Testing performance measures within maintenance, through case study research into lean thinking activities

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Abstract

A lean manufacturer operating in the automotive sector is currently participating in research that aims to measure performance of the maintenance function. The results described in this paper indicate that the company, already employing lean manufacturing practices, can improve its maintenance activities further by applying lean thinking. By adopting a performance measurement approach to identify the activities that align with lean thinking, it is possible to show how a lean approach to maintenance can contribute to the business objectives of the company. The research has identified a set of performance measures that can be used to analyse the impact of lean thinking within the maintenance function. The value of these performance measures has been verified using data collected by the company.

Introduction

Case study research has been undertaken to investigate the impact, practical use, and usefulness of lean thinking within the maintenance function of an automotive manufacturer. Specific attention focuses on the combined issues of lean thinking, maintenance, and performance measures to identify the impact of lean thinking within maintenance.

Literature review

From a lean thinking perspective, improved efficiency and profitability can be sought by increasing value within an organisation through the elimination of waste (Womack and Jones, 1996; Womack *et al.,* 1990). Nonetheless, a strategy for generic lean practice implementation within organisations to achieve leanness throughout, lacks strong evidence and is still not clear to many (Comm *et al.,* 2000; Chang 2001). Even within well-established organisations (using lean production techniques), the most fundamental capabilities for sustained lean behaviour development can still take more than five years to achieve (Emiliani, 1998).

Literature (Blanchard, 1997; Kutucuoglu *et al.*, 2001) shows that maintenance operations should extend beyond technological improvements to blend more with managerial concepts, to be in harmony with an organisations' business objectives. From a maintenance perspective, these have been identified by the use of additional lean approaches and techniques, such as total productive maintenance (TPM) (Nakajima, 1998) and others to assist their activities (Davies and Greenough, 2001).

Although various lean measures for maintenance have been developed (Kutucuoglu, 2001; Nakajima, 1988; Dal *et al.,* 2000) and described as beneficial monitors, they are not really suitable as sole performance measures, or require further research (Kutucuoglu. *et al*, 2001; Dal *et al.,* 2000).

To summarise, research shows that maintenance may benefit from using lean techniques and approaches that align with the business objectives of an organisation. However, there is little evidence of generic implementation or a comprehensive list of lean practices for maintenance in particular. Furthermore, there are no clearly defined measures of performance to indicate improvement within maintenance generally. The aim of this research therefore, is to identify the impact, practical use, and usefulness of lean thinking within maintenance through measurement.

Research method

For this investigation, qualitative and quantitative methods of information are used to help identify the practical use, usefulness, and impact of lean thinking within maintenance. Quantitative analysis will seek to provide meaningful information of raw data retrieved from sources such as maintenance management information systems used by the company. Qualitative analysis, through semi-structured interviews and observation, will help to determine the level of practical use and perceived usefulness of lean thinking approaches used by the maintenance function. A research hypothesis is also proposed that may, through investigation, satisfy the aim of this research. The following hypothesis has been used as a basis for this research: *Lean thinking improves the effectiveness of the maintenance function*.

The maintenance function under investigation was known to use a range of lean thinking techniques before this investigation. However, assumptions could not be made concerning the scale of lean, or use of performance measures. As no comprehensive list of lean activities or performance measurements used by the maintenance function were identified or referred to, an alternative methodology was used. As such, development by this researcher, of a lean reference framework and overall measure of maintenance performance is used as a reference for investigation. For reasons of scale, only explanation of the lean issues and related performance indicators derived from the overall measure of maintenance performance concerning this investigation are presented here.

Lean techniques and performance indicators

Based on three criteria: ease of data retrieval, cost of retrieval and ease of understanding the results, a spreadsheet application was used to calculate an output for the performance indicators used for this investigation. The availability and type of data recorded by the maintenance function also determine the selection of usable indicators.

Table 1 summarises the lean activities used by the maintenance function under investigation and the year of implementation. The perceived benefits of using these lean activities are also included in Table 1. The benefits of using lean techniques, from a practitioner's point of view within maintenance, are discussed later within this paper.

