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An Identification of the Enabling Factors for the Development of a Unified Approach to Maintenance Strategy Development within the Automotive Supply Chain

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Abstract The maintenance of modern production equipment has become an increasingly important and complex activity – particularly within the automotive supply chain. Tier-1 suppliers need a world-class manufacturing infrastructure to remain competitive, and therefore a matching maintenance strategy to support their operations. The opportunity exists for many automotive Tier 1, and potentially Tier 2 suppliers, to see substantial improvements to their competitiveness and profitability by improving their maintenance performance within an industry where research has shown modern maintenance practices are, at best, limited. Other Industrial sectors have a different performance profile in terms of maintenance. For example, aerospace production and their supply chain companies are seen to be 'high achievers' in maintenance. Part of the reason for these differences is the ability, within an individual sector, to identify the cost benefits of improving maintenance performance, as well as other drivers – such as health and safety, or regulatory requirements. The adoption of modern maintenance practices within the automotive industry is often led by available budgets and the absence of any strategic vision. This paper will present a review of the literature regarding manufacturing and maintenance practices within two industrial sectors, automotive and aerospace. In addition, the paper will identify the need for the development of a unified approach to maintenance which could be suited to automotive Tier 1 and Tier 2 suppliers.

Key words: Maintenance Strategy Development, Automotive Supply Chain

1.0 Introduction

Maintenance is crucial to manufacturing operations. In many organisations the production equipment represents the majority of invested capital. Any deterioration of these facilities and equipment increases production costs and reduces product quality. Over recent years, the importance of maintenance, and therefore maintenance management within manufacturing organisations has grown. The maintenance function has become an increasingly important and complex activity – particularly as automation increases. The opportunity exists for many organisations to benefit substantially through improvements to their competitiveness and profitability by adopting a new approach to maintenance management. Several tools and technologies including Total Productive Maintenance (TPM), Condition Based Maintenance (CBM), Reliability Centred Maintenance (RCM) and more recently E-Maintenance have been developed under the heading of Advanced Maintenance Strategies. However, the adoption of advanced maintenance strategies and their potential benefits are usually demonstrated in large organisations with the hope that the good maintenance practices filter to the lower tiers in the supply chain. The original equipment manufacturers (OEM) involved within aviation design and manufacture are often seen as the leaders in supply chain management. In recent years the aviation supply chain has addressed many of their working practices and relationships which have led to a non-adversarial approach to the way the supply chain supports each other to create a more collaborative relationship, which hopefully leads to mutual benefits for the entire supply chain. The very nature of the production methodology adopted by an OEM within automotive manufacturing signifies a critical requirement of having a strong and efficient supply chain. Consistent deployment of lean principles throughout the supply chain, combined with a sharp focus upon the high demands of the OEM, have led to an operating environment which would see huge benefits in deploying supply chain management principles. Conversely, it is the key automotive drivers of cost, quality and on time delivery that have led to a more combative relationship between the OEM and its upstream supply chain. A consistent, annual cost cutting requirement from the OEM of its suppliers, combined with high demands on production have led to constraints in the development of unified maintenance strategies. One particular symptom of these dynamics is the creation of isolated pockets of excellence within the supply chain, where the sharing of technical information would aid and accelerate the development of the maintenance function. Currently, the sharing of best practices is unusual, limited in its effectiveness as well as being viewed by Tier 1 and Tier 2 suppliers with some caution. Additionally, a lack of resources encourages a short term, 'best fit' maintenance strategy, where a longer term view would prove more beneficial. This can be linked directly to the grave implications of failing to adhere to the business requirements of the downstream partner, leading to a culture of austerity emerging in maintenance development and supply chain practice.

Regardless of the context, whether aviation or automotive, the OEM's supplier-specific approach to purchasing and supply chain management can either be transactional or relational by nature. According to Axelsson et al. [3], the transactional purchasing strategy is symbolized by arm's length, short-term relationships that exploit cross-supplier competition, whereas the relational alternative relies on building long-term relationships that capitalize on cooperation and joint development. High asset specificity is typically required in relational purchasing, which relates to companies having invested in the relationship by concentrating on product and/or process customization [2]. That being said, each supplier relationship eventually culminates to making a fairly simple decision between "buying products" and "buying capabilities", and the latter approach is emphasized within the modern practice. The lack of resource sharing among the partners often defines a success or a fail in strategic supply chain management [12]. However, inter-organizational trust, and subsequent openness of data, information and knowledge are the cornerstones of the relational purchasing strategy. As Kajüter and Kulmala [14] have mentioned, there is a philosophy called 'open-book accounting' that can be seen as both a means for improving the cost efficiency of supply chains as well as a trust building tool. Even though the concept has its roots originally in management accounting literature, the fundamental principle that seeks to promote cooperation and transparency could be applied to maintenance management throughout multiple tiers of suppliers. If companies are, to some extent, capable to align their joint research and development as well as manufacturing efforts, why should maintenance be any different?

