximum number possible)

	Punctuality	Q. Consist	Q. Capabil.	Inv. Capital Turnover	PCS/ Turnover
Delivery Time	12 %	23 %	23 %	23 %	17 %
Punctuality		16 %	32 %	44 %	38 %
Q. Consist.			5 %	22 %	21 %
Q. Capab.				22 %	21 %
Inv. Capital Turnover					16 %

The average of these results is 22.3 % compared with an expected value of 25 %. This difference is not statistically significant. Two pairs of performance areas give results outside the 95 per cent confidence limits. Quality consistency and quality capability showed significantly lower trade-off than expected for independence indicating that very good performance in one was rarely associated with very bad performance in the other. Punctuality and turnover of invested capital showed significantly higher trade-off than expected for independence. In other words, very good performance in one was frequently associated with very bad performance in the other.

The last part of the paper addresses the third research proposition that high levels of compatibility between performance types are accompanied by high overall levels of distinctive competence. The authors measured the correlation between the number of performance types that are simultaneously compatible for a given plant and the average of the following 4 measures of distinctive competence.

Process and product technology - manager's perceptions of level of product and process technology compared to that of competitors

Management systems - managers' perceptions of quality management systems and production flow: whether they are superior to those of competitors

Human resources - managers' perceptions of the presence of internal relations with employees: whether they are better than those of competitors

External relations - managers' perceptions about relations with suppliers and customers: whether they are better than those of competitors

Using the basic compatibility function C(j, G) a correlation coefficient of .35, significant at the 0.05 level was obtained. Using the more stringent compatibility

function SC(j, G) a correlation coefficient of 0.42, significant at the 0.01 level, was obtained. Although these results appear to support the research proposition, the measures of distinctive competence used were all subjective and could have been influenced by the performance levels being achieved by the plant. The results obtained are consistent with the hypothesis that plant performance influences managers' perceptions of competence levels within the plant. As no statistical testing of the direction of causality was carried out it is not possible to draw any conclusions regarding the relationship between cause and effect.

Discussion of the results

Statistical analysis of these results provides little evidence of trade-offs between the performance areas studied. The only trade-off identified is between punctuality ant turnover in capital investment. However, there is evidence for compatibility between at least some of the performance areas studied. Excellent performance on one measure is more frequently associated with excellent performance on other measures than might be expected by chance. Does this mean that Schonberger is right and Skinner and New are wrong? Before that conclusion can be reached there are a number of difficulties to be overcome.

Firstly there is the problem that the sample of plants included half who were judged by experts to be world class manufacturers. This is almost certainly higher than the proportion of world class manufacturers in industry as a whole, biasing the results and making it difficult to reach generalisable conclusions. Even if this was not a problem, how consistent are the results with the various trade-off theories?

Schonberger [6, 7] argues that the distinctive competences which lead to continuous improvement in one performance area are the same competences which lead to improvements in other areas. Schonberger would therefore predict that plants who are leaders in one performance area will also be leaders in the other performance areas. Using the measures considered in this paper, the stringent compatibility measures on all pairs of performance types should be higher than the level expected for independence. 12 out of the 15 pairs of performance types meet this criterion. The 3 exceptions all involve production cost over turnover suggesting that although the various elements of customer service are mutually supportive, high levels of customer service still involve a cost penalty.

New [4] and Skinner [8] have both restated their views on trade-offs in order to provide clarification of their original ideas and to take into account the effect of lean manufacturing. They both argue that trade-offs are dynamic and that relationships between different types of performance can be positive or negative depending on how improvements in performance are achieved. New believes that current improvements in manufacturing plants can simultaneously improve quality consistency, delivery reliability, lead times and manufacturing costs. However, increases in product features, greater product variety and higher rates of new product introduction cannot be achieved without some increase in manufacturing costs. If this is correct we would expect to see high levels of compatibility between all the factors studied with the exception of quality capability which should exhibit high trade-off levels with the other

factors. For both the basic and stringent compatibility/trade-off criteria only 9 of the 15 pairs of factors behave as predicted by this model.

The sand cone model [2] assumes that quality is the prerequisite for all other types of performance , followed by dependability, flexibility and then cost. The measures that match most closely with the measures used in Ferdows and De Meyer's original study are as follows,

Quality	Quality consistency
Dependability	Punctuality
Flexibility	No suitable measure available
Cost	Production cost over turnover

The sand cone model would predict that in this study the average level of stringent compatibility with all other factors will be highest for quality consistency, followed by punctuality and then production cost over turnover. The actual figures are as follows,

Measure	Average of Stringent compatibility measures
Quality consistency	38.2 %
Punctuality	30.0 %
Production cost over turnover	27.8 %

This does seem to provide limited evidence in support of the sand cone model.

Suggestions for further research

In spite of the 20 year history of trade-off analysis there have been few attempts to provide statistical evidence in support of any of the prevailing theories. Filippini et al have made a start in developing a methodology for testing the nature of strategic trade-offs. However, their data is limited to one industry and is based on a relatively small sample of plants. They consider only a few aspects of manufacturing performance, ignoring performance measures which relate to flexibility and innovativeness. Also, their analysis suffers from the deficiencies described in this paper.

More data is needed, for a larger sample of plants drawn from a wider range of industries. For each plant, a greater variety of performance measures needs to be identified so that more thorough testing of the various trade-off theories can be carried out. This will probably require some refinement of the measures suggested by Filippini et al. It might then be possible a unified model of strategic trade-offs which resolves the different views expressed by the various writer on this subject.

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