The impact of maintenance practices on operational and business performance

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Introduction

The premise that good maintenance and plant engineering processes are fundamental to success in manufacturing is beyond question (Hanson, 1995; Madu, 2000). Indeed, the logic of total productive maintenance (TPM) is to plan ahead to anticipate and avoid problems and improve performance by eliminating the causes that reduce equipment effectiveness (Nakajima, 1988). The theory is well documented: planned maintenance, autonomous maintenance, preventative engineering, design for manufacture of product and education and training of personnel to support these activities (Tajiri and Gotoh, 1992; Davis, 1995). As organisations strive to achieve world-class performance, much has been written to support the contribution that effective maintenance makes to manufacturing strategies and business performance. Schonberger (1987) declared TPM as being one of the four prime pursuits towards world-class manufacturing (WCM) leading to improvements that the customer cares about. Willmott (1994) suggested that it offers significant "competitive advantage". In addition, support for other operational philosophies, e.g. "lean production" (Womack and Jones, 1996) and "just-in-time" (Ohno, 1998) has been indicated. Sharp and Kutuoguoglu (in Bamber *et al.*, 1999) show that it can significantly contribute to profitability.

To recognise companies' achievements in terms of world-class and business excellence, award models have been developed (Deming Application, Baldrige, European Quality of Excellence *et al.*). The Japan Institute of Plant Maintenance Award encourages deployment of good maintenance practice for TPM. This is the most prestigious prize in the field of maintenance, and Dale (1994) points out that it is one of the most difficult awards to achieve.

During the 1970s, the importance of organisations reviewing their physical assets in terms of investment, costs and performance outcomes led to the concept of "Terotechnology". This is the application of managerial, financial, engineering and other practices to extend the operational life, increase efficiency and monitor the effectiveness in business terms of equipment, buildings and machinery. In the UK, the then Department of Industry set up the Committee for Terotechnology, recognising the importance of the gains to be made by focusing attention on all these functions in all business sectors. Hill (2000) points out that maintenance is the largest aspect of terotechnology and that many activities in the business cycle both affect and are affected by it in terms of operational and business performance.

The benefits of organisations adopting good practice in maintenance, therefore, should be obvious, but what should this encompass? Pure TPM may not be applicable to Western organisational culture. Schaffer (1991) queries whether it is just another activity-centred management theory rather than a result-driven approach, and Labib (1999) proposed that maintenance methodology should be keyed to specific results rather than to widespread objectives. Yarrow *et al.* (1999) indicated that good maintenance practice was "common sense" but questioned whether it is adopted as "common practice".

So, what degree of attention is given to deploying best practice in maintenance and plant engineering processes compared to other processes in manufacturing? Do they impact on operational and business performance? This paper investigates the extent to which good maintenance practices are deployed and the links between these and performance outcomes suggested in the body of theory. Empirical evidence from a major benchmarking project carried out in the North East of England during 1997 and 1998, is used to test the relationships between these practices and performance criteria in a relatively large sample of manufacturing organisations. Results for the practice deployment question are further tested in other research on a smaller sample of companies. The findings presented may typify current practice and performance among many manufacturers in this part of the UK. Variation between sectors and sizes of companies will be highlighted and discussed.

Analysis

The methodology used was adapted from the "Made in Europe Studies" (Hanson *et al.*, 1994, 1996; Voss *et al.*, 1998). This allowed companies to benchmark their practices and performance against world-class standards through assisted selfassessment and comparison across a range of (practice and performance) indices. Benchmarking and self-assessment are being used increasingly in this way to establish the extent to which organisations are deploying and achieving world-class, best practice and performance (leaders and laggers) and to identify areas for improvement.

Data were collected from 298 North East of England manufacturers who responded to a series of questions that compared their practices and performance to world-class standards for key aspects of the model developed in the European studies. Each question was allocated a score from 1 to 5, inclusive. Data consistency was ensured through a series of participant workshops, which supported the self-assessment exercise (Robson and Yarrow, 2000). Maximum scores were allocated only where adoption and achievement were on a par with the best. One question related to the level of maintenance practice adoption and is shown in Figure 1. The level to which good practice in maintenance has been deployed, its score compared to other practice indices and its relationship to key performance outcomes have been considered. Significant associations or differences between groups are indicated at one of three levels, 0.1 per cent, 1 per cent and 5 per cent.

A further set of case studies was carried out on the question of deployment of good maintenance practice. In this, data were collected from a random sample of 23 companies in the region using a benchmarking questionnaire which focused on the maintenance process itself. This examined 71 scales in nine aspects of maintenance practice and performance that allowed comparison on deployment to be made with those from the main exercise. It should be noted that not all of these companies had taken part in the main study and that other elements were being investigated in the second study.