2.0 Review of the Literature

2.1 Automotive Sector

The automotive manufacturing industry operates with lean production principles, which are characterised by concepts such as Just in Time (JIT), TPM and Total Quality Management (TQM) [19]. The success of this principle relies on each function within the business operating with maximum efficiency. This idea applies not only within any individual plant, but throughout the supporting supply chain. As a direct result, the success of any partner within the supply chain is heavily dependent upon the performance and influence of their upstream supplier and downstream customer. Senior partners within the supply chain have a responsibility to promote effective working practice and build relationships. Within a lean production environment, the management of relationships is essential to the success of both the production principle and any value added activity [1, 19]. The crucial nature of the relationship a Tier 1 manufacturer has with its supply chain is magnified due to the lean production system adopted. Thun et al. (2011) noted that whilst lean management and production can lead to efficient supply networks, it may also expose weaknesses within the supply chain. It is possible that these weaknesses can be alleviated through supply chain development and value transfer.

Lean production can offer multiple benefits, but also cause performance issues if not managed correctly. The attention directed towards business efficiency within this production environment, results in cost being a key driver within the supplier/customer relationship. Singh et al. [23] discusses that the very nature of a lean production system can dictate that a relationship within a supply chain may be defined by cost down requirements, as opposed to targeting improved manufacturing efficiency. The consistent cost down culture experienced within automotive manufacture may encourage a contractual relationship, hindering supply chain development. A lack of communication at this level would inhibit the opportunity to improve technical functions such as maintenance. The benefits of sharing technical information throughout the supply chain as well as 'strategic partnering' can reduce the influence of problematic areas and improve business efficiency [13]. Kumar et al.(2013) discusses the benefits of improving a technical function such as maintenance, whereby a refined and efficient maintenance department can have a dramatic effect upon the performance of a business.

The UK automotive industry is beginning to recognise the challenges it faces going forward. Bettsworth and Davies [6] highlight the skills deficit within the industry, not least at key operational positions such as maintenance technician. Additionally, Davies et al. [8] indicate that the geographical location of both Tier 1 and Tier 2 suppliers must be considered when formulating the business relationship and the strategic direction of the company. The report indicates a desire for OEMs and Tier 1 manufacturers to source local suppliers to mitigate supply and quality risk, but 'technical capability' is preventing this. An additional concern is the business model of a Tier 2 supplier, who may engage with other industries in addition to automotive manufacture. Whilst this is a prudent strategy, the sphere of influence a particular industry such as automotive may have on a Tier 2 business is reduced. These particular dynamics must be accommodated and addressed, as a lack of recognition would limit growth and improvement.

2.2 Aviation Manufacturing Sector

It would be incorrect to call the entire gamut of supply in aviation industry as a chain. The relationships amongst players in the sector are far from being a simple vertical chain. The aviation manufacturing and aftermarket (MRO) industry is a complex web of intricate relationships that exist across national boundaries and has multiple stages. The industry consists of up to 4 tiers of suppliers that sit below the final integrator; the OEM. Aircraft manufacture can be broadly conceptualized as dependent on tiers of platform assembly, large and small-scale integration, value added parts and assemblies, make to print parts and assemblies and raw materials [22]. The relationships between the players gets complex as in most of the cases, the tier 3 and 4 suppliers are distributing parts to different OEMs. These 3rd and 4th tier suppliers are generally located in the countries where the labour and resources are cheap and they compete on the basis of lower costs. This globalization actually increases the logistical complexity when organizations move from centralized, single-site manufacturing facilities to geographically dispersed networks of resources [26]. The aviation industry has suffered due to the economic slowdown of the global economy. This has resulted in highlighting the flaws of the supply network in the sector and provided an excellent opportunity to tackle these inefficiencies and improve business practice.