		Literature research		
Lean techniques used by maintenance	**Implementation**	**Lean emphasis** (example)	**Perceived benefit** (example)	**Source**
Standards	1996	Improvement	Standardised work	Bicheno 2000
Pokayoke	1996*	Prevention	Improved throughput	Shingo 1989
Root cause problem solving	1996*	Improvement	Defect reduction	Bicheno 2000
Process activity mapping	1996	Time	Improved utilisation	Bicheno 2000
TPM	1996	Prevention	Asset uptime	Nakajima 1988
Inventory management	1999	Waste	Improved turnover	Bicheno 2000
Story boarding	1999	Visibility	Information access	Bicheno 2000
Visual management	1999	Task visibility	Workforce involvement	Henderson *et al* 1999
Self audits	1999	Visibility	Self-evaluation	Bicheno 2000
5S (CANDO)	2000	Participation	Improved asset M'tance	Monden 1994
Continuous improvement	2000	Gemba	Improved efficiency	Bicheno 2000
* Considered company standards and pre-date lean implementation, although previously described differently				

Table 1, Lean techniques used by maintenance under investigation

Table 2 summarises the appropriate performance indicators chosen for this investigation, based on the lean techniques used and availability of data from the maintenance management information system (MMIS) used by maintenance.

Performance indicator		**Indicator calculation**	**Description**	**Desired outcome**	**Source**
I	Utilisation	$\frac{\text{Standard hours}}{\text{Total clock time}}$	Percentage index used to identify non-productive time. "Periodic studies show how well a remedy is working"	Trend increase	Niebel, 1994 Priel, 1962
II	Breakdown repair hours	$\frac{\text{Number of Hours spent on breakdowns}}{\text{Total direct M'tance hours}}$	Index used to guage effectiveness of M'Tance program. In particular, preventative maintenance	Trend decrease	Priel, 1962
III	Length of running	$\frac{\text{Total production output in units or hours}}{\text{Qty repairs during same period}}$	Index to show whether added service in hours, parts or frequency would give noticeable results	Value increase	Priel, 1962
IV	Emergency and other unscheduled tasks	$\frac{\text{Man-hours emergency, unscheduled jobs}}{\text{Total direct M'tance hours worked}}$	One of four indicators used for overall maintenance effectiveness indices. Focus on unscheduled tasks	Trend decrease	Niebel, 1994

Table 2, Maintenance performance indicators used for this investigation

The indicators presented in Table 2 are used to measure the impact of the lean techniques presented in Table 1, and the subsequent impact they have upon the maintenance function. However, for this research, only four of the eleven techniques presented in Table 1 could be investigated. These are: Process activity mapping, TPM, Pokayoke and root cause problem solving.

Case study investigation of the maintenance function

The investigation process conducted over three visits, involved interviews, observations, and data collection from an MMIS used by maintenance. The

interviewees were two maintenance managers, one of whom is the lean initiative project leader, one maintenance supervisor, and a technician involved with recording maintenance activities. Overall the company employs approximately 2500 people on site, of which maintenance accounts for 100 personnel.

- **Interviews and observations**

Semi-structured interviews and visual checks were conducted to determine the level of use, and to understand the application of lean thinking practices from a maintenance perspective.

Interviewees claimed that the introduction of lean thinking to the maintenance function had reduced downtime, improved communication between maintenance and production, and among other benefits, created better team unity. However, they also stated downsides to lean thinking within maintenance, such as the difficulty in translating production oriented lean activities to suit the maintenance function. The managers in particular were more aware of the need for continuous improvement of lean activities within maintenance, for instance, introducing greater decision making autonomy and improved communication.

An example of lean production wastes and analogous wastes within maintenance was explained to interviewees, who were then asked to identify similar wastes within the maintenance department and explain how they are tackled. Table 3 highlights the maintenance wastes identified by the interviewees, and explanations of how they are tackled. Although all of the interviewees understood the important issue of waste elimination, the managers had a better understanding of lean wastes present within maintenance.

Production wastes	Identified maintenance wastes	How the maintenance wastes are tackled
Overproduction	Excessive PM activities	Planned / scheduled PM activities
Waiting	Waiting for resources	Satellite workshops / stores, lineside trays etc.
Transporting	Centralised maintenance	Decentralised lineside maintenance
Processing	Excessive TPM activities	Escalation capping, (i.e., capability guidelines)
Inventory	Excessive stock	First in - first out spare parts
Motions	Could not define	Could not define
Defects	Poor maintenance	Skills matrix, *EEM / **NEPT teams
Human potential	Lack of training	Skills matrix, taught courses
Inappropriate systems	Poor information	Automated fault systems, training
Energy and water	Energy management	ISO 14001
Materials	Poor re-design	NEPT / EEM teams
Service and office	Could not define	Could not define
Customer time	Poor procedures	Standards / Storyboarding
Customer defection	Poor maintenance	Skills matrix, Training

* Early equipment management team
** New equipment purchasing teams

Table 3, Production wastes, maintenance wastes, and tackling the maintenance wastes