Survey findings and discussion

Adoption of good maintenance practice

A majority of North East manufacturers (52 per cent) have only poor to fair levels, with only 16 per cent adopting strategies which extend beyond preventive maintenance and the deployment of corrective action teams, as indicated by Figure 2. The case studies indicated corresponding figures of 56 per cent and 17 per cent, respectively. Only one organisation in this sample had deployed TPM.

The level of adoption is associated to the company's world-class status with significance at the 0.1 per cent level. The leaders are more likely to have adopted higher levels of practice in this area, while those with a weaker overall profile are more likely to score poorly in this area. Company size (in terms of number of employees) is also a significant factor (0.1 per cent level), with large organisations being more likely to score highly and (interestingly) the medium sized as well as small manufacturers scoring poorly. No significant differences were found to exist between different manufacturing sectors. It was noticed that the extent to which companies are good or poor at adopting best practice in general is exemplified by that for maintenance. This may suggest that, at the TPM concept level, TPM, Total Quality Management (TQM) and business excellence are complimentary or

Figure 1
Maintenance question from PILOT benchmarking study

		1	2	3	4	5	Score
23	**Maintenance**	Crisis maintenance		Preventive maintenance, corrective action teams		Total preventive maintenance, maintenance scheduling synchronised with production, performed by operators	

even overlapping philosophies which are perceived as more applicable in larger enterprises and that they tend to be adopted in organisations that truly can be described as world-class.

In relation to other manufacturing practices, maintenance is the second worst performer overall, as indicated by Table I. It is interesting to note that this relatively poor level of attainment is repeated sector by sector, for each size band and also within each world-class status category. It is only among the large companies and the leading manufacturers where an average score of 3.0 is attained. Moreover, the average levels of practice adoption in areas such as pull-scheduling, job flexibility, batch sizes and housekeeping are significantly higher at the 0.1 per cent level. To a lesser extent, levels of practice adoption are significantly higher also in terms of design for production and product use (1 per cent) and equipment layout (5 per cent), as indicated by Table II.

Table II shows that the manufacturing sector has vastly superior levels of implementation on most of the key business practices compared to their levels of adopting world-class maintenance standards. There is only one area of practice which is significantly weaker in comparison; namely, product life cycle planning.

Apart from the large manufacturers, there is significant association between the relative attainments for each of the practices between the other size bands. The level of maintenance attainment is related significantly to size band, with significance at the 0.1 per cent level. The level of attainment being significantly higher for the large manufacturers compared to each of the other size bands can explain this. Indeed, this is the only size band with an average attainment greater than 3.0, the others being significantly lower in comparison. Table III indicates that the large companies typically have better levels of practice adoption than the other three size bands.

Large manufacturers have levels of maintenance practice, which are significantly weaker in comparison to fewer of their other practices compared to their smaller counterparts in the manufacturing sector, as indicated by Table IV. In relative terms, maintenance adoption is particularly weak among the medium-sized organisations.

Looking at manufacturing sectors, apart from the comparison between the electrical sector and the household and process cohorts, there is significant association between the ranked attainments for each of the other manufacturing groupings. There is no significant difference between the sectors in terms of their maintenance attainment. All industrial sectors are particularly weak in this area, with average scores significantly lower than 3.0, as indicated in Table V.

Figure 2
Levels of practice adoption in maintenance

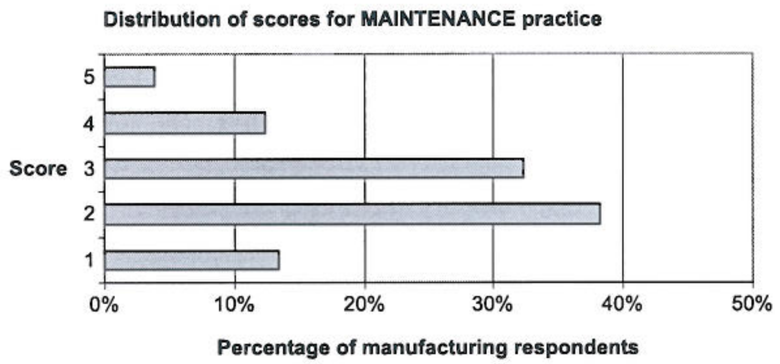

Table I
Relative average attainment for key practices

Practice	Overall mean	Rank
Order release into manufacturing	3.762	1*
Job flexibility	3.240	2*
Batch sizes	3.122	3*
Housekeeping	3.102	4*
Design for production and product use	2.902	5
Equipment layout	2.769	6**
Manufacturing strategy	2.730	7**
Kanban	2.677	8**
Maintenance	2.550	9**
Product life-cycle planning	2.357	10**

Notes: * represents mean scores which are significantly higher than 3.0; ** represents mean scores which are significantly lower than 3.0

