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Company-wide integration of strategic maintenance: An empirical analysis

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Abstract

This paper discusses the maintenance/production interface, and emphasises the importance of integration for organisational design and strategic planning. Firms with various maintenance visions, goals and plans and company-wide integration of maintenance are differentiated. Data was gathered from 293 Swedish maintenance managers in manufacturing firms. Analysis showed that integration and long-term planning of maintenance both affect prevention, quality improvement and manufacturing capabilities.

Keywords: Maintenance management; Manufacturing strategy; Quality; Prevention; Integration

1. Introduction

Coordination of manufacturing and maintenance work is important when formulating strategy, planning, scheduling and in daily operations, but maintenance should also be integrated into manufacturing for better long-term benefits [1,2]. In several total productive maintenance (TPM) cases [1–7] it has been shown to be profitable to integrate maintenance activities into multifunctional production teams with decentralised responsibilities, in which the production department drives the TPM process, while maintenance assists. Maggard and Rhyne [6], for example, showed in a case study that most maintenance work could be performed by teams of operators.

The fully production-integrated maintenance approach is not simple to apply. It must be carefully planned and implemented. TPM development is based on human factors, supported by the top management and information system. Takahashi [8] and Yamashina [9], for example, emphasised highly motivated teams using everybody's skill, and an understanding and acceptance of the life-cycle approach for continuous improvement of the overall performance of equipment. Other studies (e.g. (9)) have, following TQM authors, focused on the top management commitment for developing such capable human resources. The information systems have not been emphasised to the same extent as human and managerial aspects. However, Bohoris et al. [7] showed that the Computerised Maintenance

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Management System (CMMS) was a contributor, providing prompt and accurate information, enabling successful TPM implementation.

TPM is not the only one in focusing on the maintenance/production interface. Reliability Centred Maintenance (RCM) [10], Terotechnology [11], and Capital Asset Management [11] all emphasise the importance of "system-wide" or "asset centred" maintenance. Other approaches linking maintenance to production are presented by Gits [12] and Ben-Daya and Duffuaa [13].

Production-integrated maintenance may affect the competitive capabilities and long-term benefits of organisations. It is important as a value adding activity in increasingly integrated business and manufacturing strategies. Maintenance could be integrated into manufacturing strategy and planned to support reliability and quality, and so contribute to an holistic proactive overall strategy. This increased strategic and integrated role of maintenance is still new in the industry. Poor strategies, lacking or deficient in integration have been reported (e.g. [14]).

There is lack of empirical studies explaining maintenance effects on manufacturing strategy, and linking maintenance to manufacturing capabilities. This paper focuses on the links between company-wide integrated maintenance, perceived existence of long-term maintenance visions, goals and plans; and the emphasis on quality improvement, prevention and manufacturing capabilities (Fig. 1). The analyses are based on an empirical survey to Swedish manufacturing firms.

2. Potential effects of strategic maintenance

Theoretical concepts describing the strategic role of maintenance in manufacturing are scarce. Empirical studies, though, group competitive factors of manufacturing into four main capabilities: quality, delivery performance, flexibility and cost (e.g. [15–21]). The same approach looks feasible for linking maintenance to competitive strategy.

The capabilities are different and complement each other if pursued in proper order. The natural sequence in most firms is quality, delivery, flexibility followed by cost efficiency [16,18]. Consequently, when high levels of the "foundation capabilities" quality and delivery are achieved, the organisation can improve with others and become "world-class". Studies [19–21] indicate that high-performing firms compete simultaneously on multiple capabilities. Quality improvement is not only a basic competitive capability. It is also an important part of a proactive manufacturing strategy that is considered essential for long-term performances [22,23].

The need for quality has led to improved need for reliability in machinery sustained by maintenance. Without proper preventive maintenance it is likely that the equipment will fail periodically and experience speed losses or lack of precision. Equipment maintenance affects the level of prevention, proactiveness and stability of the production process, leading to increased quality and delivery performance. Decreased equipment wear out may also affect positively the flexibility of the production process and the overall life-cycle costs. Consequently, maintenance can be a business driver because it improves most manufacturing capabilities.