Visual checks of the maintenance function and production line were conducted over two visits. The site has a dedicated administration centre on the shop floor co-ordinating the manufacturing systems operations. The use of 5S was evident throughout the plant and maintenance areas, although it did fall short of a clean desk policy within office areas. Issues concerning TPM activities, responsibilities,

ownership etc., were shown on storyboards throughout the factory, but not as visual machine-side record sets. Storyboards were positioned throughout the factory and satellite maintenance areas, providing up to date information on: quality / environmental / safety standards, training, fishbone diagrams, activity updates, top ten losses, trend charts and action plans. As part of the visual checking process conducted in this investigation, a manager also showed documentation concerning NEPT and EEM practices, and vendor feedback documentation as used by maintenance.

Overall, the interviewees considered those lean activities used within the maintenance function simply as additional, practical and useful tools to help them do their jobs better. The managers though, felt that despite selecting what they considered to be the best lean tools to suit their workforce culture and maintenance requirements, success still depended on management control.

- **Measuring the maintenance function**

The maintenance function comprises of six zones, each accountable for measuring its own performance. Some zones were found more reliable than others, with the poorest recording less than 50% of its activities. The most reliable zone, with the highest level of reporting consistency, was trackside maintenance. The primary production equipment within trackside maintenance has been in place since 1993. In line with the rest of the maintenance department, trackside has a low staff turnover rate, nominally less than 2% per annum throughout. The focus of investigation therefore, regarding performance measurement is in the area of trackside maintenance.

- **Output results**

Based on the available information provided by maintenance, Figures 1-4 represent the values of the performance indicators shown in Table 2. For the maintenance function within this company, emergency events were classified with other unscheduled events, such as line stoppage. All emergency tasks were categorised as breakdown tasks or repairs.

