A LEAN MAINTENANCE SUPPLY CHAIN FRAMEWORK FOR ROLLING STOCK MAINTENANCE: A CASE STUDY

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ABSTRACT

In order for the benefits of Lean Maintenance to be realised to their full potential, there is need for the supporting structures of the Maintenance organisation to be streamlined through a lean Maintenance Supply Chain (MSC). Unfortunately, most of the existing research focuses on supply chains in manufacturing oriented industries and does not give much attention to service oriented functions like maintenance, and much less in an area like rolling stock maintenance. In this article, the development of a lean MSC framework is investigated for use in a rolling stock maintenance environment with a case study at the Salt River depot of Metrorail in South Africa. The research involves carrying out a critical literature review of lean thinking and its application in the MSC with a view of identifying appropriate benchmarks comprising organisational objectives and key performance indicators. A study of the existing supply chain strategies at Salt River is then conducted with the aim of comparing them to the theoretical benchmarks obtained from literature. Based on the findings, a general framework is recommended that will assist the organisation to move towards a lean MSC.

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1 INTRODUCTION

This study looks at adding to the current body of knowledge concerning lean thinking and its use in maintenance operations by investigating the principles of lean thinking and how they can be applied in the rolling stock maintenance environment with emphasis on the supporting supply chain. The study develops a framework that is based on observations from a case study at the Rolling Stock division of Metrorail, Salt River depot in South Africa.

2 LITERATURE REVIEW

Lean thinking as a principle has come a long way since rising to prominence through the work of Womack et al. [1] and has found application in areas outside the traditional domain of the production line. According to Kister et al. [2], Lean is a comprehensive package that includes amongst other things, using a Lean supply chain. When lean thinking is used in the context of the Maintenance function, there is need for its supporting structures to be streamlined through a lean Maintenance Supply chain (MSC). MSCs fall within the category of service supply chains which according to Ellram et al. [3] have not been adequately researched in comparison to manufacturing supply chains. Of the little academic and practical work that has been done in services supply chains, not much has focused on MSCs. Notable studies in MSCs include those of Jeong 2003 [4] and MacDonnell et al. [5] who specifically look at aerospace maintenance supply chains. Cook [6] similarly presents an improved model for use in military helicopter maintenance and it consists of the aircraft cycle and the stock cycle intersecting at the corrective maintenance activity. Androjna et al. [7] investigate an MSC for nuclear power plants and describes the relationships between the main contractors and subcontractors and also how information, decisions, transactions, material and services flow in the supply chain. One outstanding feature of all the work mentioned so far with regards to MSCs is that they all propose frameworks/models to illustrate the underlying concepts in their approaches. Fabry et al. [8] also present an MSC optimization model which has its context in spare parts management and the logistic chain. In as far as lean thinking in the MSC is concerned, research is even scarcer. MacDonnell et al. [5] present one such paper that has a model used to tie into the Lean enterprise model developed by the Lean Aircraft Initiative programme at the Massachusetts Institute of Technology. It provides proven benefits of new potential to minimise stock holding costs of the whole supply chain and also minimise non-flying time of the aircraft. Cook [6] presents mathematical models that help create an intelligent and reactive supply chain for helicopter maintenance programmes. Studies in Rolling Stock maintenance are relatively rare, a view shared by Cheng et al. [9] who also present a study on maintenance strategy selection and calculation of spare part’s quantities and replacement intervals for the components of rolling stock. Even more uncommon in literature is research that combines lean concepts and rail maintenance. One of these is given by Zwas [10] who investigates the use of lean manufacturing techniques in bus and rail maintenance with a case study at the Chicago Transit Authority in Illinois, USA.

3 RESEARCH METHODOLOGY

The research carried out is largely based on a non-empirical conceptual analysis with a case study approach being applied so that the end result is the building of a conceptual framework. The non-empirical conceptual analysis part of the research involved a literature review focusing on the areas of lean thinking, supply chain management and maintenance management. The case study part of the research was conducted at the Rolling stock division of the Metrorail, Salt River depot in South Africa. Information used for this research was mainly collected through interviews with various heads of sections in the relevant departments. Other information was gathered through direct observation and contact with people on the workshop floor. These included technicians in the rolling stock workshop, stores and inventory controllers and buyers. In addition to these interviews and contact sessions, print-outs from the organisation’s Facility Maintenance Management System (FMMS)
and SAP databases were also made available. The above were then used to form the theoretical foundation for the conceptual framework of a lean maintenance supply chain for rolling stock.