For high equipment effectiveness, the maintenance process must be coordinated with production, to support it without interruptions. Traditionally, emphasis has been placed on the downstream organisational activities associated with factory maintenance and support. Less progress has been made in the area of maintainability improvement at

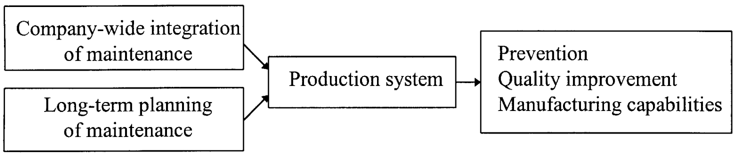

Fig. 1. The links between integration and planning of maintenance and prevention, quality improvement and manufacturing capabilities

the equipment design stage or capital investment process [24]. Both areas of production-integrated maintenance are considered important for meeting the business objectives and achieving long-term performances.

The above discussion indicates potential long-term effects of planned and integrated strategic maintenance and therefore the following hypothesis was derived:

H1: Firms with company-wide integrated maintenance and long-term maintenance visions, goals and plans emphasise quality improvement, prevention and most manufacturing capabilities to a greater extent than firms without long-term maintenance visions, goals and plans and/or company-wide integrated maintenance.

3. Contextual factors for maintenance

The context in which maintenance is integrated (production process, industry, company size and breakdown consequences) could help explain differences in level of long-term visions, goals and plans (shortened to "plans" hereinafter) and company-wide integration, and differences in benefits so derived.

3.1. Production process

In project or jobbing processes, redundancies and flexibility are built in. Machines are often idle and working hours flexible. In continuous processing full standbys are rare and usually productive capacity is lost, but since redundancies and inventories exist it may be possible to survive breakdowns without optimising maintenance. The situation is more problematic for firms using hybrid batch processing to achieve both scale and scope economies. There, most machines are bottlenecks, inventory levels are minimised and delivery tight. This leads to hypothesis (H2):

H2: The importance of company-wide integration of maintenance and long-term maintenance visions, goals and plans varies between different types of production processes.

3.2. Industry

Studies of manufacturing strategy taxonomies (e.g. [25]) showed correlation between manufacturing strategy groups and type of industry. None of these studies deals with maintenance and integration, though. Perhaps some industries' production processes need company-wide integrated and long-term maintenance plans. However, we choose to state the hypothesis (H3) in a manner consistent with lack of knowledge:

H3: The importance of company-wide integration of maintenance and long-term maintenance visions, goals and plans does not vary between industries.

3.3. Size

Large firms may have more hierarchical, formalised and complex organisational structures than small firms. This would make it more difficult to integrate maintenance into manufacturing in these firms. On the other hand, small firms probably favour jobbing processes and to a lesser extent line or continuous processes. This would lead overall to less need for long-term maintenance plans and company-wide integrated maintenance in small firms. Thus, we formulate hypothesis H4:

H4: Large firms do not have company-wide integration of maintenance and long-term visions, goals and plans to a greater extent than small firms, or vice versa.

3.4. Breakdown consequences

There are two aspects of breakdown consequences, stoppage costs and environmental risks. Positive correlation is expected between the severity of stoppage costs and degree of long-term and integrated maintenance. Breakdowns also create safety and environmental risks, causing direct and indirect losses. Maintenance could reduce this. Risks are difficult to measure and are therefore sometimes omitted. If they are serious they still lead to increased maintenance, though. Hypotheses H5 and H6 are therefore:

H5: Firms with high stoppage costs have implemented company-wide integrated maintenance and long-term maintenance visions, goals and plans to a greater extent than firms with low stoppage costs.

H6: Firms with high environmental risks have implemented company-wide integrated maintenance and long-term maintenance visions, goals and plans to a greater extent than firms with low environmental risks.