2.2.1 Peculiarities of Aviation Manufacturing and Maintenance

The aviation sector has seen more rapid growth in developing countries. This has also resulted in the manufacturing sector shifting its base from the traditional manufacturing hubs to newer markets including Brazil, India and China. These countries are also becoming the centre of the tier3 and tier4 manufacturers. This has forced tier1 suppliers as well as the OEMs, to relocate their manufacturing site(s) alongside these fast growing markets. The OEMs are focussing on integrating the systems assembly rather than manufacturing in-house. Collaboration with the lower tier suppliers has become mandatory to survive. There are emerging competitors that are eating into the market share of existing OEMs. This also means that these new players and new markets have reduced the variations in demand. However, the real competition still lies in the lower tiers of the supply chain. It has become easier to globalize the aviation supply chain by importing component parts and components from manufacturing hubs that cost less per unit. This has intensified the competition at the lower levels. In the future too, it is envisaged that the higher tiers will compete on value and skills; lower tiers on cost [7].

The aftermarket supply chain has its own peculiarities. In some cases, the service centres have been located close to the customer to ensure minimum lead times. On the other hand, there are certain cases where the supply centres have been located centrally in order to achieve better satisfaction within a smaller inventory through the use of aggregation of demands. The aftermarket supply chains are keen to follow the second model of centrally locating the centres; however the first option will continue to exist to guarantee shorter lead times for the customers.

Engine OEMs in the aviation sector have traditionally provided MRO facilities to the airlines. This business has proved to be more profitable than manufacturing. This has prompted many companies to attempt to access the managing of MRO services to the airlines, by providing nose-to-tail services for the complete aircraft. The commonly used model is Power By the Hour (PBH) which is replacing the Time and Material (T&M) contracts. The companies are providing complete solutions to the aircraft maintenance problems and are charging flat rate contracts to do so. There are 3 major types of players in this market; first are the MRO suppliers that are only in the business of providing maintenance services; second are the OEMs and; third are the consortiums of major tier1 suppliers. These services are suited to the low cost airlines which do not have the resources to have a dedicated maintenance department. Aftermarket suppliers have taken on the responsibility of keeping the airline flying. With the OEMs and the tier1 suppliers jumping into the aftermarket maintenance business, MROs are providing better and expanded services to the airlines to survive in the market. Aftermarket suppliers are dependent upon refurbished old spare parts and assemblies to stay in competition on the basis of lower costs.

The existing and new market businesses in the aviation industry have worked on collaboration, integration and supply chain visibility in order to survive. This will remain the biggest trend in the future in this sector. The firms of today are trying to consolidate and leave value added parts and small-scale integration to focus on large-scale integration and platform assembly. This can be demonstrated by businesses redirecting themselves away from technical operations associated with machining, workforce management and manufacturing control, whilst investing in others. This would include systems integration, offset, mergers, politics and contracts (Williams, 2002).

2.2.2 Key Impact Areas for Automotive Sector: Lessons from the Aviation Sector

The peculiarities discussed in the previous section offer a new direction for the automotive industry. The methodologies that the aviation sector has adopted to survive through a period of challenge and change can be emulated by the automotive industry. The prominent areas of the automotive sector that can be addressed in order to make it more effective are as follows.

- The automotive industry must aggressively consolidate their supplier base. They must evolve strategies to have fewer suppliers with improved relationships to help assure supply. Risk sharing models should be developed and implemented in the automotive industry by the OEMs.

- Tier1 suppliers must aim to improve their current level of innovation. R&D efforts by OEMs in collaboration with these suppliers, like in aviation industry, will strengthen their capabilities to provide assured supply. These suppliers must be developed to become competitive globally.

- There is a need to have a more effective collaboration between the OEM and the suppliers at the design and development stage [5]. Certain critical components must be co-designed as there is more expertise available with the suppliers. There is a need to increase trust and transparency between the stakeholders for the collaboration to bear fruit in the real sense. Sinha et al. [24 highlight trust amongst partners as an important factor affecting the entire process of supply chain management.

- The regulations in the automotive industry have been changing continuously. This has forced the OEMs to invest in R&D to evolve better fuel efficient technologies. The regulations have been strict in the field of emission norms; leading to better designs of the engines. The trend is likely to continue. The automotive sector must keep investing in R&D to stay abreast with the demands of the changing regulations.

- Lean principles like Just in time, kanban system etc have revolutionized the automotive sector. Concepts like vendor managed inventory (VMI) have been developed to optimize the inventory management by letting the experts take over parts of the supply chain. There is a need to further improve these concepts.

- The attention and resource directed towards the review of the design and manufacture environment within the automotive sector, must be afforded towards the engineering maintenance function. Isolated pockets of good practice are in evidence, which have self-evolved within each individual business. As a result, this practice remains unstable if key resources are removed.

- Supply chain performance within automotive manufacture must consolidate practice in technical function to maximise efficiency and knowledge.