4 MAINTENANCE SUPPLY CHAIN CASE STUDY

4.1 Case Study Background

Metrorail is owned by the Passenger Rail Agency of South Africa (PRASA), which in turn is a wholly State-Owned Enterprise (SOE). Metrorail transports over 1.7 million passengers on weekdays in major Metropolitans made out of five regions of South Africa. According to Metrorail [11], these five regions combined occupy about 478 stations with a fleet of over 270 train sets making up to 3100 coaches. The supply chain of the Rolling Stock maintenance division of Salt River depot in Cape Town will be the focus of study with a pilot case study being conducted in the traction motor repair and maintenance section. Figure 1 gives a diagrammatic representation of its supply chain.

![Diagram of Salt River Rolling Stock Maintenance Supply Chain](image)

Figure 1: Salt River Rolling Stock Maintenance Supply Chain

4.2 Observations from Case Study

- In the case study’s supply chain, the following areas of waste were observed:
  - Procurement procedures are too lengthy and as a result there is delay in securing material and parts that may be urgently required.
  - Some of their major suppliers have to wait for material coming from overseas before they can produce and deliver urgently required components to them.
  - Suppliers sometimes provide incorrect material and parts which then have to be returned and in a number of those cases, it involves third party suppliers which further delays replacement.
  - Cases of redundant or obsolete stock which keep being ordered by the maintenance department were observed. This greatly increases stock holding costs.
  - Generally, a “push” system exists in as far as delivery of critical components is concerned with the organisation aiming to have a safety margin of +/- 20 % to cover unforeseen circumstances.

- It was noted from the case study that there is a tendency to neglect the role of the sub-contractor as an important member of the supply chain. Situations where it would have been better for the maintenance organisation to do the job rather than outsourcing (e.g. winding of armatures), were observed.

- According to a recent study carried out by Rommelspacher [15] the current overall maintenance policy is time directed maintenance (TDM) or run to failure (RTF). There is however, currently a shift within the organisation to move from TDM to Condition Directed maintenance/Predictive maintenance.

- For the case study, the fact that it is a State-Owned Enterprise means that it is heavily influenced by government policy which prioritises affordability, safety and
reliability of its services. There are also legislative frameworks such as the Preferential Procurement Regulations Act National Treasury [16] that weigh heavily on the efficient and timely execution of the supply chain.

- It was observed that no formal performance measures were in place with one of the few exceptions being a Supplier Evaluation form which is presently hardly used. Related to the issue of performance measures is the issue of quality inspections which are performed on selected items that have been supplied. Unfortunately, this does not extend to critical parts like traction motor bearings where no quality inspections are in place making it difficult to trace a faulty bearing back to the supplier.
- In its current state, the case study’s supply chain relies on a mix of the SAP and Facility Maintenance Management System (FMMS) although these systems are not being fully exploited.
- There is also a general lack of risk management/assessment procedures in place for the supply chain in the case study at hand.

5 LEAN MAINTENANCE SUPPLY CHAIN FRAMEWORK

Given in Figure 2 is a diagrammatic representation of the proposed conceptual framework for a lean MSC which incorporates observations mentioned in Section 4 from the case study.

**Lean Thinking**

- Lean Thinking is, according to Womack et al. [12], a way to specify value, line up value creating actions in the best sequence, conduct these activities without interruption whenever some body requests them, and perform them more and more effectively. Murman [13] describes it as a dynamic, knowledge-driven, and customer focused process through which all people in a defined enterprise continuously eliminate waste with the goal of creating value. Three intrinsic properties of lean thinking emerge from this description, namely, waste elimination, value addition and continuous improvement.

**Supply Chain Components**

- Supply Chain components in maintenance environments differ from those in manufacturing oriented environments which typically consist of raw material suppliers, 1st tier and 2nd tier suppliers, wholesalers, retailers and the end customer. For the MSC it typically involves Original Equipment Manufacturers, material suppliers, sub-contractors, the main contractor or maintenance organisation and the end-user.

**Maintenance Strategies**

- Maintenance strategies range from non-tactical, such as breakdown or corrective maintenance, to tactical such as condition-based maintenance.
More mature maintenance organisations will also have optimisation strategies such as Reliability Centred Maintenance or Total Productive Maintenance (TPM) as their maintenance strategy. Smith et al [14] consider TPM to be the foundation of Lean Maintenance.

**Organisational Objectives and Regulatory Frameworks** - An organisation’s objectives consist of the overall purpose, mission and goals that it aims to achieve. Regulatory frameworks on the other hand, are a system of regulations and the means to enforce them, usually established by a government to regulate a specific activity.

**Performance Measurement** - After the maintenance organisation has established its maintenance strategy, taken account of the overall business objectives, identified and prioritised all components of its Supply Chain and factored in its lean objectives, there arises a need to put performance measures in place. This is achieved through Key Performance Indicators (KPIs) which combine several metrics and indicators to yield an assessment of critical or key processes as defined by Smith et al. [14]. Table 1 gives useful metrics that guide an organisation in evaluating its performance in as far as lean thinking is concerned.