4. Methodology

4.1. Sample

The empirical study is based on a survey mailed to 747 Swedish maintenance or manufacturing managers identified from the SEMA Group database (food, timber, paper, chemical, mechanical engineering and steel industries). 253 relevant answers were returned. 210 non-respondents were followed up by telephone calls. 30 were not interested. 40 telephone interviews were conducted. 101 non-respondents said they were thinking about answering the questionnaire, but would not answer by telephone. 39 out of 210 firms telephoned (19%) had no manufacturing. If 19% of all addresses were irrelevant the sample size is down to 605 firms. This makes the response rate 42 to 48%. Chi-square tests showed no significant difference ($p = 0.05$) between early and late answers regarding maintenance plans and company-wide integration. Response rates did not differ significantly ($p = 0.05$) between industries or between firms of different sizes.

4.2. Scales and statistics

Most data were subjective in nature; since a respondent's own opinion and subjective figures are given. The operationalisation and measures are discussed in the section "Data Analysis and Findings". Different statistical techniques were used in the analysis, F-tests (ANOVA and Scheffe's pairwise comparison) when the data are in interval scales, mean rank tests (Kruskal–Wallis and Wilcoxon–Mann–Whitney) when the data is on the ordinal level and chi-square tests when the data are on a nominal scale.

5. Data analysis and findings

The analysis has three parts. The first defines empirical maintenance typologies, based on the realisation of long-term plans and company-wide maintenance. The second explains how the typology groups emphasise prevention, quality improvement and manufacturing capabilities, and the third explains contextual differences between the groups.

5.1. Identification of maintenance typology

Classification into maintenance typologies was based on an empirical analysis of their long-term maintenance plans and company-wide integration of maintenance.

1. *Long-term plans*: In the first test, the respondents were asked if they considered that their companies had long-term written or oral maintenance plans, and if these were separated from or integrated into the manufacturing or corporate strategies. Three groups of firms were identified; (1) those claiming to have long-term written or oral integrated plans; (2) those claiming long-term written or oral separate plans, (3) those without long-term plans for maintenance. The measure indicated the respondents' perception of existing long-term plans, and did not say anything about the actual existence of specific long-term maintenance plans or strategies.

2. *Company-wide integration*: The second test consisted of three parts; company-wide maintenance knowledge, commitment to maintenance issues, and participation in the process to formulate plans for maintenance. First, the respondents were asked to indicate to what extent *maintenance knowledge* was spread among various levels of the production function. Five alternatives were given: (1) only the maintenance function has knowledge about maintenance; (2) operators have a little

knowledge about maintenance; (3) all levels within the production function have some, but not very good, maintenance knowledge; (4) operators have very good maintenance knowledge and the other production personnel have some knowledge; (5) the entire production function has very good knowledge and understanding of maintenance. Knowledge had to be spread to at least level three for passing the test.

Commitment to maintenance issues was the second part of the second test. The respondents were asked to mark their perception of commitment to maintenance of production management and production personnel. A six point Likert scale was used. At least level four commitment for every group of personnel was necessary for passing the test.

Production management and personnel's *participation in the formulation* of the long-term maintenance plans was the last test. The respondents were asked to what extent production management and personnel participated in the formulation process. A six point Likert scale was used. At least level four participation for production management and level three participation for production personnel were necessary for passing the test.

We could then identify six groups of companies, based on three levels of long-term maintenance plans and two levels of company-wide integration of maintenance. The group with separate plans and company-wide integration contained only four companies and was therefore omitted. The remaining groups were named interactors, functionalists, functional strategists (Integrated), functional strategists (Separate), and integrated strategists (Fig. 2).

We know from the test on company-wide integration that interactors and integrated strategists differ from functionalists and integrated functionalists, regarding the company-wide integration variables, but not how significant the differences are. Nor do we know anything about differences between groups in the same categories. Another test was therefore conducted (Table 1). This analysis of company-wide integration differs from the former test, since it focuses on the mean ranks and means of the variables. Kruskal–Wallis and pairwise Wilcoxon–Mann–Whitney tests of mean ranks were used for analysing the knowledge variable. ANOVA and Scheffe's pairwise comparison tests of mean differences were used for the aggregated values of commitment and participation (the scores