Table II
Significant difference in attainment compared to maintenance

Practice	Significance
Order release into manufacturing	***
Job flexibility	***
Batch sizes	***
Housekeeping	***
Design for production and product use	
Equipment layout	**
Manufacturing strategy	*
Kanban	
Product life-cycle planning	**[a]

Notes: *** represents significant differences in mean scores at the 0.1 per cent level; ** at the 1 per cent level; and * at the 5 per cent level. In each case, maintenance levels are significantly lower, except when indicated by [a]

Table III
Relative average attainment for key practices by size band

	Large	Medium	Small	Micro
Order release into manufacturing	1*	1*	1*	1*
Job flexibility	2*	5	2	3*
Batch sizes	8	3	4	2*
Housekeeping	3*	4	3	4
Design for production and product use	7	2	8**	5
Equipment layout	4*	7**	5**	9**
Manufacturing strategy	5*	6**	9**	7**
Kanban	10	8**	7**	6**
Maintenance	9	9**	6**	8**
Product life-cycle planning	6	10**	10**	10**

Notes: * represents mean scores which are significantly higher than 3.0; ** represents mean scores which are significantly lower than 3.0

Table IV
Significant difference in attainment compared to maintenance by size

	Large	Medium	Small	Micro
Order release into manufacturing	***	***	***	***
Job flexibility		**	**	**
Batch sizes		***	*	***
Housekeeping	**	***	**	***
Design for production and product use		*		
Equipment layout	*	**		
Manufacturing strategy	*	**	*	
Kanban		**		
Product life-cycle planning			**[a]	

Notes: *** represents significant differences in mean scores at the 0.1 per cent level; ** at the 1 per cent level; and * at the 5 per cent level. In each case, maintenance levels are significantly lower, except when indicated by [a]

Table V
Relative average attainment for key practices by industrial sector

	Electrical	Engineering	Household	Process
Order release into manufacturing	1*	1*	1*	1*
Job flexibility	2	3	3	2*
Batch sizes	5	2	4	5
Housekeeping	3*	4	2	4
Design for production and product use	7	5	8**	3
Equipment layout	6	6**	5	7
Manufacturing strategy	9**	8**	7**	6
Kanban	8**	7**	9**	8**
Maintenance	10**	9**	6**	9**
Product life-cycle planning	4	10**	10**	10**

Notes: * represents men scores which are significantly higher than 3.0; ** represents mean scores which are significantly lower than 3.0

Relatively, maintenance adoption in each of the four main sectors is particularly weak in comparison to similar initiatives, as indicated by Table VI. These include "Order release into manufacturing", "Batch sizes" and "Housekeeping".

The impact of maintenance practice on performance

The central hypothesis in the European Studies was that the adoption of best practice is strongly correlated to the achievement of high operational performance, which in turn

Table VI
Significant difference in attainment compared to maintenance by sector

	Electrical	Engineering	Household	Process
Order release into manufacturing	***	***	***	***
Job flexibility		**	*	**
Batch sizes	**	***	*	**
Housekeeping	***	***	***	**
Design for production and product use				
Equipment layout	**	*		
Manufacturing strategy				**
Kanban				
Product life-cycle planning				

Notes: *** represents significant differences in mean scores at the 0.1 per cent level; ** at the 1 per cent level; and * at the 5 per cent level. In each case, maintenance levels are significantly lower, except when indicated by [a]

leads to superior business performance. This has been assessed using a collective index of performance and a number of key individual measures covering both operational and business performance.

In terms of collective index of performance, the manufacturers have been categorised as "leaders", "middle" and "laggers". The "leaders" are those manufacturers in the sample whose average performance score positions them within the top 20 per cent of companies in the survey. In contrast, the "laggers" are the poorest 20 per cent by performance indicator. The relative levels of agreement between the ranks for each of the groups are significant at least at the 1 per cent level.

There is a significant difference between the three groups in terms of their maintenance attainment, with significance at the 0.1 per cent level. The leaders are significantly higher than the middle cohort, who, in turn, score significantly higher on average compared to the laggers. This profile is repeated for all of the practices considered. While maintenance is seen as a weak area of practice adoption across the manufacturing sector, it is interesting to see the high performers are one group who have a reasonably high level of maintenance adoption, as indicated in Table VII with a mean score significantly higher than 3.0. The "across-the-board" respective strengths and weaknesses of the performance leaders and laggers are directly associated to their levels of practice adoption, thus supporting the established belief that if a company adopts best practice, then this will lead to high operational performance.

Table VIII illustrates that as the relative performance position of the manufacturer improves, the relative inferiority of their maintenance strategy (as indicated by other practices being significantly superior) diminishes. However, the manufacturing sector as a whole has initiatives in "order release", "job flexibility" and "housekeeping", which are consistently closer to world-class standards than their maintenance strategies.