**Table 1: Performance Measures within a lean MSC (Source: Trent [17])**

<table>
<thead>
<tr>
<th>Supply Chain Area</th>
<th>Measures</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean Supply</td>
<td>Supplier Scorecard Measures</td>
<td>Includes regular reports of supplier performance, including performance areas that support lean objectives.</td>
</tr>
<tr>
<td></td>
<td>Procurement overhead as a percent of total sales</td>
<td>Reflects the efficiency of the procurement organisation.</td>
</tr>
<tr>
<td>Lean Transportation</td>
<td>Percent of receipts delivered on a just-in-time (JIT) basis</td>
<td>Reflects the maturity of a JIT delivery network.</td>
</tr>
<tr>
<td>Lean Operations</td>
<td>Percent of inbound receipts that do not move to storage</td>
<td>Reflects the amount of material that downstream entities within a facility require immediately.</td>
</tr>
<tr>
<td></td>
<td>Overall equipment effectiveness</td>
<td>Measures the availability, efficiency, quality performance, and nonplanned downtime for equipment.</td>
</tr>
<tr>
<td>Lean distribution</td>
<td>Perfect customer order rates</td>
<td>The percent of orders that ship to customers with zero defects.</td>
</tr>
<tr>
<td></td>
<td>Order fill rates</td>
<td>Unfilled orders due to lack of stock create supply chain waste, costs, and lost sales.</td>
</tr>
<tr>
<td>Planning and control</td>
<td>Inventory record accuracy</td>
<td>Reflects the differences between physical and computer records for inventory across the supply chain.</td>
</tr>
<tr>
<td></td>
<td>Raw material, work-in-process, and finished goods inventory turnover.</td>
<td>Reflects how often inventory moves across the supply chain.</td>
</tr>
<tr>
<td>Customer value satisfaction</td>
<td>Customer repurchase rate</td>
<td>When everything comes together, repurchase rates should be higher than industry averages.</td>
</tr>
</tbody>
</table>

**Information Technology** - Information Technology (IT) is very important for the support of maintenance and maintenance support operations within the supply chain. Smith et al. [14] state that for an effective enterprise-wide transformation of lean, the IT group should be actively pursuing continuous improvement of the support efforts that they provide for the
maintenance operation. IT solutions have evolved with time from the days of computerised maintenance management systems (CMMS), to Enterprise Asset Management (EAM), to customised CMMS/EAM and now to enterprise resource planning (ERP) systems. This evolution has been necessitated by the need to address the multiplicity of business functions within the supply chain. Singer [18] observes that most ERP vendors initially chose not to offer maintenance management modules although this has changed with time with vendors like SAP and JD Edwards being major players in the market. Sekatzek et al. [19] present a useful technical measurement methodology based on KPIs which can help an enterprise adapt its current standard business software to suit emerging trends.

Risk Management/ Assessment - Risk management is an integral part of a supply chain and it takes an even more important role when lean thinking is applied. For instance, having fewer total suppliers or purchasing of smaller quantities on a more frequent basis has risks attached to it. There are also risks involved with outsourcing as emphasised by McIvor [20]. There are even risks associated with implementing enterprise software to support your objectives, with Ayers [21] considering this particular risk very high. There is therefore a need to incorporate risk assessment before and during execution of the supply chain.

Improvement Models - After having measured and established the MSC’s position in the road to becoming lean, there is a need to put in place improvement models. Poirier [22] gives examples of and classifies models that can be used to reach higher levels of achievement in the supply chain. He includes models for purchasing, procurement and strategic sourcing, forecasting, demand management and capacity planning and models for order management and inventory management. These and other improvement models will be on-going since lean-thinking calls for continuous improvement and they will exist for the lifetime of the organisation.

6 CONCLUSION AND FUTURE WORK

This study has developed a framework for implementing a lean MSC in a rolling stock maintenance environment. The study first established that a gap exists in literature for this kind of study. The study then determined the variables that act as input for executing a lean MSC. These were determined from a literature study combined with observations from a case study at the Rolling Stock division of Metrorail Salt River depot. Based on the shortcomings observed in the case study, the framework recommends, amongst other things, the use of relevant performance measures, up-to-date information technology, risk management strategies and improvement models for meeting a maintenance organisation’s lean objectives. The framework is meant to be used as a guideline in a rolling stock maintenance environment that seeks to eliminate waste, add value and continuously improve its supply chain. Possible future work would include validating this framework through practical implementation and measuring improvements in the performance of an operational rolling stock maintenance supply chain.
REFERENCES