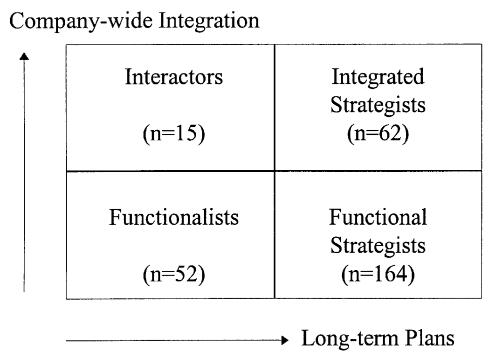

Fig. 2. The maintenance typology

Table 1
Company-width variables by maintenance typology

Measure	Interactors	Maintenance typology groups				Statistics
		Functionalists	Functional strategists (S)	Functional strategists (I)	Integrated strategists	
	(n = 15)	(n = 52)	(n = 36)	(n = 128)	(n = 62)	
Knowledge	(2,3,4)	(1,4,5)	(1,5)	(1)	(2,3)	$\chi^2 = 109.1$
Mean Rank	**228.2**	**85.9**	100.2	133.6	220.6	$p < 0.001$
Commitment	(2,3,4)	(1,3,4,5)	(1,2,5)	(1,2,5)	(2,3,4)	$F = 40.8$
Mean (std dev)	9.7 (0.9)	**6.5** (1.5)	7.5 (1.9)	7.8 (1.5)	**9.9** (1.0)	$p < 0.001$
Participation			(5)	(5)	(3,4)	$F = 19.1$
Mean (std dev)	–	–	**7.7** (2.3)	8.4 (1.7)	**9.8** (1.3)	$p < 0.01$

Note: Numbers in parentheses indicate the group numbers from which this group was significantly different at the $p < 0.05$ level according to pairwise Wilcoxon–Mann–Whitney and Scheffe's tests. χ^2 and F statistics and associated p-values are derived from Kruskal–Wallis statistics and one-way ANOVAs. Numbers in **bold** indicate the highest and lowest group centroids for that measure.

of production personnel plus production management).

The results indicate that the company-wide integrated groups (interactors and integrated strategists) are distinct from the not company-wide integrated groups (functionalists and functional strategists). The group without both long-term maintenance plans and company-wide integration (functionalists) had lower level of company-wide integration compared to the group with long-term plans and without company-wide integration (functional strategists).

5.2. *Prevention, quality improvement and manufacturing capabilities*

The typology was examined to determine differences across groups in terms of emphasis on manufacturing capabilities, prevention, quality improvement, production process, industry, size and breakdown consequences.

H1 indicated that firms with long-term maintenance plans and company-wide integrated maintenance emphasise quality improvement, preventive and manufacturing capabilities to a greater extent than the others. The first, out of four tests, considered time spent on corrective maintenance policies, the second preventive maintenance techniques, the third quality improvement programmes and the fourth manufacturing capabilities.

1. *Time spent on correction* (*Table 2*(*a*)): The functionalists spent significantly more time on correction than all other groups. Time spent on correction was almost twice as high for functionalists (68.5%) compared to the integrated strategists (35.8%). The other differences were more modest. It is difficult to specify the optimum proportion for correction, although, several authors (e.g. [14]) assert that it should seldom exceed about 40%.

2. *Preventive maintenance techniques* (*Table* 2(*b*)): To further verify the preventive status of the groups, the respondents were asked to indicate which of condition monitoring, human senses, maintenance optimisation, annual service, other preventive maintenance, and emergency or correction, respectively, were their most and second most important maintenance techniques. The importance of emergency and corrective maintenance was significantly higher for the groups without company-wide integration (functionalists and functional strategists) compared to the integrated strategists. Emergency was less important for interactors also, but only significantly less than the functionalists. Emergency and correction were most important activities for 17% of the integrated strategists, for 57% of the functionalists, and for 23% of the total sample.

3. *Quality improvement programmes* (*Table 2*(*c*)): The third test concerned the present quality improvement status. The respondents were asked to indicate one of the five scenarios; (1) no specific quality improvement activities during the last year, (2) quality improvement activities have increased in importance, but are still rare, (3) some employees work on quality improvement issues, (4) continuous quality improvement activities are important parts of the corporate strategy-several employees participate, (5) quality has a central role in the organisation – improvement programmes have for several years been important for continuously improving production and maintenance – all employees participate.