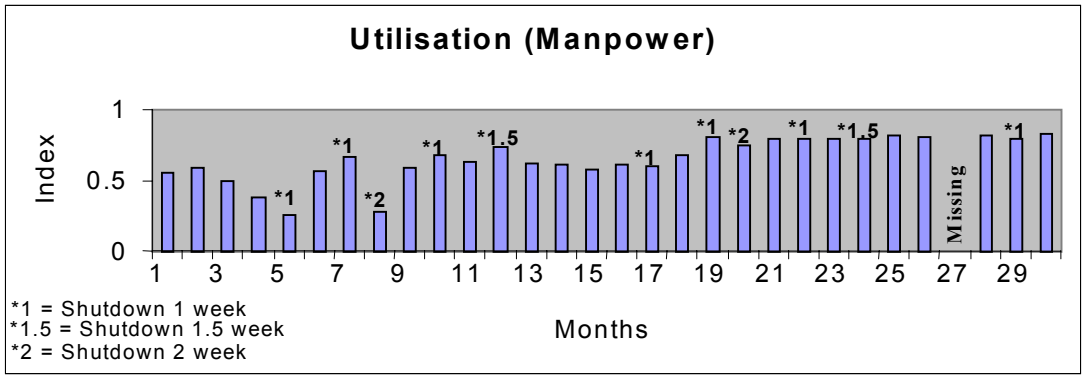

Figure 1, Utilisation index, January 1997 to June 1999

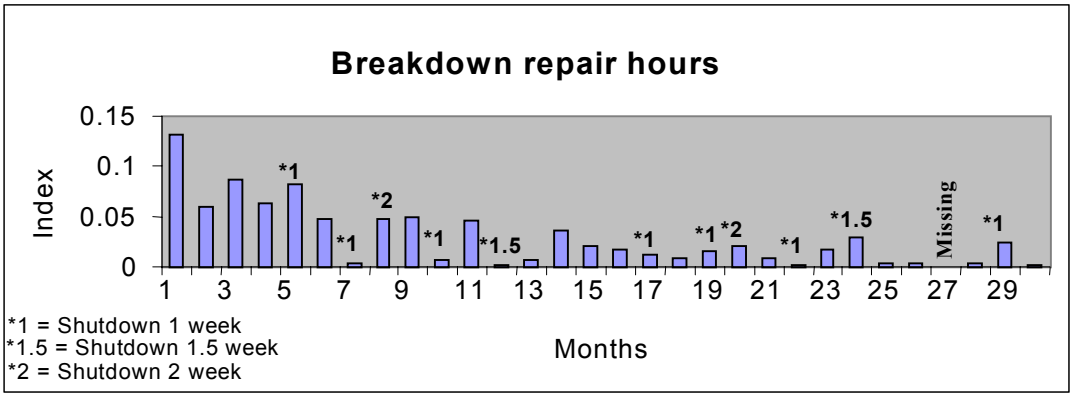

Figure 2, Breakdown repair hours index, January 1997 to June 1999

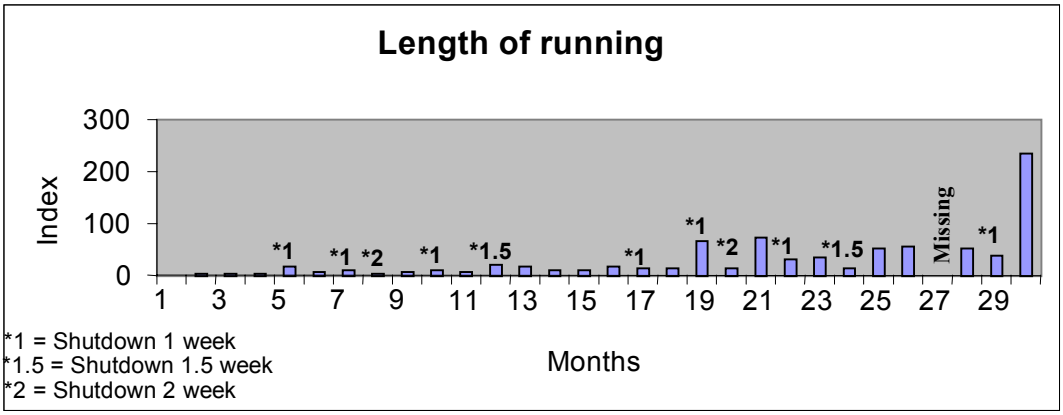

Figure 3, Length of running index, January 1997 to June 1999

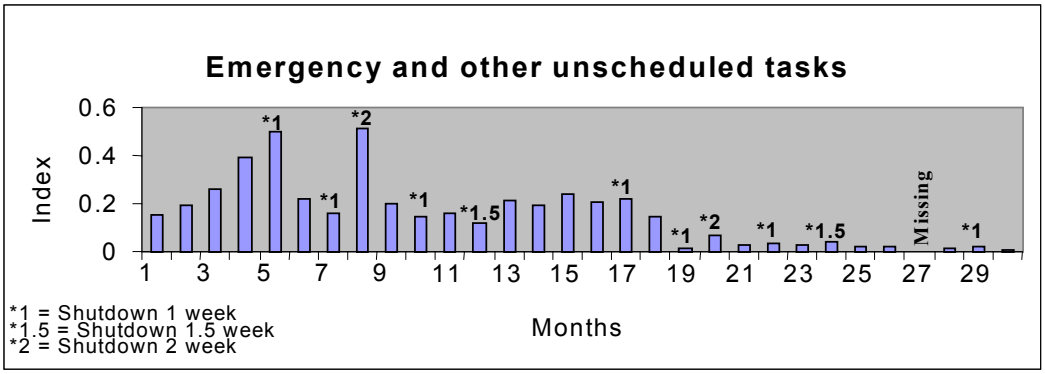

Figure 4, Emergency and other unscheduled tasks index, January 1997 to June 1999

- **Summary of results**

During the period of investigation, data showed that within the maintenance function the levels of (manpower) utilisation, breakdown repair hours, length of running and emergency and other unscheduled task indexes had improved. All had satisfied the desired outcome of the indicators presented in Table 2. Additionally, this period of investigation also saw an improvement in the total production running time and most importantly, an increase in product throughput through the zone under investigation.

Concluding summary

The company had already adopted various lean thinking practices within its maintenance function. Subjectively, the users accepted the role of lean thinking and considered certain elements useful. The period of investigation of the maintenance function covered the recent introduction of TPM in 1996, through subsequent lean additions up unto June 1999. There were no other direct influences during the measurement period, i.e., new equipment introduction, process changes or manpower fluctuation. Therefore, it appears that for the period under investigation, the use of lean thinking within the maintenance function has improved its effectiveness in all practically measurable areas of performance.

Future work

Future research will continue to investigate and develop performance indicators for lean maintenance. The overall aim is to develop a standard methodology for measuring improvements within maintenance, against the introduction and use of lean thinking.

Further case study research has been undertaken to identify lean thinking within maintenance of different (manufacturing) companies, and to investigate the value of such measures of performance. Present findings show a greater use of lean thinking by maintenance than literature suggests, and that improvements have been noticeable, both subjectively and quantitatively. As such, this research will continue to develop the themes discussed within this paper, and in conjunction with several co-operative companies, will analyse the actual on-going effectiveness of the measures.

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