- The automotive sector needs to learn from the aviation sector in the field of providing aftermarket maintenance support. Specialized maintenance organizations that have developed and found favour in the aviation sector raises hope for similar ventures in the maintenance of manufacturing assets in the automotive sector as well.

- The automotive supply chains need to evolve a real collaborative chain in order to stay efficient. The sector is marred with the problems of “pseudo” collaboration where OEMs have simply shifted the inventories towards the suppliers and claimed to have implemented *just in time* method of supplies. In effect, the problems of large inventories have only changed locations. The costs of holding large inventories continue to be present in the system.

3.0 Maintenance Strategy Development

Strategies such as RCM and TPM are noted as being developed and aligned with the aviation and automotive industry respectively [15, 27]. It may be argued that their suitability for all areas within the aviation and automotive supply chain are questionable. The deployment of these strategies indicate the need for extensive resources, where Murthy et al. [10] argues that both are a concept for optimum conditions, possibly not accounting for overloading of production, or process degradation. These two symptoms alone would be prevalent in the high volume, cost restrictive environment of the automotive supply chain. It could be reasoned that the increase in equipment complexity, decrease in mechanical condition as well as monetary restrictions may force Tier 1 and Tier 2 suppliers to look to each other to solve their maintenance and manufacturing issues. Indeed, Doran [11] endorses the responsibility a 'mature' Tier 1 supplier has for relationship management and value transfer within the supply chain. Without the development and implementation of an effective strategy for maintenance operations, the business will continue to operate in an inefficient, reactive and expensive manner. The improvements and advantages a manufacturer may expect if a functional and suitable strategy is deployed within maintenance is explored by Raouf et al. [21]. This includes the journey towards exploiting maintenance to its full potential within the business. The ability of maintenance to offer a competitive advantage improves with the utilisation of a bespoke strategy for the supply chain. The strategy should consider a full range of decision elements that are related to both structure and infrastructure. This is recognized by Pinjala et al. [20] who proposes that if a maintenance department is to be considered effective and contribute towards the key operational drivers of the business, then there are 'key' decision areas when forming a strategy. Additionally, there are ten decision elements that should be considered when proposing and developing an effective maintenance strategy. They are listed in Table 1, and aligned as being either being infrastructure or structural in their nature. The decisions taken in these areas will have a significant impact on the ability of the maintenance department to support and contribute towards the goals and objectives of the business [20].

Table 1 Maintenance Decision Elements

Decision element	
Maintenance capacity	**Structure**
Maintenance facilities	
Maintenance technology	
Vertical integration	
Maintenance organisation	**Infrastructure**
Maintenance policy and concepts	
Maintenance planning and control systems	
Human resources	
Maintenance modifications	
Maintenance performance measurement and reward systems	

This initial review of literature describes the need for the supply chain to operate effectively if it is to be successful within a lean production environment. A key requirement of success would be consistent communication on a technical level – not restricted to quality or production data. Additionally, there remains scope to introduce a technique to develop maintenance within the automotive supply chain, which would unify maintenance practice. The new maintenance concept would be specific as opposed to generic, and look to accommodate the complex dynamics of Tier 1 and Tier 2 suppliers.

3.1 A holistic solution

There are some prominent challenges which are emerging within maintenance practice in the automotive industry. Two key areas of focus have come to the fore through continuing research within the supply chain of the automotive industry (UK). These are allocation of resources and strategy development [9]. Consistent feedback from Tier 1 suppliers indicate that resources are restricted on a number of levels and consistently hinder the effectiveness of the maintenance department. As can be seen in Table 2, constraints are identified and listed which have emerged from ongoing research contextualised in the paper by Dixon et al. [9]. This research has developed from a series of case studies, focussed upon the automotive supply chain at Tier 1 and Tier 2. Data collection is ongoing, but the rich data gathered up to this point has been refined and aligned with the decision elements summarised in Table 1. The addition of 'Supply chain partner' has been included for relevancy to that work, and its impact on maintenance effectiveness.

These constraints to maintenance effectiveness have led the author to the conclusion that construction of a strategy development tool, which provides focus on previously discussed barriers, will provide the following benefits.

- Specific key performance indicators that are directly linked to maintenance improvement.
- Medium to long term skill development for current and future operational staff.
- Alleviation of budgetary pressure due to 'cost down' initiatives.
- Addressing adverse institutional opinions through directed and visible business-wide efficiency improvements.

The constraints described are not unusual to a maintenance researcher or practitioner, yet the sector dynamics have created a unique situation which must be addressed. Constructing a strategy development tool by itself would not be sufficient. Continuing the direction discussed by Doran [11] and the requirement of a tier 1 supplier in ensuring value transfer is essential. The target of value transfer can be gained from two separate activities.