Integrated strategists have implemented quality improvement most, and significantly more than the groups without company-wide integration. Interactors are the second highest group. They differ significantly from the functionalists and the functional strategists with separate strategy.

4. *Manufacturing capabilities* (*Table 2*(*d*)): The integrated strategists emphasised all manufacturing capabilities, but tied up capital to a greater extent than the other groups. The emphasis on production costs, rapid product change and prompt deliveries were significantly higher than for the functionalists. The relative ranking of manufacturing capabilities did not differ between groups. Defect rates was the most important capability for all groups, and delivery performance and tied-up capital the two least important.

All tests support H1. The analysis also indicated that the variable "company-wide integration" was more important than "long-term maintenance plans" for verification of the hypothesis. This may be supported by the fact that integration has a central role in most maintenance concepts (e.g. [9–13]) and successful TPM case studies (e.g. [3–7]).

Table 2
Prevention, quality improvement and manufacturing capabilities by maintenance typology

Measure	Interactors	Maintenance typology groups				Statistics
		Functionalists	Functional strategists (S)	Functional strategists (I)	Integrated strategists	
	($n = 15$)	($n = 52$)	($n = 36$)	($n = 128$)	($n = 62$)	
(*a*) *Strategic planning*	(–)	(5)	(–)	(–)	(2)	$F = 3.9$
Mean (std dev)	10.0 (10.4)	**5.2** (6.8)	11.3 (9.4)	9.7 (8.9)	**12.2** (10.8)	$p < 0.01$
(*a*) *Prevention*	(2)	(1, 3, 4, 5)	(2)	(2)	(2)	$F = 10.0$
Mean (std dev)	36.3 (22.2)	**16.6** (11.6)	37.1 (17.9)	32.5 (20.4)	**38.8** (19.7)	$p < 0.001$
(*a*) *On-condition*	(–)	(–)	(–)	(–)	(–)	$F = 1.1$
Mean (std dev)	9.8 (11.0)	9.6 (13.2)	9.8 (9.7)	**9.1** (7.2)	12.6 (9.7)	$p < 0.33$
(*a*) *Correction*	(2)	(1, 3, 4, 5)	(2)	(2)	(2, 4)	$F = 14.9$
Mean (std dev)	44.2 (24.1)	**68.5** (20.5)	41.4 (41.4)	48.8 (22.0)	**35.8** (21.1)	$p < 0.001$
(*b*) *Condition monitoring*	(–)	(3, 4, 5)	(2)	(2)	(2)	$\chi^2 = 13.9$
Mean rank	134.5	**124.5**	136.1	143.3	**156.2**	$p < 0.01$
(*b*) *Human senses*	(–)	(–)	(–)	(–)	(–)	$\chi^2 = 3.3$
Mean rank	146.5	**133.2**	144.2	136.6	**154.4**	$p = 0.52$
(*b*) *Maint. optimisation*	(–)	(–)	(–)	(–)	(–)	$\chi^2 = 9.0$
Mean rank	140.4	130.5	138.5	140.5	151.6	$p = 0.06$
(*b*) *Annual service*	(–)	(–)	(–)	(–)	(–)	$\chi^2 = 2.7$
Mean rank	131.9	**150.8**	143.2	140.3	**131.7**	$P = 0.61$
(*b*) *Other preventive*	(2)	(1, 4,5)	(–)	(2)	(2)	$\chi^2 = 10.3$
Mean rank	158.5	**114.1**	136.8	142.0	**159.8**	$p < 0.05$
(*b*) *Emergency*	(2)	(1, 4, 5)	(5)	(5)	(2, 3, 4)	$\chi^2 = 32.5$
Mean rank	123.0	**184.6**	148.7	137.3	**102.2**	$p < 0.001$
(*c*) *Quality improvement*	(2, 3)	(1, 4, 5)	(1, 4, 5)	(2, 3, 5)	(2, 3, 4)	$\chi^2 = 47.9$
Mean	170.2	**94.9**	99.8	152.3	**182.6**	$p < 0.001$
(*d*) *Production costs*	(–)	(5)	(–)	(5)	(2, 4)	$F = 4.5$
Mean (std dev)	4.53 (1.25)	**3.86** (1.48)	**4.28** (1.23)	4.27 (1.24)	**4.89** (1.09)	$p < 0.05$
(*d*) *Tied up capital*	(–)	(–)	(–)	(–)	(–)	$F = 2.0$
Mean (std dev)	2.53 (0.83)	**2.92** (0.96)	2.61 (1.02)	**2.43** (1.13)	2.49 (1.12)	$p = 0.09$
(*d*) *Rapid product change*	(–)	(4, 5)	(–)	(2)	(5)	$F = 4.3$
Mean (std dev)	3.60 (1.72)	**3.24** (1.57)	3.94 (1.37)	4.04 (1.28)	**4.29** (1.42)	$p < 0.01$
(*d*) *Rapid vol/set-up change*	(–)	(–)	(–)	(–)	(–)	$F = 0.3$
Mean (std dev)	4.13 (1.36)	4.28 (1.39)	**4.11** (1.53)	4.33 (1.30)	**4.34** (1.28)	$p = 0.91$
(*d*) *Fast/dependable delivery*	(–)	(5)	(–)	(–)	(2)	$F = 3.3$
Mean (std dev)	3.07 (1.83)	**2.88** (1.59)	3.00 (1.30)	3.34 (1.40)	**3.81** (1.35)	$p < 0.05$
(*d*) *Defect rate/product perf.*	(–)	(–)	(–)	(–)	(–)	$F = 2.2$
Mean (std dev)	5.00 (1.25)	**4.68** (1.27)	4.80 (0.99)	5.13 (1.04)	**5.16** (0.85)	$p = 0.07$