To see if any association between maintenance levels and key performance outcomes may exist, 17 individual measures, where it is reasonable to assume such association, have been considered (eight operational and nine business performance). A number of measures show association with the deployment of maintenance practices, with significance being at the 0.1 per cent level and are listed in Table IX. In each case, the higher the level of practice that is adopted, the higher the level of business or operational performance is achieved.

In addition, significant association is found with:

- Business performance in cash flow, return on net assets, capital investment, market share, customer satisfaction and employee morale (all significant at the 1 per cent level).
- Operational performance in inventory turns, rate of introduction of new products (significant at the 1 per cent level) and production cycle times (significant at the 5 per cent level).

The findings of the main study establish the veracity of both the theory and literature on the proposition that good maintenance practices will have significant impact on performance, although more so on operational outcomes than overall business performance. However, the wider impact should not be underestimated. Cause and effect cannot be claimed from this study and these questions leave room for further research that could include mapping and correlating with the findings of other, larger surveys mentioned.

Table VII
Relative average attainment for key practices by performance status

	Leaders	Middle	Laggers
Order release into manufacturing	1*	1*	1*
Job flexibility	2*	2*	3
Batch sizes	4*	3*	2**
Housekeeping	3*	4*	4**
Design for production and product use	9	5	5**
Equipment layout	5*	7**	6**
Manufacturing strategy	7*	6**	7**
Kanban	6*	8**	8**
Maintenance	8*	9**	9**
Product life-cycle planning	10	10**	10**

Notes: * represents mean scores which are significantly higher than 3.0; ** represents mean scores which are significantly lower than 3.0

Table VIII
Significant difference in attainment compared to maintenance by performance status

	Leaders	Middle	Laggers
Order release into manufacturing	***	***	***
Job flexibility	**	***	**
Batch sizes		***	***
Housekeeping	**	***	***
Design for production and product use			
Equipment layout		*	*
Manufacturing strategy		*	
Kanban			
Product life-cycle planning			*[a]

Notes: *** represents significant differences in mean scores at the 0.1 per cent level; ** at the 1 per cent level; and * at the 5 per cent level. In each case, maintenance levels are significantly lower, except when indicated by [a]

Table IX
Performance outcomes significantly associated to maintenance adoption

Performance outcome	Area
Productivity growth	Business performance
Production costs	Business performance
Cycle times – concept to production	Business performance
Customer deliveries met	Operational performance
Process capability	Operational performance
Internal defects	Operational performance
Progress chasing	Operational performance
Cycle times – production to availability	Operational performance

The case studies verified the results of the main benchmarking exercise on deployment of good practice which in turn confirmed some of the research literature reviewed.

Conclusions

This paper has outlined the strategic implications for organisations to deal effectively with maintenance and reliability issues and points to definite links between practice and performance in this area. These have been empirically tested with a large sample, where previously they may only have been assumed. It suggests that good maintenance practice (GMP) lends force to other broader practices and strategies that may well synergise to give superior performance and that maintenance tactics do, indeed, form a result-driven approach.

Manufacturing companies in the North East of England appear to treat maintenance in Cinderella fashion and may be losing out on the contribution it can make to manufacturing strategies aiming at superior performance and world-class competitiveness. The case research underlined that there is a bias towards manufacturers in the region adopting a conventional view on maintenance being "preventative" at best adoption level and they look on it merely as a "low level" supporting process.

The main sample indicated a wide contrast in GMP levels between leaders and laggers and the world-class group scores suggest that there is much room for improvement to be made by even the best practitioners. Also, the lagging group may need to question how sustainable their businesses may be without more systematic approaches being made to adopting better practices in maintenance strategies. There are particularly important lessons to be learnt from this for small and medium enterprises (SMEs) in the manufacturing sector of the North East region. They make up a large proportion that is benchmarked as "laggers" and whose future business levels may be vulnerable without due attention to such areas for improvement (i.e. losing to those with smarter practice).

Further, SMEs now represent over 90 per cent of the manufacturing sector's population in the North East region and account for around 40 per cent of this sector's economy (and 11 per cent of the region overall). The benchmarking survey may draw attention to the need for improved practices in general in this important sector. There may be serious consequences from the "knock-on" effect right through to the level of the region's competitiveness overall. The research was carried out in one particular region in the UK. We do not know how other regions compare, but if the North East region's apparent standards of maintenance (and other practices) are reflected widely, then this article may prompt the necessary call for action in the manufacturing sector.

The case study on 23 companies emphasised that "broad-brush" benchmarking could provide a means to genuine advances in the transfer of maintenance best practice. This points to another topic for research.

On a wider scale, the research suggests that companies systematically adopting best practices do achieve higher performance and that there are many opportunities for organisations to identify, investigate and adopt good manufacturing practices and achieve performance improvement using benchmarking methodologies. They may also provide useful means of assessing regional strengths and areas for improvement in business performance

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