- o Formulating the strategy development tool, which will utilise evidence and feedback from both tier 1 and tier 2 suppliers. The cross pollination of constraints, requirements as well as good practices have informed the initial stages of development.

- o Engaging each supplier within an information sharing environment, where a community of practice begins to emerge.

Table 2 Constraints and strategy elements for the automotive supply chain [9]

Identified constraints and influences	**Key Maintenance decision elements**	**Structure/ Infrastructure**
Senior management attitudes Parent Company and Organisational culture Training	Human Resources	Infrastructure
Equipment and spares Technology Skills	Maintenance facilities	Structural
Staff resources Production system Maintenance shift system	Capacity	Structural
Budget Key performance indicators Audit	Maintenance measurement, planning and control.	Infrastructure
Supply chain partner	Supply chain	External

The second point may be seen as being the more difficult to implement, as event attendance or input would compound the constraint on budget and resource. Yet this would be a short term cost which would lead to the longer term removal in barriers to maintenance improvement. The sharing of technical information through a collective knowledge base would reduce isolating issues such as skill gaps or even senior management attitudes. The fundamental device which will facilitate a change in direction is in the early stages of development, and can be seen in Figure 1.

The tool is based upon a model proposed by Slack [26]. The performance objectives in yellow are unique to the business and may be changed. As can be seen from the example, performance objectives are in place. The maintenance elements listed horizontally (in green) are refined from research carried out by the author and can be referenced to Table 2. It is proposed that the interaction area of the maintenance element and performance objective will result in the opportunity to formulate a current and future strategic direction for maintenance in that area. It is this aspect of the tool which is currently under development. It is anticipated that the vertical travel of the user from each individual maintenance element across each performance objective will result in increased maintenance resource utilisation in that element area. Conversely, horizontal travel from each performance objective across each maintenance element will result in the department becoming more competitive and effective within the business.

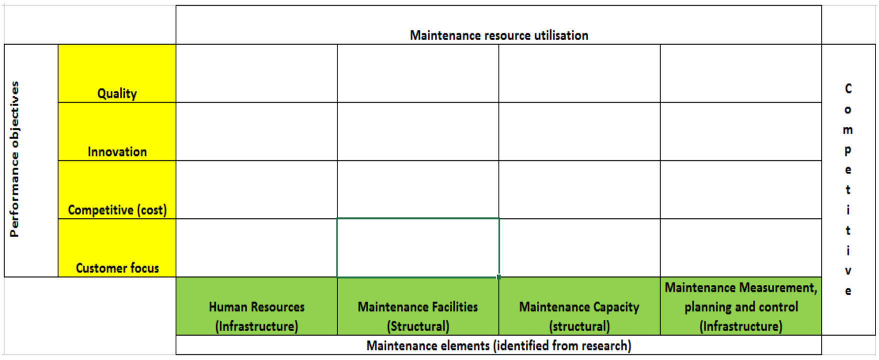

Figure 1 Maintenance strategy development tool

4.0 Conclusion

There is a need for the automotive supply chain to become increasingly visible. In fact, the aim should be to achieve predictability in the supply chain operations. This could be possible by leveraging what is termed Big Data and its analysis in order to gain better insights. This is outside the scope of this paper. The supply chain within the automotive industry has begun to address the issues of relationship management and performance improvement. This is of merit, but must be balanced with the continued austerity that exists within the UK market. Specific attention must be paid to the remaining areas of the supply chain which have not been maximised for performance improvement – engineering maintenance. Current practice of information sharing and striving for a relational partnership, provide part of the solution. What is crucial is acknowledgement of the continued challenges of cost reduction and improved efficiency that exist.

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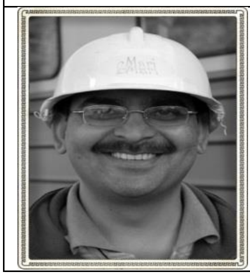	**Pankaj Sharma** Pankaj Sharma holds M. Tech Degree in Industrial Engineering from the Indian Institute of Technology, Delhi, India. He is currently working as a maintenance engineer in the Indian Army for last 19 years. He has dealt with maintenance of mechanical equipment and material supply chain extensively. He is currently pursuing his PhD from Indian Institute of Technology Delhi, India. His research areas include Logistics and Supply Chain Management, Maintenance Strategy Developement and use of Big Data Analytics in optimizing the supply chains and Asset Management.