Note: Numbers in parentheses indicate the group numbers from which this group was significantly different at the $p < 0.05$ level according to pairwise Wilcoxon–Mann–Whitney and Scheffe's tests. χ^2 and F statistics and associated p-values are derived from Kruskal–Wallis statistics and one-way ANOVAs. Numbers in **bold** indicate the highest and lowest group centroids for that measure.

5.3. Contextual factors

We expected to find variation across firms with different production processes, different breakdown consequences, but not across firms from different industries and of various sizes, with respect to long-term maintenance plans and company-wide integration of maintenance.

The analysis could only reveal significant differences between the groups regarding production process (Table 3). Functionalists had significantly lower proportion of continuous process and line plants ($p < 0.05$) than expected. Therefore, hypotheses two, three and four were verified, but hypotheses five and six were rejected. Consequently, type of industry, size and breakdown consequences are not very important for implementation of company-wide integrated long-term maintenance plans, and production process less important than we expected. We conclude that; perhaps maintenance should be considered a basic strategic foundation in firms, no matter what the production environment is.

6. Conclusions and comments

A maintenance typology of four groups have been generated and interpreted.

Interactors have a low relative emphasis on long-term maintenance plans, but high emphasis on company-wide integration of maintenance. Only 5% (15 members) belong to the group. They have the second highest emphasis on prevention

Table 3
Contextual factors by maintenance typology

Measure	Interactors	Maintenance typology groups				Statistics
		Functionalists	Functional strategists (S)	Functional strategists (I)	Integrated strategists	
	($n = 15$)	($n = 52$)	($n = 36$)	($n = 128$)	($n = 62$)	
Major process (#)						
Continuous process	2	8-	8	41	18	$\chi^2 = 24.7$
Continuous line	5 +	1-	5	14	3	
Batch	7	29	17	51	29	$p < 0.05$
Job	1	13	6	21	10	
Project	0*	0*	0*	1*	2*	
Industry(#)						
Food	2*	5	5	15	4	$\chi^2 = 17.6$
Timber	2*	7	7	4	4	
Paper	1*	6	2	22	10	$p = 0.13$
Chemical	1*	5	5	22	9	
Mechanical engineering	9*	26	15	53	23	23
Steel	0*	0*	1*	5*	5*	
Other	0*	3*	1*	7*	7*	
Size	(−)	(−)	(−)	(−)	(−)	$\chi^2 = 3.5$
Mean rank	**119.0**	136.7	144.7	**151.7**	141.8	$p = 0.48$
Stop costs	(−)	(−)	(−)	(−)	(−)	$\chi^2 = 6.1$
Mean rank	**75.7**	95.8	84.1	105.8	**106.5**	$p = 0.19$
Safety/environment	(−)	(−)	(−)	(−)	(−)	$F = 1.9$
Mean (std dev)	1.93 (1.94)	**1.69** (1.36)	1.83 (1.28)	2.24 (1.62)	**2.37** (1.59)	$p = 0.12$

Note: Numbers in parentheses indicate the group numbers from which this group was significantly different at the $p < 0.05$ level according to pairwise Wilcoxon–Mann–Whitney and Scheffe's tests. χ^2 and F statistics and associated p-values are derived from Kruskal–Wallis statistics and one-way ANOVAs. Cells with (*) are not included in chi-square tests. (+) and (−) indicate cells that significantly (at the level $p < 0.05$) differ from expected value. Numbers in **bold** indicate the highest and lowest group centroids for that measure.

and quality improvement, and differ significantly from functionalists regarding time spent on correction, importance of emergency techniques and quality improvement programs. This group has more small and medium-sized companies than the others, but not significantly more.

Functionalists consist of 18% of the total sample. They emphasised prevention, quality improvement and manufacturing capabilities less than all other groups. They were named functionalists because of their low emphasis on both long-term maintenance plans and company-wide integration of maintenance. They showed lowest level of knowledge and commitment of all groups.

Functional strategists form the largest group. It consists of the functional strategist (S) group with 36 members and the functional strategist (I) group with 128 members, altogether 56%. They consider themselves to have long-term plans for maintenance, but they do not have integrated maintenance on a company-wide level. They emphasise prevention and quality improvement more than the functionalists, but less than interactors and integrated strategists. They spend significantly less time on correction and emphasise quality improvement programmes to a greater extent than the functionalists. They consider emergency and corrective maintenance techniques to be significantly more important and emphasise quality improvement programmes to a less extent than the integrated strategists.

Integrated strategists place much emphasis on company-wide integration of maintenance, as well as on long-term maintenance plans. This is the group that spends least relative time on correction and attaches least importance to emergency and corrective maintenance techniques. At the same time it has implemented quality improvement programmes on higher relative levels than all other groups and places greater emphasis on most manufacturing capabilities than the other groups.

The analysis of the groups verified the hypothesis that firms with perceived long-term maintenance plans, and company-wide integrated maintenance emphasise quality improvement, prevention and most manufacturing capabilities more than other firms. However, integration seemed to be more important than long-term plans for verification of the hypothesis.

The maintenance and manufacturing environments of the groups were quite homogeneous. However, companies with perceived integrated long-term plans had more serious breakdown consequences than those without, and the group without long-term plans and without company-wide integration had a significantly lower relative proportion of firms with continuous line processes. Industry, size or breakdown consequences did not differ significantly between the groups. This indicates that company-wide integrated maintenance and long-term maintenance plans may be important for most firms, regardless of the production environment.

A few comments and suggestions for future research follow. It is difficult to identify what a maintenance strategy is. The perceived existence of long-term plans has been studied and not the existence of a maintenance strategy. The measures for company-wide integration of maintenance could be further developed or tested. Existing competitive and manufacturing strategies were not analysed in any detail, and the characteristics of these strategies could perhaps explain some of the links between maintenance and manufacturing capabilities. Dependent and independent variables were not fully identified. Correlations between variables, and not direct cause-and-effect relationships, were analysed. A more comprehensive study that included more competitive strategy, manufacturing process and maintenance variables, leading to cause-and-effect links, would therefore be valuable.

The success or profitability of long-term and integrated maintenance was not directly explained in the study, although, references indicate that high performing firms emphasise simultaneously multiple manufacturing capabilities, prevention and quality improvements, while low performing firms do not. The present study identified that firms with long-term maintenance plans and integrated maintenance emphasised most capabilities, preventive activities and quality improvement programmes to a greater extent than the other firms. Finally, since the study is based on survey data it would be interesting to conduct complementary case studies that exemplify the characteristics of the typology and further verify the links between maintenance, manufacturing capabilities and the context.

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